LCA Pave: A Tool to Assess Environmental Impacts of Pavement Material and Design Decisions

User Manual

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16. Abstract

LCA Pave is a Microsoft® Excel®-based tool developed by FHWA that can be used to assess environmental impacts of pavement material and design decisions. The tool can be accessed from this webpage: https://www.fhwa.dot.gov/pavement/lcatool/

This document serves as the user manual for *LCA Pave*. The user manual provides the following:

- A general introduction to the tool, its data flow process, and the underlying analysis approach.
- Step-by-step instructions for navigating and using the tool to conduct analyses.
- Explanations of the key features of the tool, along with instructions on their use.
- Details on identifying appropriate inputs for particular analyses, and instructions on preparing and importing that data into the tool.
- Instructions on generating and customizing outputs.
- Examples using illustrating tool features.

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CHAPTER 1. INTRODUCTION

1.0 BACKGROUND

Life-cycle assessment (LCA) is a technique that can be used to evaluate the environmental burden of a product or process by examining all the inputs and outputs over the life cycle, from raw material production to end of life. This systematic approach identifies where the most relevant impacts occur and where the most significant improvements can be made while identifying potential trade-offs[1]. It gives agencies the ability to investigate areas where they can improve.

> Sustainability is often described as being made up of the three components— environmental, social, and economic needs—that collectively are referred to as the "triple-bottom line." In the context of pavements, sustainability refers to system characteristics that encompass a pavement's ability to (Van Dam et al. 2015):
>
> - Achieve the engineering goals for which it was constructed.
> - Preserve and (ideally) restore surrounding ecosystem.
> - Use financial, human, and environmental resources economically.
> - Meet basic human needs such as health, safety, equity, employment, comfort, and happiness.

Although some LCA tools exist, the Federal Highway Administration (FHWA) sought the transparent development of an LCA tool for pavements, in collaboration with key stakeholders, that made use of publicly available data. The resultant tool, *LCA Pave*, can be used to support transportation agencies in conducting LCA and can accept data from industries' Environmental Product Declarations (EPDs). The tool is also complementary to the FHWA's Infrastructure Carbon Estimator (ICE) tool which was originally designed by FHWA for pre-engineering analysis of greenhouse gas (GHG) emissions for infrastructure construction and maintenance. The tool was subsequently improved through a pooled fund initiative and can be found at: https://www.fhwa.dot.gov/environment/sustainability/energy/tools/carbon_estimator/index.cfm

LCA Pave is a project-level tool and does not relate to or interface with pavement management systems. It is also not intended to be used in pavement type decisions (i.e. asphalt vs. concrete). The LCA Pave tool is intended to be used as a training and informational product only, and for voluntary use by agencies and individuals with an understanding of fundamental LCA principles. Its use is not required by Federal statute or regulation. The tool can be accessed at: https://www.fhwa.dot.gov/pavement/lcatool/

1.1 DOCUMENT PURPOSE

The user manual provides the following:

- A general introduction to the tool, its data flow process, and the underlying analysis approach.
- Step-by-step instructions for navigating and using the tool to conduct analyses.
- Explanations of the key features of the tool, along with instructions on their use.
- Details on identifying appropriate inputs for particular analyses, and instructions on preparing and importing that data into the tool.

[1]Pavement Life Cycle Assessment Framework - https://www.fhwa.dot.gov/pavement/sustainability/hif16014.pdf

- Instructions on generating and customizing output.

In addition, this document describes how the tool can be customized to include data from other sources such as EPDs[2]. Examples illustrating various tool features are also provided.

1.2 TOOL SCOPE

The general scope for the tool is:

- Include an initial set of pavement material technologies.
- Focus on project-level analysis.
- Include the materials and construction life-cycle stages in a full analysis period, including the sequence of materials and construction activities throughout the life cycle. This analysis also includes transportation and equipment mobilization and activities including construction, maintenance, and rehabilitation.
- Use publicly available national averages for default material, process, and activity data.
- Allow the user to add, store, and call upon agency data that have been stored in the tool's library.
- Allow the user to add EPDs for pavement materials.

The life-cycle stages considered by the tool are shown in figure 1-1.

1.3 TOOL USE CASES

The goal of the tool is to aid agencies in assessing, quantifying, benchmarking, and communicating the environmental impacts for the following *use-cases:*

1. Comparisons supporting the evaluation of alternative pavement materials, pavement structures, pavement treatments, materials transportation, recycling, and construction approaches for a given project.
2. Environmental impacts from pavement materials and structural designs that are not necessarily a complete project, or actually applied.
3. Comparisons of alternative conceptual decisions and pavement designs during project-level design studies.

