

Life-Cycle Cost Analysis

RealCost

USER MANUAL



U.S. Department of Transportation
Federal Highway Administration

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Introduction

Purpose of the User Manual

This manual provides basic instruction for using RealCost, software that was developed by the Federal Highway Administration (FHWA) to support the application of life-cycle cost analysis (LCCA) in the pavement project-level decisionmaking process. The manual provides direction on how to enter the data required to perform LCCA and how to incorporate the software's outputs into project-level decisionmaking. The User Manual is addressed to pavement designers and design decisionmakers who wish to use LCCA and RealCost to compare the cost-effectiveness of alternative project proposals. Following this introduction, the manual contains instructions on installing RealCost, descriptions of its features, and directions on using the software in performing pavement decisionmaking analyses.

About LCCA

LCCA is an engineering economic analysis tool useful in comparing the relative economic merits of competing construction or rehabilitation design alternatives for a single project. By considering all of the relevant costs—agency and user—incurring during the projected service life of an asset, this analytical process helps transportation officials to identify the lowest cost option. Additionally, LCCA introduces a structured methodology that quantifies the effects of agency activities on transportation users and provides a means to balance those effects with the construction, rehabilitation, and preservation needs of the system itself.

LCCA can be used in making certain transportation investment decisions. Specifically, when a project has been selected for implementation, LCCA will assist in determining the lowest cost way to accomplish the performance objectives of the project. LCCA cannot, however, be used to compare the economic merits of projects that provide different levels of benefit for highway users, such as comparing a road-widening project with a rehabilitation of existing roadway lanes. A cost-centric analysis, LCCA accounts only for cost differences between project alternatives and is applicable only to decisions where benefits are equal for all alternatives being considered.

In brief, the LCCA process begins with the development of alternatives to accomplish the structural and performance objectives for a project. The analyst then defines the schedule of initial and future activities involved in implementing each of the project design alternatives. Next, costs of these activities are estimated. Best practice LCCA calls for including not only direct agency expenditures (for example, construction or maintenance activities), but also costs to the project's users that result from agency work zone operations.

The predicted schedule of activities and their associated agency and user costs form the projected life-cycle cost stream for each design alternative. Using an economic technique known as discounting, these costs are converted into present dollars and then summed for each alternative. The analyst can then determine which alternative is the most cost-effective.

Life-Cycle Cost Analysis Steps

1. Establish design alternatives
2. Determine activity timing
3. Estimate costs (agency and user)
4. Compute life-cycle costs
5. Analyze the results

Two different computational approaches can be used in LCCA, deterministic and probabilistic. The methods differ in the way they address the variability associated with the LCCA input values.

In the deterministic approach, the analyst assigns each LCCA input variable a fixed, discrete value. The analyst determines the value most likely to occur for each parameter, usually basing the determination on historical evidence or professional judgment. Collectively, the input values are used to compute a single life-cycle cost estimate for the alternative under consideration.

Traditionally, applications of LCCA have been deterministic. A deterministic life-cycle cost computation is straightforward and can be conducted manually with a calculator or automatically with a spreadsheet. Sensitivity analyses may be conducted to test input assumptions by varying one input, holding other inputs constant, and determining the effect of the variation on the outputs. The deterministic approach, however, fails to address simultaneous variation in multiple inputs, and it also fails to convey the degree of uncertainty associated with the life-cycle cost estimates.

Probabilistic LCCA inputs are described by probability functions that convey both the range of likely inputs and the likelihood of their occurrence. Probabilistic LCCA also allows for the simultaneous computation of differing assumptions for many different variables. Outputs, like inputs, express the likelihood that a particular life-cycle cost will actually occur. Because of the dramatic increases in computer processing capabilities of the last two decades, the process of probabilistic analysis has become more practical. Simulating and accounting for simultaneous changes in LCCA input parameters can now be accomplished easily and quickly.

About RealCost

RealCost was created with two distinct purposes. The first is to provide an instructional tool for pavement design decisionmakers who want to learn about LCCA. The software allows the student of LCCA to investigate the effects of cost, service life, and economic inputs on life-cycle cost. For this purpose, a graphical user interface (GUI) was designed to make the software easy to use. The second purpose is to provide an actual tool for pavement designers, which they can use to incorporate life-cycle costs into their pavement investment decisions.

RealCost automates FHWA's LCCA methodology as it applies to pavements. The software calculates life-cycle values for both agency and user costs associated with construction and rehabilitation. The software can perform both deterministic and probabilistic modeling of pavement LCCA problems. Outputs are provided in tabular and graphic format. Additionally, RealCost supports deterministic sensitivity analyses and probabilistic risk analyses.

While RealCost compares two alternatives at a time, it has been designed to give the pavement engineer the ability to compare an unlimited number of alternatives. By saving the input files of all alternatives being considered, the analyst can compare any number of alternatives. Furthermore, the software has been designed so that a basic understanding of the LCCA process is sufficient to operate the software.

The software automates FHWA's work zone user cost calculation method. This method for calculating user costs compares traffic demand to roadway capacity on an hour-by-hour basis, revealing the resulting traffic conditions. The method is computation intensive and ideally suited to a spreadsheet application.

The software does not calculate agency costs or service lives for individual construction or rehabilitation activities. These values must be input by the analyst and should reflect the construction and rehabilitation practices of the agency.

While RealCost compares the agency and user life-cycle costs of alternatives, its analysis outputs alone do not identify which alternative is the best choice for implementing a project. The lowest life-cycle cost option may not be implemented when other considerations such as risk, available budgets, and political and environmental concerns are taken into account. As with any economic tool, LCCA provides critical information to the overall decision-making process, but not the answer itself.

How RealCost Works

RealCost consists of a Microsoft Excel 2000 worksheet with additional Visual Basic for Applications (VBA) code. The VBA code provides the ability to perform Monte Carlo simulation in the analysis, and it is used to construct the GUI. The software has two interface mechanisms, the form and the worksheet.

Form Interface

The form GUI is the primary means to work with the software. Each form has four components, and some data entry forms have a fifth function that supports probability analysis.

Form Name	Name used in RealCost to refer to the form.
Data Entry Field	Area for data input.
Data Field Description	Phrase used to identify the data entry field.
Command Button	GUI device that triggers a command or series of commands to the software.
Probability Button	Specific type of command button that opens a form where probabilistic inputs can be assigned.

The components of a form are identified in Figure 1.

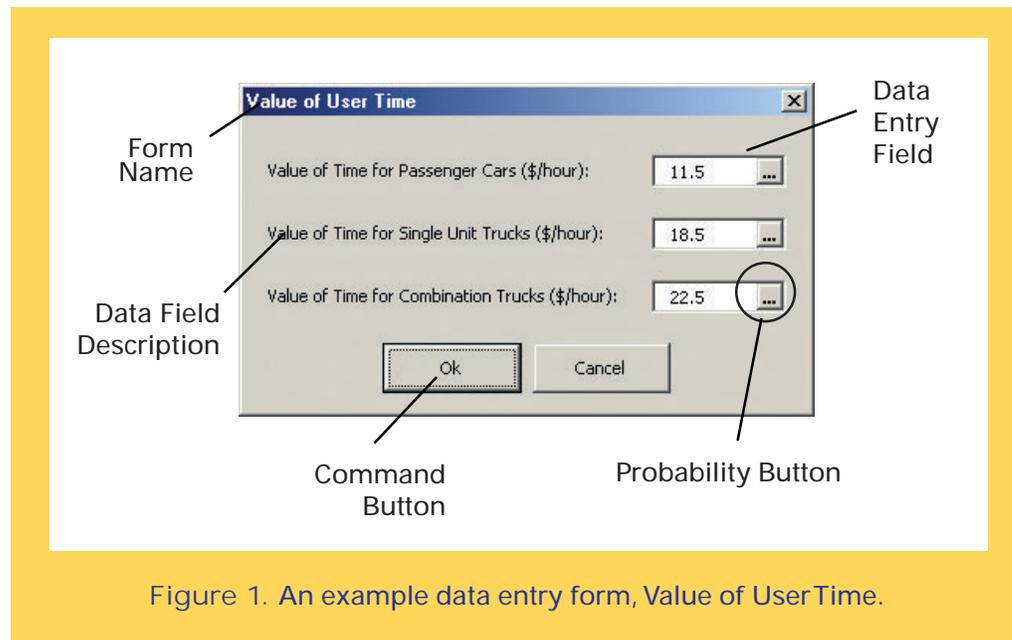


Figure 1. An example data entry form, Value of UserTime.

Worksheet Interface

The worksheet interface is available when the form interface is closed. Data may be entered in the appropriate worksheet cells, which carry the same labels as the corresponding fields on the form interface. While the form GUI is the primary means of interacting with the software, all of the entered data is stored in Excel 2000 worksheet cells. Data entered into a form's data entry field are automatically transferred to corresponding cells in the appropriate underlying worksheet. For example, the worksheet extract in Figure 2 contains the data entered in the Value of User Time form shown in Figure 1. Data can be entered directly in the worksheets as well, but the form interface is required for some functions.

All outputs (e.g., calculation results, analysis results) are also written to worksheets. These outputs are accessed just as data inputs are.

Note: Excel 2000 files are composed of one or more worksheets. The collection of worksheets in a file is termed a workbook.



1. Economic Variables	
Value of Time for Passenger Cars (\$/hour)	\$11.50
Value of Time for Single Unit Trucks (\$/hour)	\$18.50
Value of Time for Combination Trucks (\$/hour)	\$22.50

Figure 2. An example worksheet extract, Value of User Time.

Suggested Reading

RealCost follows FHWA's best practice LCCA methodology, which is fully documented in FHWA's Technical Bulletin, *Life-Cycle Cost Analysis in Pavement Design* (FHWA SA-98-079). The Technical Bulletin presents a formal treatment of LCCA methodology, the economic basis of discounting future expenditures, and probability, and it recommends input values. The Bulletin is also the source of RealCost's default values. LCCA best practices are outlined in FHWA's *Life-Cycle Cost Analysis Primer* (FHWA IF-02-047).

Although this User Manual provides a working knowledge of RealCost, these related documents, particularly the Technical Bulletin, can provide a more in-depth understanding of the process that is helpful for including LCCA in the pavement decisionmaking process. The Primer and the Technical Bulletin are available in electronic format on the FHWA's LCCA Web page (www.fhwa.dot.gov/infrastructure/asstmgmt/lcca.htm) or by request from FHWA's Office of Asset Management. Additional references and contact information are listed at the end of this manual.

The Basics

Installation
Startup, Navigation, and Exiting
RealCost Switchboard Functions

Installation

System Requirements

RealCost is designed to run in Microsoft Excel 2000 and is not supported by versions earlier than Excel 2000. In addition, up-to-date service packs for Windows and Office 2000 (or Excel 2000) are essential to run the software.

Following are the recommended minimum system requirements for using RealCost:

- Excel 2000 with current service pack loaded
- Windows 98 (or higher) with current service pack loaded
- Printer (RealCost requires a printer driver in order to function properly)
- 350 MHz Pentium processor
- 128 MB RAM
- 100 MB HD available

TIP

Current Microsoft service packs are required to run RealCost successfully. Check your computer online at <http://v4.windowsupdate.microsoft.com/en/default.asp> or by running Windows Update on the Start Menu.

Installing RealCost

To install RealCost, run the file, “Setup.exe.” It is recommended that you allow the installation program to install the software to its preselected location.

Setup.exe contains an Excel 2000 workbook file named “RealCost.xls” and several dynamic link library (DLL) files. A DLL is a collection of small programs that can be called upon when needed by the LCCA worksheet. The DLL provides instructions to the LCCA worksheet to carry out particular functions.

