

**LIFE CYCLE COSTS FOR LIME
IN HOT MIX ASPHALT**

VOLUME III - LCCA SOFTWARE USER'S GUIDE

by

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FOREWARD

This is Volume III of a three-volume report:

- Volume I – Final Report: describes the study, summarizes findings, and provides conclusions and recommendations.
- Volume II – Appendices: contains all of the supporting data for the study.
- Volume III – LCCA Software User’s Guide: is a user’s guide for the Windows-based software program developed specifically for this study.

The final report (Volume I) and appendices (Volume II) will be of interest to State highway agency personnel and hot-mix asphalt paving contractors responsible for conducting and/or reviewing pavement design life cycle cost analyses. The software user’s guide (Volume III) will be of interest to those practitioners that wish to use the LCCA software.

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ABSTRACT

Life cycle cost analysis (LCCA) is recognized by public agencies as an effective tool to assist in the selection of highway construction, maintenance, and rehabilitation treatments. Accordingly, the Federal Highway Administration (FHWA) has developed an LCCA methodology that will likely become the standard in the industry. The methodology can be used to evaluate the life cycle costs (LCC) of paving materials with additives/modifiers, such as hydrated lime.

This report uses information from past highway projects to:

- identify the benefits and costs of adding lime;
- compile past performance data into an LCCA model; and
- compare the LCCs for asphalts with and without lime.

Estimated lives used in the LCCA model are based on interviews and on engineering judgment. Practitioners can use project-specific data with the LCCA software to generate project-specific estimates of life cycle costs.

This report presents the LCCA results for interstate and state highway projects. The findings show that lime is the most cost effective design for all of the applications studied. Life cycle cost savings from lime are, on average, \$2 to \$3 per square yard; or, \$13,000 to \$21,000/lane mile (13% to 15% of project life cycle costs). These results are based on the widely accepted use of lime as an additive that reduces stripping. Additionally, new information shows that lime creates other benefits in asphalt, which would further increase the life cycle benefits of using lime.

ACKNOWLEDGMENTS

The authors are grateful for the assistance of the following agencies and contractors that provided the information to perform life cycle cost comparisons:

- | <u>Agencies</u> | <u>Contractors</u> |
|------------------|-----------------------------|
| • Arizona | • APAC |
| • California | • FNF Construction |
| • Colorado | • Granite Construction |
| • FHWA (WFLHD) | • Kiewit Pacific |
| • Georgia | • Lafarge |
| • Mississippi | • C.W. Matthews Contracting |
| • Oregon | • Morse Brothers |
| • Nevada | • Staker Construction |
| • South Carolina | • Dean Word Company |
| • Texas | • Young Contractors |
| • Utah | |

The information provided and used in the analyses was verified by those surveyed.

DISCLAIMER

The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy presented herein. The contents do not necessarily reflect the official views of the agencies and contractors that provided information in support of the study. Users of the LCCA model need to apply their judgment when using the results of this report or the software described in this volume.

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1.0 INTRODUCTION

1.1 Overview

The LCCA (life cycle cost analysis) software package is a Windows-based application that was developed to perform economic analyses of two pavement alternatives that are subject to future maintenance and rehabilitation (M&R) activities. The methodology is based on the approach developed by the Federal Highway Administration (Walls and Smith, 1998). The software allows analyses for both new construction and rehabilitation projects and allows inclusion of lane rental fees as a surrogate for user delay costs. It also supports both deterministic and probabilistic analyses. The deterministic approach uses mean (average) values of the input variables. In the probabilistic approach, real world variability of certain input variables is mimicked through a Monte Carlo simulation process, which is based on the means and standard deviations of the input variables.

The graphical user interface (GUI) interacts with a 32-bit Microsoft Access 97 database. All data utilized by the LCCA software package is contained in the database.

1.2 Assumptions

Several assumptions were made in the development of the LCCA software package. These are summarized as follows:

- 1) Vehicle operating costs and crash costs have been assumed to be equivalent for the two alternatives under consideration.
- 2) Lane rental fees have been used as a surrogate for user delay costs.
- 3) User costs associated with a new construction project for initial construction are assumed equal to zero.

- 4) Salvage value (credit for remaining life) is determined as a prorated cost of the final rehabilitation activity based on the portion of life consumed relative to the expected life of the rehabilitation treatment.
- 5) The parameters varied in the Monte Carlo simulation process (i.e., treatment lives, treatment costs, and the discount rate) have been assumed to follow normal (Gaussian) distributions. Low and high estimates for these parameters have been assumed to represent the 10 and 90 percentile values, respectively.

1.3 Limitations

The LCCA software has several limitations. The major limitations of the software are listed below:

- 1) The analysis results are only as good as the inputs. Every effort should be made to ensure that the inputs are accurate.
- 2) Only one type of maintenance treatment can be applied to a pavement alternative.
- 3) Future costs are in real (constant) dollars and the discount rate is a real discount rate (one that does not reflect an inflation premium).

2.0 INSTALLATION

This section provides guidance for installing the LCCA software package. It includes a description of the recommended attributes of the computer system on which the software is to be installed, followed by instructions for installing the software.

2.1 Recommended System Attributes

The LCCA software package was developed to run on a computer system that has reasonably up-to-date hardware components. As a guide to the minimum system requirements on which the software will run, the following system attributes are required and/or recommended:

- Operating system: Windows 98, Windows 2000, or Windows NT 4.0 is required.
- Central processing unit (CPU): Pentium is required; Pentium II or better is recommended.
- Free hard disk space: at least 20 megabytes is required; more is recommended.
- Random access memory (RAM): 16 megabytes is required; 64 megabytes or more is recommended.
- Monitor type and resolution: VGA set to 1024 × 768 pixels is required; SVGA or better set to 1024 × 768 pixels or greater is recommended.
- Drives: Compact disc (CD) drive is required.
- Mouse or other similar device.

2.2 Installation

The LCCA software package is bundled in an installation program contained on the LCCA Software Package compact disc (CD) or in a file located on the National Lime Association web site (or other web site to which the NLA web site directs you). You

must execute this program to be able to run the LCCA software on your computer system and such a system must have the minimum attributes detailed in Section 2.1 of this user's guide. The following sections provide guidance for installing the LCCA software package.

Installation Using a File Located on a Web Site

Use the following steps to install the LCCA software package on a computer using a file located on a web site:

1. Download the installation package file (e.g., NLA_LCCA_v1_3.exe, or similar) from the web site address to which the NLA has directed you. Tip: Download the file to a location on your hard disk such that the file can be easily found (e.g., C:\Temp).
2. Click on the Windows Start menu button and select Run...
3. Select Browse... and when the Browse dialog box opens, navigate to the location to which you downloaded the installation package file.
4. Double-click on the installation package file (or highlight the file and click on Open).
5. Click on the OK button on the Run form.
6. Follow the instructions given in the Setup Wizard.

Installation Using a Compact Disk (CD)

Use the following steps to install the LCCA software package on a computer from a compact disc:

1. Insert the LCCA Software Package CD in the CD drive.
2. Click on the Windows Start menu button and select Run...

3. Select Browse... and when the Browse dialog box opens, navigate to the CD drive.
4. Double-click on the Setup.exe file (or highlight the file and click on Open).
5. Click on the OK button on the Run form.
6. Follow the instructions given in the Setup Wizard.

3.0 USING THE SOFTWARE

This section provides guidance for using the LCCA software package. It addresses the type of analysis approach to use, details regarding the required inputs for a particular life cycle cost analysis (LCCA), and details about viewing and printing results.

3.1 Main Module Form

Executing the Software Program

The LCCA software can be executed using the Windows Start menu as indicated in Figure 1. Clicking on the Start button, scrolling the mouse to highlight the Programs menu choice, then highlighting and clicking on the NLA LCCA Version 1.3 menu choice accomplishes this. Note that executing the software can be accomplished in other ways including creating a shortcut on the desktop, using the Windows Explorer, or using the My Computer feature. The Windows help system provides details on how to use these features.

Executing the program loads the Main Module form into memory and shows the Disclaimer dialog shown in Figure 2. Either answer “no” by clicking on the button labeled “No, I do not want to use the software!”, which exits the software, or answer “yes” by clicking on the button labeled “Yes, I want to use the software!”, which indicates that you accept the disclaimer. Answering “yes” continues to load the software by first displaying the Splash Screen shown in Figure 3, which is shown only briefly. After the Splash screen, the form shown in Figure 4 is displayed. This form is used to select the type of approach (deterministic or probabilistic) to use for a given life cycle

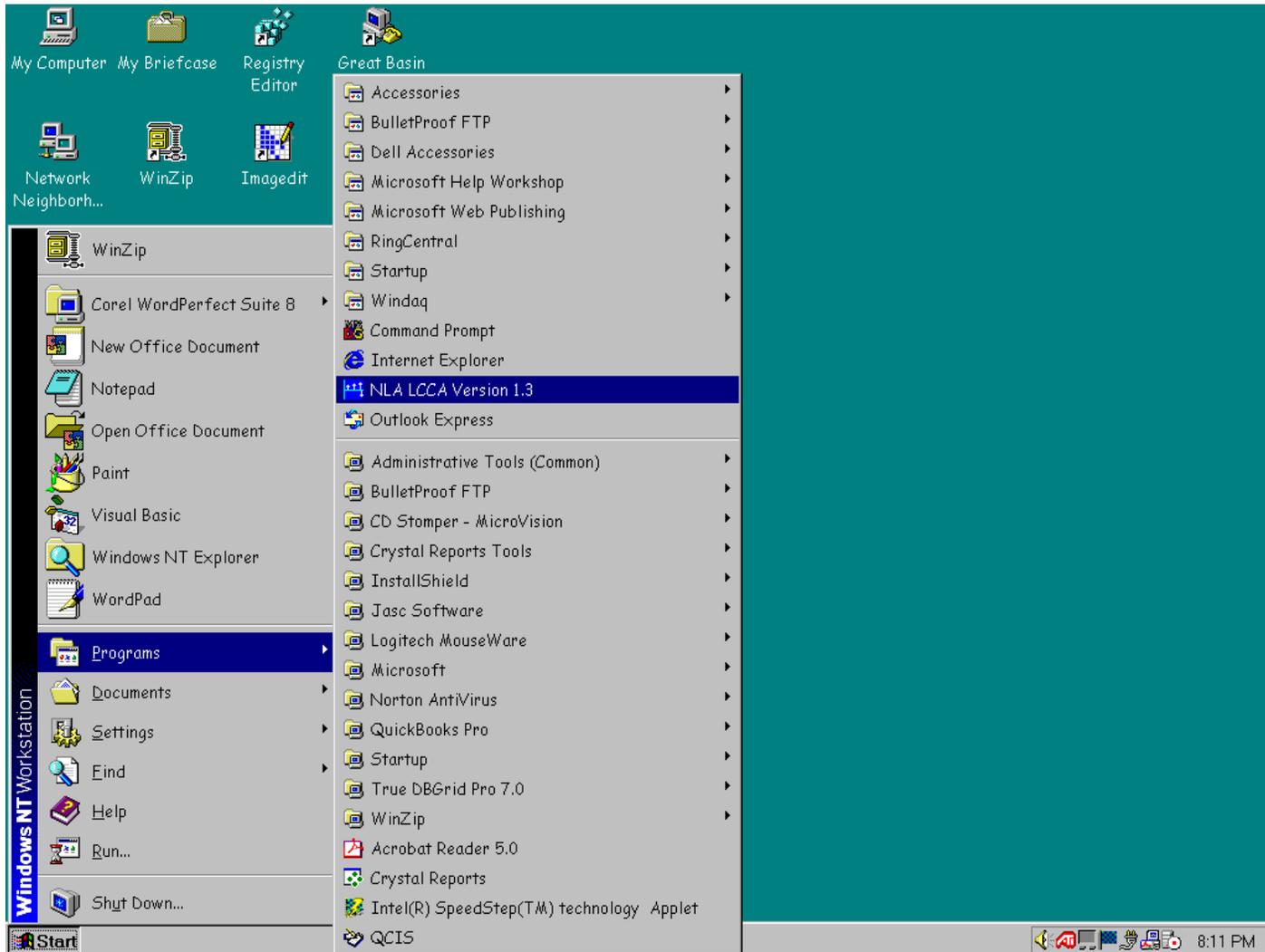


Figure 1. Selecting the LCCA Software Program Using the Windows Start Menu.

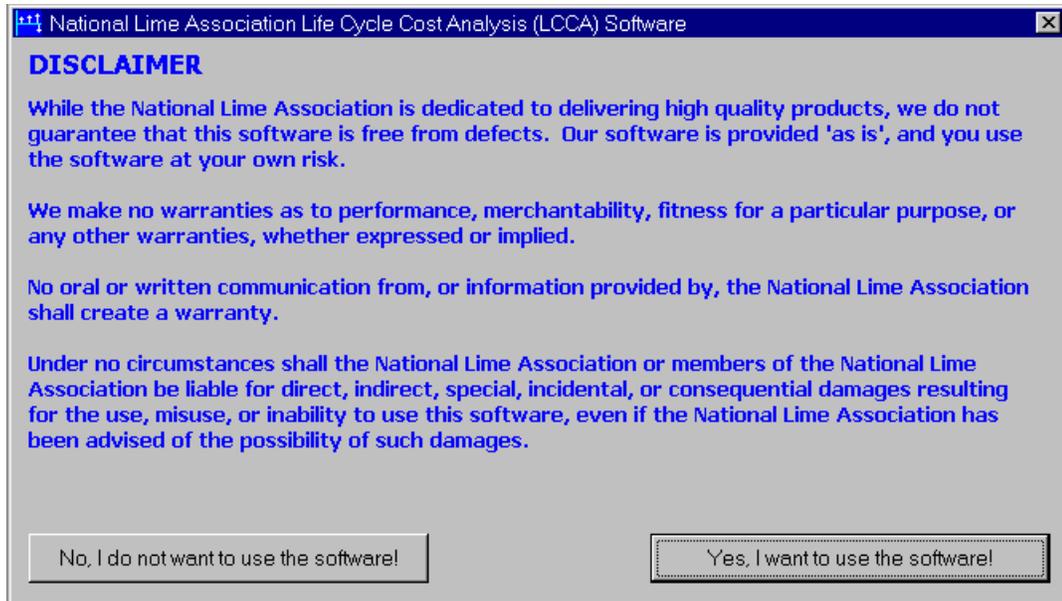


Figure 2. Disclaimer for the LCCA Software.

cost analysis or to open an existing (previously saved) project. Prior to describing the inputs required for a life cycle cost analysis, the following paragraphs provide details regarding the Main Module form.

Main Module Features

The Main Module form is a container for all other forms that make-up the LCCA software package. As indicated in Figure 4, it contains a menu bar at the top of the form with three menu choices: File, Units, and Help.

