Federal Railroad Administration

Office of Policy and Program Development

Training Course and Workbook

October 2003

FEDERAL RAILROAD ADMINISTRATION

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

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MODULE 1 INTRODUCTION

1.1 Introduction of Instructors and Participants

1. The course will be conducted by instructors from FRA or its consultant.
2. Participation is critical to success in the course. Participants bring invaluable local experience to the course. Instructors intend to learn from the participants and incorporate their experiences in the course as it evolves.
3. This course was originally developed in 2001 by DecisionTek, LLC under the leadership of FRA's Office of Policy and Program Development with input and oversight by the Offices of Railroad Development and Safety.
4. The course will be divided in time between presentation/discussion sessions and lab sessions. The lab sessions will involve hands-on direct use with GradeDec.NET.

1.2 Course Goals and Objectives

1.2.1 To gain a working knowledge of:

- The evaluation of safety impacts from grade crossing improvements.
- The evaluation of other benefits from grade crossing improvements.
- The use of GradeDec.NET to support resource allocation decisions.
- The use of GradeDec.NET to plan and evaluate grade crossing solutions on proposed Next Generation High Speed Rail corridors.

1.2.2 Discussion of Goals and Objectives

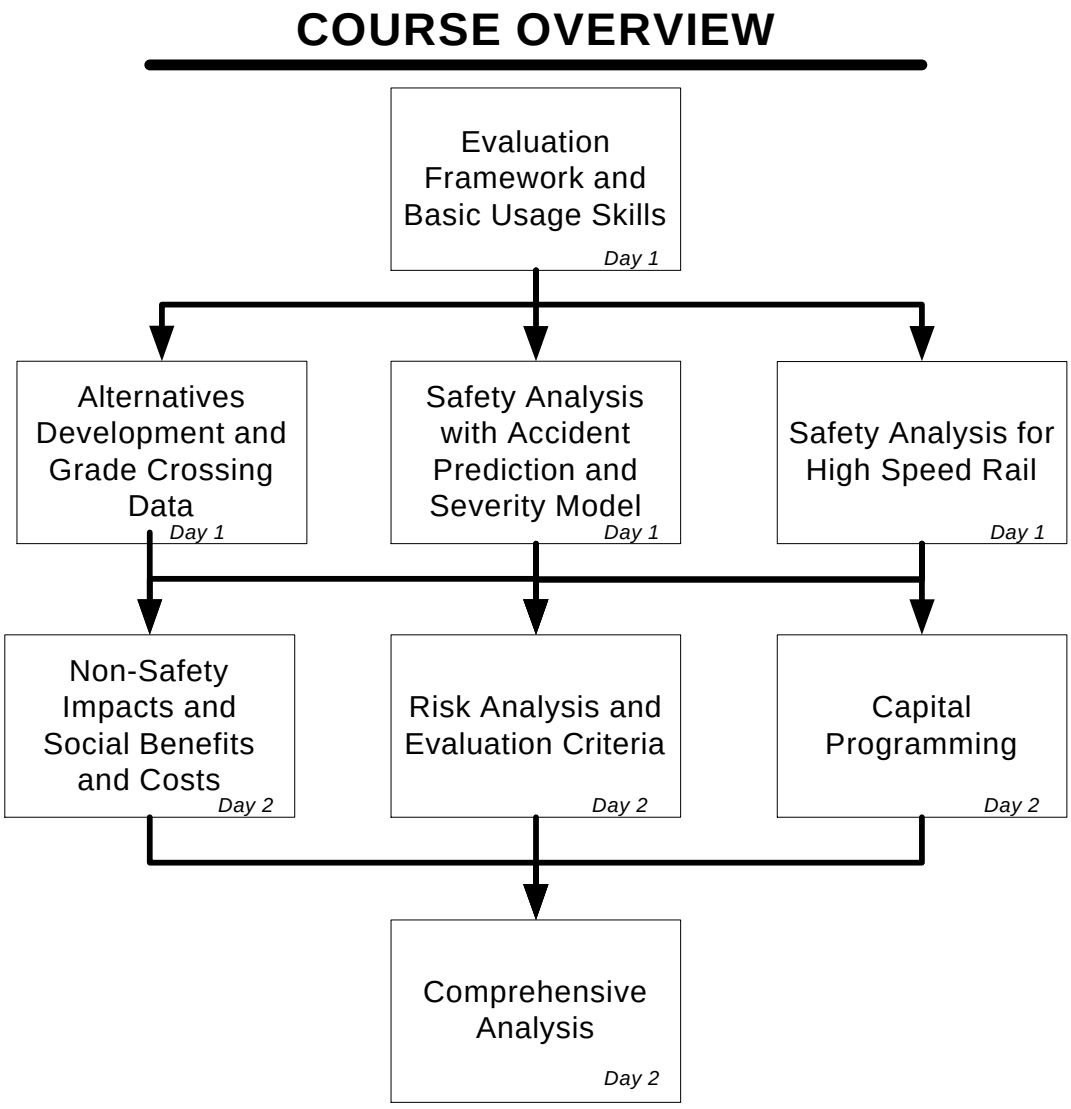
The goal of this course is to provide a comprehensive and practical understanding of the GradeDec.NET software for the planning and evaluation of highway-rail grade crossing improvements. Cost-benefit analysis of infrastructure investment is often a complex process that may require close interaction and coordination among professionals, decision-makers, rail operators and citizen groups. GradeDec.NET incorporates best practice models, analytic tools and data management capabilities to facilitate the analysis, whose purpose is to assess a range of economic, social and environmental impacts and tradeoffs so as to enable informed decision-making.

This course seeks to impart a good working knowledge of using GradeDec.NET while reviewing the principles and practice of benefit-cost analysis that are critical to supporting sound decisions. The course presents: a conceptual framework; methodologies of evaluation used in GradeDec.NET; review of computational algorithms; modes of use; and, a discussion of data requirements. The sections on safety and non-safety impacts include explicit exercises that replicate the calculations in the software. A hypothetical case study accompanies the course and demonstrates the practical application of GradeDec.NET.

1.3 Course Overview

The course is presented over a period of two days and covers 10 modules, including this Introduction (Module 1). Presentations will be interspersed with lab sessions in which participants will work with GradeDec.NET and apply skills acquired.

Figure 1 Course Overview



1.4 Course Materials

- Workbook
- PC or terminal with browser and Internet connection
- User's Manual

- Reference Manual

MODULE 2 USING GRADEDEC.NET

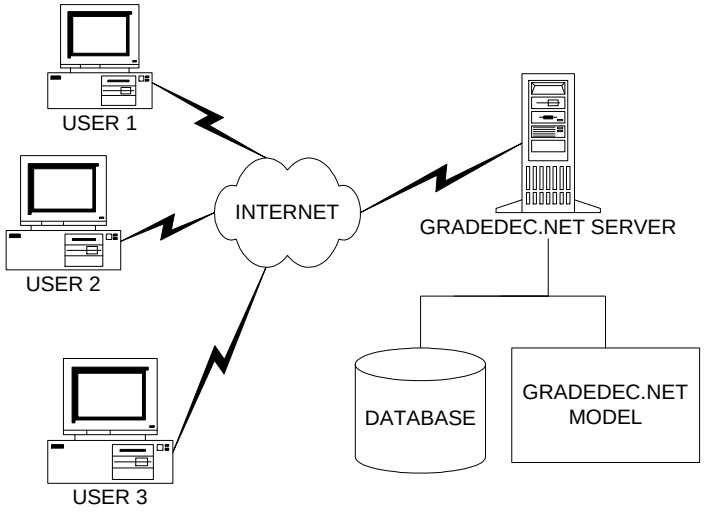
2.1 Introduction

This section is a description of GradeDec.NET and how to use it to conduct analyses. Parts of this section will be covered in the "Introduction" session of the workshop. The remaining parts of this section are for the participant's reference. The material in this section also appears in the User's Manual.

2.2 GradeDec.NET – System Overview

GradeDec.NET is a web-based application deployed over the Internet. This enables many users to access the system simultaneously, while using minimal resources from each user's computer.

Figure 2 Schema of GradeDec.NET



Advantages to the web-based system over desktop systems:

- No special hardware or software user requirements
- No need for installation on secure systems
- Model and data updates immediately accessible to all users
- Few demands on user to manage data and analyses

2.3 Registration and Logon

To use GradeDec.NET you must register the first time you logon. You will then use the user ID and password that you select during registration to logon during subsequent sessions.

The logon page includes a toolbar at the top, which link to "About", "Terms of Use" and "Messages". You should check the messages periodically. Also, read and understand the terms of using the system.

2.4 Navigation

After logging in, you will be shown the Settings page. From this page you select the data object (see 1.8 below). On the left side of the screen is a navigation bar, which enables access to all the pages of GradeDec.NET.

2.5 Modes of Use

GradeDec.NET has several modes of use, and the specific mode of use that you choose will depend upon the type of decision that your analysis should support. This section identifies and describes the two principal modes of use with *GradeDec.NET*. These are:

- Safety analysis, and
- Full investment analysis

2.5.1 Safety Analysis

For a safety analysis, the user examines predicted accidents at grade crossings and for the corridor (or region) as a whole. The safety analysis is, essentially, a comparison of a "before" and "after" situation, where "before" represents the *status quo* and "after" reflects the impact of crossing improvements (through device upgrade, closures, separations, traffic management measures, etc). The safety analysis is restricted to examining the safety impacts at a crossing. The safety analysis reflects a snapshot of current conditions and does not account for the forecast growth of highway traffic or rail operations.

2.5.2 Full Investment Analysis

A full investment analysis supports resource allocation and planning decisions. The full investment analysis accounts for safety benefits and, as well, other highway user costs. These user costs include time savings, vehicle operating costs and emissions. The full investment analysis monetizes the benefits from each benefits category and sums the benefits from the improvements over the time horizon of the investment. This analysis includes user assumptions regarding the forecast of traffic growth, by highway and rail, and analyzes the risk associated with the forecast values.

A "safety analysis" will involve a subset of the *GradeDec.NET* features required for a "full investment analysis". The following table shows the two modes of use, purposes associated with each, and the functional pages in *GradeDec.NET* used in each type of analysis.