Startup, Navigation, and Exiting

Before First Use

Because Excel 2000 treats the VBA code in RealCost much like a macro, Excel must be set to allow macros to run before RealCost can be used. As shown in Figure 3, before starting the software, open Excel 2000, check the macro security settings, and ensure that they are adjusted to allow macros to run. The security settings are accessed from the Excel 2000 menu bar.

On the Excel 2000 Menu bar:

Tools >> Macro >> Security...

... choose Medium Security and exit from Excel 2000.

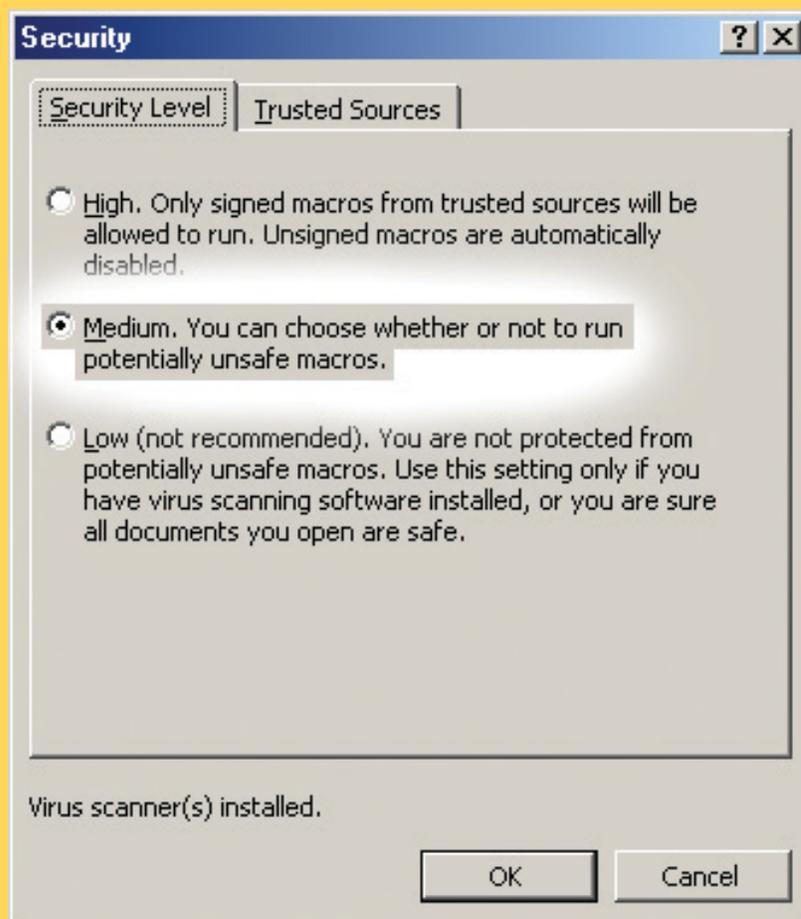


Figure 3. Excel 2000 macro security form.

Starting RealCost

RealCost is initiated from the Windows Start Menu (see Figure 4).

Start >> Programs >> RealCost >> RealCost 2.1

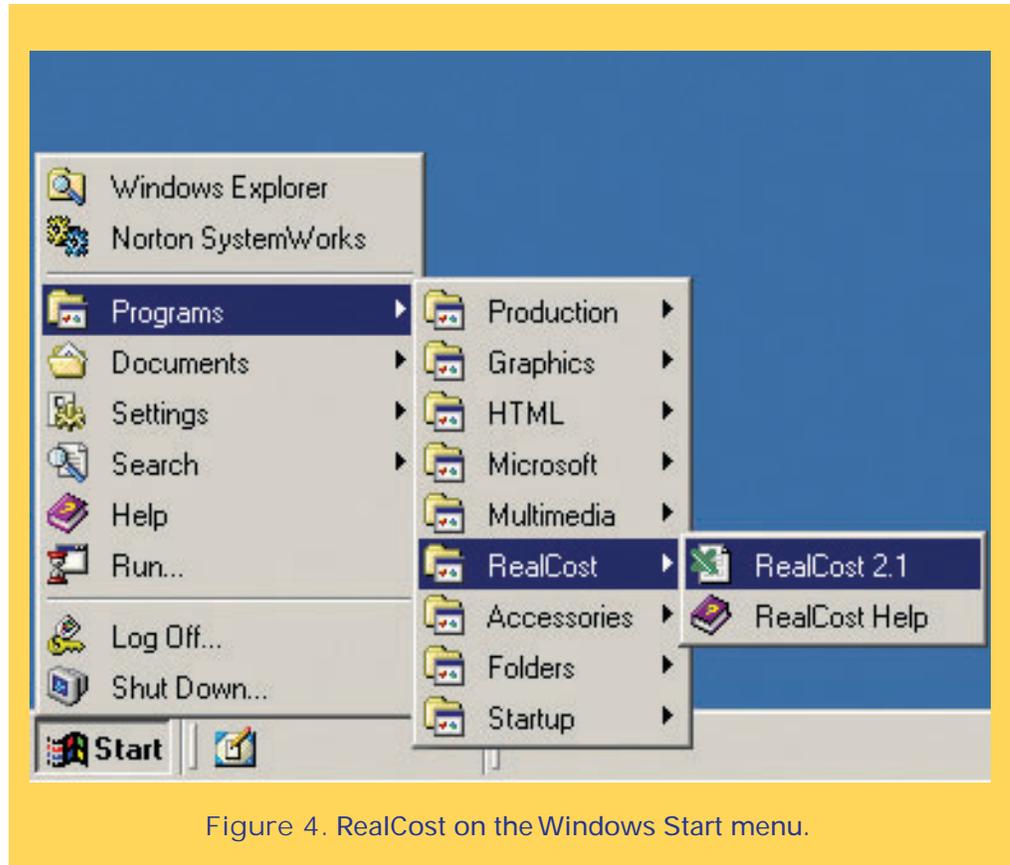


Figure 4. RealCost on the Windows Start menu.

This command opens Excel 2000 as well as the file “RealCost.xls.” Alternatively, a Windows desktop shortcut link to RealCost.xls can be created to open the software.

If the security setting for Excel 2000 is “medium,” Excel presents the option to enable macros, as shown in Figure 5, each time RealCost is opened. To run RealCost, choose “Enable Macros.” If the macro options form does not appear, check that the Excel macro setting is “medium” (see “Before First Use,” page 13).

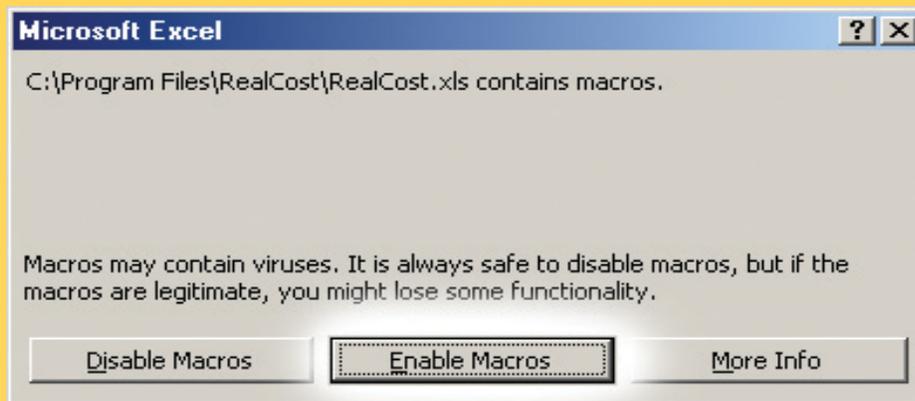


Figure 5. Excel 2000 macro options form shown at each RealCost startup.

Moving Between the Switchboard and Worksheets

RealCost opens to the main menu form, called the “Switchboard,” a form superimposed on an Excel worksheet. The Switchboard buttons, shown in Figure 6, provide access to almost all of the functionality of the software—data entry, analysis, reports, and utilities. These capabilities are discussed in more detail in “RealCost Switchboard Functions” (page 18). Basic navigation and the Administrative Functions are described here.

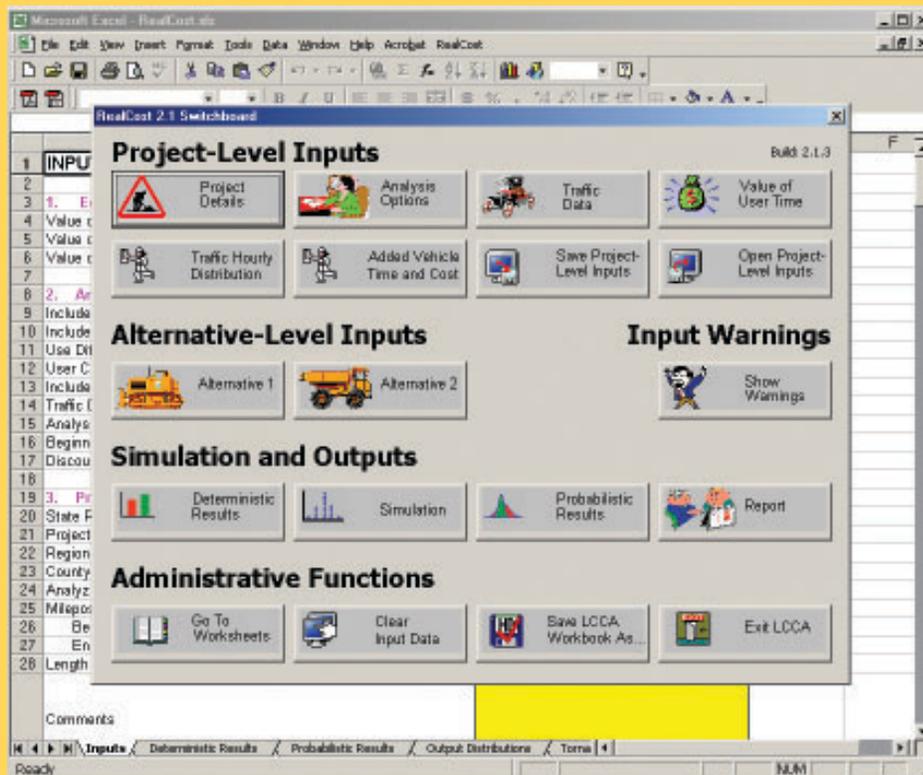


Figure 6. The RealCost Switchboard.

When the Switchboard is active, the underlying Excel 2000 worksheets, which capture the data entered through the Switchboard forms, and the Excel menu bar are not accessible. If you want to minimize RealCost, you will need to switch to worksheet mode using either of two options:

- Use the Go to Worksheets button in the Administrative Functions section of the Switchboard to display and select from a list of worksheets.
- Use the Switchboard's "x" button (located in the upper right-hand corner of the form) to close the Switchboard.

To reopen the Switchboard from a worksheet, use the drop-down RealCost menu in the Excel 2000 menu bar, as shown in Figure 7.