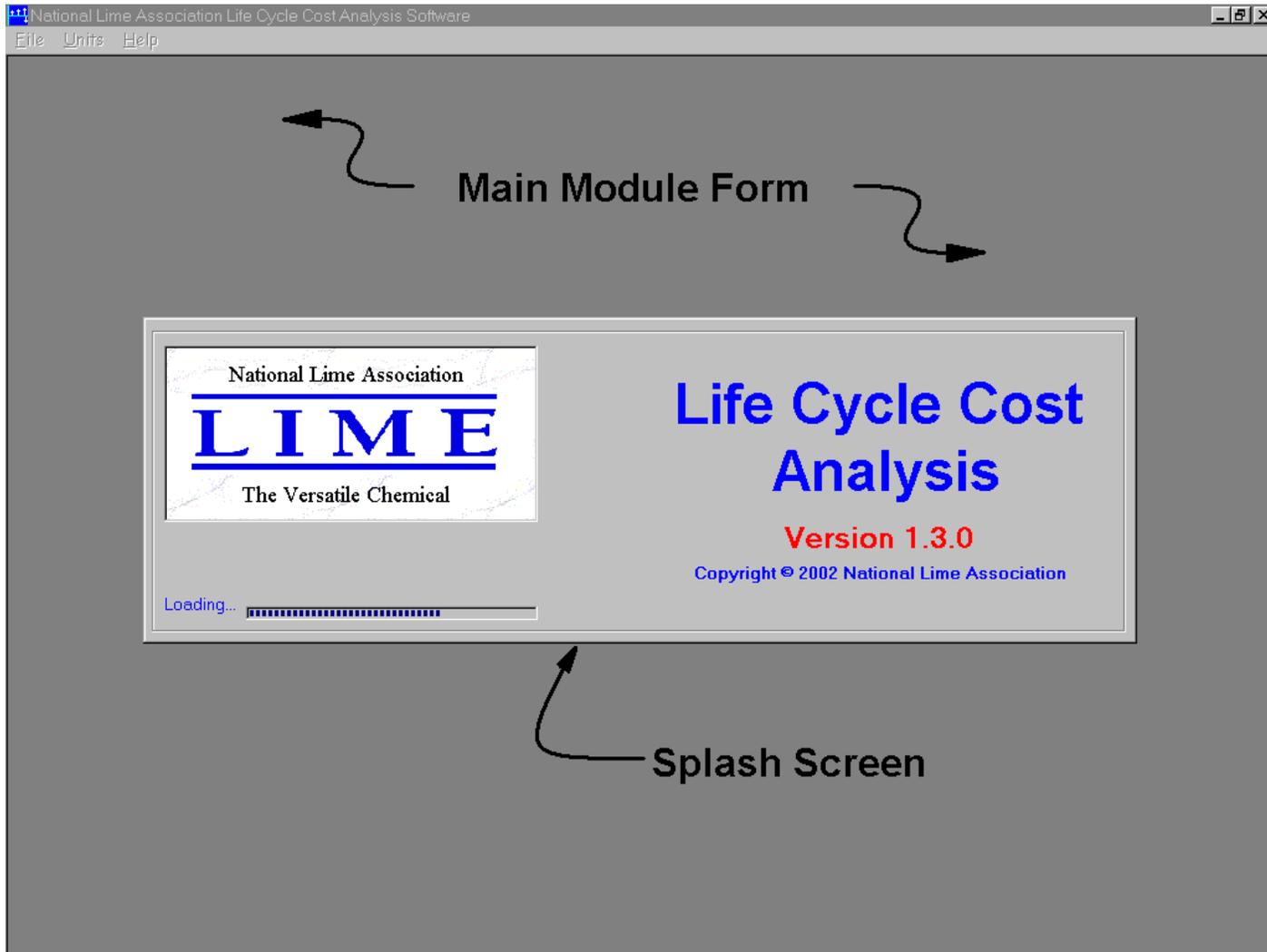


Figure 3. Main Module Form with Splash Screen.



Figure 4. Form for Selecting an Analysis Approach or Opening an Existing Project.

File Menu

The File menu contains the two menu choices shown in Figure 5. Clicking on the word File, or holding down the Alt key and pressing the F key, displays these menu choices. Once displayed, clicking on a particular menu choice, or holding down the Alt key and pressing the underlined letter in the menu choice, selects a particular menu choice. Under the File menu selecting the Del... menu choice allows previously saved projects to be deleted whereas selecting the Exit menu choice quits the LCCA software package. Deleting existing projects is discussed in further detail below (see **Deleting an Existing Project** in this section).



Figure 5. Menu Choices in the File Menu.

Units Menu

The Units menu contains the menu choices shown in Figure 6. The menu is used to select the units to be used in a given LCCA. Selecting the US menu choice sets the units to U.S. Customary units, whereas selecting the SI menu choice sets the units to *Système Internationale d' Unités* (metric units). The type of units in force is indicated by the check mark adjacent to the menu choice. For example, Figure 6 indicates that U.S. Customary units have been previously selected and are currently in force. The units in force at the time the LCCA software package is terminated (exited) become the default units the next time the software package is run. This allows selecting either US units or SI units as the default units. Units can only be changed when the form shown in Figure 4 is displayed (i.e., units cannot be changed “on-the-fly” in the middle of an analysis).

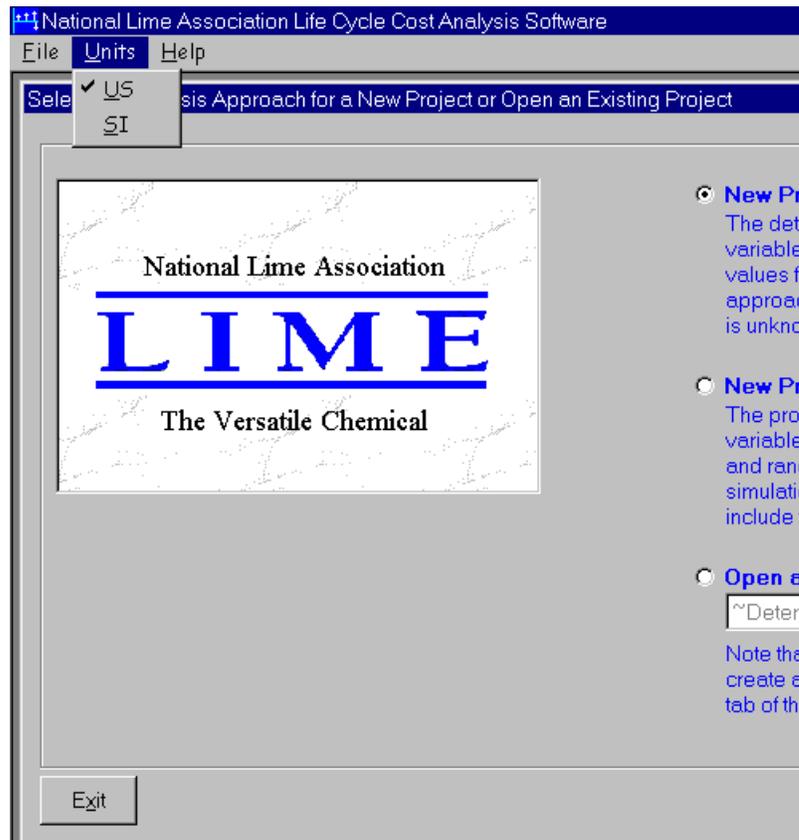


Figure 6. Menu Choices in the Units Menu.

Help Menu

The Help menu contains the menu choices shown in Figure 7. Selecting either the Contents menu choice or the Search for Help On... menu choice opens the Help system. Further details of the Help System are discussed below (see **Using the Help System** later in this section). Selecting the About menu choice displays the About dialog shown in Figure 8, which has no functionality other than to display the information shown.



Figure 7. Menu Choices in the Help Menu.

Selecting an Analysis Approach

The LCCA software provides two analysis approaches: 1) the deterministic approach, and 2) the probabilistic approach. Deterministic analyses do not consider variability in that only the mean (average) values of the inputs are utilized in the analyses.

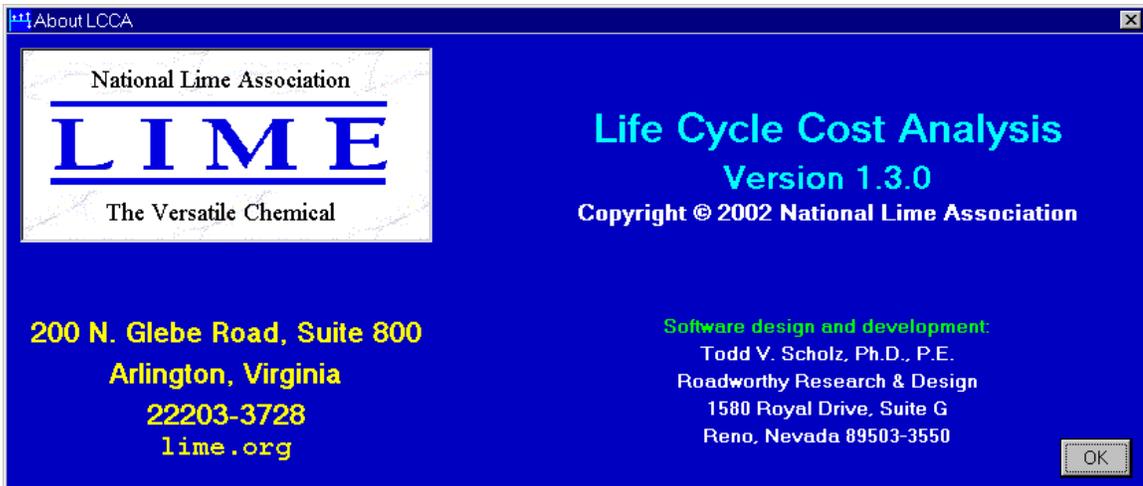


Figure 8. The About Dialog.

Deterministic analyses are appropriate whenever the variability of the maintenance and rehabilitation treatment lives and costs are not known. Probabilistic analyses, on the other hand, consider the variability of the M&R treatment lives and costs (as well as variability in the discount rate) through a Monte Carlo simulation process. However, this form of analysis requires knowledge (or estimation) of the variability of the inputs varied during the analysis. The Federal Highway Administration (FHWA) recommends use of the probabilistic approach (Walls and Smith, 1998).

The form used to select the analysis approach was shown in Figure 4 and is shown on a slightly larger scale in Figure 9. Clicking on the radio button (see Figure 9) adjacent to the desired analysis approach (or the words themselves) selects the approach to be used for new projects. Figure 9 indicates that the deterministic approach has been selected as indicated by the black dot in the radio button. Once an analysis approach is selected, click on the OK button to open the Project Inputs form (see **Section 3.2**).

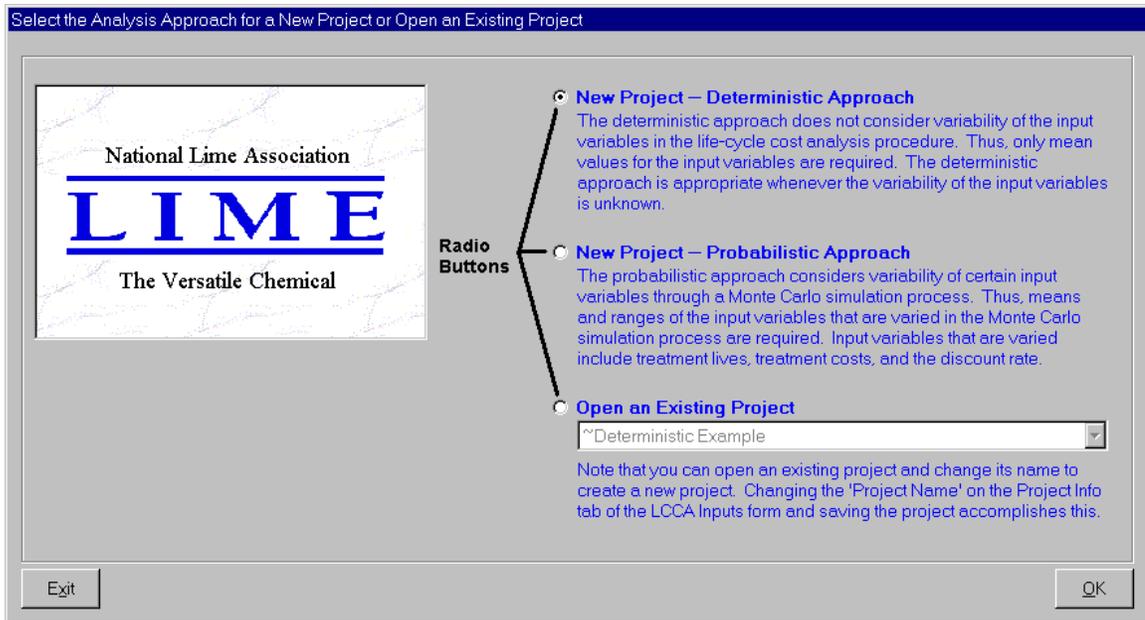


Figure 9. Selecting an Analysis Approach.

Opening an Existing Project

The form for selecting an analysis approach (Figure 9) also includes a radio button and drop-down list for opening existing (previously saved) projects. Clicking on the radio button adjacent to the words “Open an Existing Project” (or the words themselves) activates the drop-down list as shown in Figure 10. Clicking on the drop-down button (▾) at the right side of this control displays the contents of the list. Highlighting and clicking on the name of the desired project selects the project. Figure 10 indicates that the project named “Arizona Interstate Deterministic” is being selected. Once selected, clicking on the OK button opens the project. If results exist for the project, a dialog shown in Figure 11 is displayed indicating that results exist and asks if you want to display them. Answering “yes” by clicking on the Yes button opens the Results Viewer form (see **Section 3.3**) whereas answering “no” by clicking on the No button opens the Project Inputs form (see **Section 3.2**).

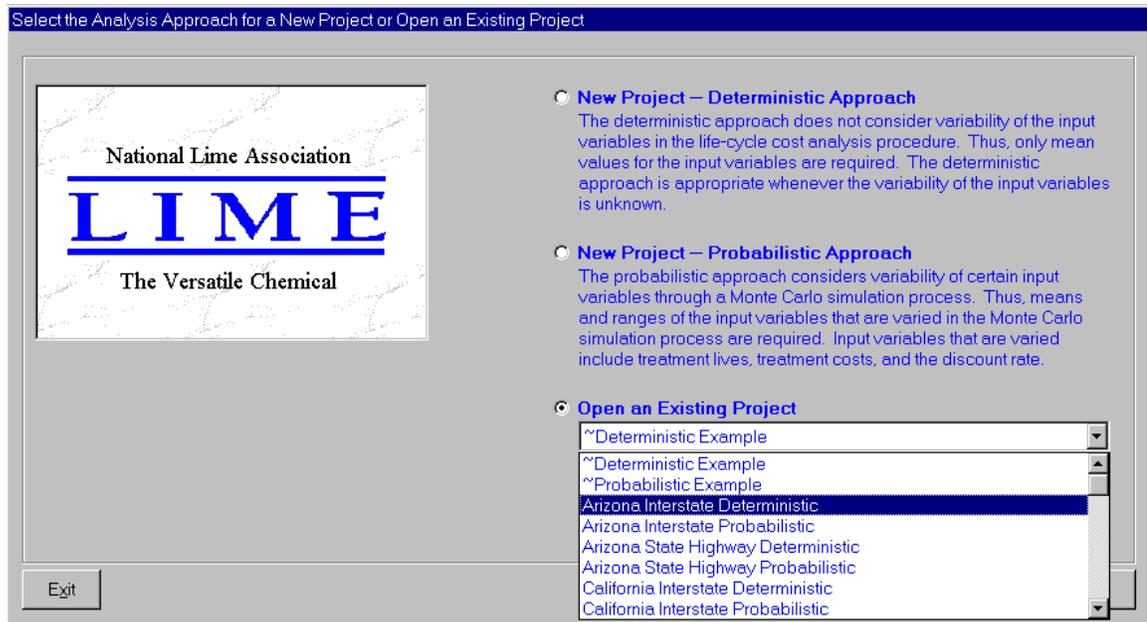


Figure 10. Selecting an Existing Project to Open.

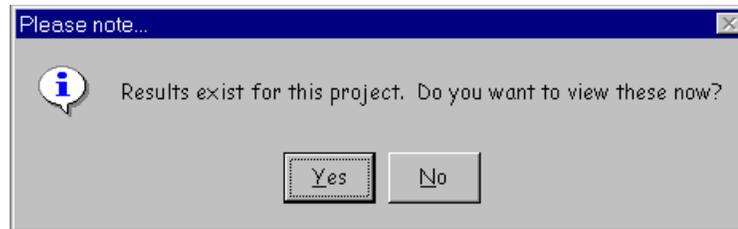


Figure 11. Dialog Indicating Results Exist for the Project Being Opened.

Deleting an Existing Project

Existing projects can be deleted from the database using the File/Delete... feature.

Clicking on the File menu and selecting the Delete... menu choice (see Figure 5)

accesses this feature. This feature has been provided so that the database can be

maintained to a reasonable size¹.