Table 1 GradeDec.Net Modes of Use

Mode of Use	Purpose	Functional Pages in GradeDec.NET to Use
Safety analysis	Calculate accident risk and impacts of improvements, identify improvement programs, analyze safety regulatory impacts Support safety and regulatory compliance decisions.	**Settings, Import, Crossings, Parameters**
Full investment analysis	Benefit-cost and risk analysis of programs of improvements; analyze safety, delay and user cost impacts Support resource allocation and investment decisions. Support planning process.	**Settings, Import, Crossings, Parameters, Scenario, Simulation, Results**

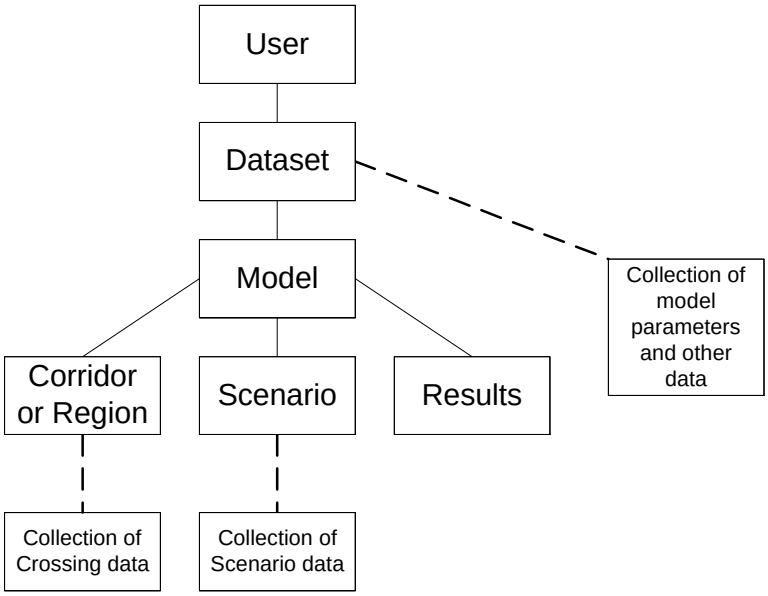
2.6 *The Data Hierarchy in* GradeDec.NET

In order to conduct analyses effectively in *GradeDec.NET* you should be familiar with its data hierarchy.

Every active session of *GradeDec.NET* has a data hierarchy that is populated with values at all times. These values correspond to the current selections of data collections that are viewable, editable and are used in *GradeDec.NET* model calculations. You navigate among different data collections by making selections on the **Settings** page, which sets the values in the data hierarchy.

The data hierarchy is shown in the figure below. A brief description of each of the nodes (boxes) in the figure follows at the end of this section.

Figure 3 Data Hierarchy in GradeDec.NET



The connecting lines in the data hierarchy figure mean that the lower node is a "child" of the parent node above it to which it is connected. When you change the value of a parent node (by making a selection in the **Settings** page) you are also re-populating the nodes in the hierarchy below the parent with values that represent data collections belonging to the newly selected parent node value.

For example, when a newly registered user logs on, the data hierarchy is populated with values like in the table below.

Table 2 Data Heirarchy at New User Logon

Data Hierarchy Node	Value
User	Your user id
Dataset	"Initial dataset"
Model	"Corridor Model"
Corridor	"South Empire"
Scenario	"Strong rail growth"
Result	"Placeholder – Corridor Model"

Suppose the user then changes the Model selection in the **Settings** page to "Regional Model". The data hierarchy will then be populated with the following values (changed values in italics):

Table 3 Data Heirarchy After Changing Model

Data Hierarchy Node	Value
User	Your user id
Dataset	"Initial dataset"
Model	*"Regional Model"*
Region	*"Montgomery, MD"*
Scenario	*"Strong highway growth"*
Result	*"Placeholder – Regional Model"*

For every parent node value there are designated default values for its child nodes, which fill the data hierarchy when the parent node value is selected. When you first register as a *GradeDec.NET* user you are assigned an "Initial Dataset" that includes data collections with sample values, and the system designates some of these data collections as defaults. You can never delete a data collection that is a default of its parent node. You can designate another data collection to be a default, and then delete the collection that was previously designated as default. You can create and delete data collections, set their defining values and set defaults from the **Settings** page.

The following are descriptions of the nodes in the data hierarchy.

2.6.1 User

When you log in to *GradeDec.NET*, a value representing your user account is set in the User node. This never changes during your session and ensures that users can only access their own data and not those of others.

2.6.2 Dataset

User data for analyses are organized in datasets in the *GradeDec.NET* database. A user may create and maintain up to 10 datasets. A dataset is a comprehensive container of data collections used in *GradeDec.NET* analyses. Note that data from different datasets cannot be combined in a single analysis. You can use datasets to preserve a baseline analysis, and then develop new analyses from copies of the baseline. You can download a dataset to your computer and restore it to the system at a later date. You can also share data with a colleague by sending him or her your downloaded dataset, which your colleague can then upload during a session with *GradeDec.NET*.

Access the options for selecting, creating, deleting, downloading and uploading datasets from the **Settings** page.

2.6.3 Model Parameters and Other Data

Each dataset contains a set of model parameters (including: crossing device effectiveness rates; model coefficients for emissions and fuel consumptions calculations; high speed rail model calculations – see the *Model Reference* for a full description). "Other data" refers to traffic time-of-day distributions and cost data for grade crossing device and supplementary safety measures.

These parameter and data are specific to the selected dataset and can be viewed and modified from the **Parameters** page.

2.6.4 Model

GradeDec.NET has both a corridor model and a regional model. The data requirements are slightly different for each model so that data collections below the Model node are specific to the selected model.

2.6.5 Corridor

A corridor has a set of defining values (these can be viewed and modified in the data grid at the bottom of the **Settings** page – see Section 2.1 Settings Page below) and refers to a collection of grade crossings along a single rail alignment. A corridor is selected in the data hierarchy only if the Model node is set to the corridor model. A dataset will contain at least one corridor and may contain as many as 50.

Create and delete corridors, and modify their defining values in the **Settings** page. After selecting a corridor, view or modify its crossings data from the **Crossings** page.

2.6.6 Region

A region has a set of defining values (these can be viewed and modified in the data grid at the bottom of the **Settings** page – see Section 2.1 Settings Page below) and refers to a collection of grade crossings in a designated region. A region is selected in the data hierarchy only if the Model node is set to the regional model. A dataset will contain at least one region and may contain as many as 50.

Create and delete regions, and modify their defining values in the **Settings** page. After selecting a region, view or modify its crossings data from the **Crossings** page.

2.6.7 Scenario

A scenario has a set of defining values (a description, start year, last year of near term, and end year) and an associated collection of scenario data. A dataset will contain at least one scenario for each of the two models, and may contain as many as 30 scenarios for each model.

Create and delete scenarios, and modify their defining values from the **Settings** page. After selecting a scenario, view and modify the scenario data from the **Scenario** page.

2.6.8 Results

GradeDec.NET sets the defining values of a results set automatically when you run a simulation. You can set the description for a results set.

Create and delete result sets, and modify its description from the **Settings** page. After selecting a results set and running a simulation, view results from the **Results** page.

2.7 Steps in Conducting a GradeDec.NET *Analysis*

2.7.1 Overview

The following table shows a sample set of steps that you would undertake to conduct each of the two analyses. The sections that follow walk you through these steps in a sample analysis.

Table 4 GradeDec.Net Modes and Sample

Mode of Use	Functional Steps	Page
Safety analysis	(Optional) Create and select a new dataset	Settings
	Create and select a new corridor (or region)	Settings
	Set values for corridor (or region)	Settings
	(Optional) Set default crossing device cost data	Defaults
	Import data from Grade Crossing Inventory	Import
	Verify and refine data, assumptions and choice of alternative	Crossings
	Calculate predicted accidents, view/print reports and charts	Crossings
Full investment analysis	Conduct all of the steps in the "Safety analysis" mode of use listed above	
	Create new results set	Settings
	Create new scenario	Settings
	Populate the scenario data with forecast data and assumptions	Scenario
	Verify and modify parameters and other data values	Parameters
	Set the simulation parameters and run the simulation	Simulation
	View results table and charts, print report	Results

2.7.2 Safety Analysis

In this example you will set up an analysis for 10 crossings in a freight rail corridor in Lincoln County, Nebraska.

2.7.2.1 (Optional) Create and select a new dataset

If you skip this step, then in subsequent steps you will be using the default or other existing dataset.

On the **Settings** page, click on the link "New" on the row with "Selected Dataset". This will transfer you to the **New Dataset** page. On this page you choose to either "Copy an

existing dataset" – in which case you select one of your datasets from the drop down list – or choose "Use sample values". Select the second option.

Enter a name for the new dataset (i.e., "Sample analyses".) and then click create. This will transfer you back to the **Settings** page. From the dataset drop down list, select the dataset that you just created.

2.7.2.2 Create and select a new corridor (or region)

This section will assume that the Corridor Model is suitable for your analysis.

Select the "Corridor Model" (or ensure that it is selected) from the drop down list

On the **Settings** page, click on the link "New" to the right of "Selected Corridor". This will transfer you to the **New Corridor** page. On this page select "Use sample values and no crossings (modify values and add crossings later)". Enter a name for the new corridor (e.g., Lincoln 1) and then click create. This will transfer you back to the **Settings** page.

Enable the "Corridor" drop down list by selecting the radio button by "Selected Corridor" (or, ensure that it is selected).

From the "Selected Corridor" drop down list, select the corridor that you just created.

2.7.2.3 Set values for corridor (or region) characteristics

In the table at the bottom of the **Settings** page you need to set the characteristics that correspond to your corridor. This includes: the number of daily trains by type, the time-of-day distribution for rail operations in the corridor, specify yes/no whether highway traffic signals in the corridor are synchronized with crossing signals.

In this example, set:

- Passenger trains to 0
- Freight trains to 108
- Switch trains to 1
- Rail TOD (time-of-day) distribution to Uniform
- Signal Synchronization to False

Set these values by clicking "Edit" in the table next to the value to modify, enter or select the suitable value, then click on "Update".

2.7.2.4 (Optional) Modify or Add Time-of-Day Traffic Distributions

If the sample time-of-day traffic distributions provided, adequately reflect the distributions of highway traffic at crossings and for rail movements in the corridor, then skip this step. Otherwise, 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 "Other data".

Add new time-of-day crossings distributions as needed.

2.7.2.5 (Optional) Set default crossing device cost data

If in your analysis of safety you have no interest in the costs of improvements, then skip this step.

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 "Other data". From the drop down list select crossing device costs. Enter alternative values to the ones listed, as needed.

2.7.2.6 Import data from Grade Crossing Inventory

From the main navigation menu, select the **Import** page. From the drop down lists on the left select:

- State: Nebraska
- County: Lincoln
- Area: Whole County

The "Selected Areas" table will show your selection. Click on the button "Create list of corridors in selected areas". The list of corridors will appear as options in the following drop down list. Select the corridor: *UP Nebr Eastern 4 Crossings*. This is the corridor with crossings in the selected area for the UP railroad, Nebraska division, Eastern subdivision. In this example there are four crossings.

You can view the National Grade Crossings Inventory data for the selected crossings at the table at the bottom of the page. You can modify the options and criteria that appear on the right side of the page (see the section 5.1 Import Page section for full description), or you can just click on "Import crossings data" to import your data to your Lincoln 1 corridor. After clicking import, your browser will automatically shift to the **Crossings** page.

2.7.2.7 Verify and refine data, assumptions and choice of alternatives

In the **Crossings** you can browse the imported data and make any modifications that you need. Also, in the "General" section you can view and modify the choices for the improvement alternative.

2.7.2.8 Calculate predicted accidents, view/print reports and charts

When you are satisfied with the data and the alternative selections, click on the calculator button on the toolbar in order to calculate the predicted accidents for each crossing and for the whole corridor. You can view the results in the "Accident Prediction" section of the page.

You can generate a report for viewing and printing by pressing the report icon button. You can view a chart of the predicted accidents by selecting the chart icon button.

2.7.3 Full Investment Analysis

For a full investment analysis, complete the steps above for the safety analysis.

2.7.3.1 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 "Lincoln UP, 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.