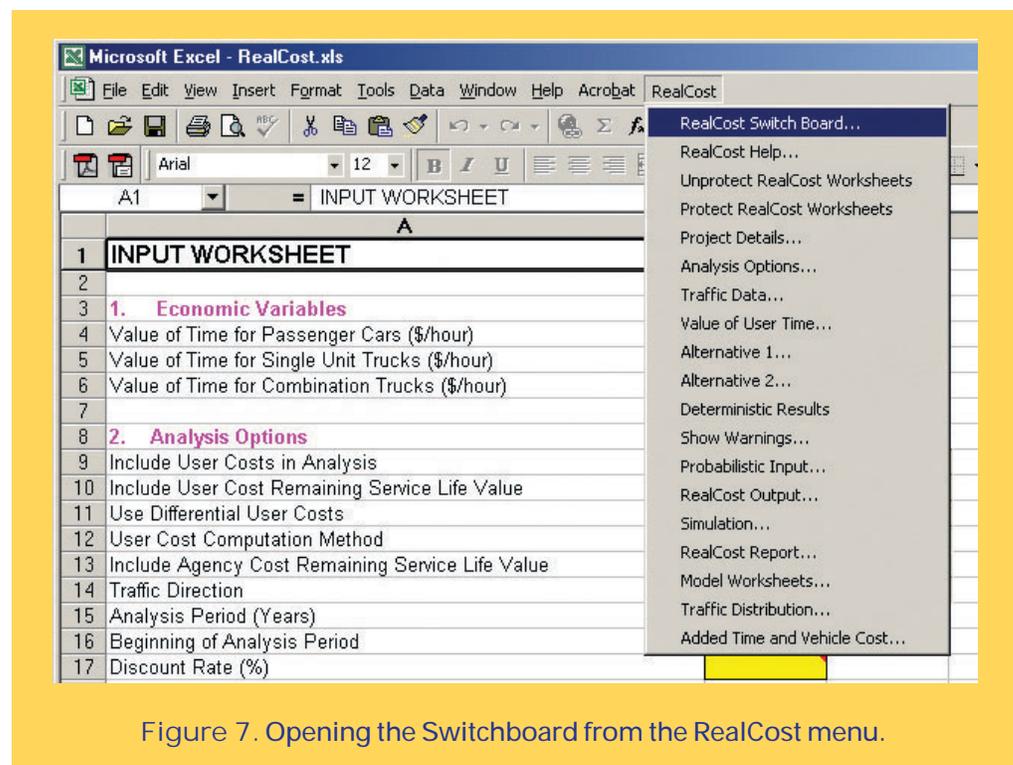


Figure 7. Opening the Switchboard from the RealCost menu.

Some users may prefer to work in worksheet mode, and others via the Switchboard forms. Most functions can be performed in either mode, with these

exceptions: Creating a new probabilistic input or an LCCA output requires working in worksheet mode and using the respective options on the RealCost drop-down menu. Saving alternative data input files requires using the Switchboard.

TIP

Alternative data input files can only be saved through the Switchboard.

Should the RealCost 2000 menu disappear from the Excel menu bar (this may occur if you open another application or file while RealCost is running), you can retrieve the menu through the Excel 2000 drop-down Tools menu:

On the Excel 2000 menu bar:

*Tools >> Macro >> Macros >> AddLCCAMenu
(i.e., run that specific macro)*

Administrative Functions on the Switchboard

Commands in the Administrative Functions section of the Switchboard execute important housekeeping tasks: moving to the worksheets, clearing data, saving the entire Excel 2000 file (the “workbook”), and exiting the software (see Figure 8). These functions are similar to ordinary Windows functions, such as file saving and file opening, but are performed within RealCost.



Figure 8. Administrative Functions in RealCost.

Administrative Functions

Go to Worksheets Allows direct access to specific worksheets within the workbook. To close the Switchboard and choose from a list of individual worksheets, use the Go to Worksheets button. You can also access the worksheet that is currently active by clicking on the “X” in the upper right-hand corner of the Switchboard.

Clear Input Data Deletes *all* project-level data, alternative-level data, and computation outputs. Creates a “clean slate.”

Save Workbook As Saves the entire Excel 2000 workbook, including both inputs and results worksheets. Saving a workbook is the only way to save analysis results. An analysis file is often 8 MB or greater, and saving can take several seconds. Saving a workbook can also be performed from the Excel menu bar.

Analysis results can only be saved by saving the RealCost workbook. This file should be saved with a descriptive name.

TIP

Exit LCCA Closes RealCost. The software will ask you whether the file should be saved. The exit command on the Excel File menu and the RealCost menu present the same save options. As noted above, to save the analysis results it is necessary to save the entire Excel 2000 workbook. An analysis file is often 8 MB or larger, and saving can take several seconds. However, data input can be saved via *.LCC (project-level inputs) and *.LCA (alternative-level inputs) files without saving the entire workbook.

Closing RealCost

Saving and Exiting via the Switchboard

RealCost can be closed by using the Exit LCCA button in the Administrative Functions section of the Switchboard. When exiting, however, it is necessary to save the entire workbook to retain analysis results. The Exit LCCA button prompts you to save the workbook. The Save RealCost button can be used to save the workbook at any time. Both Exit and Save buttons prompt for a file name and location.

Saving and Exiting via Worksheets

To save a workbook and exit while in worksheet mode, it is advisable to use the “save as” option on the Excel 2000 menu before closing. Saving under an appropriate name will preserve the analysis results. If you save your work in the RealCost workbook, it will be necessary to clear the data when you begin to analyze another project.

RealCost Switchboard Functions

The Switchboard, shown in Figure 9, has five sections:

Project-Level Inputs	Data that will be used for all alternatives. These data document the project characteristics, define the common benefits that all alternatives will provide, and specify the common values (e.g., discount rate) that will be applied with each alternative.
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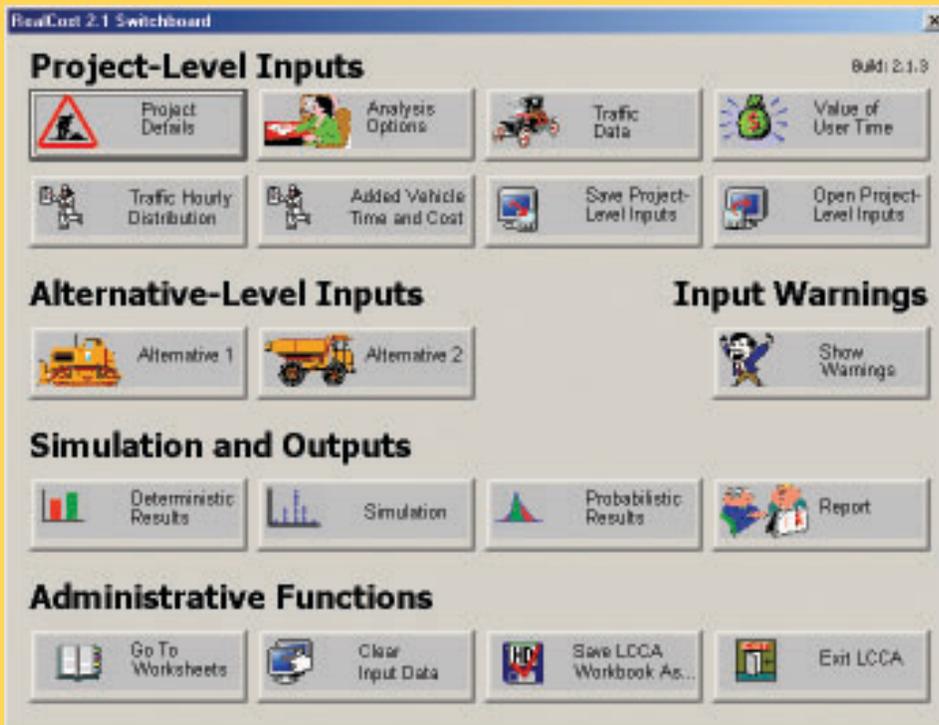


Figure 9. The five sections of the RealCost Switchboard.

Alternative-Level Inputs	Data that will be used for a specific design alternative. These data differentiate alternatives from each other.
Input Warnings	List of missing or potentially erroneous data. The software identifies and displays a list of potential problems before the analysis is run.
Simulation and Output	Forms used to view deterministic results, run Monte Carlo simulation of probabilistic inputs, view probabilistic results, and print reports.
Administrative Functions	Forms used to save, clear, and retrieve data and to close the Switchboard or RealCost.

The 19 Switchboard buttons and their functions are listed in Table 1, page 20. Inputting data and using RealCost features in the LCCA process are discussed in the following section.

Table 1. RealCost forms and command buttons and their functions.

Switchboard Button/Form	Functionality
Project-Level Inputs	Data that will be used for all project alternatives. These data define the characteristics, values, and benefits that are common to the project alternatives being compared.
Project Details	Stores descriptive data that identify the project.
Analysis Options	Project-level data that apply to all alternatives being considered (e.g., analysis period, discount rate, costing options).
Traffic Data	Existing normal operations traffic data: amount, vehicle types, capacity.
Value of User Time	Hourly value of user time for three vehicle types.
Traffic Hourly Distribution	Distribution of annual average daily traffic throughout the day, with separate data fields for rural and urban traffic patterns.
Added Vehicle Time and Cost	Cost and time to slow or stop by vehicle type. Provides a cost escalation mechanism.
Save Project-Level Inputs	Saves the project-level data to an *.LCC file.
Open Project-Level Inputs	Retrieves project-level data from an *.LCC file.
Alternative-Level Inputs	Data that will be used for a specific design alternative. These data differentiate alternatives from each other.
Alternative 1 or 2	All alternative-level data: alternative-level agency activity cost, service life, duration, and work zone data. Each alternative includes commands to save and recall individual alternative data sets.
Input Warnings	Identifies missing or potentially erroneous data.
Show Warnings	Identifies suspect data values and errors due to missing or out-of-bounds data. Warnings are displayed on the Simulation Warnings worksheet.
Simulation and Outputs	Forms used to view deterministic results, run Monte Carlo simulation of probabilistic inputs, and view probabilistic results.
Deterministic Results	Calculates and displays deterministic results based upon either deterministic or most likely values of probabilistic inputs.
Simulation	Performs simulation with probabilistic inputs.
Probabilistic Results	Displays probabilistic results. Allows access to probabilistic results worksheets.
Report	Produces a printable report that shows inputs and results.
Administrative Functions	Forms used to save data, retrieve data, and close the Switchboard or RealCost.
Go to Worksheets	Provides direct access to Excel 2000 worksheets.
Clear Input Data	Clears project-level inputs, alternative-level inputs, and results from the software. Creates a "clean slate."
Save LCCA Workbook As...	Saves the entire Excel 2000 workbook under a user-specified name.
Exit LCCA	Closes RealCost.

Using RealCost in Life-Cycle Cost Analysis

Entering, Saving, and Loading Data
Simulation and Output

Entering, Saving, and Loading Data

RealCost data needs are identical to the data needs of the FHWA’s best practice LCCA process. When the data have been entered, the software performs the required calculations to produce life-cycle costs. Furthermore, the software permits the analyst to quickly consider natural modifications to the data that result from analysis of earlier LCCA iterations. The LCCA steps and their corresponding data entry and output forms are listed in Table 2.

Table 2. Life-cycle cost analysis (LCCA) steps and corresponding RealCost forms.