¹ A substantial amount of information is saved to the database whenever probabilistic analyses are run. When numerous projects of this type are contained in the database, the database gets very large and this can substantially reduce the performance (speed) of the analysis process. Thus, for best performance, it is recommended that the number of projects utilizing the probabilistic approach be kept to a minimum. **Saving Project Information** in Section 3.2 provides further details on how projects of this type can be retained in the database while keeping the database to a reasonable size.

Figure 12 shows the form that is displayed when the File/Delete... feature is accessed. It includes a drop-down list of all of the projects contained in the database. Clicking on the drop-down button (▼) at the right side of this control displays the contents of the list as shown in Figure 13. Highlighting and clicking on the name of the project selects it for deletion. This figure indicates that the project named “Mt. Rose – Arlington to Wells” is being selected for deletion. Once the project is selected, click on the Delete button to delete the project from the database.

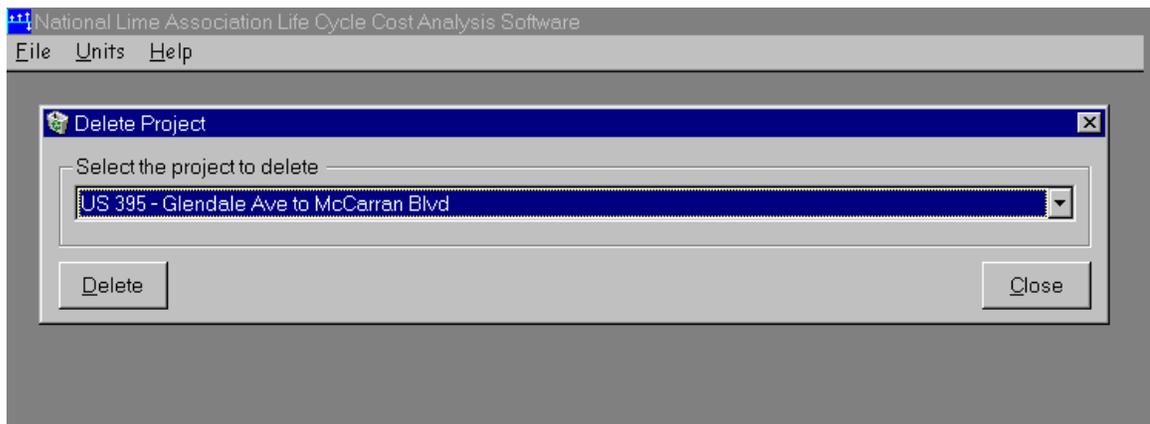


Figure 12. Form Used for Deleting Projects from the Database.

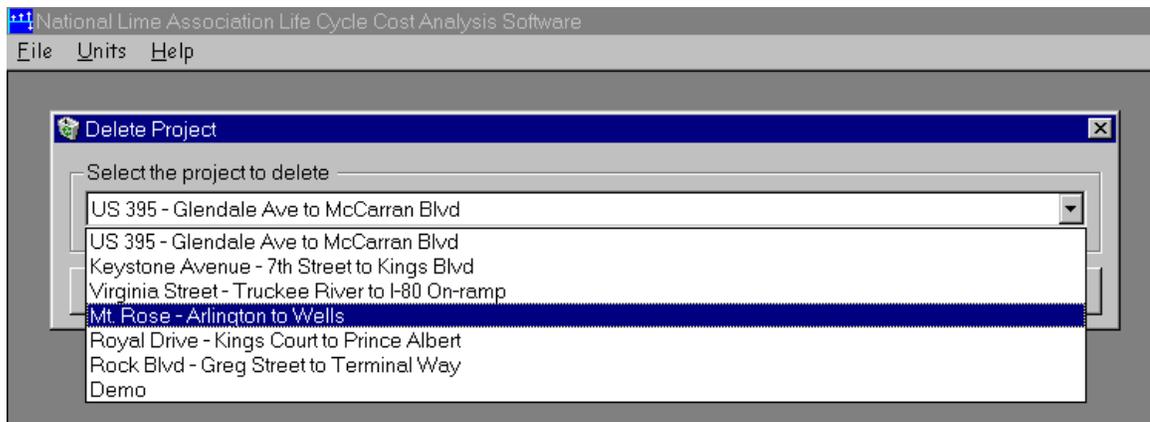


Figure 13. Selecting a Project to Delete from the Database.

You will be asked to confirm the deletion as indicated in Figure 14. Answering “yes” by clicking on the Yes button will result in the LCCA software deleting the selected project from the database whereas answering “no” by clicking on the No button will abort the deletion process and the selected project will be preserved in the database. Any time a project is deleted from the database, the LCCA software compacts the database resulting in a reduction in its size.

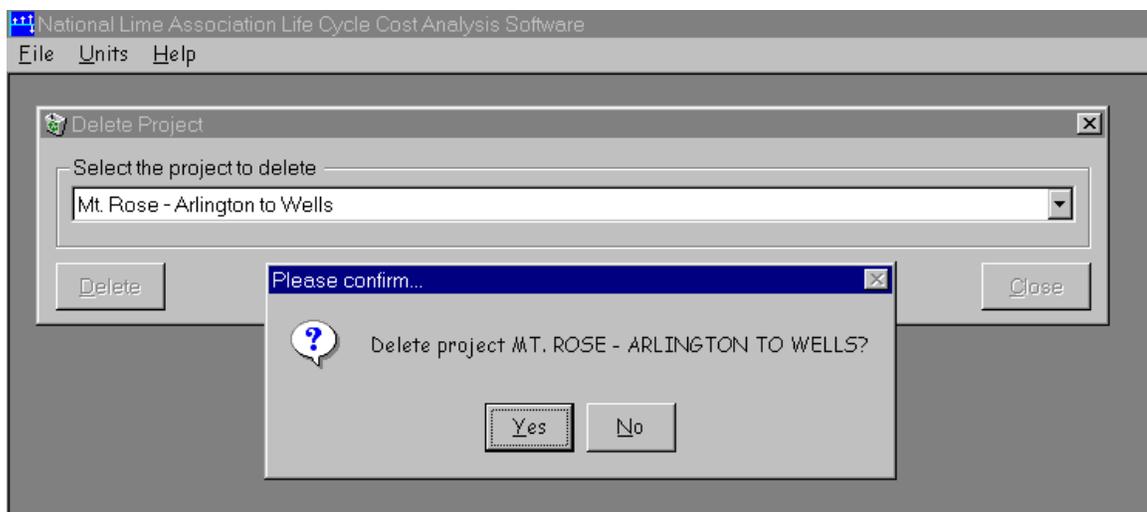


Figure 14. Dialog to Confirm Deletion of a Project From the Database.

Using the Help System

Most elements of this user’s guide are contained in an on-line Help system (i.e., a system that can be accessed from within the LCCA software package). Clicking on the Help menu and selecting either the Contents or Search For Help On... menu choices (see Figure 7) opens the Help system. Selecting the Contents menu choice displays the Contents page of the Help system dialog as shown in Figure 15.

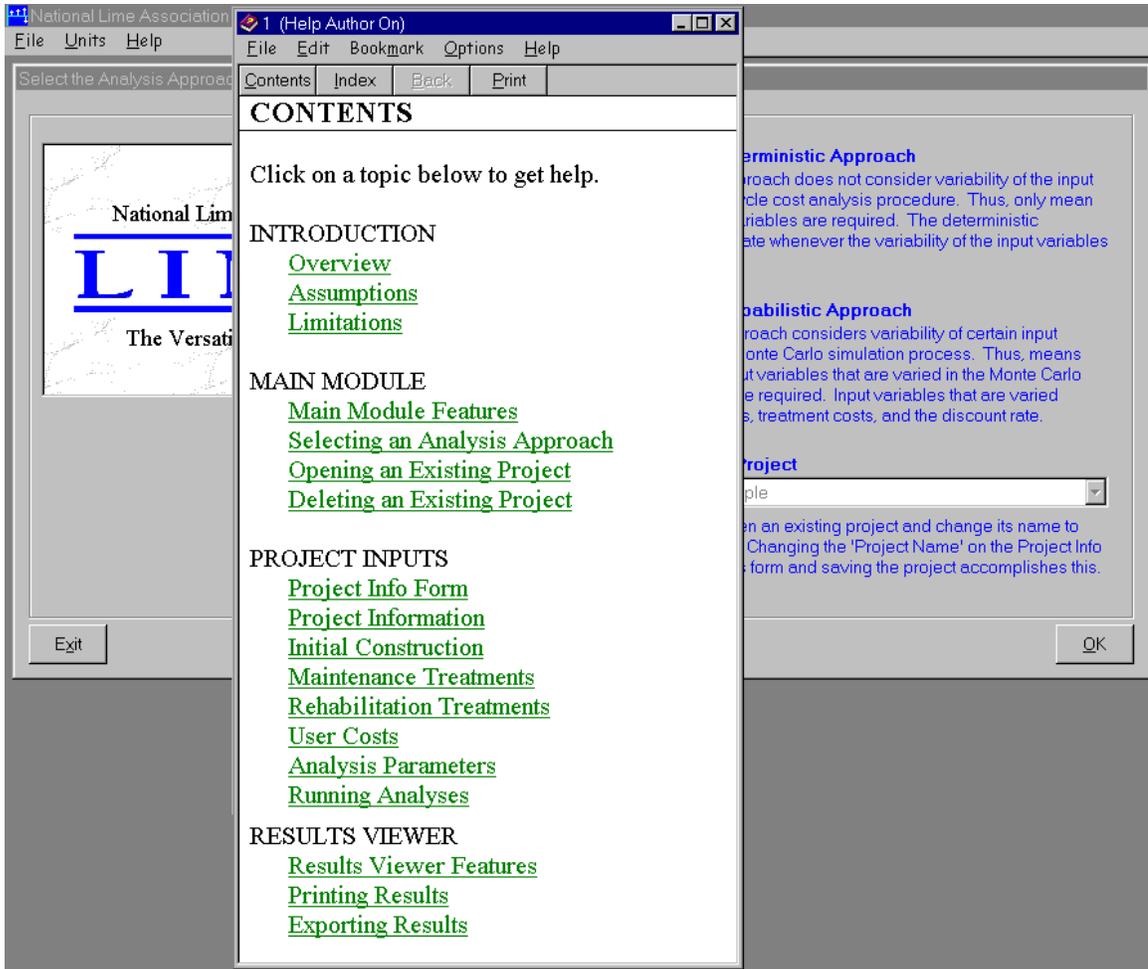


Figure 15. Contents of the Help System Dialog.

Clicking on the topic (shown in green lettering and underlined) displays contents of the help system for the topic. For example, Figure 16 indicates that the topic Overview (under the topic heading of INTRODUCTION) has been selected and the contents of the Help system for this topic have been displayed.

Selecting the Search For Help On... menu choice from the Help menu displays the index to the Help system as shown in Figure 17. Highlighting an item in this list and clicking on the Display button displays the contents of the Help system for the selected item.

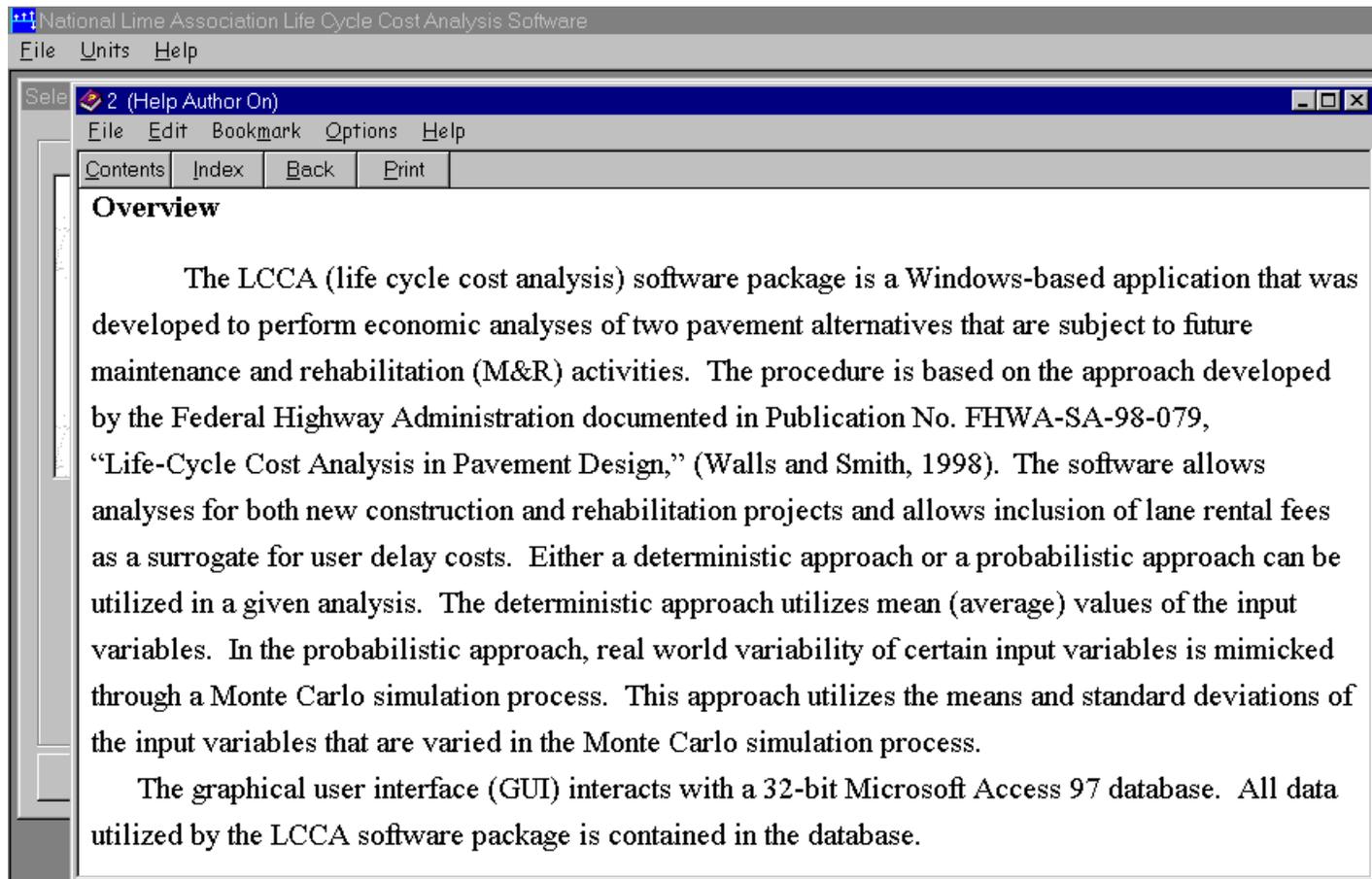


Figure 16. Example of the Contents of the Help System for the Topic Covering the Software Overview.