2.7.3.2 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: 2003, last year near term: 2007, end year: 2027) 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., 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.

2.7.3.3 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.

2.7.3.4 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.

2.7.3.5 Set the simulation parameters and run the simulation

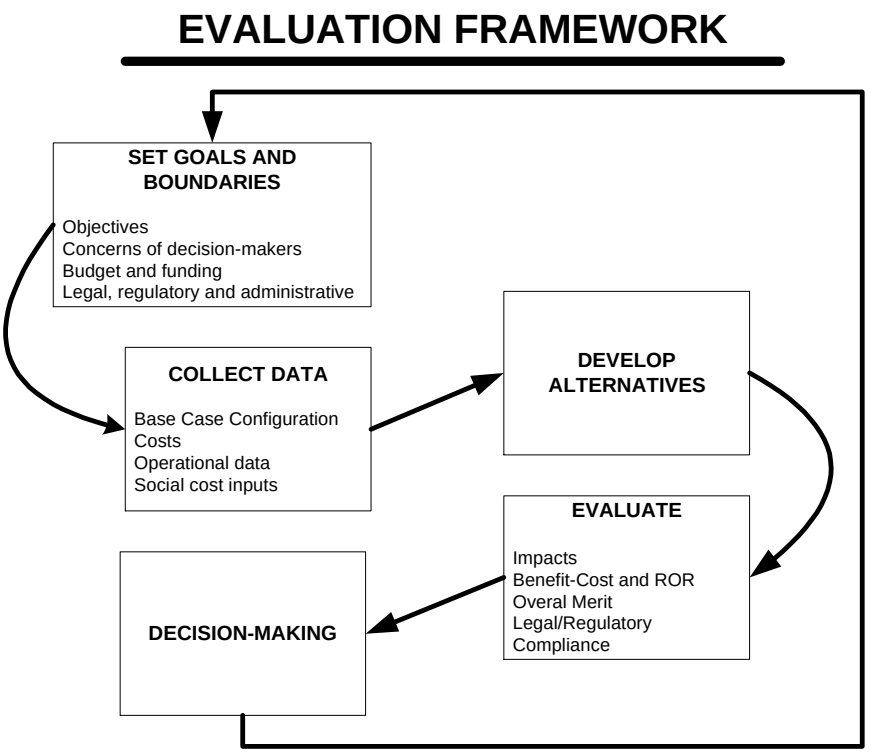
Browse to the **Simulation** page by clicking on the link on the main navigation menu. On this page set the parameters for running a risk analysis of the benefit-cost of the program of improvements defined in **Crossings**, with the probability distributions described in **Scenario**. You can run your 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.

2.7.3.6 View results table and charts, print report

On the **Results** view your analysis results on the tables and charts that this page makes available.

MODULE 3 STRATEGIC CONSIDERATIONS IN EVALUATION

3.1 Conceptual Framework for Evaluation



3.2 Objectives of Evaluation

An analysis of grade crossing improvements can have one or several objectives:

- To address acute safety issues for a crossing, corridor or region.
- To support funding allocation decisions for safety improvements.
- To support investment analysis decisions considering the additional benefits of congestion relief and emissions reduction.
- To develop a grade crossing improvement program to accommodate high speed rail initiatives.
- To evaluate compliance with new and emerging regulations that govern horn-blowing, whistle bans and grade crossing quiet zones.

3.2.1 Safety Analysis

- Estimate predicted accidents and severity for specified corridor or region and evaluate the safety impacts of improvements and mitigating measures.
- Mitigation of risk for high-speed rail corridors.

3.2.2 Analysis of Compliance with 49 CFR Parts 222 and 229

- Analyze the change in predicted accidents and severity in corridor or region with "quiet zones" and mitigating measures.

3.2.3 Non-Safety Impacts

- Non-safety benefits stem from reduced queuing at crossings. In general, these benefits (or, disbenefits) will accrue only in the event that improvements include grade separations. Grade crossing closures may result in safety benefits, but also may cause highway travelers to drive circuitous routes and queue more at other crossings.

3.2.4 Investment Analysis and Resource Allocation Decisions

- Conduct analyses supporting resource allocation decisions. Evaluate the comprehensive benefits and costs associated with improvement alternatives in a crossing or region.
- Recommend alternatives based upon objective decision criteria

3.3 Evaluation Context

- Conduct your evaluation with concerns of decision makers in mind.
- Conduct discussions with stakeholders to gauge their concerns. Listen especially to the concerns of the rail operators, affected agencies and affected citizens.
- Understand the impacts of rules, regulations and pre-existing agreements that could affect improvements and their cost- and liability-bearing implications.

MODULE 4 WORKSHOP CASE STUDY

4.1 Introduction

In this section we present a case study from which subsequent examples in the course will be drawn. The case study is a hypothetical analysis that does not correspond to an actual plan under consideration.

4.2 The Case Study

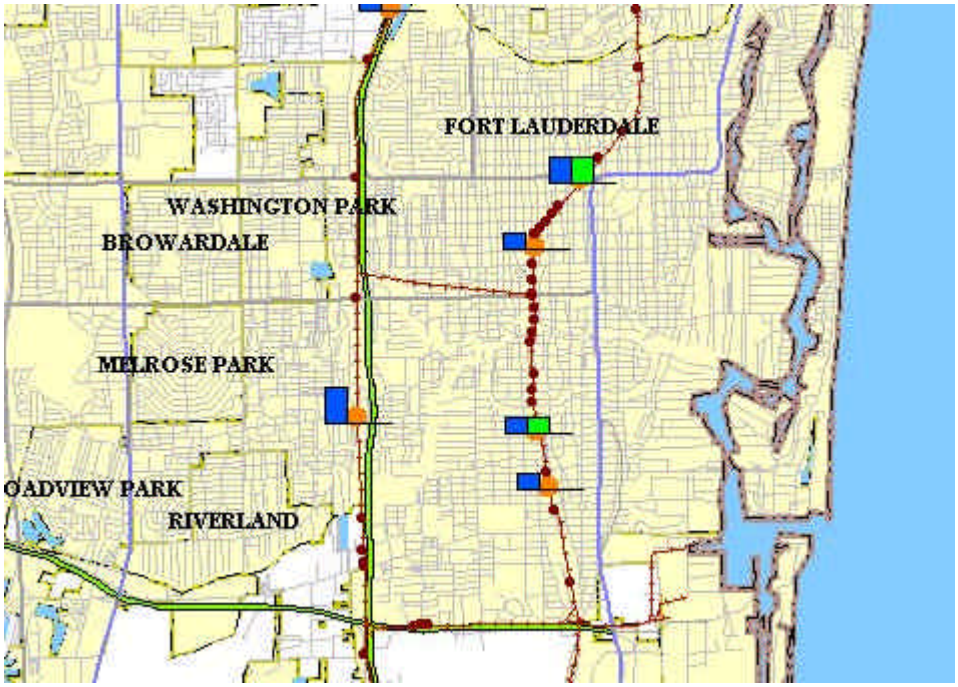
4.2.1 The Study Area

(Note: the case study has been developed for exposition purposes and use in the training workshop. While based on an actual corridor, some of the data do not reflect actual conditions in this corridor).

The corridor under evaluation is a six-mile segment of a freight line belonging to CSX in Broward County, Florida (on the map below, it is the western alignment). The corridor is situated within a dense, urban highway network and there are 5 crossings, some with highway traffic volumes between 13000 and 59000 AADT. At two of the crossings there have been accidents in the previous five years. There are 38 daily freight trains and 3 switch trains in the corridor. The time-of-day distribution of rail traffic closely resembles the AM Peak distribution.

The local jurisdiction seeks solutions for improved safety and reduced highway congestion. Initial budget guidelines include up to $5 million for rail crossing device improvements and up to $15 million of highway funding for roadway improvements including grade separations.

Figure 4 Map of the Case Study Area



4.3 The Case Study Data in GradeDec.NET

From the Settings page select the corridor labeled "CSX - South Florida

4.3.1 Customizing the Crossing Data for the Analysis

With the default options in the Import Crossing Data Form, alternate crossing improvements were assigned to each crossing that was imported. You can manually customize the alternate crossing. In addition, you should review each crossing and set data and parameters that best reflect the conditions at the crossing. This should be done in conjunction with developing alternatives (see the following section).

In particular you should review and examine the following factors:

- **Supplementary Safety Measures** – *GradeDec.NET* allows for seven supplementary safety measures that are available for gated crossings and you can include these in your crossing improvements. The seven measures are: four quadrant-gates (without detection), four-quadrant gates (with detection), four-quadrant gates with 60 foot medians, mountable curbs, barrier curbs, one-way street, and photo enforcement.
- **Time-of-day Traffic Distribution –** In the corridor definition (see the Settings Form), the user sets the time-of-day distribution for rail operations in the corridor. The time-of-day distribution of highway traffic at the crossing will determine the degree of exposure to accident risk. For each crossing, the user can set the time-of-day distribution

for each of three highway traffic segments: car, truck and bus. There are five default time-of-day distributions. However, you can enter additional distributions in the Default Values and Parameters Form. See the Reference Manual for additional discussion of the time-of-day distribution.

- **Traffic Management Measures –** An additional option to consider in the alternate case is the implementation of traffic management measures (i.e., signage, restricted turns, restrictions on trucks, periodic closure of crossings) that result in changes to the flow of highway traffic at the crossing. If the box is checked for "Measures in alternative the re-direct traffic flow at crossing", then the user needs to specify the anticipated changes to AADT and time-of-day distribution of traffic by segment (car, truck, bus) at the crossing.
- **Costs (for investment analysis only)** – The base case costs (operating and maintenance, other lifecycle) and alternate case costs (O&M, other lifecycle and capital costs) should be specified for each crossing. The user can specify default values (set in the Default Values and Parameters Form).

4.3.2 Additional Data (Required for Investment Analysis)

The data in the previous section are all entered from the Corridor Crossings Form. 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.

4.3.2.1 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 as zero.

4.3.2.2 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.

4.3.2.3 Sources of Data

Users can look to a number of sources for your data. For rail and highway operations data, the railroads and state DOTs are good, likely sources. Regarding forecast traffic growth the best source is likely to be the local MPO (for metropolitan areas). For social costs you may want to rely on the default values that come packaged with *GradeDec.NET*, unless the user has access to better sources reflecting local conditions.

The Reference Manual contains a complete description of the data requirements for *GradeDec.NET*. Appendix A contains blank and sample data sheets that you can use for collecting data for your analysis.

MODULE 5 DEVELOPMENT OF ALTERNATIVES

5.1 Introduction

In this section we review the crossing data and identify improvements in accordance with the study's objectives. For the Case Study, the objectives are: Improve safety and mitigate traffic congestion.