FHWA LCCA Steps	RealCost Data Entry and Output Forms
1. Establish Design Alternatives	Project Details Analysis Options Traffic Data Traffic Hourly Distribution Value of User Time Added Vehicle Time and Cost
2. Determine Activity Timing	Alternative 1 and Alternative 2
3. Estimate Agency and User Costs	Alternative 1 and Alternative 2
4. Compute Life-Cycle Costs	Deterministic Results Simulation
5. Analyze the Results	Deterministic Results Probabilistic Results

Project-Level Versus Alternative-Level Data

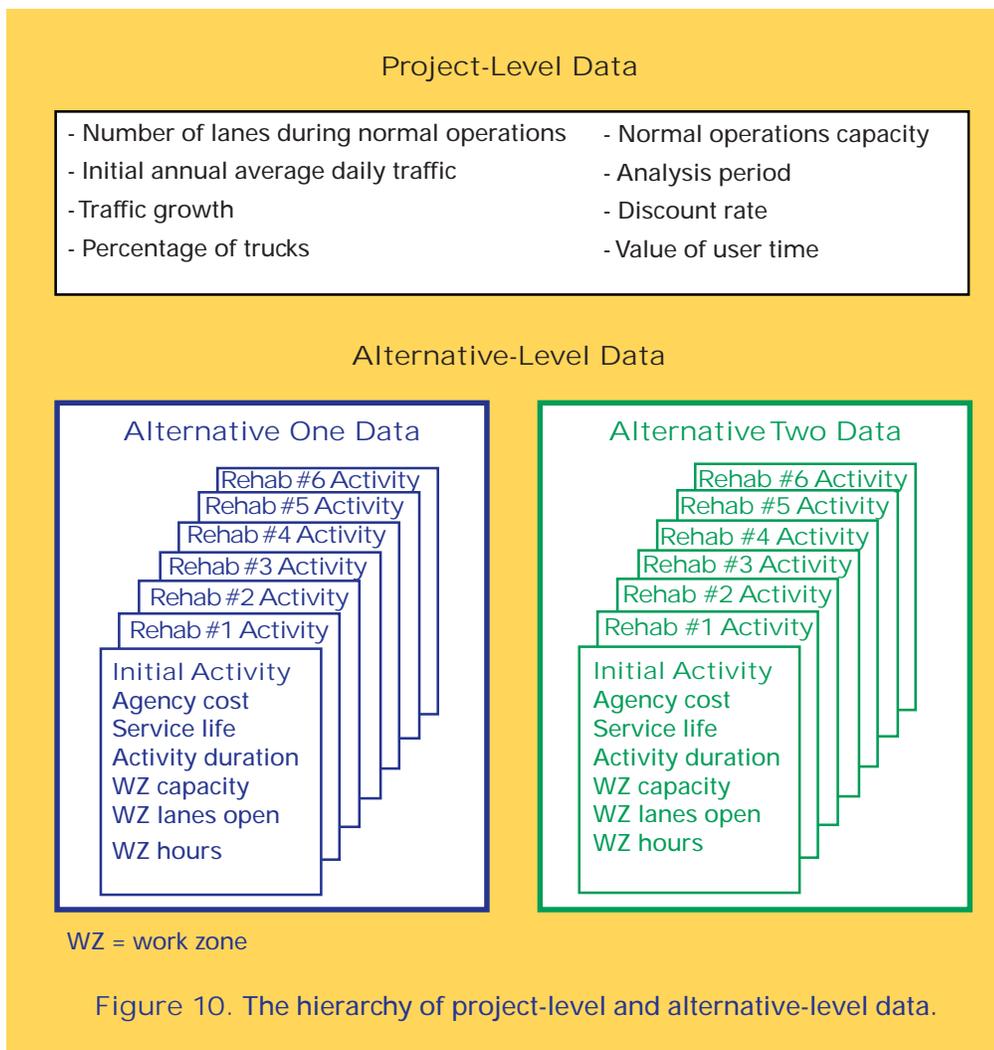
The LCCA process requires two levels of information: 1) data pertaining to the proposed pavement project and 2) data defining the pavement design alternatives that are being compared for accomplishing the project.

Project-level data apply to all alternatives being considered for the project at hand. FHWA’s best practice LCCA methodology requires that the analysis period, discount rate, normal operations traffic data, and normal operations roadway geometry be the same for all alternatives.

Alternative-level data define the differences between project alternatives (e.g., agency costs and work zone specifics for each alternative’s component activities).

In comparisons of alternative designs intended to similarly fulfill the performance requirements of a project, LCCA requires that each alternative carry the same amount of traffic during normal operations throughout the life of the project. In this way, the benefits to road users provided by all alternatives are the same. The exception to this rule is during periods of work zone operations, when traffic flow may be restricted in some fashion. Work zone traffic flow restrictions are modeled by RealCost with the user cost methodology described in the FHWA technical bulletin *Life-Cycle Cost Analysis in Pavement Design*.

To emphasize the difference between the two types of inputs, RealCost requires that project-level data be entered separately from alternative-level data. Figure 10 illustrates the division between project-level and alternative-level data.

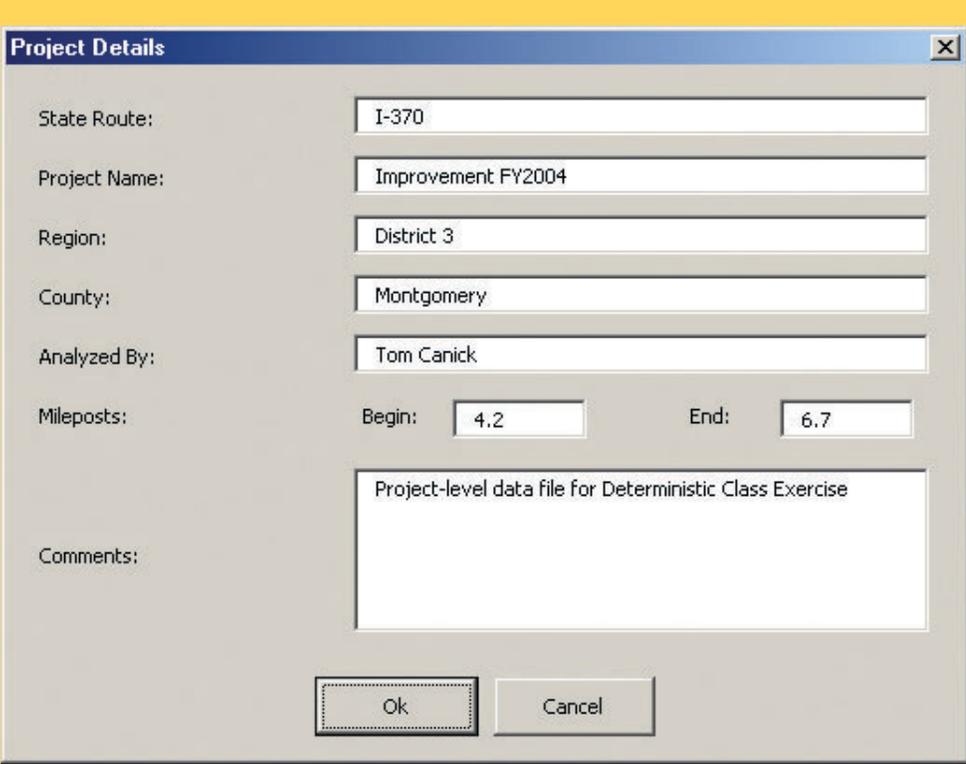


Project-Level Data Input Forms

The options selected and data entered in the project-level data input forms apply to all alternatives being considered to fulfill the performance requirements of the single project. If the project-level data or options are changed, all alternatives must be reconsidered with the new data and options in order to be properly compared. Alternatives analyzed using different project-level options cannot be directly compared in LCCA.

Project Details

The Project Details form (Figure 11) is used to identify and document the project. Data entered into this form are not used in the analysis. The analyst may enter data according to the field names on the form or may use the fields to include other project documentation details.



The screenshot shows a software window titled "Project Details" with a close button (X) in the top right corner. The form contains the following fields and values:

- State Route: I-370
- Project Name: Improvement FY2004
- Region: District 3
- County: Montgomery
- Analyzed By: Tom Canick
- Mileposts: Begin: 4.2, End: 6.7
- Comments: Project-level data file for Deterministic Class Exercise

At the bottom of the form are two buttons: "Ok" and "Cancel".

Figure 11. Project Details form.

Analysis Options

Generally, analysis options are decided by agency policy rather than the pavement design decisionmaker. Options defined in the Analysis Options form include the analysis period, discount rate, beginning year, inclusion of residual service life, and the treatment of user costs in the LCCA (see Figure 12). A checked box equals “yes,” an unchecked box equals “no.” The data inputs and analysis options available on this form are discussed in Table 3, with FHWA’s recommendations.

LCCA requires that all alternatives in an analysis produce the same benefits. If project-level data or options are changed, all alternatives must be reconsidered using the new data and options.

TIP

The screenshot shows a dialog box titled "Analysis Options" with the following fields and controls:

- Analysis Period (years): 40
- Discount Rate (%): 4
- Beginning of Analysis Period: 2003
- Include Agency Cost Remaining Service Life Value:
- Include User Costs in Analysis:
- User Cost Computation Method: Calculated
- Traffic Direction: Both
- Include User Cost Remaining Service Life Value:

Buttons: Ok, Cancel

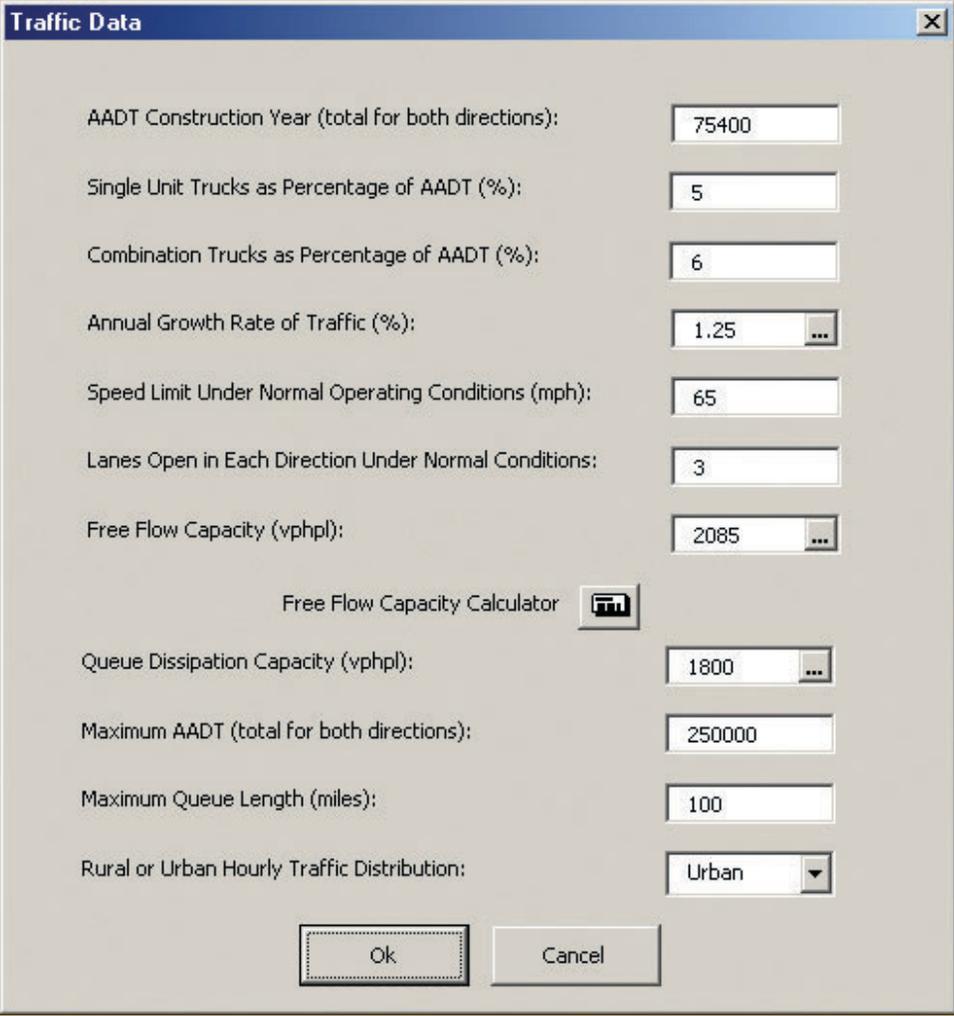
Figure 12. Analysis Options form.

Table 3. Analysis Options form inputs.