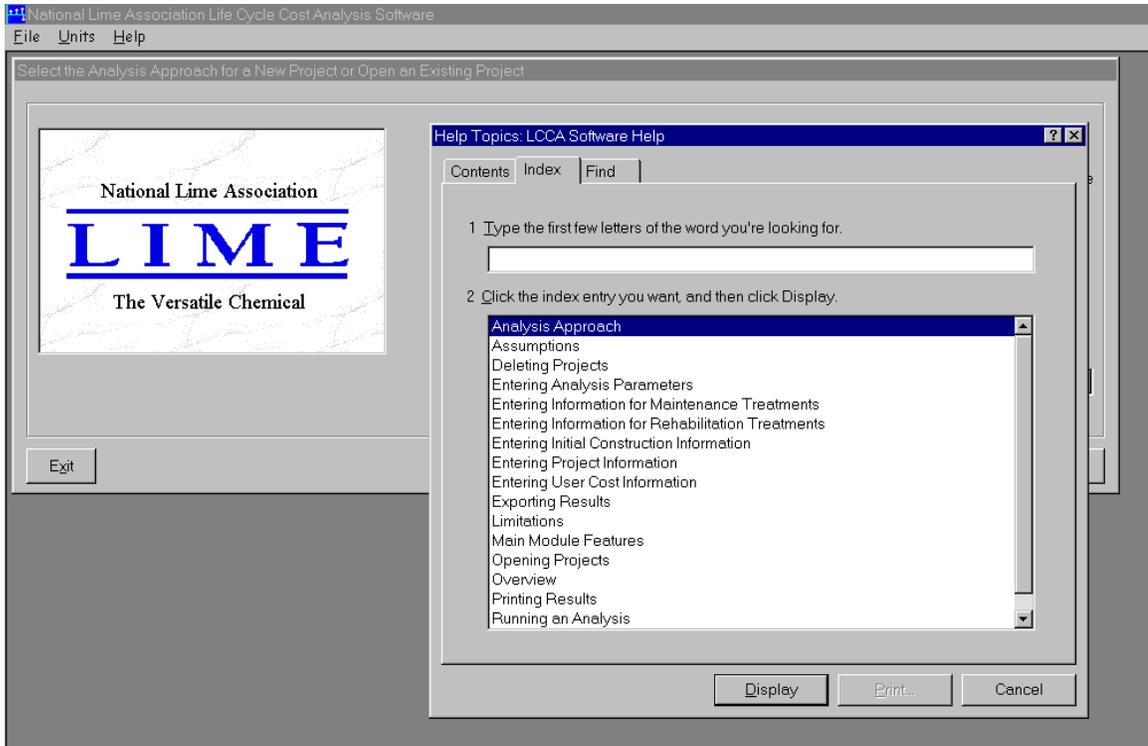


Figure 17. Help System Dialog Showing the Index for the Help System.

The Help system also contains a “find” feature that can be used to search the Help system. Figure 18 shows an example search where the letters p and r were entered in the box at the top of the dialog.

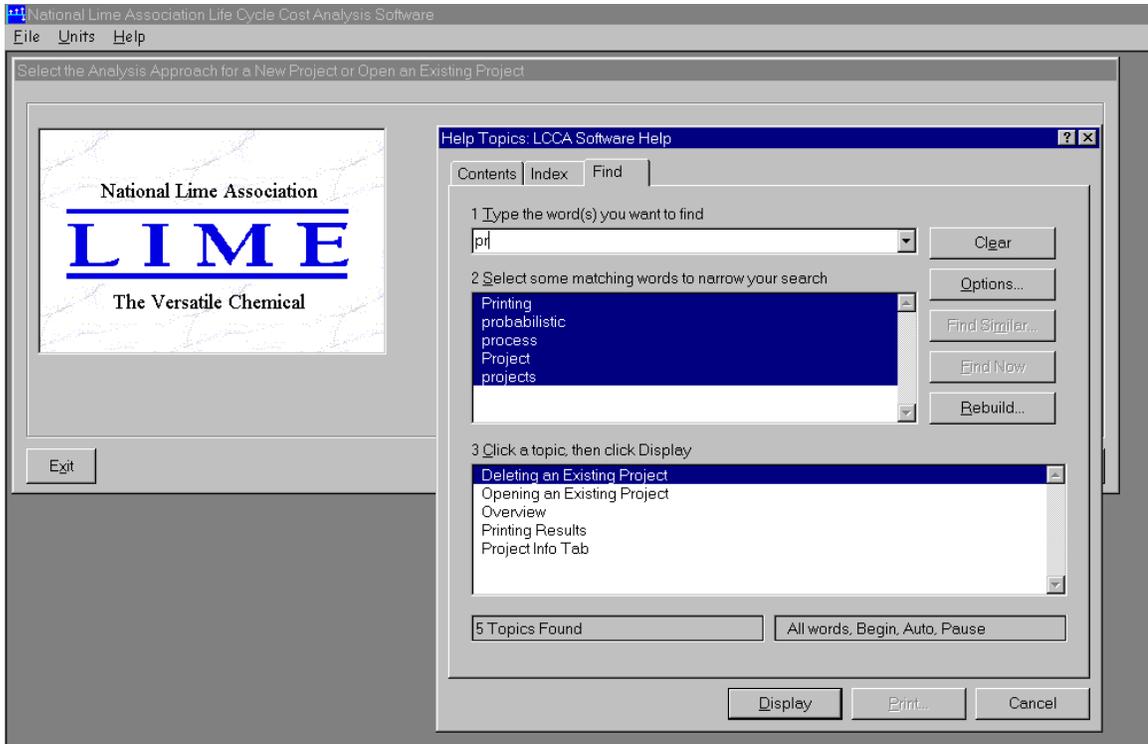


Figure 18. Help System Showing the Find Feature Tab.

3.2 Project Inputs Form

This section provides detailed information regarding the required inputs for conducting life cycle cost analyses. It provides guidance for defining:

- project specific information;
- information regarding the initial construction alternatives;
- maintenance treatments applied to the initial construction and rehabilitation alternatives;
- rehabilitation treatments applied throughout the analysis period;
- user costs in terms of lane rental fees; and
- analysis parameters.

Project Information

Figure 19 shows the Project Info tab of the Project Inputs form. Use this tab to enter information about the project. Controls colored yellow indicate required input whereas controls colored white indicate optional input. For example, Figure 19 indicates that a project name, lane configuration, lane width, and project beginning and ending stations are required, whereas all information on the Project Location and Description frame is optional. The following provides further details about the controls on this tab:

- **Project Name (Required):** Use this text box to enter a name for the project. Clicking on the yellow box and typing a name accomplishes this. The name can be up to 100 characters in length (spaces count as characters). Figure 19 indicates that the name “Demo” has been entered for the project name.
- **Project Location and Description (Optional):** Double-click on the words within these text boxes and type information to replace the text. State, County, Route, and Project ID are limited to 20 characters whereas the Description can be up to 255 characters in length (spaces count as characters).
- **Lane Configuration and Dimensions (Required):** Use the controls on this frame to identify the number of lanes, included lane widths, and project termini. The lane configuration is selected from the drop-down list in the upper left corner of this frame as shown in Figure 20, whereas the number of lanes to include for the project is indicated by the check boxes. For example, Figure 20 indicates only one lane is to be included whereas Figure 21 indicates three lanes are to be included for the project.

Project Info | Initial Construction | Maintenance | Rehabilitation | User Costs | Analysis

Project Name: Demo

Project Location and Description:
 State: State | Description: Description
 County: County
 Route: Route
 Project ID: ID

Lane Configuration and Dimensions:
 Lane Configuration: Two, Undivided
 Lane 1: 12.00 feet (checked)
 Lane 2: (unchecked)

Project Length:
 Note: Stations are expressed in units of feet.
 Beginning Station: 1+50.75
 Ending Station: 26+50.75
 Project Length (feet): 2500

US Units | Quit

Figure 19. Project Info Tab of the Project Inputs Form.

Project Info | Initial Construction | Maintenance | Rehabilitation | User Costs | Analysis

Project Name: Demo

Project Location and Description:
 State: State | Description: Description
 County: County
 Route: Route
 Project ID: ID

Lane Configuration and Dimensions:
 Lane Configuration: Two, Undivided (dropdown menu open)
 Lane 1: 12.00 feet (checked)
 Lane 2: (unchecked)

Project Length:
 Note: Stations are expressed in units of feet.
 Beginning Station: 1+50.75
 Ending Station: 26+50.75
 Project Length (feet): 2500

US Units | Quit

Figure 20. Selecting the Lane Configuration for the Project.

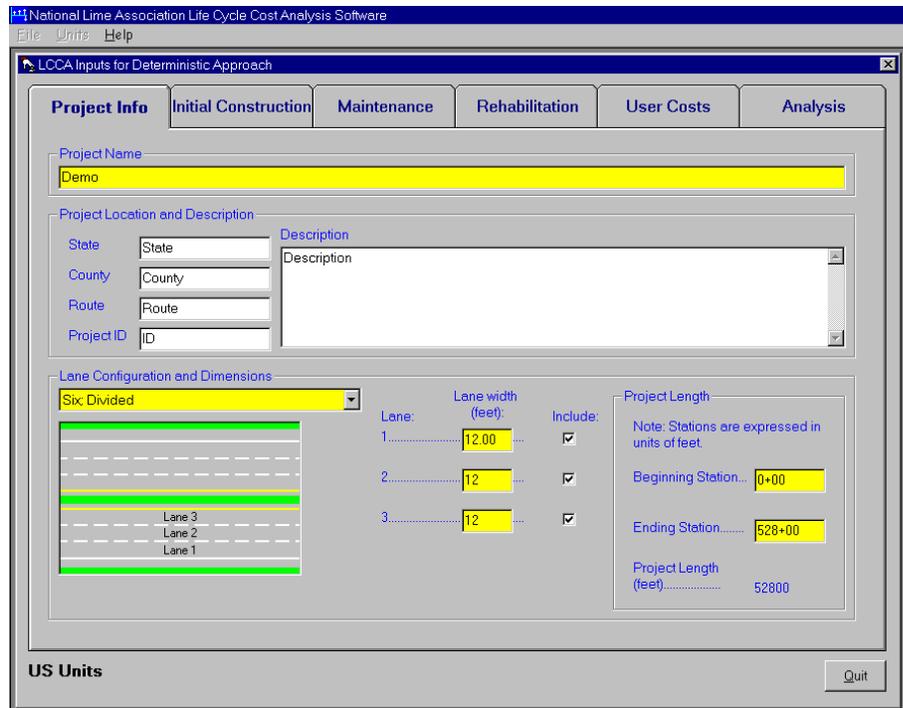


Figure 21. Using the Include Check Boxes to Indicate Which Lanes to Include.

- **Project Length (Required):** Use the two text boxes on the Project Length frame to enter the beginning and ending locations of the project. Enter these in stations. For example, Figure 21 indicates a beginning location at Station 0+00 and an ending location at Station 528+00, giving a project length of 10 miles (for 3 lanes, the total project area equals 30 lane-miles).

Initial Construction

Figure 22 shows the Initial Construction tab of the Project Inputs form. Use the controls on this tab to enter information about the two alternatives for which the life cycle cost analysis is being conducted. Controls colored yellow indicate required input, whereas controls colored white indicate optional input. The following provides further details about the controls on this tab:

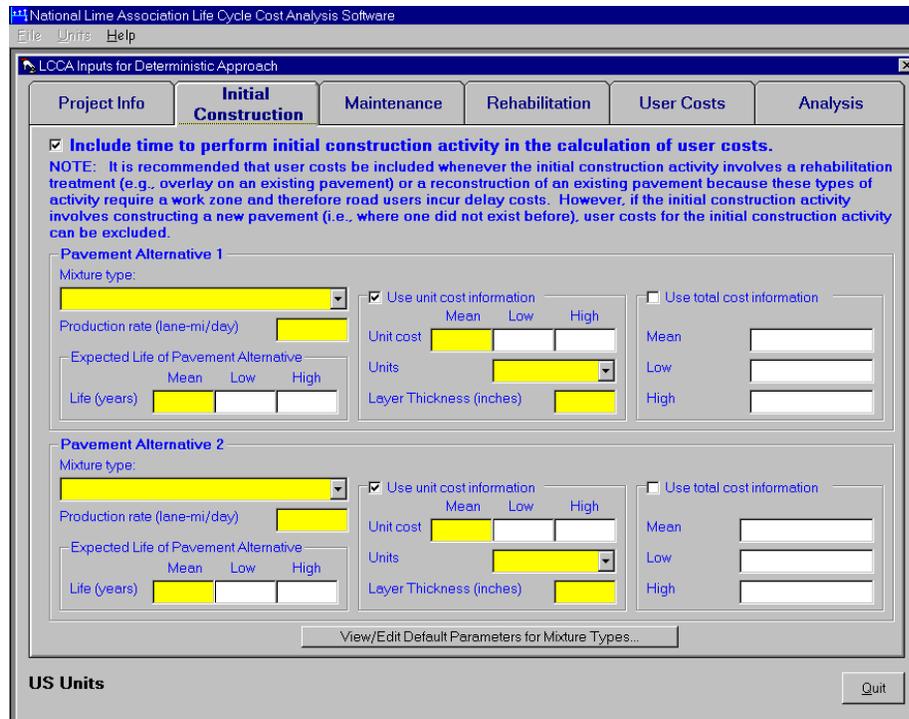


Figure 22. Initial Construction Tab of the Project Inputs Form.

- Include time to perform initial construction activity in the calculation of user costs: Check the check box (default), as shown in Figure 22, to include user costs for the initial construction activities. Uncheck the check box to exclude user costs.
- Pavement Alternative 1: Use the controls on this frame to indicate the mixture type, the production rate for constructing the pavement layer (for rehabilitation projects), the expected life of the pavement, and unit cost for construction or total cost for construction. Use the drop-down list to select the mixture type as indicated in Figure 23. Use the text box below the drop-down list to indicate the production rate in lane-miles/day or lane-kilometers/day for constructing the pavement. Use the text boxes on the Expected Life of Pavement Alternative

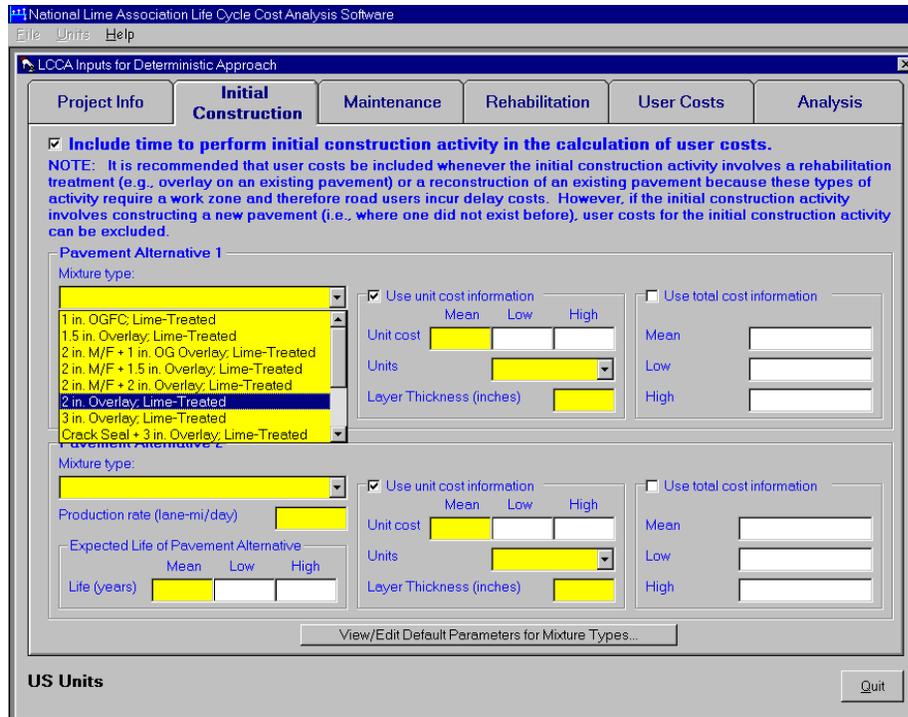


Figure 23. Selecting the Mixture Type for Initial Construction.

frame to enter the mean expected life, in years, of the pavement. If running a probabilistic analysis, enter the low and high estimates for the expected life of the pavement. The low estimate is assumed to correspond to the 10th percentile value for the life (i.e., 1 in 10 projects fail to achieve this life) and the high estimate is assumed to correspond to the 90th percentile value (i.e., 1 in 10 projects exceed this life). You can use either unit cost information (default) or total cost information to indicate the cost for initial construction. If using unit cost information, enter the mean unit cost for the mixture and select the units from the drop-down list as shown in Figure 24. Note that you can specify sq yd-in, sq yd, or ton in US units and sq m-25mm, sq m, or Mg in SI units. If conducting a probabilistic analysis, also enter the low and high estimates of the unit cost.