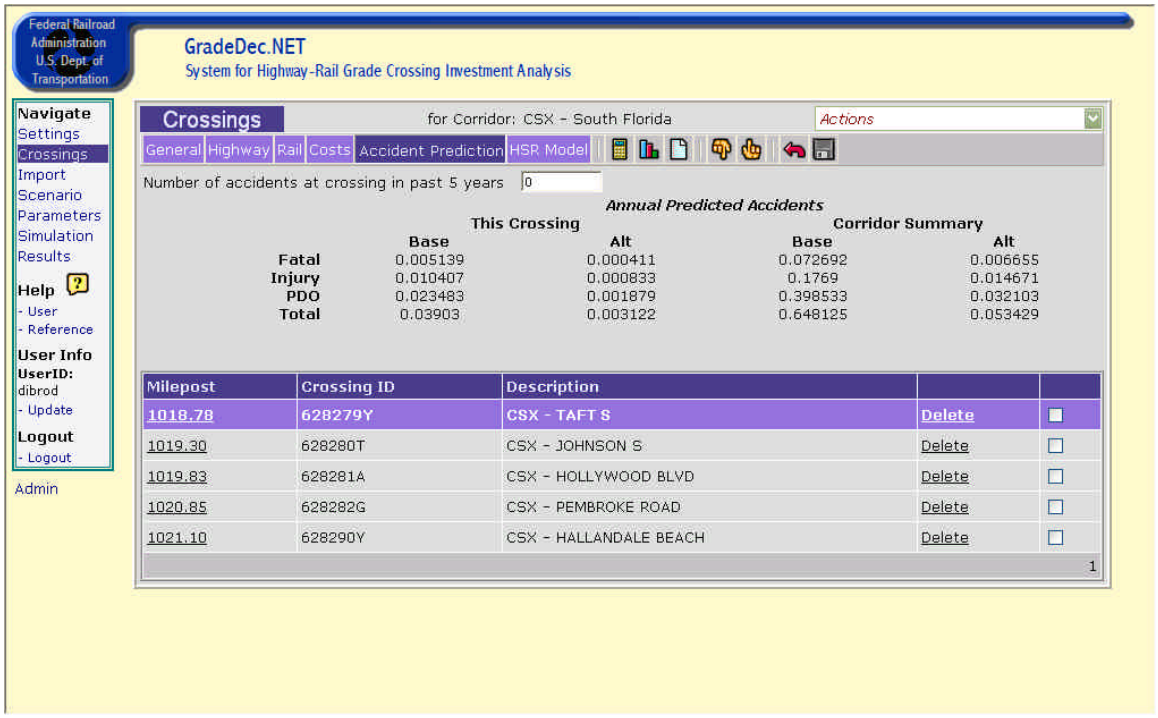
5.2 Identify Accident Risk in the Corridor

Two of the convenient features for identifying accident risk in the corridor are: 1) the corridor summary of predicted accidents and 2) the Corridor Risk Charts.

Double-click on the "Crossings" link on the navigation bar to browse to the Crossings page. On the page, click on the tab "Accident Prediction". This shows you the predicted accidents by type for the crossing and the corridor. For now we focus on the Base Case. The Alternate Case reflects the automatic assignment of improvements from the data import process – in this section we seek to refine the improvements in the alternate case.

Note that the table shows total annual predicted accidents in the corridor to be .648125 in the base case.

Figure 5 Case Study - Summary Table of Predicted Accidents

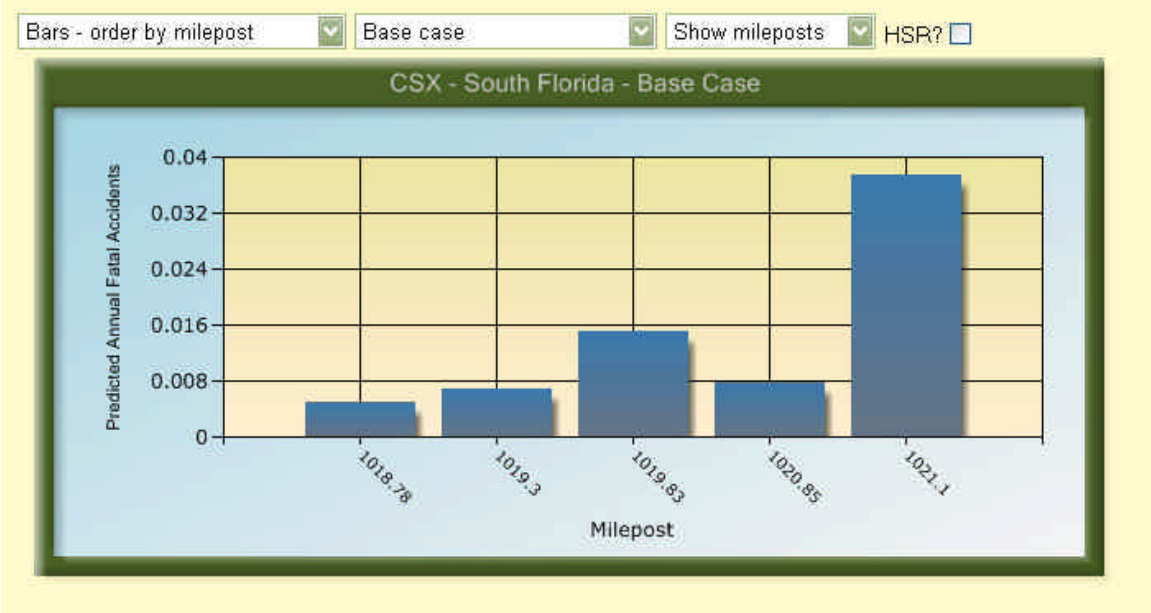


The table also shows that for the selected crossing (Milepost 1018.78) the predicted accidents in the base case is 0.03903. You can browse each crossing to find its predicted accident and pick out the higher risk crossing.

An easier way to accomplish this is using the charting feature. Click on the bar chart icon in the tool bar. The first chart you see displays crossings by predicted fatal accidents. This gives you a good initial indicator of which crossings contribute the most to accident risk in the corridor.

The chart below is the crossings for the Case Study corridor:

Figure 6 Case Study - Ranking of Accident Risk by Crossings in Corridor



By selecting options in the drop-down lists you can show the cumulative risk in the corridor and rank the crossings by predicted fatal accidents.

The chart shows us that the first two riskiest crossings contribute nearly 80% of the accident risk in the corridor. In developing alternatives, this should indicate where to devote resources to best meet your safety objective.

5.3 Summarizing Improvement Targets

For the Case Study corridor the following table shows the ranked fatal accident risk by crossing. For corridors with a large number of crossings you may want to focus only on the crossings that contribute 50 or 80 percent of the total risk in the corridor.

Table 5 Ranking of Crossings with over 50% of Accident Risk in Corridor

Rank	ID	Milepost	Predicted annual fatal accidents
1	628290Y	1021.10	0.0376
2	628281A	1019.83	0.0152
3	628282G	1020.85	0.0078
4	628280T	1019.30	0.0070
5	628279Y	1018.78	0.0051

The next table looks at crossings from the perspective of the congestion management objective. Here the crossings are ranked by AADT.

Table 6 Crossings in Case Study Corridor Ranked by AADT

Rank	ID	Milepost	AADT
1	628281A	1019.83	59000
2	628282G	1020.85	32900
3	628290Y	1021.10	29700
4	628280T	1019.30	15500
5	628279Y	1018.78	13674

All crossings in the corridor are gated.

5.4 Developing Alternatives

In developing alternatives, use the information that has been gathered in this section to screen and assign alternatives to crossings in the corridor. You should, of course, examine additional factors that are covered in a comprehensive engineering review. These factors include: roadway geometry, humped crossings, line-of-sight issues and others. For a comprehensive review of factors to consider consult the "Rail-Highway Grade Crossing Handbook".

5.4.1 Select Candidates for Closures

Candidates for closures are high-risk, low-volume crossings. Closures can adversely impact neighborhoods and businesses, especially if alternative routings are long and circuitous. Agencies considering closures should gauge the local impacts to determine the suitability of closure.

In the Case Study corridor, the low volume crossings are also the lowest risk crossings and have no accident history. No closures are recommended in the Case Study corridor.

5.4.2 Select Candidates for Grade Separation

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

5.4.3 Select Other Improvements

Other improvements in the corridor could follow a broad policy guideline. Apply the following guideline to select the other improvements in our Case Study corridor.

Upgrade crossings to four quadrant gates that meet either or both of the following criteria:

- At least one accident in the previous five year period, or
- AADT exceeds 10,000

Also, upgrade the passive crossing to lights and gates.

5.4.4 The Alternate Case

The following table shows the crossing device improvements to include in the alternate case.

Enter costs for each crossing or use the default costs. The default costs can be modified in the Parameters and Default Values Form.

Table 7 Alternatives for Crossings in Corridor

ID	Milepost	Alternative
628281A	1019.83	Grade separation
628282G	1020.85	Barrier curbs
628290Y	1021.10	4Quad - 60' medians
628280T	1019.30	Mountable curbs
628279Y	1018.78	4Quad - 60' medians

5.4.5 Creating Additional Alternatives

You can create and save more than one alternative set of improvements. Do this by returning to the Settings Form and create a new corridor, this time using the Case Study corridor as the source to copy. Give the new corridor a name like "CSX, South Florida – Alternative 2". Develop your alternative and enter the data in the crossings for the newly defined corridor.

5.5 Managing your Data and Creating Versions

GradeDec.NET automatically stores your data on the GradeDec.NET server. Data are saved automatically when you import from the National Grade Crossing Inventory and when you click on either the "Update" or "Calculate Predicted Accidents" icons.

From the Settings page you can download your dataset and save it locally as a backup (or, in case you wish to delete your data from GradeDec.NET server. You can upload your dataset for use in a subsequent session.

MODULE 6 SAFETY ANALYSIS USING THE ACCIDENT PREDICTION AND SEVERITY MODEL (APS)

6.1 Introduction

This section covers safety benefits using the Department of Transportation Accident Prediction and Severity Models. This model is one of two models in GradeDec.NET that is used for estimating safety impacts and is available for both the Corridor and Regional models. The other model, the High Speed Rail model, is available only in the Corridor Model.

In GradeDec.NET, there are two levels of safety analysis:

- The Crossing pages show predicted accidents and includes ranking charts for the base year data.
- The simulation results report on the monetized safety benefits, corridor summary and by crossings, for the full forecast time horizon. The results also report the changes between base and alternate predicted accidents for selected years.

6.2 Analysis with the Crossing Pages

In the Corridor and Regional Crossing pages, you can evaluate the predicted accidents in the base year (this is the year that precedes the "Start" year of the analysis). Select the tab "Accidents". This shows a table of the predicted accidents for the selected crossing and the corridor (or region), for each of the three accident categories (fatal, injury and property damage only). The values here are calculated based upon the data for the corridor or region and each of the individual crossings.

At the end of this section there is a demonstration of the calculation of predicted accidents using the Accident Prediction and Severity Models.

In addition to this table, by clicking on the bar chart icon on the toolbar of the Crossing page you can view summary charts that rank crossings by predicted fatal accidents in the base year.

Analysis from the Crossing page is useful in identifying those crossings with the highest risk. You can use this information to screen and develop alternatives, prior to conducting you full analysis (that covers all benefit categories and all years of the forecast time horizon).

6.3 Analysis Results

Run a simulation (see Module 9) after completing the following tasks:

- Select the alternative for each crossing and enter data as required
- Select a scenario and modify data as required
- Verify that the parameter and default values are suited to your locale

When a simulation completes the results form appears. From the results form you can view the safety benefits that comprehensively cover the time horizon of the proposed improvement program. The following results metrics track the safety benefits in GradeDec.NET. The "safety benefits" in the GradeDec.NET results is:

- The reduction in predicted accidents (base less alternate) by accident type (fatal, injury and property damage only), with each type multiplied by its social cost and summed. Total safety benefits for the corridor is summed over the crossings in each year and the present value of the safety benefit stream is reported in the "Benefits and Benefit-Cost Summary" sheet of the Results page.