[2] An EPD is a report used to communicate the environmental impacts of a specific material or product. Its use is not a Federal requirement. Details on EPDs are available in the FHWA Tech Brief: *Environmental Product Declarations––Communicating Environmental Impacts for Transportation Products* (Harvey et al. 2020).

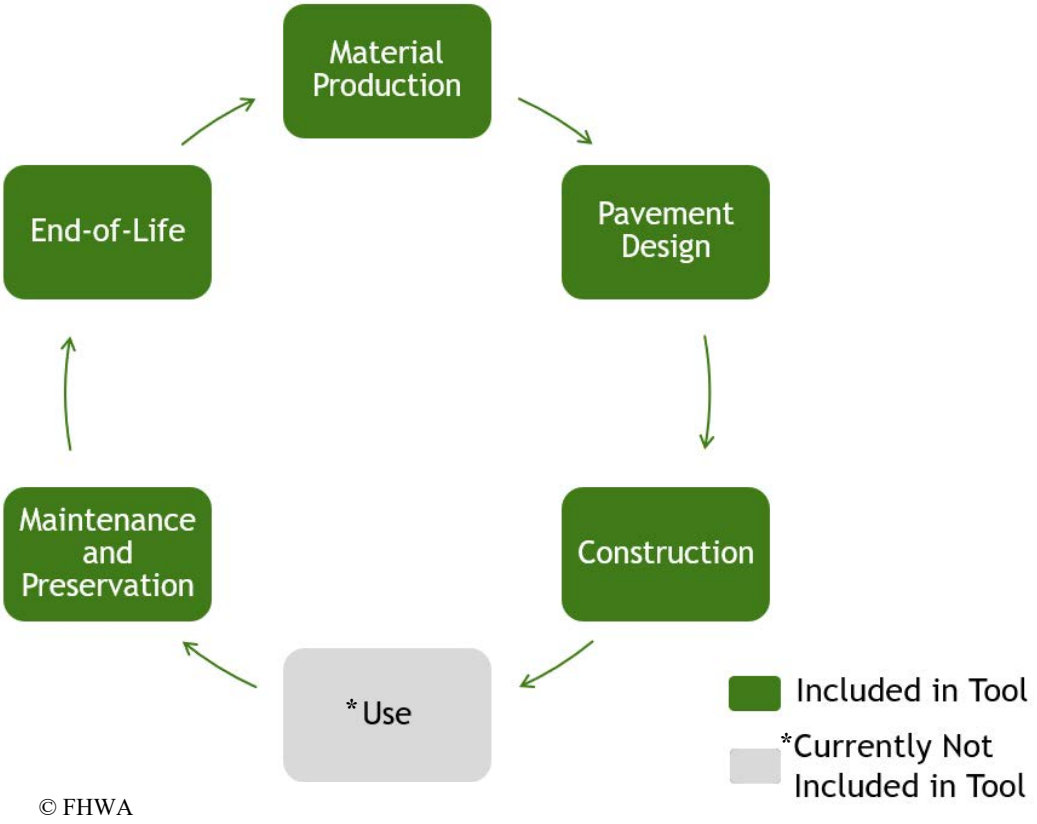


Figure 1-1. Life-cycle stages considered in the tool.

1.4 TOOL APPLICATION AND LIMITATIONS

- The user is responsible for the selection of the appropriate pavement system and input parameters.
- The tool does not check data quality. The user is responsible for reviewing the completeness, consistency, and accuracy of the data related to all items (type of item, quantity, and measurement units) used in the analysis.
- The tool provides information on the environmental impacts associated with pavement material and design decisions, which may be complementary to existing engineering and economic considerations. The impact indicators that are based on flows provide a summation of the flows throughout the model. The energy impact indicators are based on average national energy content and types. All other impact indicators are based on the US Environmental Protection Agency's (EPA) Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI) impact assessment method (Bare 2012).
- The tool does not provide complete information regarding environmental considerations because of current data limitations and the lack of consensus related to pavement use stage impacts. The following pavement use stage impacts are not included in the current version of the tool:
  - Workzone traffic-related impacts.
  - Pavement-vehicle interaction and related fuel use and emissions.
  - Ice and snow management.
  - Stormwater runoff.

  - Heat island impacts.
  - Carbonation.