These are assumed to correspond to the 10th and 90th percentile values, respectively. Also, if you select sq yd-in (or sq m-25mm) as the units,

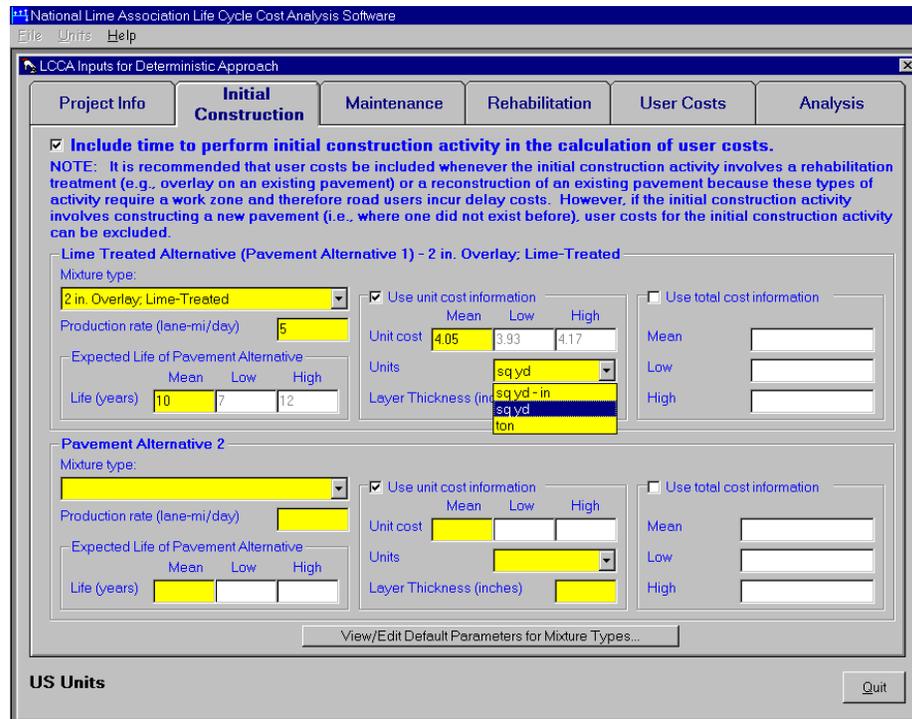


Figure 24. Selecting the Units for Unit Costs.

you will need to specify a thickness for the pavement layer. If you want to use total cost information, click on the check box on the Use total cost information frame and enter a value for the mean total cost for construction. If running a probabilistic analysis, also enter the low and high estimates for the total cost of construction. These are assumed to correspond to the 10th and 90th percentile values, respectively.

- Pavement Alternative 2: Use the controls on this frame in the same manner as for Pavement Alternative 1 to indicate values for Pavement Alternative 2.

You can edit the default values for the mixture type parameters. Clicking on the View/Edit Default Parameters for Mixture Types... button opens the form shown in

Figure 25. Changing the values on this form changes the values stored in the database.
 Values stored in the database are default values.

Description	Thickness, in	Unit Weight, lb/ft ³	Mean Life, years	Life (Low), years	Life (High), years	Use Unit Costs?	Unit Cost
1 in. OGFC, Lime-Treated	1	130	5	3	7	<input checked="" type="checkbox"/>	2.
1.5 in. Overlay; Lime-Treated	1.5	150	10	7	15	<input checked="" type="checkbox"/>	3.
1.5 in. Overlay; Unmodified	1.5	150	8	5	12	<input checked="" type="checkbox"/>	.
2 in. M/F + 1 in. OG Overlay; Lime-Treated	3	143.33	15	13	17	<input checked="" type="checkbox"/>	7.
2 in. M/F + 1 in. OG Overlay; Unmodified	3	143.33	13	10	15	<input checked="" type="checkbox"/>	7.
2 in. M/F + 1.5 in. Overlay; Lime-Treated	3.5	142	10	7	15	<input checked="" type="checkbox"/>	8.
2 in. M/F + 1.5 in. Overlay; Unmodified	3.5	142	8	5	12	<input checked="" type="checkbox"/>	8.
2 in. M/F + 2 in. Overlay; Lime-Treated	4	150	10	8	12	<input checked="" type="checkbox"/>	8.
2 in. M/F + 2 in. Overlay; Unmodified	4	150	8	6	10	<input checked="" type="checkbox"/>	8.
2 in. Overlay + Digouts; Unmodified	2	150	4	3	7	<input checked="" type="checkbox"/>	.
2 in. Overlay; Lime-Treated	2	150	10	7	12	<input checked="" type="checkbox"/>	4.
2 in. Overlay; Unmodified	2	150	8	7	9	<input checked="" type="checkbox"/>	3.
3 in. Overlay + Digouts; Unmodified	3	150	8	6	10	<input checked="" type="checkbox"/>	8.
3 in. Overlay; Lime-Treated	3	150	10	8	12	<input checked="" type="checkbox"/>	9.

Figure 25. Form for Editing Default Parameters for Mixture Types.

New mixture types can be added to the database through the form shown in Figure 25. Clicking on the **Add New...** button changes the appearance of the form to that shown in Figure 26. Type in the values requested for the new mixture type in the text boxes and click on the **OK** button to store the new mixture type in the database. Note that all information requested is required to create the new mixture type. Once created, the grid shown in Figure 25 can be used to modify the default values. Clicking on the **Cancel** button changes the appearance of the form back to that shown in Figure 25. If a

new mixture type was not created, clicking on the Cancel button cancels creation of a new mixture type.

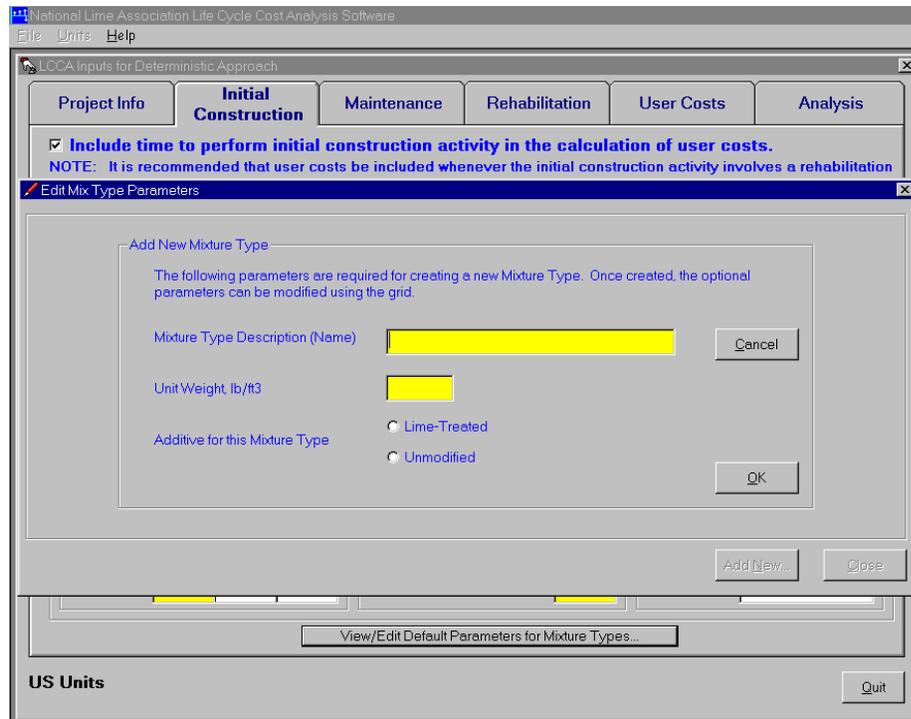


Figure 26. Controls for Creating a New Mixture Type.

Maintenance Treatments

Figure 27 shows the Maintenance tab of the Project Inputs form. Use the controls on the tab to enter information about the maintenance treatments to be applied to the two initial construction alternatives as well as the treatments applied to future rehabilitation alternatives. Use the controls on the upper frame to enter this information for the two initial construction alternatives and the controls on the lower frame for maintenance treatments applied after a rehabilitation treatment has been applied to the alternatives. Note that user costs can be determined for the maintenance activities. Clicking on the check box at the top of the tab activates this feature.

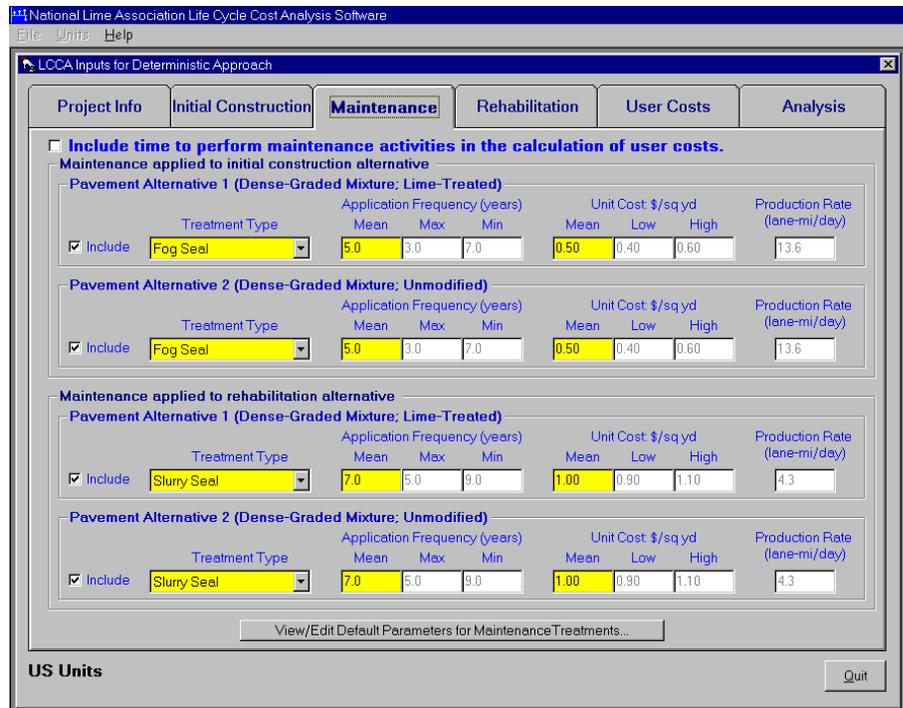


Figure 27. Maintenance Tab of the Project Inputs Tab.

Select the maintenance treatment type from the drop-down list as shown in Figure 28 and enter the application frequency (in years), the unit cost (in \$/sq yd or \$/sq m), and if including user costs, the production rate for applying the treatment (in lane-miles/day or lane-kilometers/day). If conducting a probabilistic analysis, also enter the minimum and maximum application frequencies (10th and 90th percentile values, respectively) and the low and high estimates for the unit cost of the treatment (also 10th and 90th percentile values, respectively).

Note that you do not have to include maintenance treatments in the analysis. Clicking on the Include check box next to the drop-down list for a particular treatment switches inclusion of a treatment on and off. For example, Figure 29 indicates that maintenance treatments will not be applied to the initial construction alternatives but that

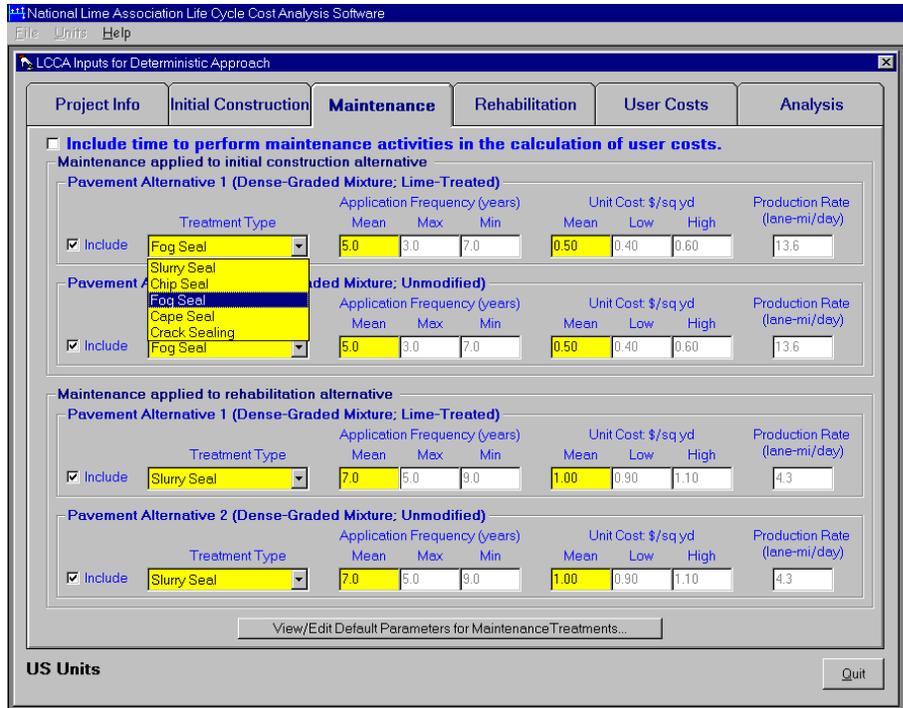


Figure 28. Selecting the Maintenance Treatment Type.

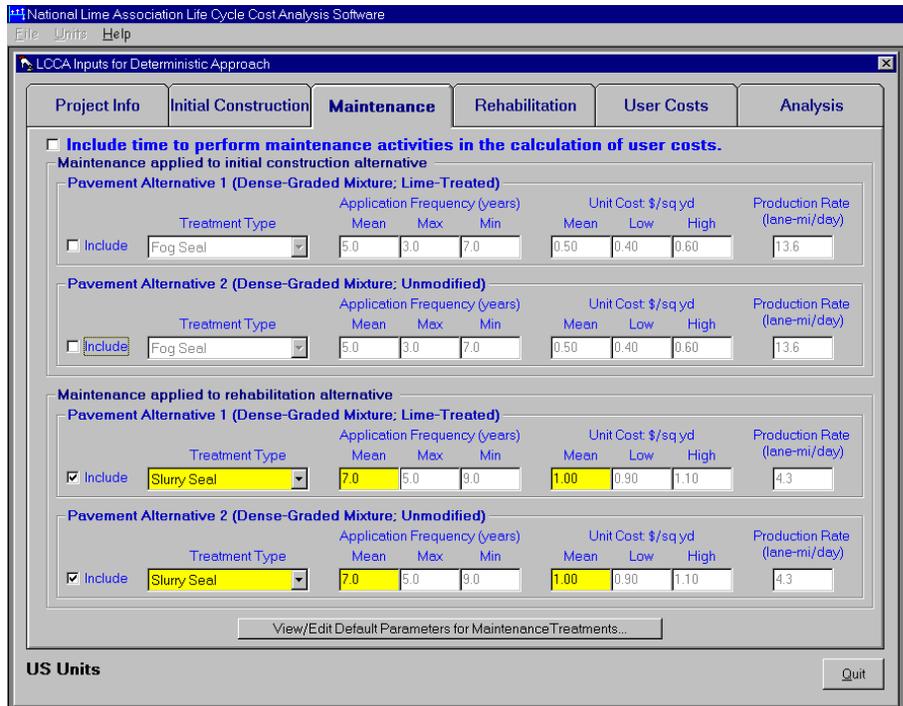


Figure 29. Switching Off Maintenance Treatments.

maintenance treatments will be applied once the initial construction alternatives have been rehabilitated.

You can edit the default values for the maintenance treatment parameters.

Clicking on the View/Edit Default Parameters for Maintenance Treatments... button opens the form shown in Figure 30. Changing the values on this form changes the values stored in the database. Values stored in the database are default values.