Safety benefits are also tracked in the results through the following:

- The present value safety benefit is given for each individual grade crossing in the "Benefit by GCX – Safety" sheet.
- A quantity measure, the decrease in predicted fatal, injury and property damage only accidents is reported for each of three years: the start year, the last year of the near term and the last year.
- The Ranking Charts Form will show a ranking of crossings by their safety benefit (charts include bar chart, horizontal bar, first/next chart, cumulative chart and benefits with costs chart).

SAFETY BENEFITS (Module 6)
A. Predicted Accidents - Calculate Exposure Correlation Factor

		D	E	F	G	
	Determine Inputs					
		Early AM	**Late AM**	**Early PM**	**Late PM**	
6	Time-of-day distribution of trains	0.4	0.1	0.1	0.4	
7	Time-of-day distribution of autos	0.1	0.4	0.4	0.1	
8	Time-of-day distribution of trucks	0.1	0.5	0.35	0.05	
9	Time-of-day distribution of buses	0.1	0.4	0.4	0.1	
10						
11	of this, % trucks	28				
12	of this, % buses	2				
13						
14	Share of auto traffic	0.7				
15	Share of truck traffic	0.28				
16	Share of bus traffic	0.02				
17						
18	**Calculate Factor**					
19	Weighted highway time-of-day distribution	0.1	0.428	0.386	0.086	=SUMPRODUCT(D7:D9,$D$14:$D$16)
20	Weighted with time-of-day distribution	0.1558				=SUMPRODUCT(D19:G19,D6:G6)
21	Sum-of-squares, train distribution	0.34				=SUMPRODUCT(D6:G6,D6:G6)
22	Sum-of-squares, weighted highway distribution	0.349576				=SUMPRODUCT(D19:G19,D19:G19)
23	Exposure Correlation Factor	0.445683				=D20/MAX(D22,D21)

SAFETY BENEFITS (Module 6)

B. Predicted Accidents - Calculate Factors and Predicted Accidents

(Calculation for a gated crossing)

	B	C	D
2			
3			
4	**Exposure - "EI"**		
5	Average daily train operations	16	
6	AADT	4500	
7	Exposure correlation factor	0.44568277	
8	Exposure factor	43320.365	=1.35*D4*D5*D6
9	"EI"	37.1323	=((D7+0.2)/0.2)^0.2942
10			
11	**Day Through - "DT"**		
12	Total day through trains	10	
13	"DT"	1.3	=((B10+0.2)/2)^0.1781
14			
15	**Maximum Timetable Speed - "MS"**		
16	Maximum timetable speed	55	
17	"MS"	1	Fixed for gated crossings
18			
19	**Number of Tracks - "MT"**		
20	Number of tracks	2	
21	"MT"	1.35310	=EXP(0.1512*B19)
22			
23	**Number of Highway Lanes - "HL"**		
24	Number of lanes	2	
25	"HL"	1.152576649	=EXP(0.142*(B23-1))
26			
27	**Highway Pavement - "HP"**		
28	Paved=1, Not paved=2	1	
29	"HP"	1	Fixed for gated crossings
30			
31	**Constant**	0.000575	Fixed for gated crossings
32	**Adjustment factor**	0.4921	Fixed for gated crossings
33			
34	**Number of accidents - first estimate**	0.044469386	=B8*B12*B16*B20*B24*B28*B30
35	**Adjusting factor**	10.58543982	=1/(0.05+B33)
36	**Number of Accidents at crossing in 5 years**	0	
37	**Number of accidents - revised estimate**	0.030203062	=((B33*B34)+B35)/(B34+5)

SAFETY BENEFITS (Module 6)
A. Number of Accidents by Severity

	B	C	D
3	Maximum timetable speed	55	
4	**Maximum speed factor fatal accidents**	0.018321	=C3^-0.9981
5	**Maximum speed factor casualty accidents**	0.252962	=C3^-0.343
6	Number of through trains	12	
7	**Through trains factor**	0.799584	=(C6+1)^-0.0872
8	Number of switch trains	4	
9	**Switch trains factor**	1.150668	=(C8+1)^0.0872
10	If urban then 1, else 0	1	
11	**Urban factor fatal accidents**	1.429179	=EXP(C10*0.3571)
12	**Urban factor casualty accidents**	1.34447	=EXP(C10*0.296)
13	Number of tracks	2	
14	**Track factor**	1.259355	=EXP(C13*0.1153)
15	**Number of predicted accidents**	0.030203	
16			
17	**Fatal Accidents**	0.000796	=C15/(1+440.9*C4*C7*C8*C11)
18	**Casualty Accidents**	0.005142	=C15/(1+4.481*C5*C7*C8*C12)
19	**Injury Accidents**	0.004345	=C18-C17
20	**Property Damage Only Accidents**	0.025061	=C15-C17-C19

MODULE 7 SAFETY ANALYSIS USING THE HIGH SPEED RAIL MODEL

7.1 Introduction

This section covers safety benefits using the High Speed Rail Model (HSR) that was developed by the Federal Railroad Administration and the Volpe National Transportation Center. This model is only available for corridor analysis.

The HSR model was developed to assist in evaluating risk along corridors that are designated for new, higher speed rail service. These services will operate with speeds exceeding 80 mph. Two of the issues for higher speed rail that are not addressed by the Accident Prediction and Severity model are:

- Accident severity increasing with train speed, and
- Identification of casualties by mode.

The first issue is important because speed is a distinguishing characteristic of proposed new rail services and the safety and risk associated with them are basic concerns. Note that in the current version of GradeDec.NET (corresponding to the most recently published version of the HSR model), predicted accidents are not a function of the crossing's accident history (as is the case with

Identifying predicted casualties by mode is important because of the need to closely scrutinize the safety of new public carrier services.

As with the APS model, there are two levels of safety analysis for the HSR model:

- The Crossing page shows predicted accidents and includes ranking charts for the base year data.
- The simulation results report on the monetized safety benefits, corridor summary and by crossings, for the full forecast time horizon. The results also report the changes between base and alternate predicted accidents for selected years.

7.2 Analysis with the Crossing Page

In the Corridor and Regional Crossing page, you can evaluate the predicted accidents in the base year (this is the year that precedes the "Start" year of the analysis). Click on the tab in the toolbar "HSR Model". This shows a table of the predicted fatalities and injuries by mode, and, then number of accidents for the selected crossing and the corridor. The values here are calculated based upon the data for the corridor or region and each of the individual crossings.

At the end of this section there is a demonstration of the calculation of predicted accidents using the High Speed Rail Model.

Use the Summary Charts as described in the previous section.

7.3 Analysis Results

Run a simulation (see Module 9) after completing the following tasks:

- Select the alternative for each crossing and enter data as required
- Select a scenario and modify data as required
- Verify that the parameter and default values are suited to your locale

When a simulation completes the results form appears. From the results form you can view the safety benefits that comprehensively cover the time horizon of the proposed improvement program. The following results metrics track the safety benefits in GradeDec.NET. The "safety benefits" in the GradeDec.NET results is:

- The reduction in predicted fatalities, injuries and property damage (base less alternate), with each incident multiplied by its social cost and summed. Total safety benefits for the corridor is summed over the crossings in each year and the present value of the safety benefit stream is reported in the "Benefits and Benefit-Cost Summary" sheet of the Results page.

Safety benefits are also tracked in the results through the following:

- The present value safety benefit is given for each individual grade crossing in the "Benefit by GCX – Safety" sheet.
- A quantity measure, the decrease in predicted fatalities, injuries and accidents is reported for each of three years: the start year, the last year of the near term and the last year.
- The ranking charts will show a ranking of crossings by their safety benefit (charts include bar chart and cumulative chart, and benefits with costs chart).

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.

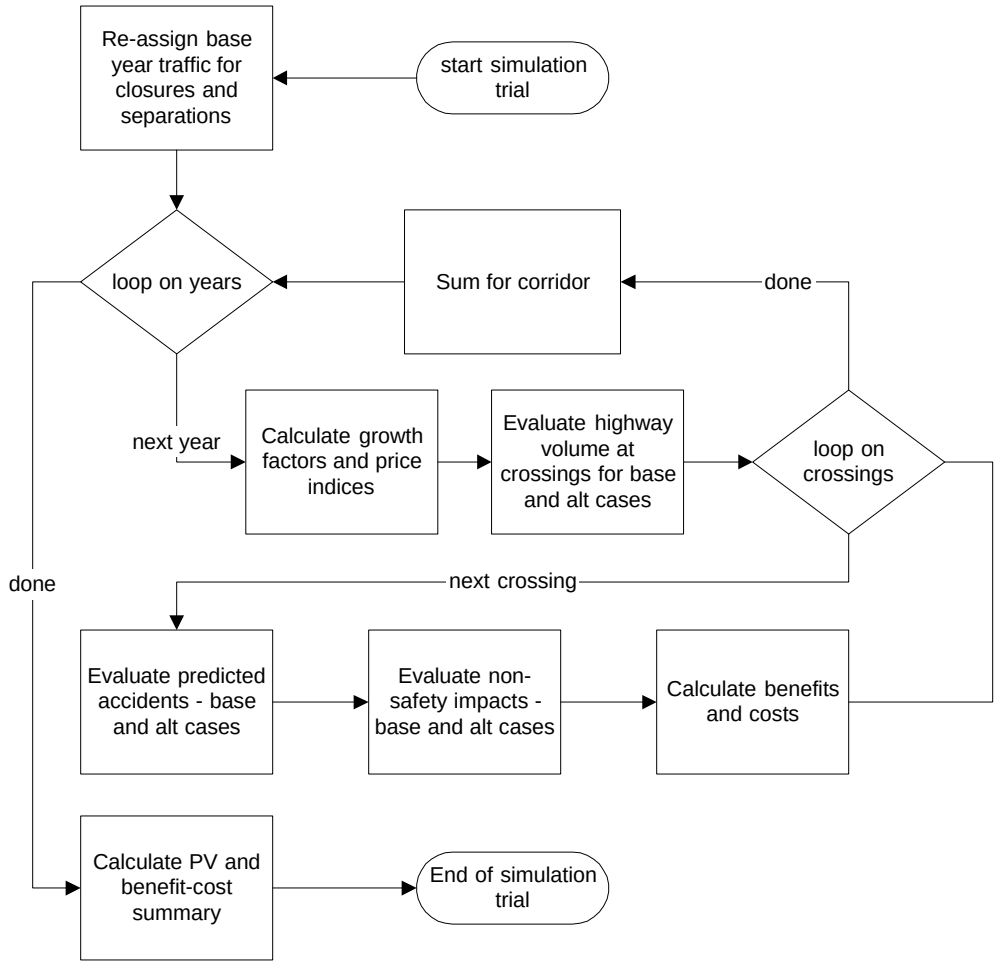


Figure 7 Investment Analysis Logic Flow in GradeDec.NET

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.