  The tool has been developed in such a way that those processes can be added with the development of future modules.

- The tool allows users to model an incomplete life-cycle, an approach that may be appropriate for some situations (e.g., if the user is only interested in comparing the environmental impacts associated with two different end-of-life strategies, such as on-site recycling and landfilling, then modeling a complete life-cycle may not be necessary).
- The tool excludes the consideration of equipment manufacturing and capital investments in construction-related production facilities.

CHAPTER 2. SETTING UP THE TOOL

2.0 TOOL OPERATING SPECIFICATIONS

LCA Pave was developed for and tested in:

- Microsoft® Windows 10 Operating System.
- Microsoft® Excel® for Office 365 (Version 16).

2.1 GETTING STARTED

To get started using *LCA Pave*, please complete the steps listed below.

2.1.1 Step 1. Copy *LCA Pave* to the User's Computer

LCA Pave is delivered as a stand-alone Excel workbook file. The first step is to download the latest version of the file from the FHWA's website and copy the file to the chosen location on the user's computer. The instructions for completing this task are as follows:

1. Open File Explorer.
2. Create a folder/directory to store the workbook.
3. Copy the downloaded file to the folder/directory created.

Complete the additional steps below before trying to run the tool.

2.1.2 Step 2. Set Microsoft Excel Trust Center Settings

For security reasons, the "Trust Center" settings in Microsoft Excel must be set to allow needed Visual Basic for Applications (VBA) code to execute. The instructions for making those needed setting changes are:

1. Open Excel.
2. Click on the "File" menu.
3. Click the "Options" button in the left information tower. This will open the *Excel Options* dialog box.
4. Select "Trust Center" in the list of options on the left side of the *Excel Options* dialog box.
5. Click the "Trust Center Settings" button to open the *Trust Center* dialog box.
6. Click "Macro Settings" in the left menu. Set toggles to those shown in figure 2-1.
7. Click "Ok" on all open dialog boxes.

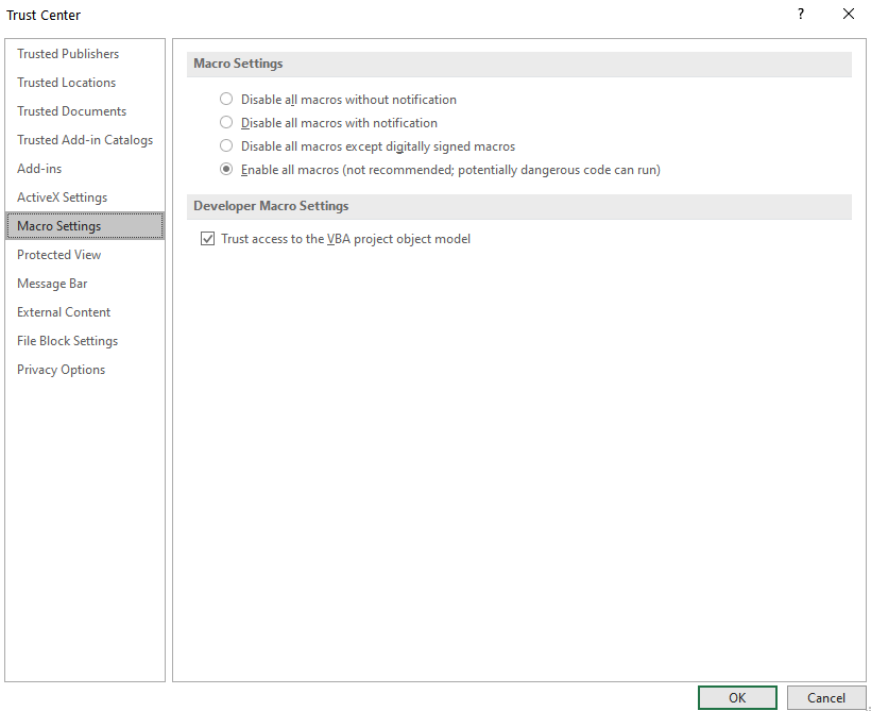


Figure 2-1. Example Excel Trust Center settings.

2.1.3 Step 3. Run Tool

Follow these steps to run the tool:

1. Open the LCA Pave file.
2. If the macro security settings are set to “Disable all macros with notification” upon opening the workbook, a security warning will be displayed near the top of the Excel window similar to that shown in figure 2-2.