The screenshot shows a software window titled "National Lime Association Life Cycle Cost Analysis Software" with a menu bar (File, Units, Help) and a main window titled "LCCA Inputs for Deterministic Approach". The "Maintenance" tab is selected. A checkbox is checked: "Include time to perform maintenance activities in the calculation of user costs." Below it, a dropdown menu shows "Maintenance applied to initial construction alternative". A sub-dialog box titled "Edit Maintenance Treatment Parameters" is open, containing a table with the following data:

Maintenance Type	Mean Frequency, years	High Frequency, years	Low Frequency, years	Mean Unit Cost, \$	Low Unit Cost, \$	High Unit Cost, \$	Production Rate, lane-mi/day
Slurry Seal	7.0	5.0	9.0	1.00	0.90	1.25	4.3
Chip Seal	7.0	5.0	9.0	1.00	0.80	1.25	3.4
Fog Seal	5.0	3.0	7.0	0.35	0.26	0.44	13.6
Cape Seal	7.0	5.0	9.0	2.00	1.75	2.25	1.7
Crack Sealing	5.0	3.0	7.0	0.45	0.28	0.63	2.0

Below the table, the text "Units for Unit Costs: sq yd" is displayed in red. There are "Add New..." and "Close" buttons. At the bottom of the main window, there is a "View/Edit Default Parameters for Maintenance Treatments..." button and a "Quit" button.

Figure 30. Form for Editing Default Parameters for Maintenance Treatments.

New maintenance treatments can be added to the database through the form shown in Figure 30. Clicking on the Add New... button changes the appearance of the form to that shown in Figure 31. Type in the values requested for the new maintenance treatment in the text boxes and click on the OK button to store the new treatment in the database. Note that all information requested is required to create the new treatment.

Clicking on the Cancel button changes the appearance of the form back to that shown in Figure 30. If a new treatment was not created, clicking on the Cancel button cancels creation of a new maintenance treatment.

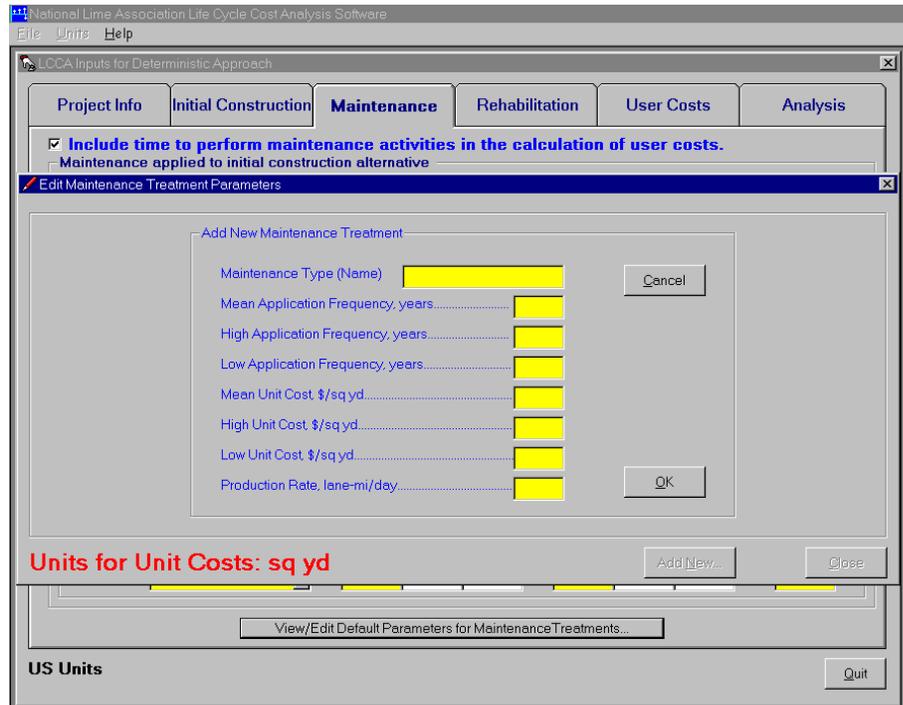


Figure 31. Controls for Creating a New Maintenance Treatment.

Rehabilitation Treatments

Figure 32 shows the Rehabilitation tab of the Project Inputs form. Use the controls on this tab to select/enter information regarding the rehabilitation treatments to be applied to the initial construction alternatives. Use the upper frame to enter information for Pavement Alternative 1 and the lower frame to enter information for Pavement Alternative 2. You can specify up to four different rehabilitation treatments per alternative. However, note that only one treatment need be specified (i.e., only one

treatment type is required). The software will apply the last treatment specified repeatedly until the end of the analysis period is reached. For example, if only one treatment is specified, it will be the only rehabilitation treatment applied throughout the analysis period.

Figure 32. Rehabilitation Tab of the Project Inputs Form.

Use the drop-down list to select the rehabilitation treatment type as shown in Figure 33. Clicking on the 2nd, 3rd, and 4th check boxes allows you to specify additional rehabilitation treatments for the pavement alternative. For example, Figure 34 indicates a second rehabilitation treatment is be specified for Pavement Alternative 1 and Figure 35 shows selection of the second treatment type from the drop-down list.

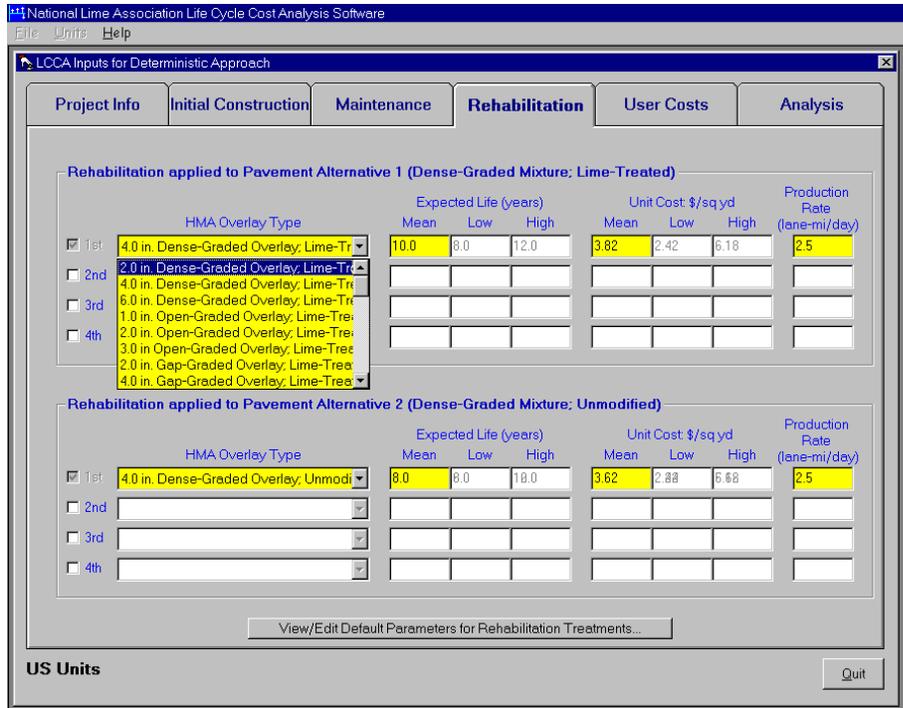


Figure 33. Selecting the Rehabilitation Treatment Type.

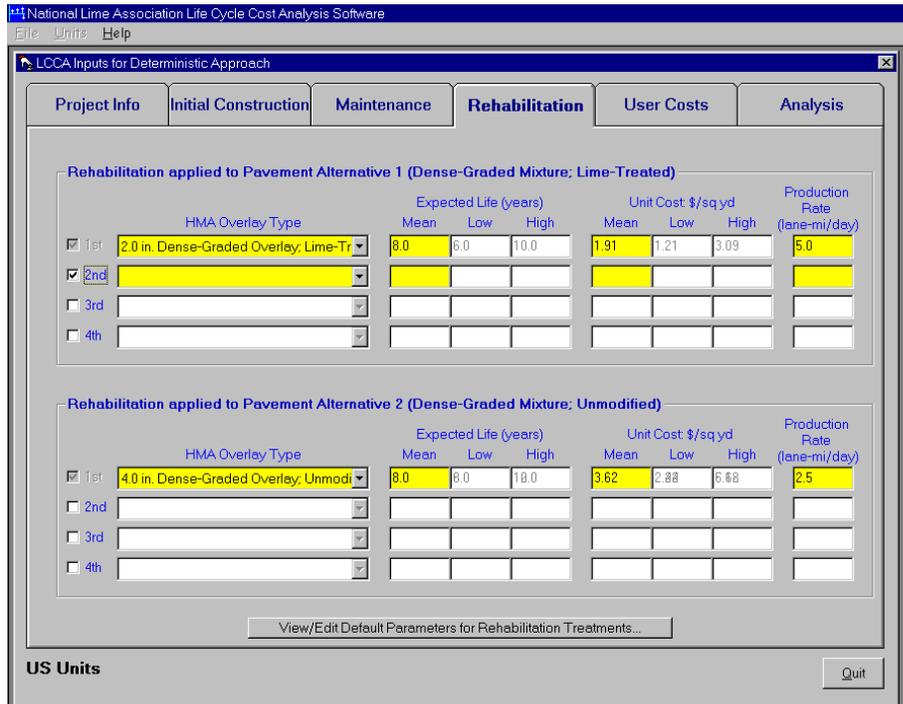


Figure 34. Specifying a Second Treatment Type for Pavement Alternative 1.

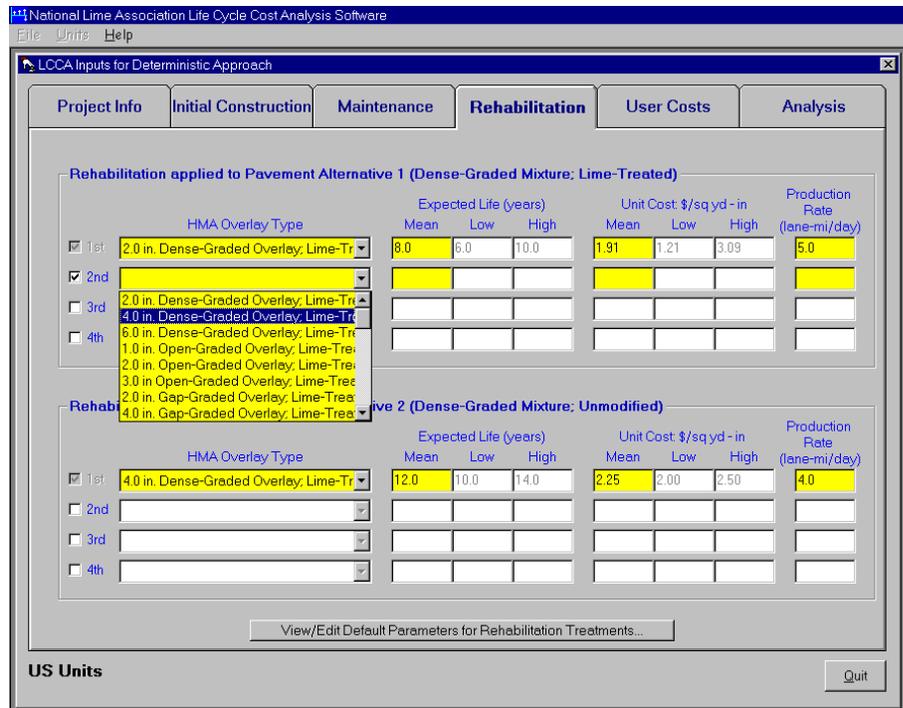


Figure 35. Selecting the Second Treatment Type for Pavement Alternative 1.

Use the text boxes to enter values for the mean expected life, mean unit costs, and production rates for each treatment specified. If conducting a probabilistic analysis, also enter low and high estimates for the expected life of the treatments and the low and high estimates for the unit costs. In both cases, the low value is assumed to correspond to the 10th percentile value and the high estimate is assumed to correspond to the 90th percentile value.

You can edit the default values for the rehabilitation treatment parameters. Clicking on the View/Edit Default Parameters for Rehabilitation Treatments... button opens the form shown in Figure 36. Changing the values on this form changes the values stored in the database. Values stored in the database are default values.

The screenshot shows the 'Edit Rehabilitation Treatment Parameters' dialog box. At the top, there are tabs for 'Project Info', 'Initial Construction', 'Maintenance', 'Rehabilitation', 'User Costs', and 'Analysis'. The 'Rehabilitation' tab is selected. Below the tabs, there is a title bar for the dialog: 'Edit Rehabilitation Treatment Parameters'. The main area contains a table with the following data:

Rehab Type	Thickness, in	Unit Weight, lb/ft ³	Mean Life, years	Life (Low), years	Life (High), years
2.0 in. Dense-Graded O	2.00	150.0	13.0	10.0	
1.0 in. Open-Graded Ov	1.00	130.0	10.0	8.0	
2.0 in. Gap-Graded Ove	2.00	140.0	12.0	9.0	
2.0 in. Dense-Graded O	2.00	150.0	10.0	7.0	
1.0 in. Open-Graded Ov	1.00	130.0	9.0	7.0	
2.0 in. Gap-Graded Ove	2.00	140.0	5.0	3.0	

Below the table, there is a dropdown menu for 'Units for Unit Costs' set to 'sq yd'. To the right of this dropdown are buttons for 'Add New...', 'Close', and 'Quit'. At the bottom of the dialog, there is a button labeled 'View/Edit Default Parameters for Rehabilitation Treatments...' and the text 'US Units'.

Figure 36. Form for Editing Default Parameters for Rehabilitation Treatments.

New rehabilitation treatments can be added to the database through the form shown in Figure 36. Clicking on the **Add New...** button changes the appearance of the form to that shown in Figure 37. Type in the values requested for the new rehabilitation treatment in the text boxes and click on the **OK** button to store the new treatment in the database. Note that all information requested is required to create the new treatment. Clicking on the **Cancel** button changes the appearance of the form back to that shown in Figure 36. If a new treatment was not created, clicking on the **Cancel** button cancels creation of a new rehabilitation treatment.

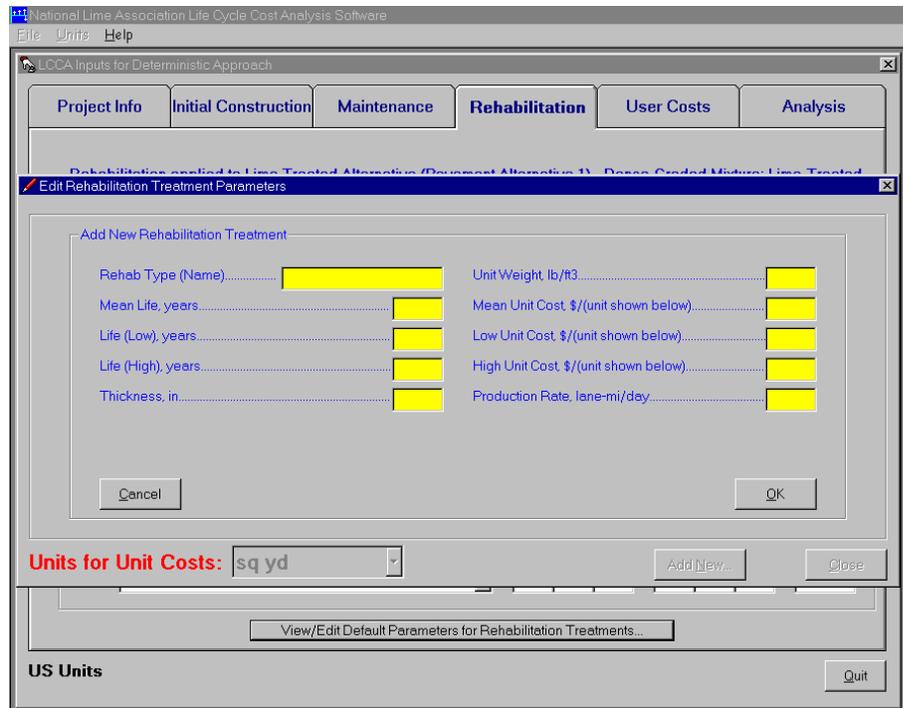


Figure 37. Controls for Creating a New Rehabilitation Treatment.

User Costs

Figure 38 shows the User Costs tab of the Project Inputs form. Use the controls on this tab to specify the lane rental fees to be used when a work zone is in place on the facility. These are used in conjunction with treatment production rates and the area of the project to determine user costs associated with performing maintenance and rehabilitation treatments, if inclusion of user costs were selected on the maintenance and rehabilitation tabs, respectively.