Measure	Threshold Value - "Passes" the Benefit-Cost Test	Meaning
NPV Net Present Value	NPV>0	The Net Present Value is the present value of benefits less the costs. 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 "bang for the buck" – it tells 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

Table 8 Summary Measures and their Meanings

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 corridor improvements meet objectives.

The main 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. For goods that are bought and sold in competitive markets, social costs are equal to the market price. However, 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 the actual dollars that are expended in some given year. 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 refer to expenditures in any year in terms of the prices from a specified year (in *GradeDec.NET*, the base year is used). 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.

In *GradeDec.NET*, all of the dollar values of the inputs (scenario data and grade crossing cross data) are constant dollar values. *GradeDec.NET* includes two price indices in the scenario data – one for general price inflation and one for fuel price inflation. Since fuel prices may diverge significantly from the general price level, these two indices are used to calculate the constant dollar value of fuel and oil cost savings (due to reduced vehicle time-in-queue at crossings) in future years. For the use of these price indices, see the *GradeDec.NET* Reference Manual, Equation 23.

8.8 The Discount Rate

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

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

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

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

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

Table 9 Example of Discounting and Present Value

SAFETY BENEFITS FOR CORRIDOR

	Constant Dollars	Present Value
2002	450.00	428.57
2003	459.00	416.33

2004	468.18	404.43
2005	477.54	392.88
2006	487.09	381.65
2007	496.84	370.75
2008	506.77	360.15
2009	516.91	349.86
2010	527.25	339.87
2011	537.79	330.16
2012	548.55	320.72
2013	559.52	311.56
2014	570.71	302.66
2015	582.12	294.01

PV for Analysis Period ======>	
	5003.60

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

8.9 Costs and Benefits

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

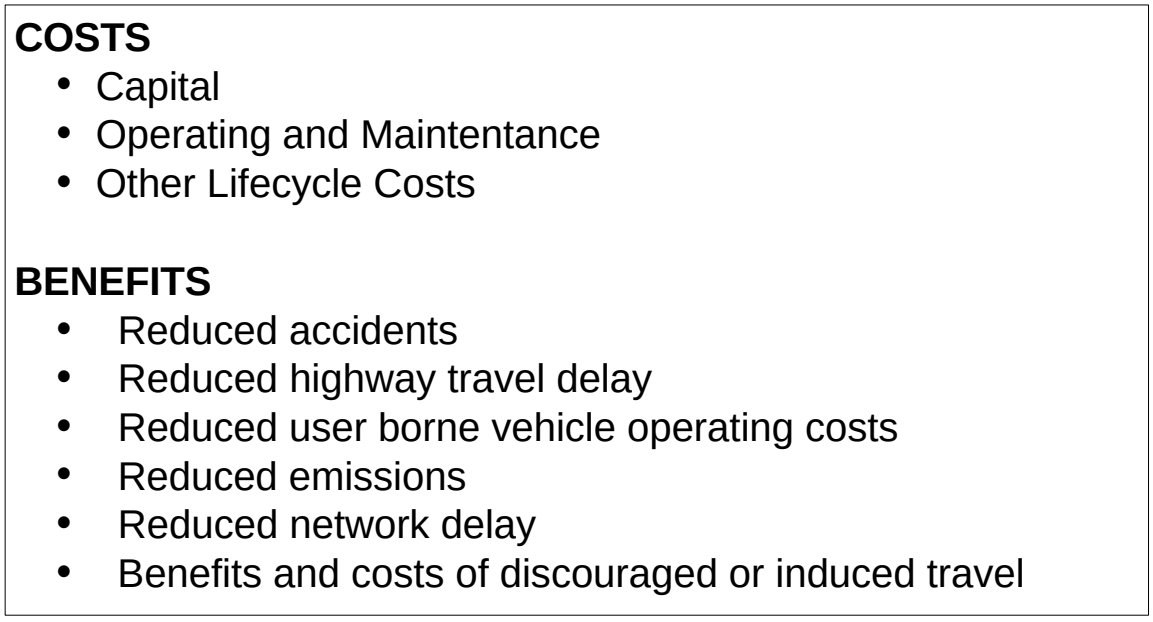


Figure 8 Benefits and Costs in GradeDec.NET

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 10 Quantity Metrics for Safety by Model

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

8.11.2 Other Benefits

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

8.11.2.1 Time Savings

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

In GradeDec.NET changes in vehicle delay occur when queue lengths change. This can happen 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.

8.11.2.5 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.

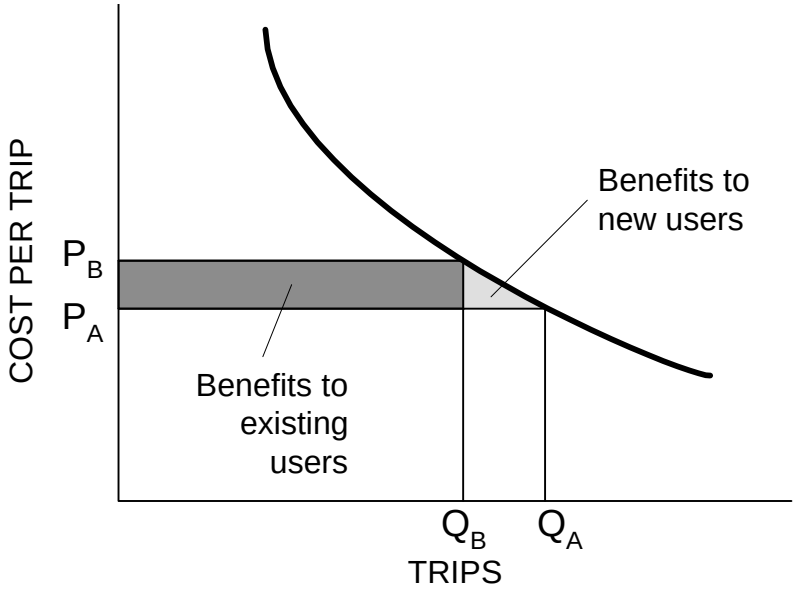


Figure 9 Consumer Surplus and Benefits to New and Existing Users

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 \$0.10[1] 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.

[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.

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

Table 11 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%

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:

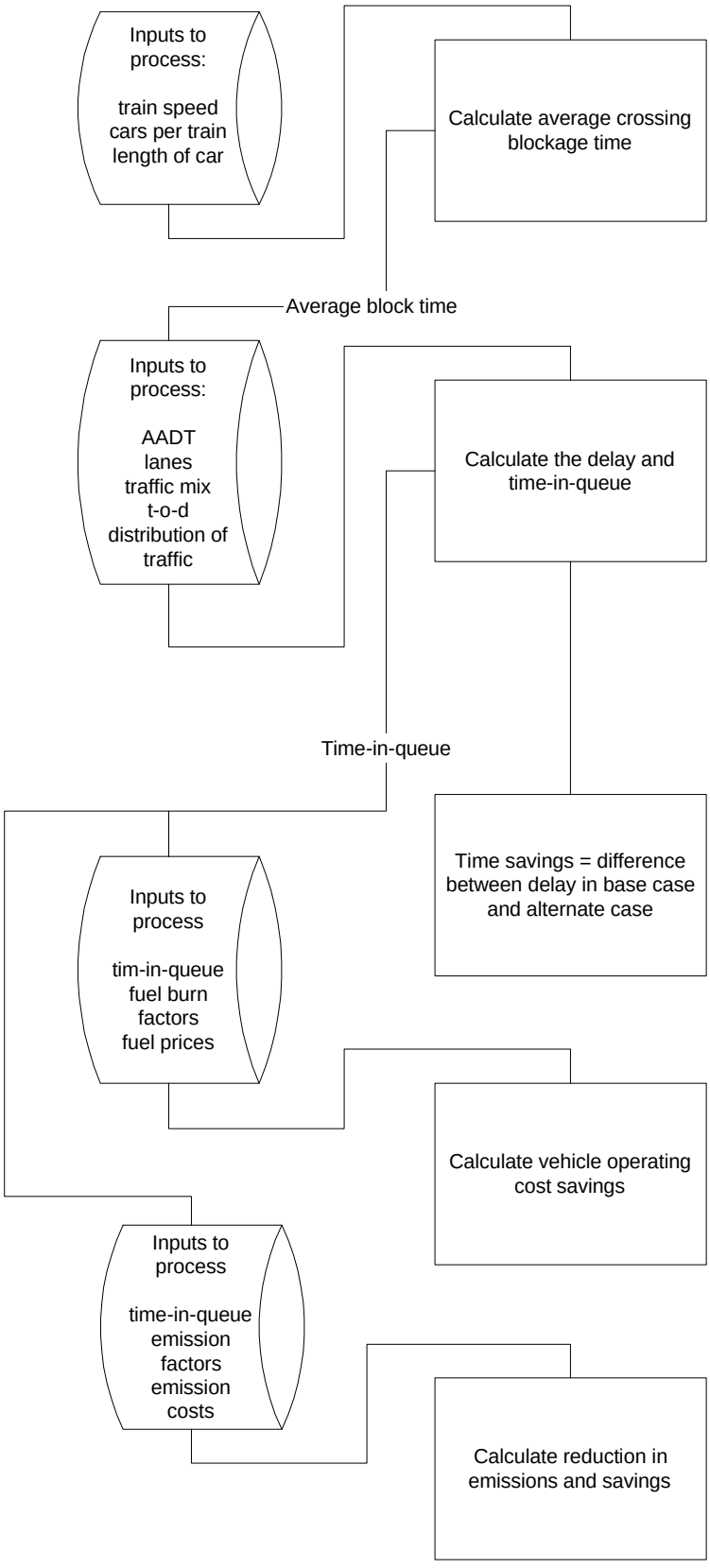
- Travel time savings
- Vehicle operating cost savings
- Emissions reductions
- Network delay savings

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 12 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[2] 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[3] 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*, Federal Highway Administration, Department of Transportation, 1985.
[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.