Option/Input	Description	FHWA Recommendation
Analysis Period	The number of years over which the alternatives will be compared.	35 to 40 years
Discount Rate	The rate by which future expenditures will be discounted to present value. This is entered as a decimal number.	Real discount rate of 3% to 5%
Beginning of Analysis Period	Sets the first year of the analysis period. RealCost expenditure diagrams draw their dates from this field and the analysis period field. This can also be referred to as the base year for the analysis.	Year the project will be undertaken
Include Agency Cost Remaining Service Life	Indicates whether the remaining service life value will include a prorated share of agency costs if the service life of an improvement extends beyond the analysis period.	Checked (Yes)
Include User Costs in Analysis	Indicates whether user costs will be included in the analysis and displayed in the results.	Checked (Yes)
User Cost Computation Method	Directs RealCost to either 1) calculate user costs ("Calculated") based upon input data in accordance to best-practice methods or 2) utilize inputted user costs ("Specified") values when calculating user life-cycle costs.	Calculated
Traffic Direction	Directs RealCost to calculate user costs for the "inbound" lanes, the "outbound" lanes, or "both" inbound and outbound lanes.	
Include User Cost Remaining Service Life	Indicates whether the remaining service life value will include a prorated share of user costs if the service life of an improvement extends beyond the end of the analysis period.	Checked (Yes)

Traffic Data

Pavement engineers use traffic data to determine their design parameters. In RealCost, traffic data (Figure 13) are used exclusively to calculate work zone user costs in accordance with the method outlined in FHWA's LCCA Technical Bulletin. The traffic data inputs are described in Table 4.



The screenshot shows a software window titled "Traffic Data" with a close button (X) in the top right corner. The window contains several input fields and a calculator icon. The inputs are as follows:

Field Label	Value
ADT Construction Year (total for both directions):	75400
Single Unit Trucks as Percentage of AADT (%):	5
Combination Trucks as Percentage of AADT (%):	6
Annual Growth Rate of Traffic (%):	1.25
Speed Limit Under Normal Operating Conditions (mph):	65
Lanes Open in Each Direction Under Normal Conditions:	3
Free Flow Capacity (vphpl):	2085
Free Flow Capacity Calculator	
Queue Dissipation Capacity (vphpl):	1800
Maximum AADT (total for both directions):	250000
Maximum Queue Length (miles):	100
Rural or Urban Hourly Traffic Distribution:	Urban

At the bottom of the window are two buttons: "Ok" and "Cancel".

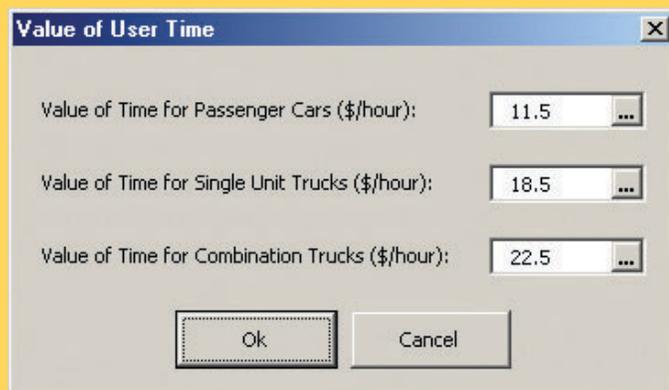
Figure 13. Traffic Data form.

Table 4. Traffic Data form inputs.

Input	Description
AADT in Both Directions	This is the annual average daily traffic in the construction or base year of the analysis. This is the total AADT for both directions.
Single Unit Trucks	The percentage of the AADT that is single unit trucks.
Combo Trucks	The percentage of the AADT that is combination trucks.
Annual Growth Rate of Traffic	The percentage by which "AADT in both directions" increases each year.
Normal Operations Speed Limit	Speed limit in normal operating conditions (the time periods between agency work zones).
Normal Number of Lanes Open	Number of roadway lanes available under normal operating conditions.
Queue Dissipation Capacity	Capacity of each lane during queue dissipation operating conditions.
Normal Free Flow Capacity	Capacity of each lane under normal operating conditions.
Free Flow Capacity Calculator	This button opens a form that calculates free flow lane capacities based upon the <i>Highway Capacity Manual, 3rd Ed.</i>
Maximum AADT in both Directions	Caps the traffic growth at this number. If traffic grows beyond this value, this value is substituted for the computed future AADT figure and future user costs are calculated based upon this maximum AADT figure. This is used to prevent growth beyond possible capacity.
Maximum Queue Length	Models the effects of self-imposed detours (traffic exiting from the work zone route yet still incurring some user costs). Queue-related user costs, which are based upon queue length, are calculated with this figure instead of the calculated queue length. However, all vehicles, even those that detour, are charged queue costs.
Rural or Urban Traffic	Allows the choice between two hourly traffic distributions. Default values for these distributions (the defaults are accessible in the software) are taken from the Texas Transportation Institute's MicroBENCOST.

Value of User Time

The Value of User Time form, shown in Figure 14, allows editing of the values applied to an hour of user time. The dollar value of user time is different for each vehicle type and is used to calculate user costs associated with delay during work zone operations.



Vehicle Type	Value (\$/hour)
Passenger Cars	11.5
Single Unit Trucks	18.5
Combination Trucks	22.5

Figure 14. Value of User Time form.

To transform annual average daily traffic (AADT) to an hourly traffic distribution, default Rural and Urban Traffic hourly distributions from MicroBENCOST are provided with RealCost. The Traffic Hourly Distribution form (Figure 15 and Table 5) is used to adjust (or restore) these settings. Distributions are required to sum to 100 percent. (Note: The rural/urban option is entered on the Traffic Data form, shown in Figure 13.)

Added Time and Vehicle Stopping Costs

“Added Time per 1,000 Stops (Hours)” and “Added Cost per 1,000 Stops (\$)” values are used to calculate user delay and vehicle costs due to speed changes that occur during work zone operations. This form (Figure 16) is used to adjust the default values for added time and added cost per 1,000 stops. The “Idling Cost per Veh-Hr (\$)” is used to calculate the additional vehicle operating costs that result from traversing a traffic queue under stop and go conditions. The costs and times are different for each vehicle type.

The Restore Defaults button functions much the same as it does on the Traffic Hourly Distribution form. The default values are drawn from NCHRP Study 133, *Procedures for Estimating Highway User Costs, Air Pollution, and Noise Effects*.

Saving and Loading Project-Level Data

The last two buttons in the project-level inputs section of the Switchboard (see

Traffic Hourly Distribution ✕

Hour	AADT Rural (%)	Inbound Rural (%)	Outbound Rural (%)	AADT Urban (%)	Inbound Urban (%)	Outbound Urban (%)
0 - 1	1.8	48	52	1.2	47	53
1 - 2	1.5	48	52	0.8	43	57
2 - 3	1.3	45	55	0.7	46	54
3 - 4	1.3	53	47	0.5	48	52
4 - 5	1.5	53	47	0.7	57	43
5 - 6	1.8	53	47	1.7	58	42
6 - 7	2.5	57	43	5.1	63	37
7 - 8	3.5	56	44	7.8	60	40
8 - 9	4.2	56	44	6.3	59	41
9 - 10	5	54	46	5.2	55	45
10 - 11	5.4	51	49	4.7	46	54
11 - 12	5.6	51	49	5.3	49	51
12 - 13	5.7	50	50	5.6	50	50
13 - 14	6.4	52	48	5.7	50	50
14 - 15	6.8	51	49	5.9	49	51
15 - 16	7.3	53	47	6.5	46	54
16 - 17	9.3	49	51	7.9	45	55
17 - 18	7	43	57	8.5	40	60
18 - 19	5.5	47	53	5.9	46	54
19 - 20	4.7	47	53	3.9	48	52
20 - 21	3.8	46	54	3.3	47	53
21 - 22	3.2	48	52	2.8	47	53
22 - 23	2.6	48	52	2.3	48	52
23 - 24	2.3	47	53	1.7	45	55
Total	100			100		

Figure 15. Traffic Hourly Distribution form.

Table 5. Traffic Hourly Distribution form inputs.

Input	Description
AADT Rural %	The percentage of the AADT that is traveling on the roadway, in both directions, during the indicated hour under the rural traffic distribution.
Inbound Rural %	The percentage of that hour's traffic that is traveling inbound on the route under the rural traffic distribution. The formula: $(AADT \text{ Rural } \%) \times (\text{Inbound Rural } \%)$ <p>describes the percentage of the AADT traveling in the inbound direction for the indicated hour.</p> <p>Note: The same interpretations apply to the urban components of Figure 15.</p>
Restore Defaults	Returns all values on this form to their original, as delivered, default values. Default values for these distributions are taken from MicroBENCOST, software produced by the Texas Transportation Institute. MicroBENCOST, which is used to calculate benefits and costs of transportation improvements, includes an hourly traffic distribution that has been adopted as a default traffic distribution for RealCost.

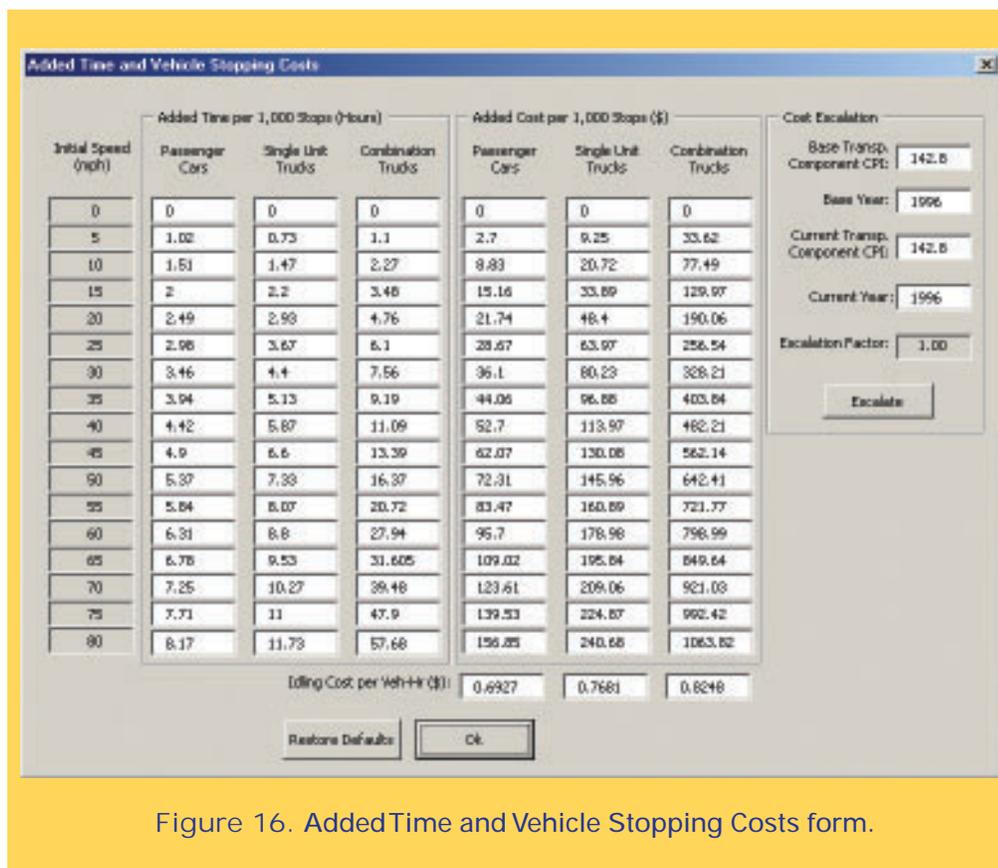


Figure 16. Added Time and Vehicle Stopping Costs form.