Use the radio buttons to indicate the expected traffic level and enter the lane rental fee (in \$/lane-mile/day for US units or \$/lane-kilometer/day for SI units) in the corresponding text box. For example, Figure 38 indicates that a moderate traffic level has been selected for the facility and that the lane rental fee is \$5000/lane-mile/day.

Low volume facility (ADT <= 5,000) 1000.00
 Moderate volume facility (5,000 < ADT <= 15,000) 5000.00
 High volume facility (ADT > 15,000) 10000.00

Lane Rental Fee (\$/lane-mi./day)

User costs can be included to account for the costs (delay costs, increased vehicle operating costs, crash costs, etc.) incurred by road users of a facility that is being rehabilitated or maintained (i.e., whenever a work zone is in place). Due to the difficulty of estimating actual user costs, particularly for future situations, the LCCA model utilizes lane rental fees as a surrogate for estimating user costs. This is accomplished by multiplying the lane rental fee unit cost (entered above) by the production rate for a particular initial construction, rehabilitation, or maintenance activity, taking into consideration the area of the facility affected. By default, user costs are determined for each analysis. However, although it is not advised, user costs can be excluded from a given analysis by unchecking the check boxes at the top of the 'Initial Construction', 'Maintenance', and 'Rehabilitation' tabs. Note that you can include/exclude calculation of user costs for any combination of the above activities. For example, you could include calculation of user costs for maintenance and rehabilitation activities but exclude these for the initial construction activity.

US Units Quit

Figure 38. User Costs Tab of the Project Inputs Form.

Analysis Parameters

Figure 39 shows the Analysis tab of the Project Inputs form. Use the controls on this tab to specify the duration of the analysis period (in years) and the mean discount rate. The analysis period must be long enough to include at least one rehabilitation treatment. The discount rate is used to discount future costs to the present values during the life cycle cost analyses and is assumed to not include an inflation premium. If conducting a probabilistic analysis, also enter the minimum discount rate, the maximum discount rate, and the number of iterations to use in the Monte Carlo simulation process (one iteration corresponds to the calculation of the life cycle costs associated with both pavement alternatives, whereas 500 iterations corresponds to the calculation of 500 life cycle costs associated with both pavement alternatives). A minimum of 300 iterations is required, but 500 or more is recommended, with the maximum being 32,767 iterations.

Use the drop-down list to select the initial units for displaying the cumulative present worth cost of the pavement alternatives on the Results Viewer form (see Section 3.3).

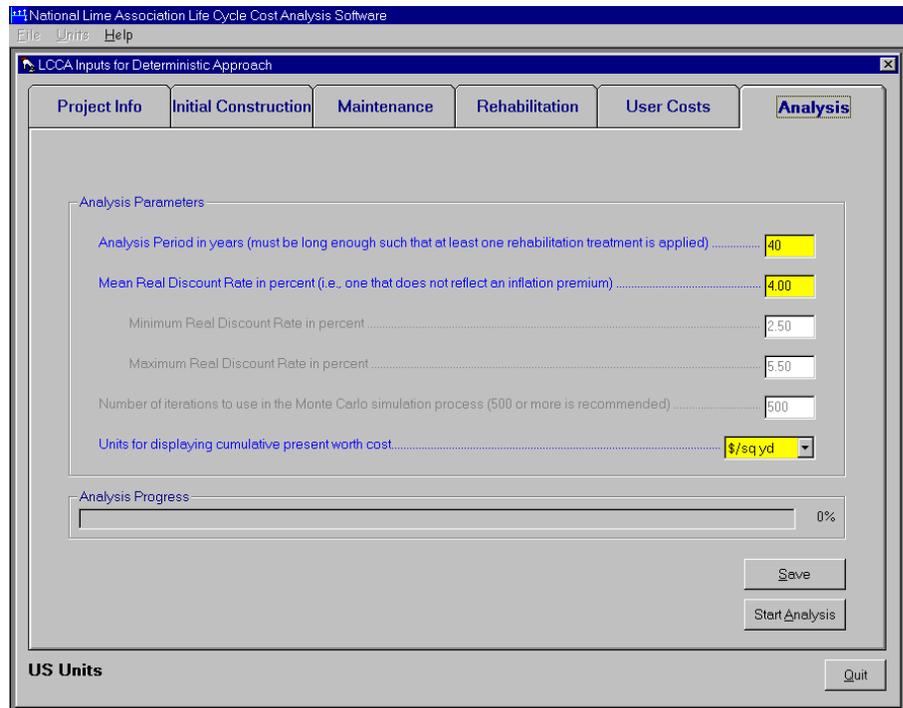


Figure 39. Analysis Tab of the Project Inputs Form.

Saving Project Information

Once all of the required inputs have been entered in the controls on all tabs of the Project Inputs form, clicking on the Save button saves this information to the database. If the information pertains to a new project, then new records are created in the database. If, however, the information pertains to a project that had been previously saved to the database, then the LCCA software deletes all information that had been previously saved, including analysis results (if any), and creates new records in the database that reflect the new contents of the controls on all tabs of the Project Inputs form, but no records containing analysis results. This feature allows retaining input data for numerous

projects without any records containing analysis results, which, for probabilistic analyses, amounts to a substantial number of records. Saving projects without analysis results can help keep the database to a reasonable size.

Running Analyses

Clicking on the Start Analysis button also saves the information to the database followed by running the life cycle cost analysis. When an analysis is running, the LCCA software plots its progression in terms of percent complete on the Analysis Progress frame. For example, Figure 40 shows that the probabilistic analysis is 70% complete, or that 350 of the 500 iterations have been completed. When the analysis finishes, the Results Viewer form is displayed. This form is discussed in the next section.

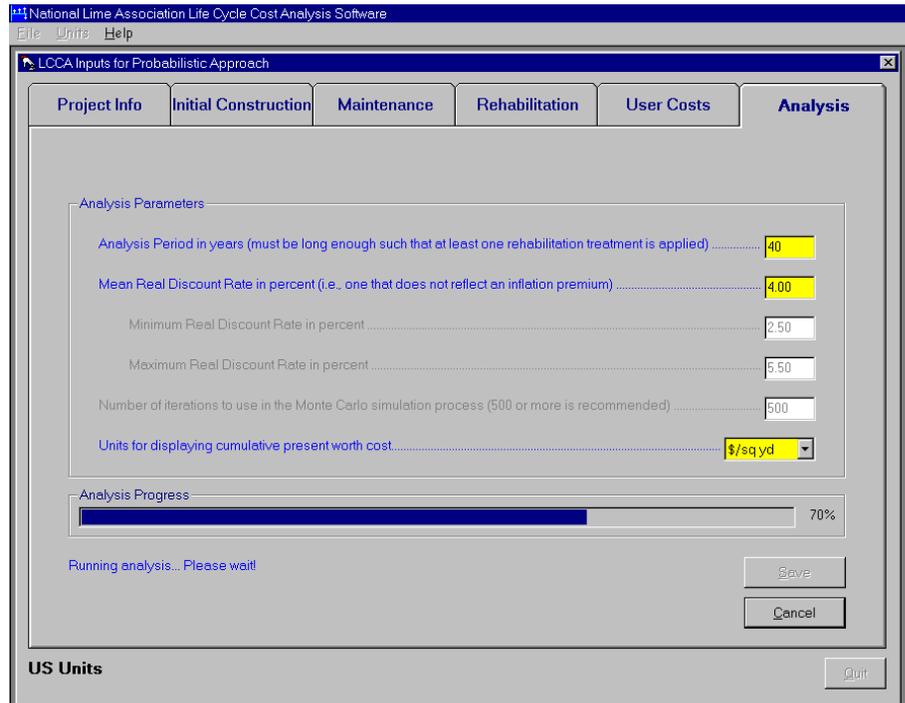


Figure 40. Display of Analysis Progression.

If an analysis has been run for a project, the Analysis tab of the Project Inputs form displays the View Results Button as shown in Figure 41. This button will be displayed whenever an existing project is opened (if an analysis was run) or when an analysis for a new project is run and the Results Viewer form has been closed. Clicking on this button displays the Results Viewer form with the results from the last analysis run. It is important to note that any changes to the input values will not be reflected in the results displayed through use of the View Results button unless a new analysis is run.

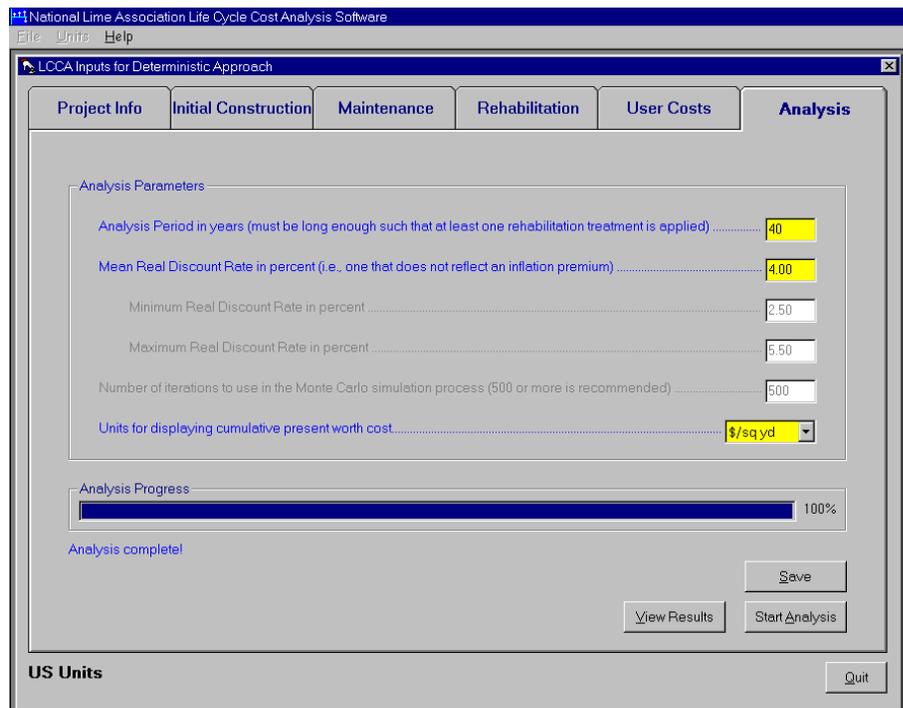


Figure 41. Analysis Tab Displaying the View Results Button.

3.3 Results Viewer Form

The Results Viewer form displays results of analyses and allows you to print the results to a printer and export the results to a comma separated value (.csv) file. This

section provides details regarding the features of the Results Viewer form as well as how to print and export analyses results.

Figure 42 shows the Results Viewer form displaying results of a deterministic analysis. The results (in the form of a cost stream) are displayed for Alternative 1 initially. Clicking on the radio button for Alternative 2 displays the results (cost stream) for Alternative 2 while clicking on the Comparison Plot radio button displays the results for both Alternative 1 and Alternative 2 graphically as shown in Figure 43.

Results Viewer
File View

Display results for: Lime Treated Alternative (Pavement Alternative 1) - 2 in. Overlay; Lime-Treated
 Non-Lime Alternative (Pavement Alternative 2) - 2 in. Overlay; Unmodified
 Comparison Plot

Lime Treated Alternative (2 in. Overlay; Lime-Treated): DEMO

Year	Cost Type	Future Cost	Associated User Cost	Total Future Cost	Present Worth Cost	Cumulative Present Worth Cost (\$/sq yd)
0	Initial Construction; 2 in. Overlay; Lime-Treated	\$0.00	\$473.48	\$0.00	\$13,973.48	\$4.19
1						
2						
3						
4						
5	Maintenance; Fog Seal	\$1,000.00	\$236.74	\$1,236.74	\$1,016.51	\$4.50
6						
7						
8						
9						
10	Rehabilitation; 2 in. Overlay; Lime-Treated	\$13,500.00	\$473.48	\$13,973.49	\$9,439.99	\$7.33
11						
12						
13						
14						
15	Maintenance; Fog Seal	\$1,000.00	\$236.74	\$1,236.74	\$686.72	\$7.54
16						
17						
18						
19						
20	Rehabilitation; 2 in. Overlay; Lime-Treated	\$13,500.00	\$473.48	\$13,973.49	\$6,377.32	\$9.45
21						

* NOTE: If a treatment is triggered in the final year of the analysis period, the salvage value does not account for user costs.

Figure 42. Results Viewer Form.

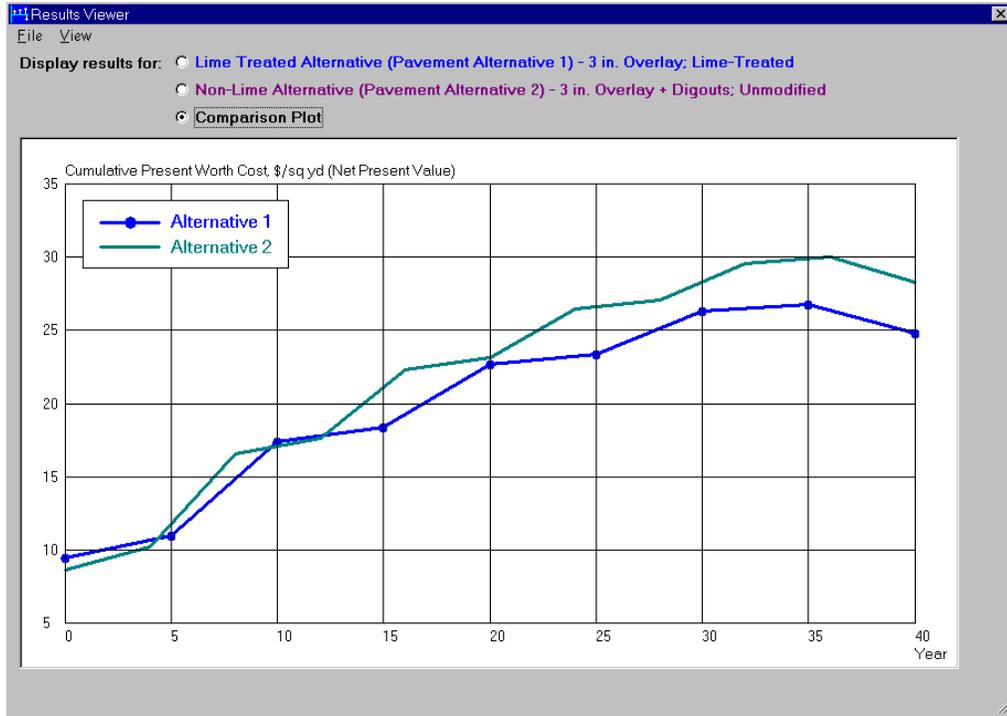


Figure 43. Comparison Plot of the Cumulative Present Worth Cost for Both Alternatives.

When the Results Viewer form is displaying a cost stream (i.e., a grid) you can change the units for displaying cumulative present worth costs through the View menu. Clicking on the View menu and selecting the desired units accomplishes this. Figure 44 indicates that units of \$/sq yd are being displayed.

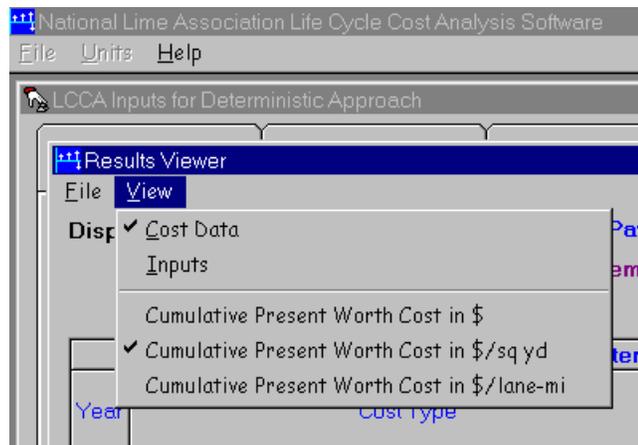


Figure 44. View Menu of the Results Viewer Form.