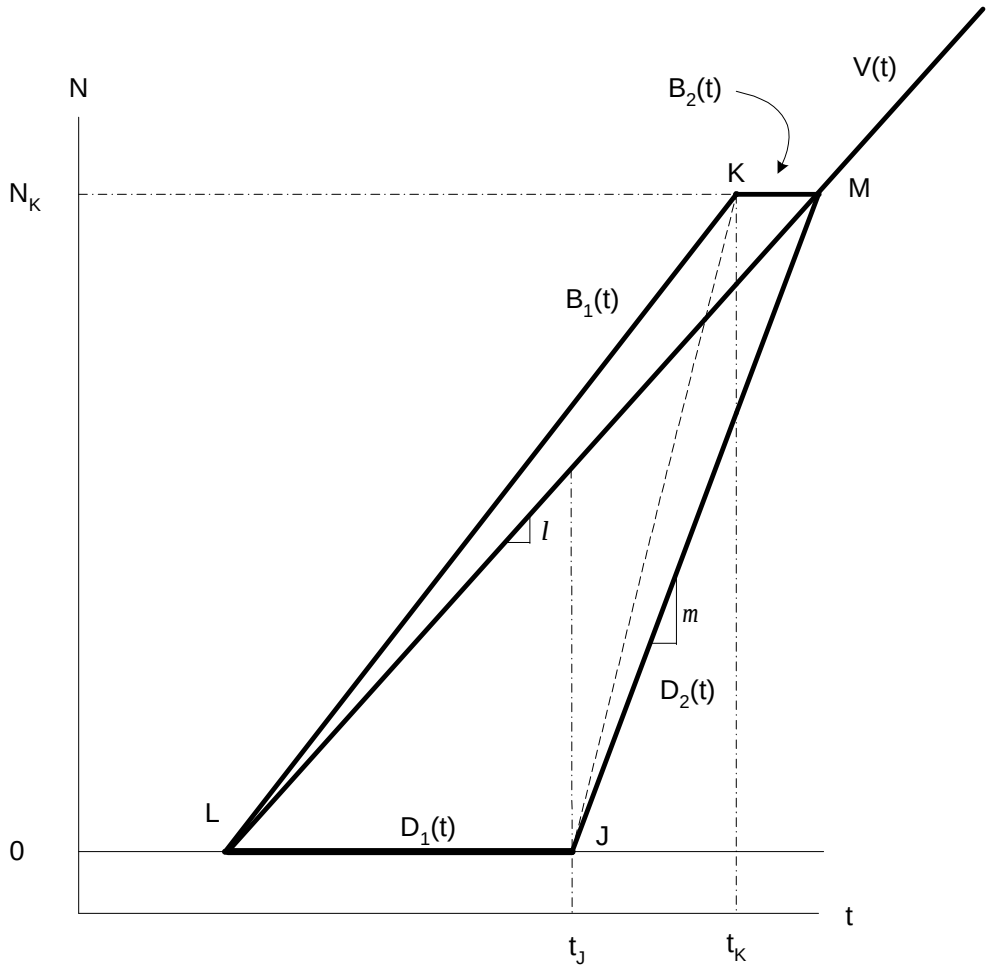


Figure 10 Model for calculating delay and time-in-queue

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 = $\frac{2774.5\ vehicles}{2\ lanes * 3600\frac{\text{sec}}{hour} * 6\frac{hours}{period}}$ = .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 = veh-hours Bus Delay=0.000427*2.8 = 20 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) Traffic density at speed 0 (see B4) Average block time (see B2) Arrival rate (see B6) Dispersal rate (see B4) Affected vehicles (see B7) Highway vehicles in period (see B5) of this, Auto Truck Bus Trains in period (see B3) Number of lanes (see B1)	45 mph 0.05 veh/ft 68.282 sec 0.0642 veh/sec/lane 0.5 veh/sec 5.032 vehicles 2774.5 1767 852.5 155 2.8 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 feet / second	
C3 Calculate the time-in-queue per lane	$\textit{Time-in-queue} = \textit{affected vehicles} * (\textit{block time} + \left(D * \frac{(\textit{affected vehicles} + 1)}{2}\right))$ $\textit{where } D = \left(\frac{1}{\textit{disperal rate}} - \frac{1}{d(\textit{back of queue})/dt}\right)$ =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 = 799 veh-hours Bus Delay=0.004415*2.8 = 2361 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	Auto Fuel .00969 Oil .00063 Truck Fuel .01841 Oil .00134 Bus Fuel .02067 Oil .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** HC 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 CO 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 NOx 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

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.

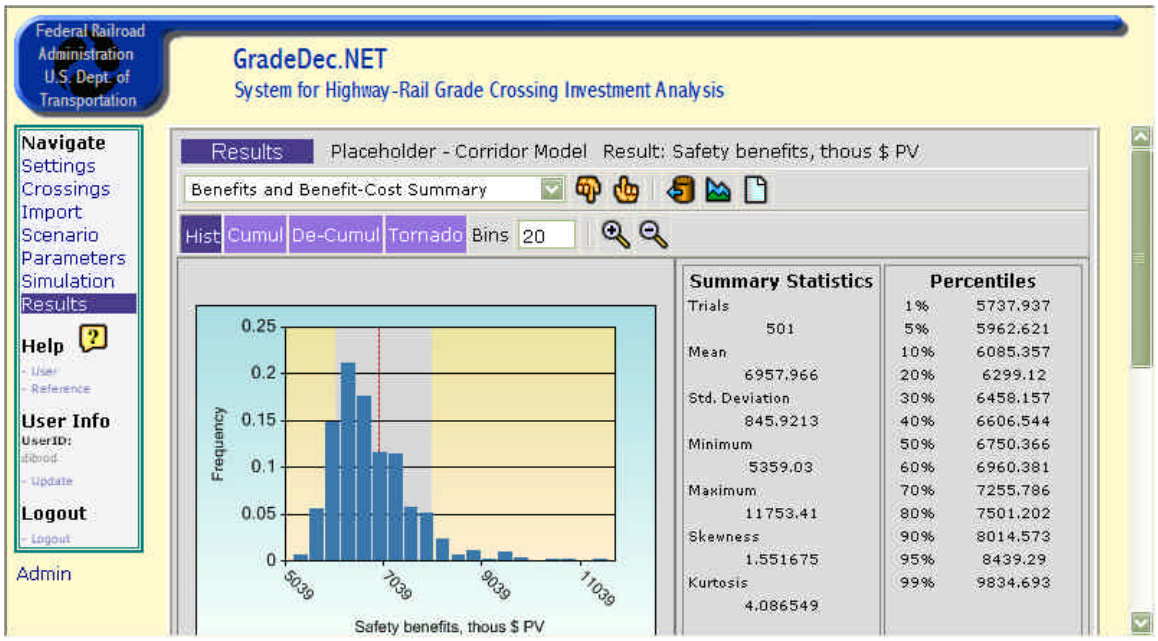
10.3 Running a Risk Analysis

Follow these steps to run a risk analysis:

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

10.4 Reading the Results

Figure 11 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 $6.958 million. 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 $6.085 million and $8.015 million.
- There is a 90 percent probability that the result will exceed $6.085 million.
- There is a 10 percent probability that the result will exceed $8.015 million.

10.5 Comparing Alternatives with Risk Analysis

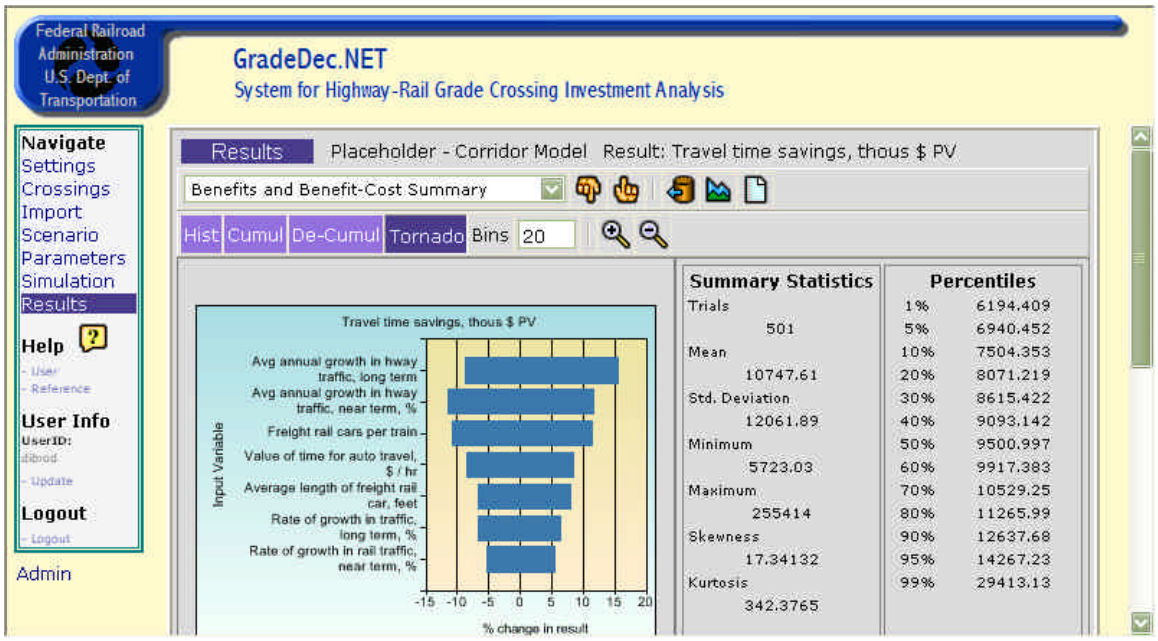
Risk matters. If the anticipated NPV of two alternatives are roughly equal, yet one has much larger downside risk, then the less risk alternative is preferred. The risk analysis of alternatives will typically offer trade-offs between the risk and yield associated with alternatives. In the figure below 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 12 Tornado Chart



MODULE 11 CAPITAL PROGRAMMING

11.1 Introduction

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 edit the value on the Settings page with Corridor (or Region) selected, “Allow capital programming?”, and change it to True. When this parameter is set to True, the format of the Crossings page will include the following changes:

- For each crossing there will be drop-down lists for Phase I improvements and Phase II improvements.
- For each crossing, in each Phase there will be a drop-down list designating the year of implementation (i.e., the year before the first year of operation with the improvement).
- In the toolbar there will be a number designating year. This is the year in the alternate case for which predicted accidents will be evaluated in the Accidents and HSR Model sections of the Corridor page. Note that while predicted accidents reflect the crossing devices in place in the alternative for the specified year, the traffic volumes and numbers of trains reflect base year conditions.

- In order to view the improved crossings in the corridor by year, there is a "Capital programming report" that is accessed from the Actions menu on the Corridor page.

Table 13 Alternatives for Crossings in Corridor (Phased)

ID	Milepost	Phase I Improvement	Year to Implement Phase I	Phase II Improvement	Year to Implement Phase II
628281A	1019.83	Barrier curbs	Base	Grade separation	8
628282G	1020.85	Barrier curbs	Base	(no Phase II)	-
628290Y	1021.10	4Quad - 60' medians	3	(no Phase II)	-
628280T	1019.30	Mountable curbs	3	(no Phase II)	-
628279Y	1018.78	4Quad - 60' medians	3	(no Phase II)	-

In the above plan, the crossings at mileposts 1019.83 and 1020.85 will be improved in the base year (first year of operation with the improvement is year 1). In year 3, the other three crossings will be improved. In year 8, the program specifies to implement the Phase II improvement that grade separates the crossing at milepost 1019.83.