Figure 17) are used to save and to retrieve (load) project-level inputs. NOTE: Alternative-level inputs are saved separately from project-level inputs. The mechanism to save and open alternative-level inputs is found on the Alternative 1 and Alternative 2 forms.

Project-level inputs are saved in a small, comma-delimited file. This file may be named via ordinary Windows conventions and is automatically saved with the *.LCC extension. Changing the file extension will prevent RealCost from recognizing the file. *Warning: Opening an *.LCC file will overwrite data in the Project-Level Inputs section.*

Alternative-Level Data Input Forms

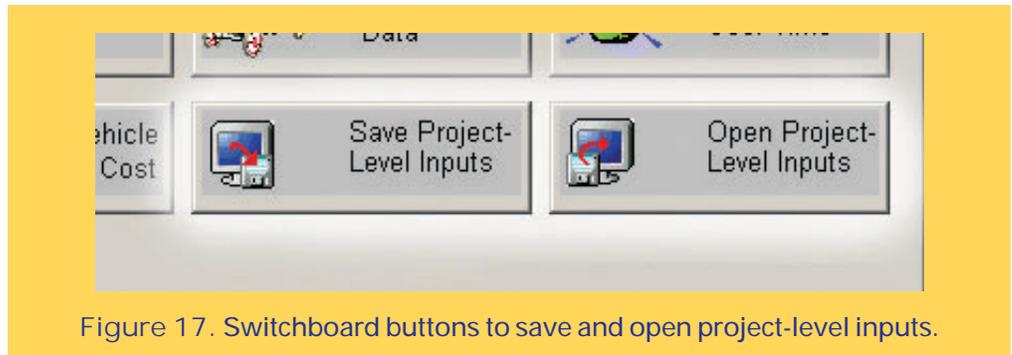


Figure 17. Switchboard buttons to save and open project-level inputs.

Data that define the differences between alternatives—the agency costs and work zone specifics for component activities of each project alternative—are alternative-level inputs. Each project alternative is composed of up to seven activities. The activities are performed in sequence. For example, Initial Construction precedes Rehabilitation 1 and Rehabilitation 3 precedes Rehabilitation 4. Data describing these activities are entered for each of the two project alternatives being compared.

Alternative 1 <or> Alternative 2 Form

The forms for Alternative 1 and Alternative 2 are identical. At the top of the form a series of tabs access project alternative activities. Each tab accesses a different activity (see Figure 18). Data in this form are used to calculate agency and user costs. The construction and maintenance data are agency cost inputs. The service life data affect both agency and user costs (by determining when work zones will be in place). The work-zone-specific data affect user costs. Each of the data inputs on this form is discussed in Table 6.

Saving and Loading Alternative-Level Data

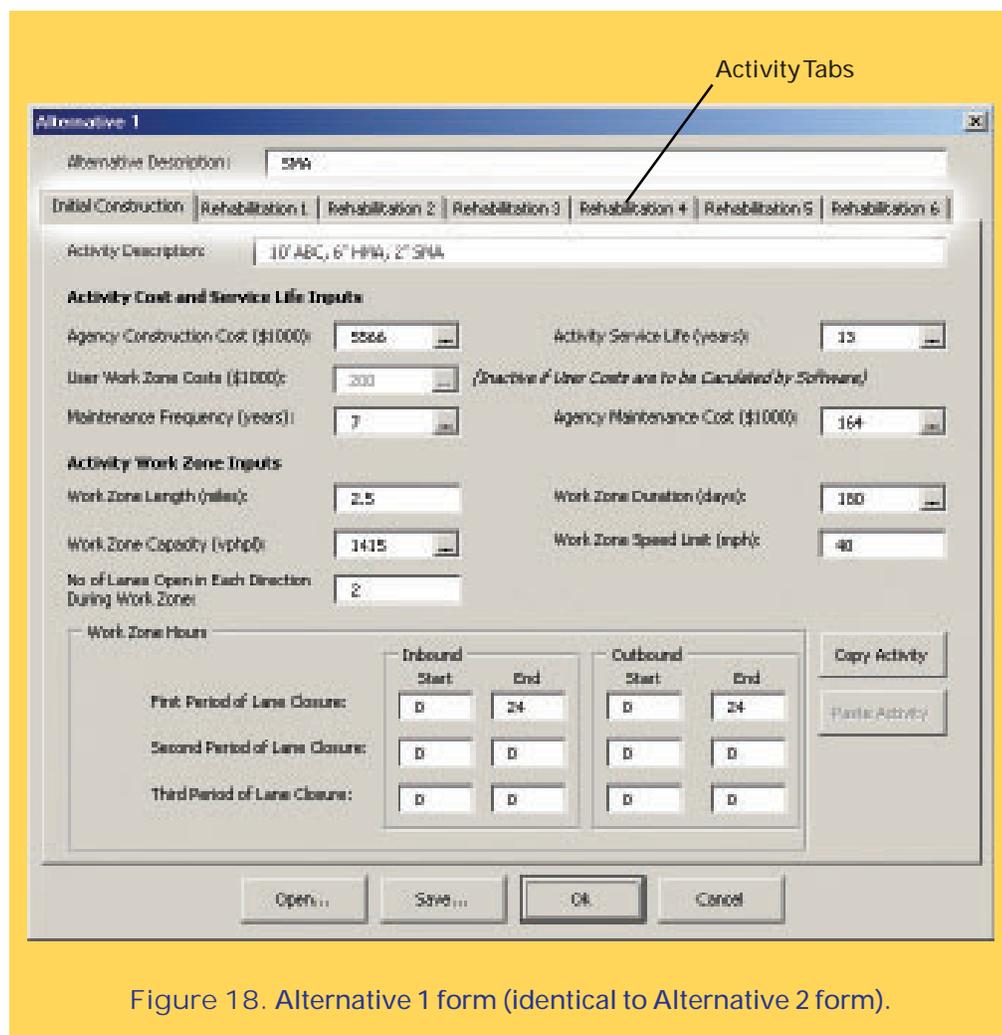


Figure 18. Alternative 1 form (identical to Alternative 2 form).

Table 6. Alternative 1 and Alternative 2 form inputs.

Input	Description	Notes
Alternative Description	Name of this alternative.	
Activity Description	Name of this activity.	
Agency Construction Cost	Agency costs that will be included in the life-cycle cost analysis for this activity of this alternative.	Thousands of dollars
Service Life	Service life of the activity. This field defines how many years after this activity the next activity will take place.	Years
User Costs	This field allows direct entry of user costs. The field is accessible only when the User Cost Computation Method field on the Analysis Options form is set to Specified. When this field is set to Calculated it will be presented in gray font and will not be accessible.	1) Thousands of dollars 2) Inaccessible if User Cost is set to Calculated.
Maintenance Cost	Cost of minor, scheduled maintenance that is performed between major activities. These minor activities incur no user costs. Their purpose is to allow for the inclusion of the agency costs of minor activities such as preventive maintenance. In order to remove minor routine maintenance from the analysis, set the value of this field to zero (0).	1) Thousands of dollars 2) Enter zero (0) if not being used.
Maintenance Frequency	Cyclical frequency of minor maintenance. This frequency only applies during the service life of the specific major activity that it is described for and expires as soon as the next major activity begins.	Enter zero (0) if not being used.
Work Zone Length	How long the actual work zone is. This is measured from the beginning to the end of the reduced speed area (where the work zone speed limit is in effect).	Miles
Work Zone Duration	Number of days that the work zone will be affecting traffic. For example, if the work zone is in effect 5 days a week for 3 weeks, this value would be 15.	Days
Work Zone Capacity	Vehicular capacity of one lane of the work zone for 1 hour.	Vehicles per hour per lane
Work Zone Speed Limit	Posted speed limit within the work zone.	Miles per hour
Lanes Open in Each Direction During Work Zone	Number of lanes open in the work zone area when the work zone is in effect. The number of lanes open applies to each direction.	

Table 6, continued

Input	Description	Notes
Work Zone Hours	Hours each day of the Work Zone Duration during which the work zone is in effect. During these hours, capacity is limited to Work Zone Capacity. Work zone timing may be modeled separately for inbound and outbound traffic. Up to three separate periods of work zone can be modeled for each day. For example, to model a work zone that is in effect from 9:00 AM to 3:00 PM and from 8:00 PM to 5:00 AM, enter these numbers: 00 05 09 15 20 24	Use a 24-hour clock

The Open... and Save... buttons at the bottom of the Alternative form are used to open and save alternative-level data. These data files may be named via ordinary Windows conventions and are automatically saved with the *.LCA extension. A name that is descriptive of the alternative should be used. Data for the alternative name and its seven major activities are saved in the LCA file. Saving alternatives individually allows different alternatives to be loaded, analyzed, and stored for use in future analyses. *Warning: Opening an *.LCA file overwrites all existing data for the alternative active in memory.* To avoid losing data, save new data to an *.LCA file before loading another alternative.

Opening an *.LCA file overwrites all existing data for the alternative active in memory. To avoid losing data, save new data to an *.LCA file before loading another alternative.

TIP

The Copy Activity and Paste Activity buttons allow data to be copied from one activity to another within the same alternative. Begin at the activity which has the data to be copied, press the Copy button, move to the activity that is to receive the data, and press the Paste button. All existing data in the receiving activity will be overwritten.

Probabilistic Input

RealCost encourages the consideration of variability (i.e., uncertainty) in analysis inputs. Input variability can be addressed by using probabilistically defined inputs.

Probability Functions

Several inputs on the Alternative 1 and 2 forms can be described either by deterministic values (single or point values) or by probabilistic values (value ranges and likelihoods of occurrence). The default value for all data is a deterministic value. The probabilistic inputs are identified by the small ellipsis button to the right of the data input field. For example, in Figure 19 the ellipsis button for the value of user time for passenger cars is circled.

Clicking an ellipsis button opens a probability function form where the analyst may assign any one of a number of probability functions to describe data. Those input fields with an ellipsis will already have the variable name included (see Figure 20).

Seven types of probability distributions are available in RealCost:

- Normal
- Truncated normal
- Triangular
- Uniform
- Beta
- Geometric
- Log normal

The most commonly used distributions are displayed in Table 7.

The example in Figure 20 shows the process of changing the value of user time for passenger car vehicles from a deterministic value to a normal

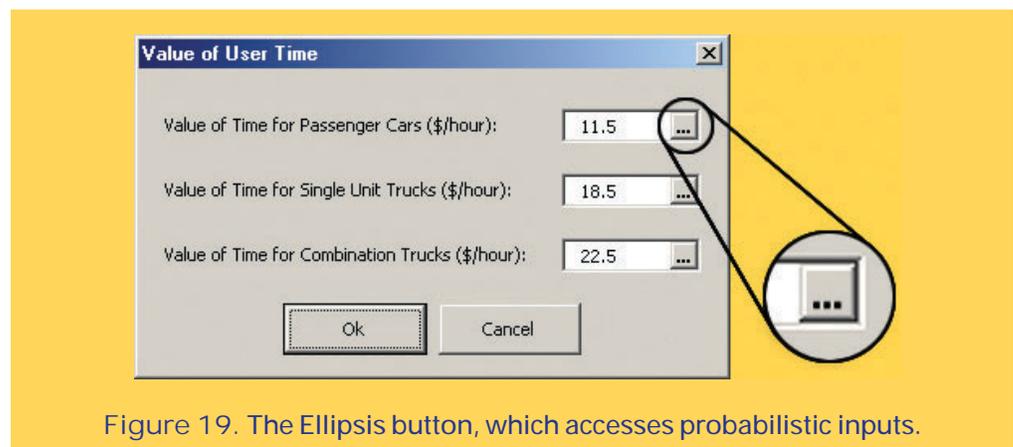
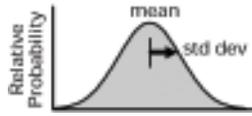
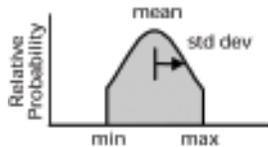
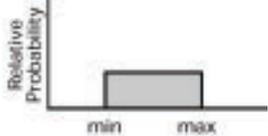


Figure 19. The Ellipsis button, which accesses probabilistic inputs.