3. Click the “Enable Content” button next to the security warning message.

Completing these steps should open the tool’s main *Home* dialog box shown in figure 2-3. If an error message is encountered, please refer to the troubleshooting section below.

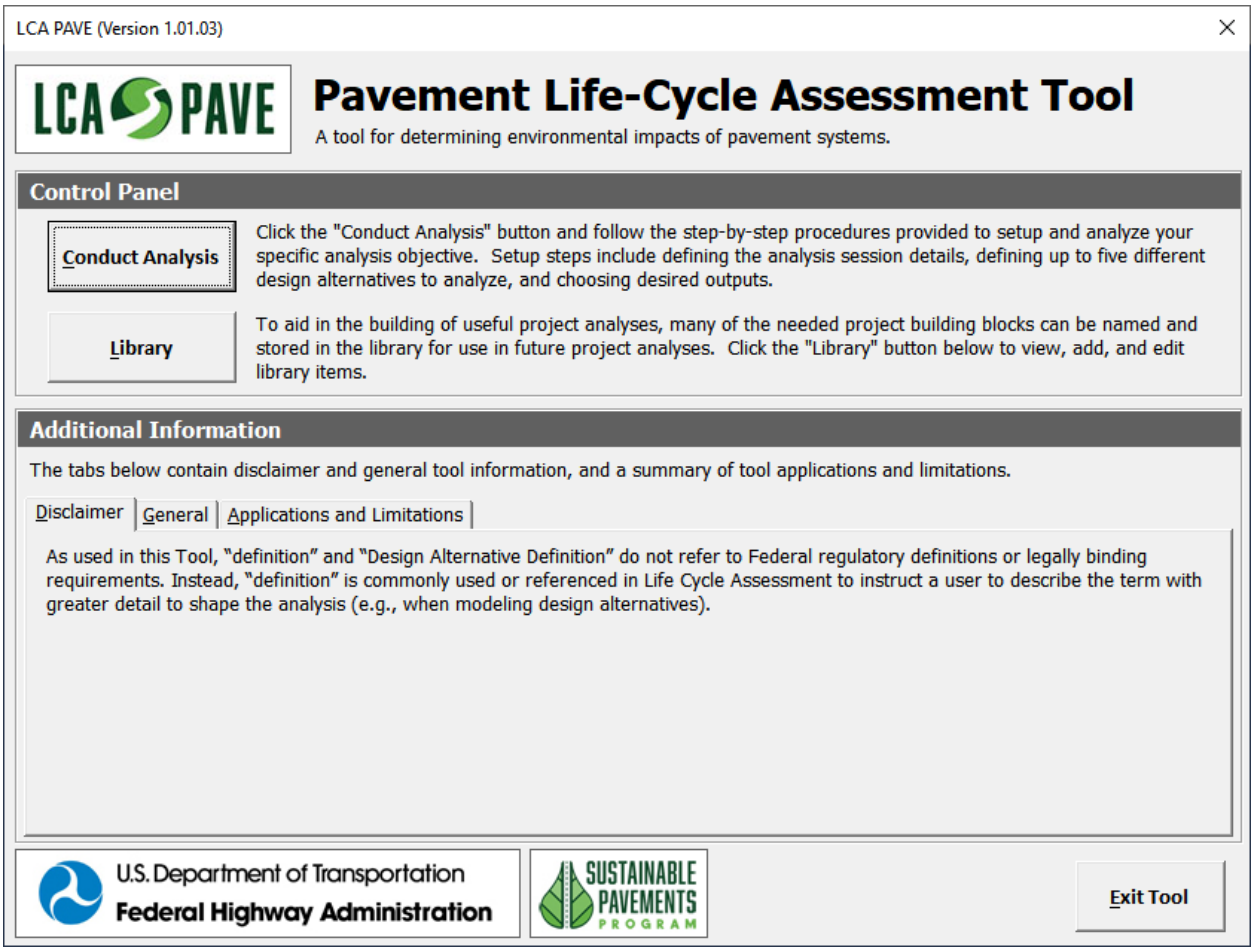


Figure 2-3. LCA Pave home dialog box.

Clicking on the “Exit Tool” button (shown in figure 2-3) will save the analysis and exit out of the tool.

2.2 TROUBLESHOOTING

2.2.1 “Excel Macro Settings Not Properly Configured” Error Dialog

When the tool is opened, it checks the “Trust Center” settings. If the tool finds that the settings are not as needed, the warning message shown in figure 2-4 is displayed, and the workbook is automatically closed. To fix this issue, complete the “Step 2. Set Microsoft Excel Trust Center Settings” instructions in the “Getting Started” section above.