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 14 Annual Capital Program for Crossing 628281A

Year	Main Device	Capital Cost (thous. $)	Supp Safety Device	Capital Cost (thous. $)	Total Capital Cost (thous. $)
Base	Gates	0	None	50	50
1	Gates	0	Barrier Curbs	0	0
2	Gates	0	Barrier Curbs	0	0
3	Gates	0	Barrier Curbs	0	0
4	Gates	0	Barrier Curbs	0	0
5	Gates	0	Barrier Curbs	0	0
6	Gates	0	Barrier Curbs	0	0
7	Gates	0	Barrier Curbs	0	0
8	Gates	5000	Barrier Curbs	0	5000
9	Separation	0	None	0	0
10	Separation	0	None	0	0

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

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APPENDIX 1 DATA SHEETS

GRADEDEC 2000 CORRIDOR DATA SHEET

Corridor Name _____

Number of Passenger Trains _____

Number of Freight Trains _____

Number of Switch Trains _____

Rail operations time-of-day distribution _____

Signal synchronization _____

Technology factor _____

For reference:

TIME OF DAY DISTRIBUTIONS				
NAME	**EARLY AM**	**LATE AM**	**EARLY PM**	**LATE PM**
Uniform	0.25	0.25	0.25	0.25
AM Peak	0.1	0.5	0.35	0.05
PM Peak	0.05	0.35	0.5	0.1
Day Flat	0.1	0.4	0.4	0.1
Night Flat	0.4	0.1	0.1	0.4

GRADEDEC 2000 CROSSING DATA SHEET **Corridor:** _____

Crossing ID: _____ **(inventory number)** **Milepost:** _____ **(Mile.hundreths)**

General		
Paved/Unpaved?		Yes/No
Urban/Rural?		Yes/No
Crossing description (street)		Street or intersection name
Base device type (see table)		Device type
Base supplementary device (gated crossings only - see table)		Device type
Alternate device type (see table)		Device type
Alternate supplementary device (gated crossings only - see table)		Device type
Highway		
Number of lanes		Number
Distance to closest intersection		Miles (i.e., 0.1 =one-tenth of a mile)
Total AADT in base year		Vehicles per day
Of AADT, percent trucks		Percent
Of trucks, percent truck-trailers		Percent
Of AADT, percent buses		Percent
Auto traffic time-of-day distribution (see table)		Distribution type
Truck traffic time-of-day distribution (see table)		Distribution type
Bus traffic time-of-day distribution (see table)		Distribution type
Alternate Case Traffic Management Measures		
In alternate case , are there measures to manage traffic at crossings?		Yes/No
if no then leave rest of this section blank		
With alternate measures - Total AADT in base year		Vehicles per day
With alternate measures - of AADT, percent trucks		Percent
With alternate measures - of trucks, percent truck-trailers		Percent
With alternate measures - of AADT, percent buses		Percent
With alternate measures - Auto traffic t-o-d distribution (see table)		Distribution type
With alternate measures - Truck traffic t-o-d distribution (see table)		Distribution type
With alternate measures - Bus traffic t-o-d distribution (see table)		Distribution type
Rail Operations		
Number of tracks at crossing (total)		Number
Maximum timetable train speed		Mph
Average passenger train speed		Mph
Average freight train speed		Mph
Average switch train speed		Mph
Accident History		
Number of accidents at crossing in preceeding 5-year period		Number
Cost Data		
Base case annual maintenance cost		Thous. dollars
Base case annualized lifecycle cost		Thous. dollars
Alternate case capital cost		Thous. dollars
Alternate case annual maintenance cost		Thous. dollars
Alternate case annualized lifecycle cost		Thous. dollars
If there are supplementary measures in the base or alternate case		
Base case annual maintenance cost - supplementary measures		Thous. dollars
Base case annualized lifecycle cost - supplementary measures		Thous. dollars
Alternate case capital cost - supplementary measures		Thous. dollars
Alternate case annual maintenance cost - supplementary measures		Thous. dollars
Alternate case annualized lifecycle cost - supplementary measures		Thous. dollars

SEE ATTACHED TABLES FOR DEVICE TYPES AND TIME OF DAY DISTRIBUTIONS

GRADE CROSSING DEVICE TYPES	TYPE CODE
Passive	**P**
Lights	**L**
Gates	**G**
Closure	**C**
Grade separation	**GS**
New technology	**NT**

SUPPLEMENTARY MEASURE TYPES	TYPE CODE
4-quadrant gates - no detection	**4QND**
4-quadrant gates - with detection	**4QDE**
4-quadrant gates - with 60' medians	**4QME**
Mountable curbs	**MC**
One-way street	**OWS**
Photo enforcement	**PE**

TIME OF DAY DISTRIBUTIONS				
NAME	**EARLY AM**	**LATE AM**	**EARLY PM**	**LATE PM**
Uniform	0.25	0.25	0.25	0.25
AM Peak	0.1	0.5	0.35	0.05
PM Peak	0.05	0.35	0.5	0.1
Day Flat	0.1	0.4	0.4	0.1
Night Flat	0.4	0.1	0.1	0.4

GRADEDEC 2000 REGION DATA SHEET

Region Name _____

Percent benefits due to closure _____

Technology factor _____

GRADEDEC 2000 SCENARIO DATA SHEET **SCENARIO NAME:** _____

SPECIFY DATA FOR SELECTED DISTRIBUTION TYPE

Start Year: _____ Last year near term: _____ End year: _____

	DISTRIBUTION TYPE										
	Fixed Value	Skewed Bell			Normal		Triangle			Uniform	
		10% Lower	Median	10% Upper	Mean	StDev	Min	Mode	Max	Min	Max
Rate of growth in rail traffic, near term, %											
Rate of growth in traffic, long term, %											
Freight rail cars per train											
Passenger rail cars per train											
Switch cars per train											
Average length of freight rail car, feet											
Average length of passenger train rail car, feet											
Average length of switch train car, feet											
Avg annual growth in hway traffic, near term, %											
Avg annual growth in hway traffic, long term											
Average auto vehicle occupancy											
Avg bus vehicle occupancy											
Annualization factor											
Elasticity of auto AADT w.r.t. generalized cost of travel											
Average % of auto trip costs that are GCX-related, percent											
Discount rate, %											
Cost of a fatal accident, thous $											
Cost of an injury accident, thous $											
Cost of a property damage only accident, thous $											
Cost per fatality (for HSR Model), thous $											
Cost per injury (for HSR model), thous $											
Average out-of-pocket cost per accident (for HSR model), thous $											
Value of time for auto travel, $ / hr											
Value of truck driver time, $ / hr											
Cost of HC emissions, thous $ / ton											
Cost of NOX emissions, thous $ / ton											
Cost of CO emissions, thous $ /ton											
Base year gasoline fuel cost, $ / gal											
Base year diesel fuel cost, $ / gal											
Base year oil cost, $ / qt											
% additional local benefits, %											
Fuel price inflation, year 2002, %											
Fuel price inflation, year 2003, %											
Fuel price inflation, year 2004, %											

GRADEDEC 2000 SCENARIO DATA SHEET **SCENARIO NAME:** _____

SPECIFY DATA FOR SELECTED DISTRIBUTION TYPE

Start Year: _____ Last year near term: _____ End year: _____

	DISTRIBUTION TYPE										
	Fixed Value	Skewed Bell			Normal		Triangle			Uniform	
		10% Lower	Median	10% Upper	Mean	StDev	Min	Mode	Max	Min	Max
Fuel price inflation, year 2005, %											
Fuel price inflation, year 2006, %											
Fuel price inflation, year 2007, %											
Fuel price inflation, year 2008, %											
Fuel price inflation, year 2009, %											
Fuel price inflation, year 2010, %											
Fuel price inflation, year 2011, %											
Fuel price inflation, year 2012, %											
Fuel price inflation, year 2013, %											
Fuel price inflation, year 2014, %											
Fuel price inflation, year 2015, %											
Fuel price inflation, year 2016, %											
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Fuel price inflation, year 2026, %											
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Fuel price inflation, year 2029, %											
Fuel price inflation, year 2030, %											
Fuel price inflation, year 2031, %											
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Fuel price inflation, year 2039, %											
General price inflation, year 2002, %											
General price inflation, year 2003, %											
General price inflation, year 2004, %											
General price inflation, year 2005, %											
General price inflation, year 2006, %											
General price inflation, year 2007, %											
General price inflation, year 2008, %											
General price inflation, year 2009, %											
General price inflation, year 2010, %											

GRADEDEC 2000 SCENARIO DATA SHEET **SCENARIO NAME:** _____

SPECIFY DATA FOR SELECTED DISTRIBUTION TYPE

Start Year: _____ Last year near term: _____ End year: _____

	DISTRIBUTION TYPE										
	Fixed Value	Skewed Bell			Normal		Triangle			Uniform	
		10% Lower	Median	10% Upper	Mean	StDev	Min	Mode	Max	Min	Max
General price inflation, year 2011, %											
General price inflation, year 2012, %											
General price inflation, year 2013, %											
General price inflation, year 2014, %											
General price inflation, year 2015, %											
General price inflation, year 2016, %											
General price inflation, year 2017, %											
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General price inflation, year 2026, %											
General price inflation, year 2027, %											
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General price inflation, year 2029, %											
General price inflation, year 2030, %											
General price inflation, year 2031, %											
General price inflation, year 2032, %											
General price inflation, year 2033, %											
General price inflation, year 2034, %											
General price inflation, year 2035, %											
General price inflation, year 2036, %											
General price inflation, year 2037, %											
General price inflation, year 2038, %											
General price inflation, year 2039, %											

GRADEDEC 2000 MODEL PARAMETER AND DEFAULT VALUES

DEFAULT COSTS FOR GRADE CROSSINGS (THOUS. DOLLARS)

Type ID	Type	Capital Costs	O&M Costs	Other Lifecycle costs
1	Passive			
2	Flashing lights			
3	Lights and gates			
4	Closure			
5	Grade separation			
6	New Technology			

DEFAULT COSTS FOR SUPPLEMENTARY MEASURES (THOUS. DOLLARS)

Type ID	Type	Capital Costs	O&M Costs	Other Lifecycle costs
1	4 quadrant - no detection			
2	4 quadrant - with detection			
3	4 quadrant - with 60' median			
4	Mountable curbs			
5	Barrier curbs			
6	One-way street			
7	Photo Enforcement			

VEHICLE EMISSIONS COEFFICIENTS - IDLING RATES, GRAMS PER MINUTE

Vehicle ID	Vehicle Type	Hydrocarbons	Carbon Monoxide	Nitrogen Oxides
1	Cars			
2	Buses			
3	Trucks			

FUEL BURN RATES WHILE IDLING

Vehicle ID	Vehicle Type	Fuel (gallons / minute)	Oil (quarts/minute)
1	Cars		
2	Buses		
3	Trucks		

EFFECTIVENESS MULTIPLIERS

Type ID	Type	<=10 trains per day, single track	<=10 trains per day, multi-track	> 10 trains per day, single track	> 10 trains per day, single track
1	Passive to lights				
2	Passive to gates				
3	Lights to gates				

EFFECTIVENESS MULITPLIERS FOR SUPPLEMENTARY MEASURES

Type ID	Type	Effectiveness
1	4 quadrant - no detection	
2	4 quadrant - with detection	
3	4 quadrant - with 60' median	
4	Mountable curbs	
5	Barrier curbs	
6	One-way street	
7	Photo Enforcement	

HSR - BREAKOUT OF ACCIDENTS BY TYPE

	Train strikes highway vehicle	Highway vehicle strikes train

HSR - MODEL COEFFICIENTS FOR TRAIN STRIKES HIGHWAY VEHICLE ACCIDENTS

Type ID	Type	Auto	Truck	Trailer
1	Highway fatalities			
2	Train fatalities			
3	% accidents with severe derailments			
4	added severity with sev. Derailments			
5	Speeds of maximum severity (highway)			
6	Lights to gates			

HSR - MODEL COEFFICIENTS FOR TRAIN STRIKES HIGHWAY VEHICLE ACCIDENTS

Type ID	Type	Auto	Truck	Trailer
1	Highway fatalities			
2	Train fatalities			