Table 7. Examples of input probability distributions typically used in RealCost.

Distribution Type	Spreadsheet Formula	Illustration
Normal	lccanormal (mean, std dev)	
Truncated Normal	lccatnormal (mean, std dev, lower bound, upper bound)	
Triangular	lccatriang (minimum, most likely, maximum)	
Uniform	lccauniform (minimum, maximum)	

distribution. More information on the use of probability distributions is provided in the FHWA technical bulletin *Life-Cycle Cost Analysis in Pavement Design*.

Simulation and Outputs

Probability Function [X]

Variable Name:

Probability Distribution:

Value:

Probability Function [X]

Variable Name:

Probability Distribution:

- Deterministic
- Uniform
- Normal**
- Log Normal
- Triangular
- Beta
- Geometric
- Truncated Normal

Value:

Probability Function [X]

Variable Name:

Probability Distribution:

Mean:

Std. Dev.:

Figure 20. Creating a probabilistic input.

The Simulation and Outputs section of the Switchboard is where deterministic life-cycle costs and simulations of probabilistic life-cycle costs are performed. Deterministic analysis is done using either deterministic inputs or most likely values for probabilistic inputs; in either case, point values are used in a deterministic analysis.

Deterministic Results

Opening the Deterministic Results form, shown in Figure 21, calculates deterministic present values for both agency and user costs and displays those values. The lowest cost alternatives for both agency and user are labeled. The form also provides a direct link to the Deterministic Results Excel worksheet, which contains all of the information required to investigate deterministic results.

Probabilistic Analysis

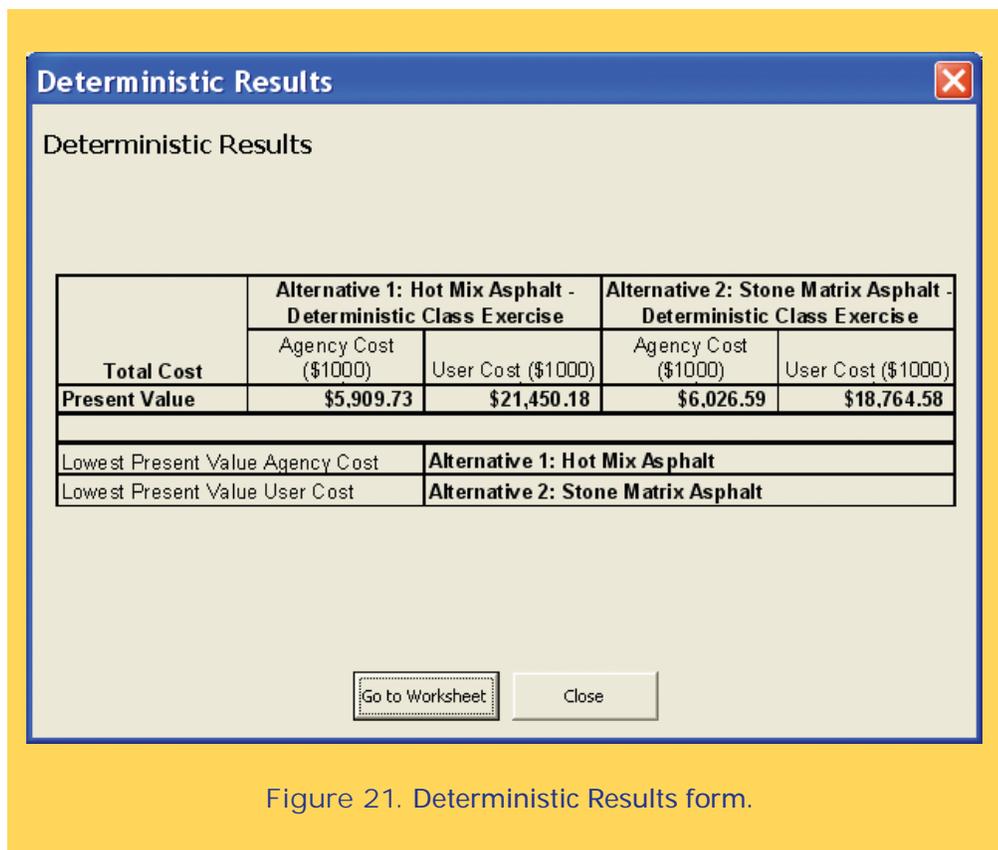


Figure 21. Deterministic Results form.

Probabilistic Analysis

Running the Simulation

Running a simulation is a necessary step toward performing a probabilistic analysis. To conduct probabilistic analysis, RealCost uses Monte Carlo simulation, which allows modeling of uncertain quantities in the model with probabilistic inputs. The simulation procedure randomly samples these inputs and produces outputs that are described by both a range of potential values and a likelihood of occurrence of specific outputs. The simulation produces the probabilistic outputs; without running a simulation, probabilistic outputs are not available. The Simulation form is shown in Figure 22.

The Sampling Scheme section of the form determines from where the software will draw its simulation numbers. Choosing Random Results causes the simulation seed value (where the simulation starts) to come from the computer’s internal clock. While not truly random, this seed value cannot be influenced by the software user, and it produces different values with each simulation.

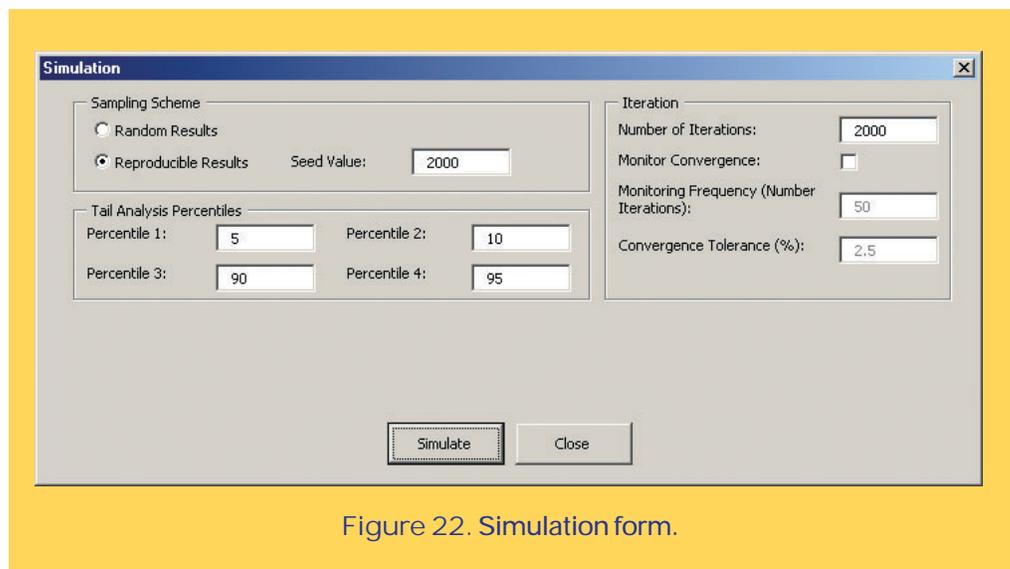


Figure 22. Simulation form.

The value of choosing Reproducible Results is that the analyst may perform separate simulation runs to compare more than two alternatives. “Reproducible Results” causes the same simulation values for each given seed value. Using reproducible results causes the same random numbers to be generated. This removes random variability associated with the seed value from the comparison, allowing the analyst to focus on actual input changes.

The Sampling Scheme section of the form determines how the software will draw its simulation numbers from the pseudo-random number generator (these numbers are not truly random but are satisfactory for simulation purposes). Choosing Random Results causes the simulation to start the random number sequence from a “seed” value taken from the computer’s internal clock. This seed value cannot be influenced by the software user and produces different values with each simulation.

The Reproducible Results option allows the analyst to specify the specific seed value to be used in all simulations. This causes the same set of random numbers to be generated from the pseudo-random number generator. Choosing Reproducible Results allows the analyst to perform separate simulation runs to compare multiple alternatives, knowing that variations from run to run will be caused by actual input changes and not variability associated with different seed values.

Tail Analysis Percentiles are used to conduct analysis on the total cost probability distribution graphics provided by RealCost, discussed on page 44. Percentile values should be entered in ascending order.

The Iteration section is used to determine the number of iterations to be performed and whether the simulation will be monitored for convergence. Output convergence can be used by the analyst to determine that a simulation has run a sufficient number of iterations to properly define its outputs. Convergence is monitored by comparing the change in the mean and standard deviation of the cumulative outputs each time a specified number of iterations is completed (specified in the Monitoring Frequency box). Once the level of change falls below the specified Convergence Tolerance, RealCost will end the simulation run without completing any remaining iterations—yielding probabilistic results while significantly shortening the time it takes to complete the analysis. The number of iterations should be 2,000 at a minimum. Monitoring Frequency is adequate at 100 iterations, and, when used, a Convergence Tolerance of 2.5 (percent) should provide appropriate probabilistic outputs.

Figure 23 shows a simulation that ended due to simulation convergence of less than 2.5 percent. Note that the convergence error is listed at the bottom of the form. This convergence error is monitored and reported during the simulation.

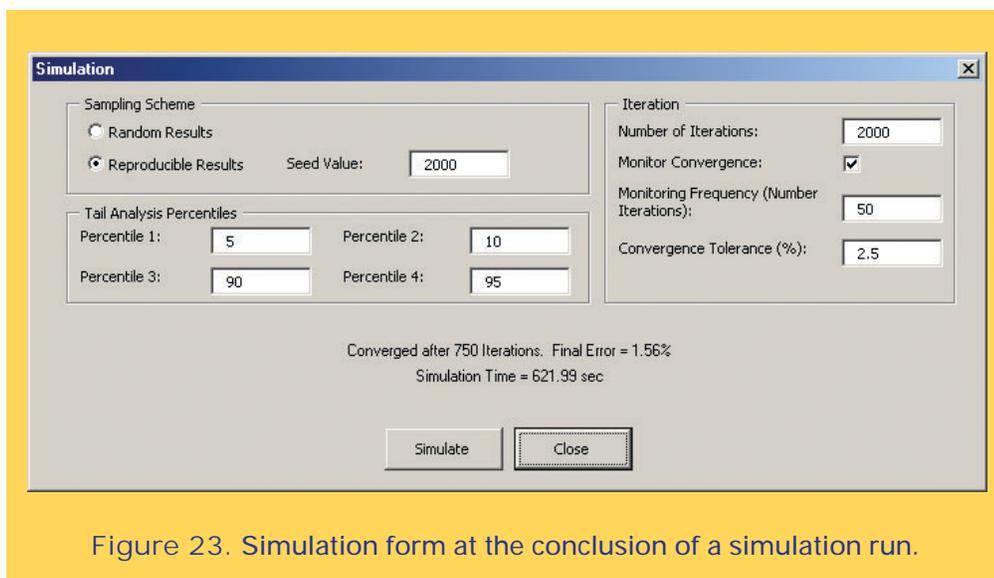


Figure 23. Simulation form at the conclusion of a simulation run.

Analyzing Probabilistic Results

After a simulation run, probabilistic results are available for analysis. A simulation must be run prior to viewing probabilistic results. Figure 24 shows the results of a probabilistic simulation.