Clicking on the Inputs menu choice of the View menu displays a summary of the inputs as shown in Figure 45.

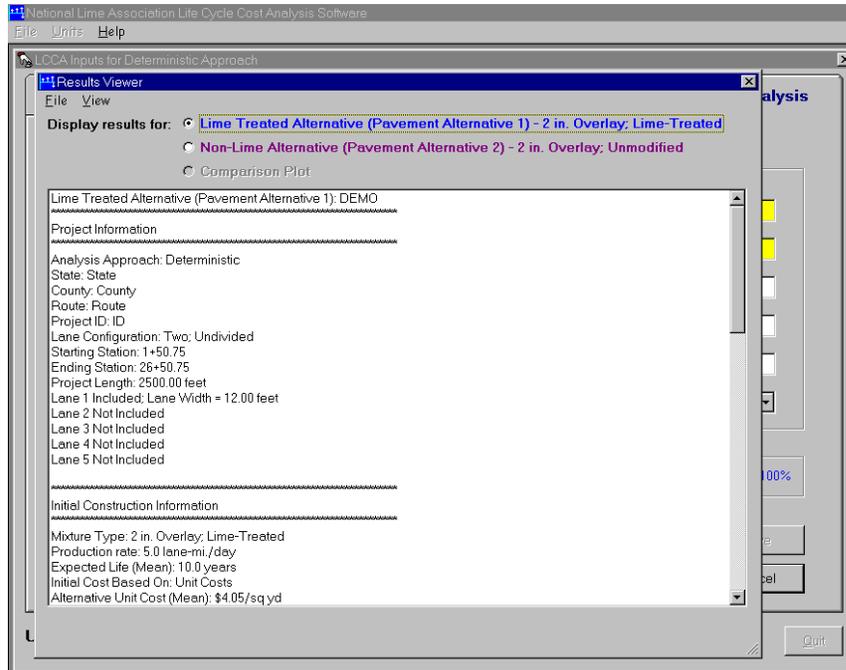


Figure 45. Summary of Inputs as Displayed by the Results Viewer Form.

Also when the Results Viewer form is displaying a cost stream (i.e., a grid) you can use the Page Setup and Print Preview features under the File menu (Figure 46) to setup the page and print the results to a printer. Figure 47 shows the Page Setup feature while Figure 48 shows the Print Preview feature.

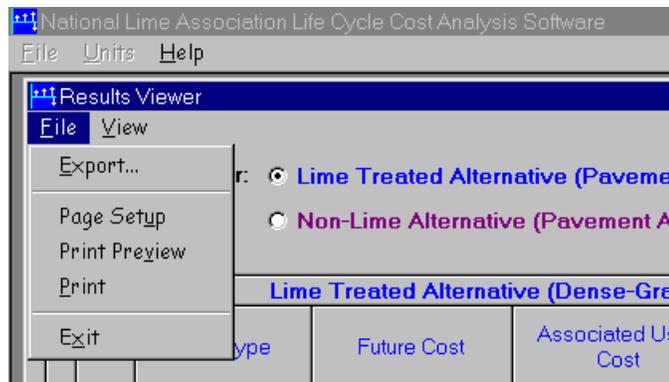


Figure 46. File Menu of the Results Viewer.

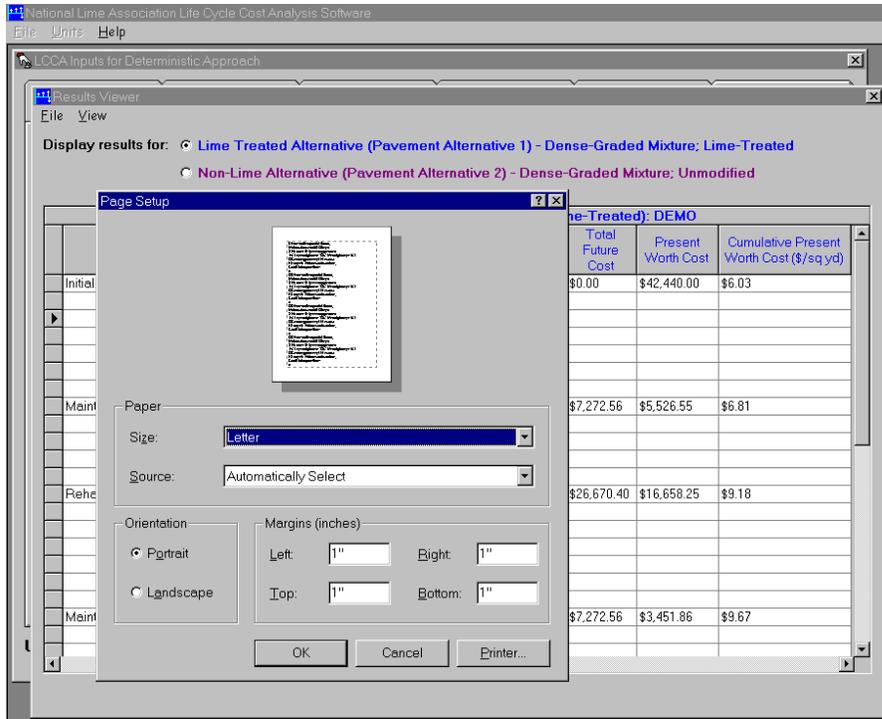


Figure 47. Page Setup Feature of the Results Viewer.

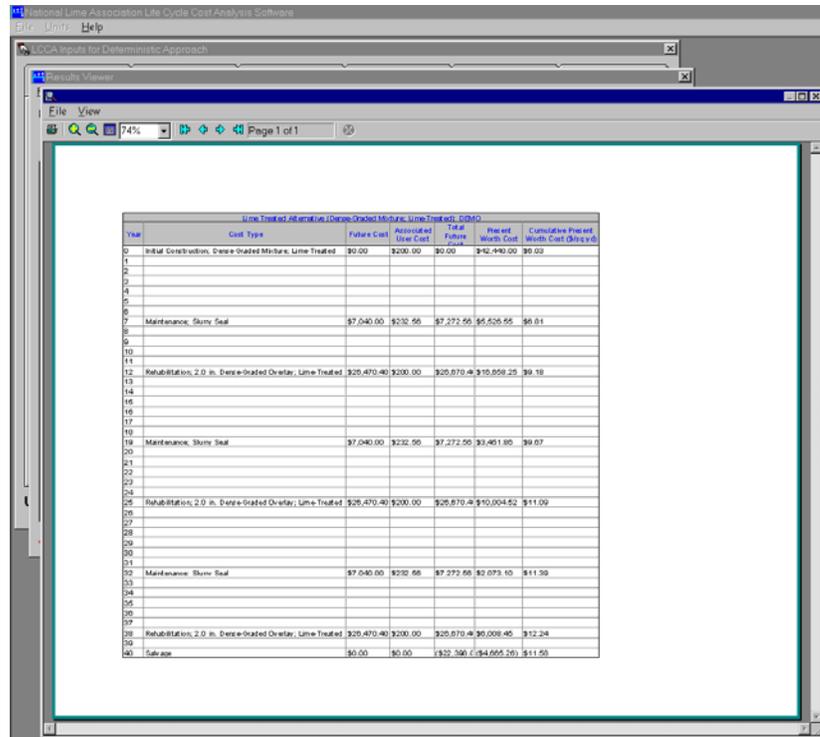


Figure 48. Print Preview Feature of the Results Viewer.

Clicking on the File menu and selecting the Export... menu choice allows you to export the data to a comma separated value (.csv) file that can be imported directly into spreadsheet programs such as Microsoft Excel or Corel Quattro Pro. Figure 49 shows the dialog that is displayed when File/Export... is selected. This dialog allows you to save the file to any disk contained in the computer (except CDs).

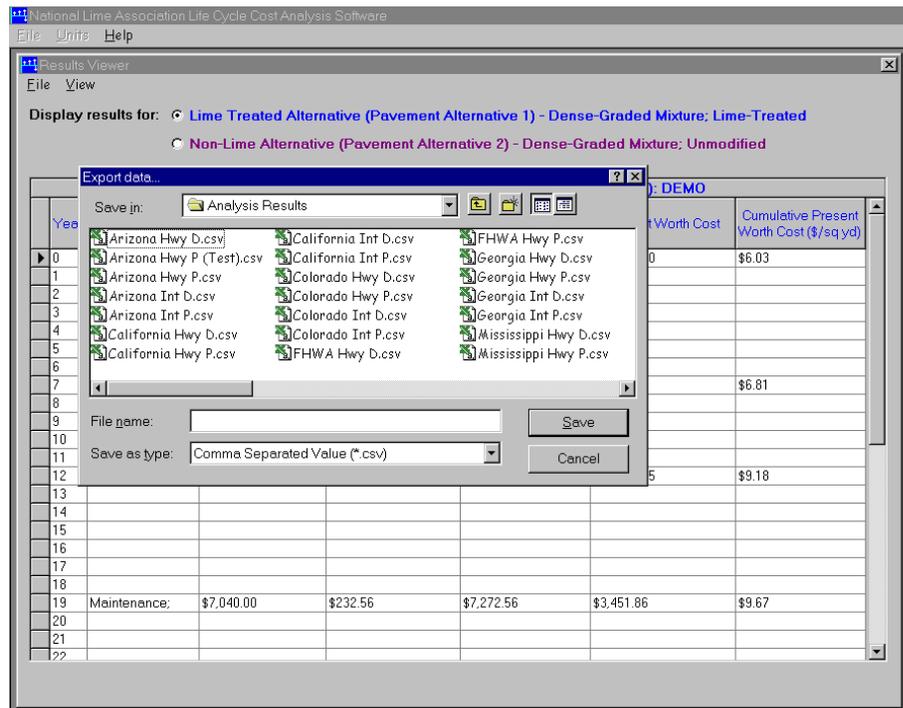


Figure 49. Dialog for Exporting Results to Disk.

Figure 50 shows the results for a probabilistic analysis. As indicated, summary statistics of the analysis are displayed. Cost streams are not displayed due to the large number of them (two for each iteration in the Monte Carlo simulation process). Instead, a cumulative probability distribution is generated from these cost streams. Clicking on the Probability Plot radio button displays the cumulative probability distribution for the analysis as shown in Figure 51. This is a cumulative distribution of the LCC of

Alternative 1 minus the LCC of Alternative 2 for all iterations in the Monte Carlo simulation process. Thus, values less than zero indicate that the LCC of Alternative 1 was less than the LCC of Alternative 2, whereas values greater than zero indicate that the LCC of Alternative 1 was greater than the LCC of Alternative 2. For this example case, approximately 86% of the LCC calculations indicated that Alternative 1 was less than Alternative 2. The plot also indicates that for this example case, the best probabilistic estimate of the life cycle cost savings from using lime was \$2.37/sq yd.

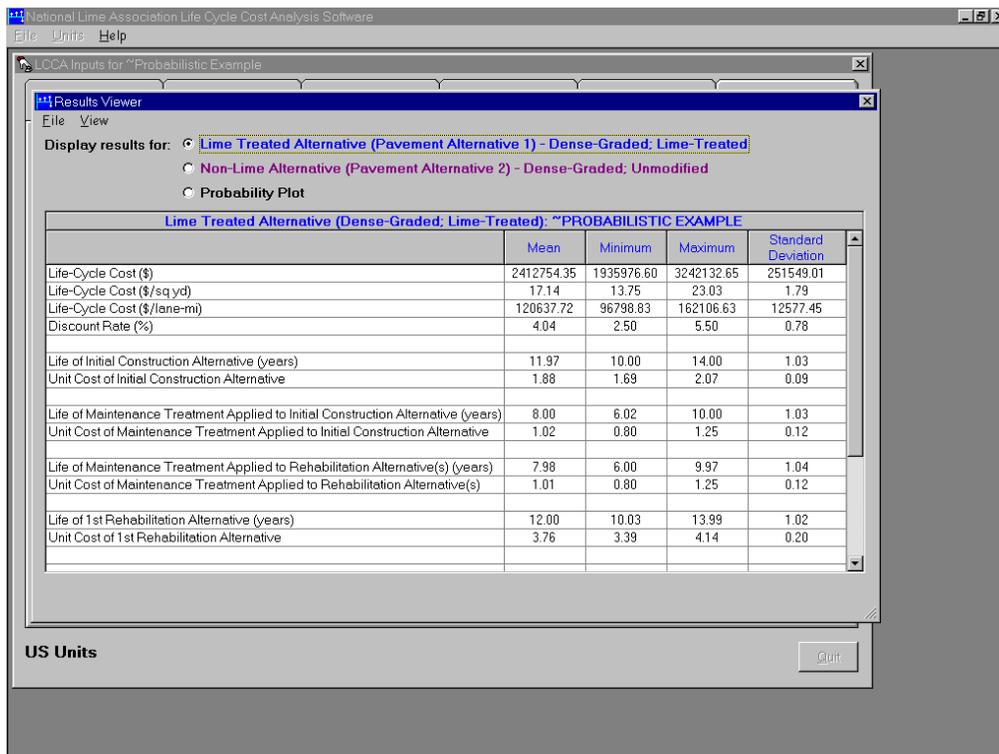


Figure 50. Summary of Results for a Probabilistic Analysis.

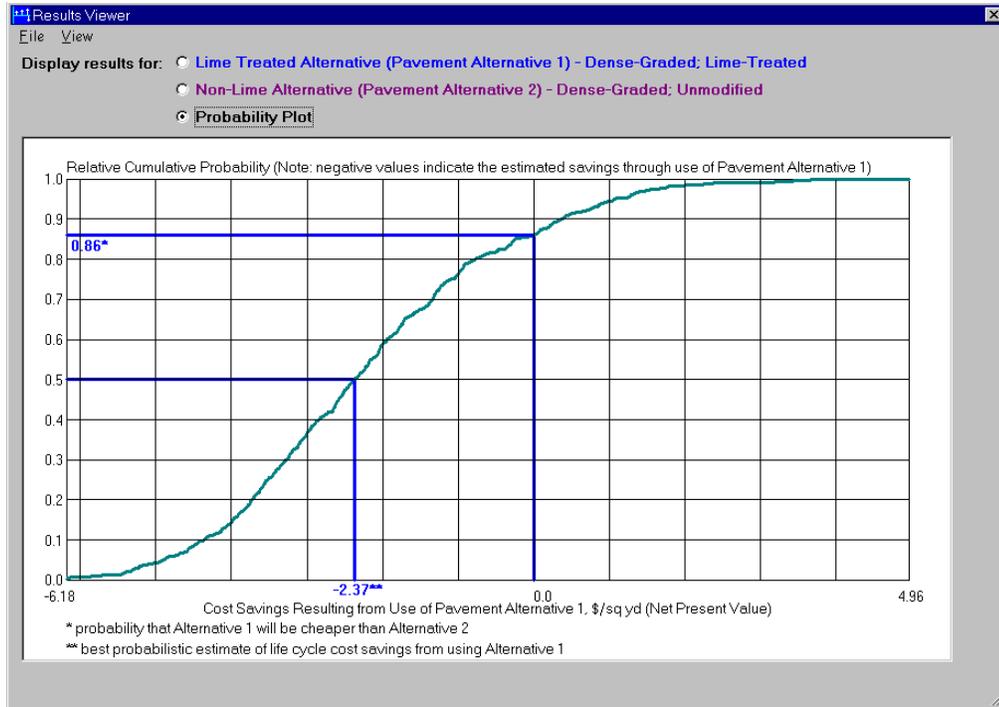


Figure 51. Cumulative Probability Plot.

Clicking on the File menu and selecting Exit closes the Report Viewer form and returns control to the Project Inputs form. Clicking on the small close symbol (✕) in the upper right corner of the Report Viewer accomplishes this as well.

4.0 REFERENCES

Walls, James and M.R. Smith, "Life Cycle Cost Analysis in Pavement Design," *FHWA-SA-98-079*, September 1998.