Four worksheets are accessible from the Probabilistic Results form. The Probabilistic Results worksheet and the Output Distributions worksheet both provide probability distribution and cumulative density functions that describe outputs. Examples of these graphs are shown in Figure 25.

The Tornado Graphs worksheet provides tornado graphs that describe how inputs affect outputs (example shown in Figure 26). For example, the input Initial Construction Cost has a significant effect on the output Alternative 1: Agency Costs. A correlation coefficient value of 1 would indicate a complete positive correlation between two variables. A value of -1 would indicate a complete inverse correlation between two variables. The value of 0 would indicate that there is no correlation between variables: they are independent. Other correlation values indicate a partial correlation; the output is affected by changes in the selected input, but may be affected by other variables as well.

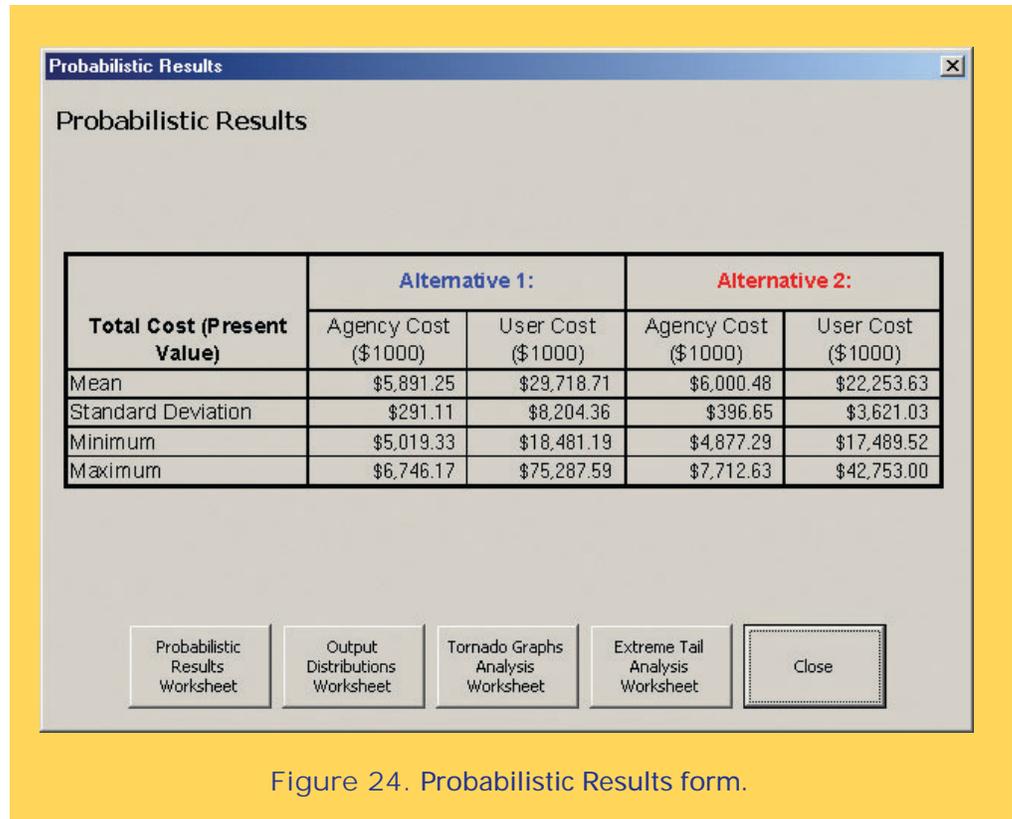


Figure 24. Probabilistic Results form.

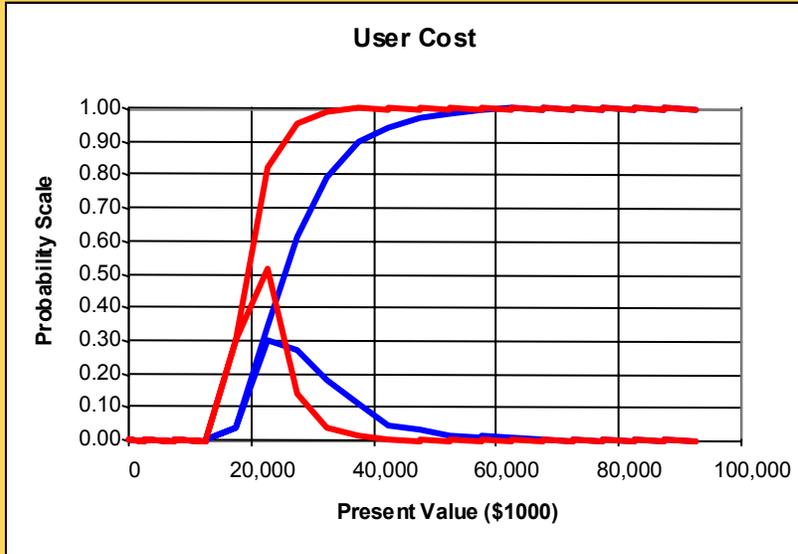
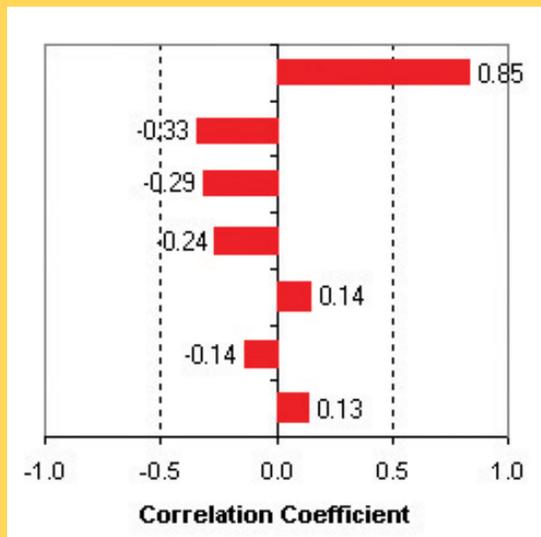


Figure 25. Probabilistic distribution density and cumulative density functions describing outputs.



LCCA Output: Alternative 1: Agency Cost	
Input Variable	Corr. Coeff.
Alternative 1: Initial Construction Cost	0.85
Alternative 1: Initial Construction Life	-0.33
Discount Rate	-0.28
Alternative 1: Rehab 1 Life	-0.24
Alternative 1: Rehab 1 Cost	0.14
Alternative 1: Rehab 2 Life	-0.14
Alternative 1: Rehab 2 Cost	0.13

Figure 26. Correlation coefficient graph (aka "tornado graph").

Total Cost Probability Distributions

While the correlation coefficient graphics describe the sensitivity of outputs to individual inputs, the total cost probability distribution graphics provided by RealCost describe the sensitivity of outputs to combinations of inputs. Particular emphasis is given to the tails of the distribution, which encompass the most extreme outcomes encountered in the analysis. The analyst may enter four Tail Analysis Percentiles (see Figure 22, Simulation form) to define the areas of the tails of most interest. RealCost demonstrates how various inputs act together to produce these four defined tail areas.

For example, Figure 27 shows an agency project alternative total cost distribution. The shaded area on the left side of the distribution curve represents a 10 percent tail of the area under the curve (the 10th percentile, or the most favorable 10 percent of all agency cost outputs). Table 8 describes the combination of input values that would lead to that outcome. The values under the “10%” heading represent the number of standard deviations from the mean value for each of the inputs needed to fall within the 10 percent tail.

The value of tail analysis is that it identifies those inputs that contribute to the success, or failure, of a project alternative. Pavement design decisionmakers are able to quantitatively identify alternatives that they believe they are able to positively influence and also those alternatives that they are not able to influence. More discussion on interpreting probabilistic outputs is given in FHWA’s LCCA Technical Bulletin, *Life-Cycle Cost Analysis in Pavement Design* (FHWA-SA-90-079).

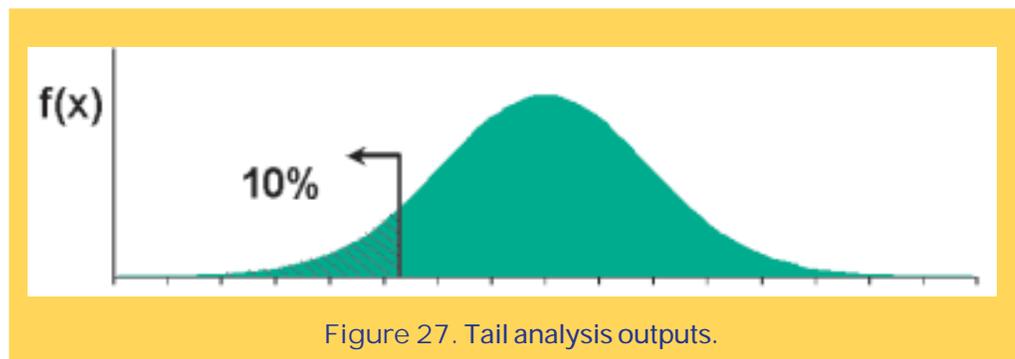


Table 8. Most favorable 10 percent of expected agency cost outcomes.

Input Variable	Alternative 1: Agency Cost			
	5%	10%	90%	95%
Name				
Discount Rate	0.56	0.74	-0.79	-1.02
Initial Construction Cost	-1.76	-1.44	1.36	1.41
Initial Construction Life	0.65	0.57	-0.54	-0.81
Rehab 1 Life	0.86	0.54	-0.37	-0.46

Glossary

Activity

A specific action performed by the highway agency, such as initial construction or major rehabilitation. An activity is defined by its agency costs, its service life, and its effects on highway users. An activity is a component of an alternative.

Agency cost

Monies spent by a transportation agency for construction or rehabilitation activities.

Alternative

The complete set of activities that define a means to achieve the performance goals of a project, including the initial and future activities. In life-cycle cost analysis, all alternatives being considered for a single project will equally meet the performance requirements of the project.

Data input field

An area on a form where data may be entered.

Form

A user interface in RealCost.

Graphical user interface

A set of window graphics that provides an easy-to-use interface to a software program.

LCCA menu

A special menu item that is created by RealCost and resides on the Excel 2000 menu bar. The menu allows access to many of the forms used as well as the Switchboard.

Macro

A stored series of commands and functions that can be run to perform a specific task or tasks.

Menu

An Excel 2000 component that allows software users to interface with the software. The menu bar typically is located at the top of the Excel 2000 window.

Project

For the purposes of RealCost, a project is the provision of a specific level of performance to the motoring public. All design alternatives being considered for a project will provide the same level of performance for road users.

Service Life

The period of time during which the product of a construction or rehabilitation activity is able to meet the performance requirements of a roadway. This period defines the time of normal operations between agency activities.

Switchboard

The primary interface mechanism in RealCost. The Switchboard appears automatically when the software is started and may also be accessed through the RealCost menu.

Tab (worksheet tab)

A selection device at the bottom of a displayed Excel 2000 workbook file that allows the software user to select and move between different worksheets within the workbook.

Visual Basic for Applications (VBA)

A tool used to automate tasks ranging from adding together two inputted numbers to performing multistep, complex operations that use multiple inputs. Visual Basic code is also used to create the form interface for RealCost.

Worksheet

A single page of an Excel 2000 workbook; a spreadsheet.

Workbook

An Excel 2000 file composed of one or more worksheets and additional Visual Basic for Applications code. The RealCost software is a workbook.

Work zone

An area of reduced roadway capacity due to agency construction or rehabilitation activities.

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For assistance in implementing a life-cycle cost analysis program or to learn more about RealCost, please contact the Office of Asset Management at 202-366-0392.

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