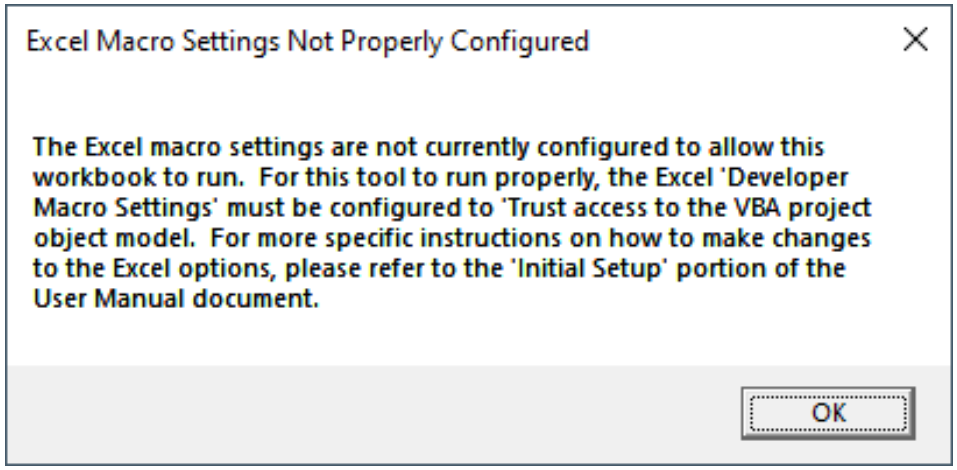


Figure 2-4. Warning message that is displayed when Excel "Trust Center" settings are not configured as needed.

2.2.2 "Missing Reference" Error Dialog

The VBA-code used in the tool is dependent on five specific VBA "References" (or code object library files):

Name: Visual Basic For Applications
Filename: VBE7.DLL

Name: OLE Automation

Name: Microsoft Office 16.0 Object Library
Filename: MSO.DLL

Name: Microsoft Forms 2.0 Object Library
Filename: FM20.DLL

Name: Microsoft Windows Common Controls 6.0 (SP6)
Filename: MSCOMCTL.OCX

Each of these five reference files contains information and instructions to make the tool run as designed. While these reference files are most likely available on the user's computer already (they are common controls often packaged with Microsoft Office), there is no guarantee that that is the case. Therefore, when the *LCA Pave* workbook is opened, the tool checks the user's computer to make sure that each needed reference file is available. If one of the needed files is missing, a warning message similar to the one shown in figure 2-5 will be displayed, and the workbook will be closed.

Note: The tool does not collect or store any personal information from the user.

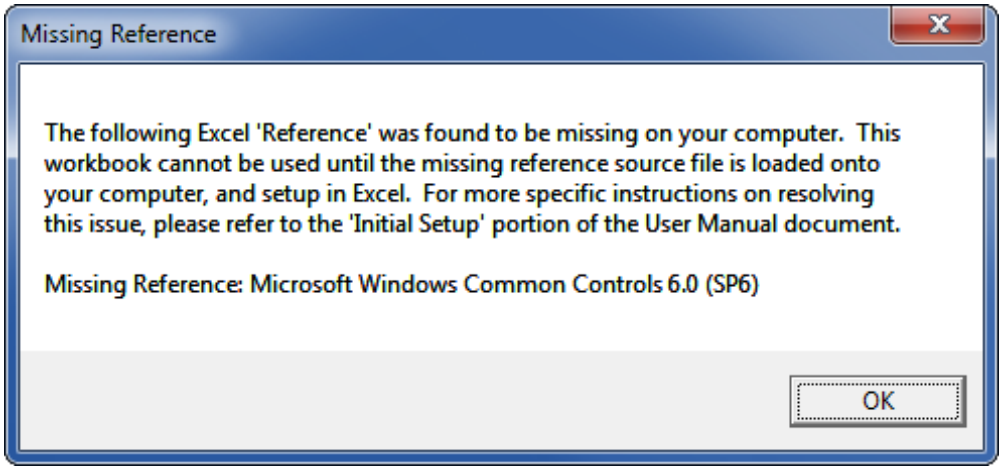


Figure 2-5. Example warning message.

If a "Missing Reference" warning is received:

1. Make note of the name of the missing reference displayed in the warning message (e.g., "*Missing Reference: Microsoft Windows Common Controls 6.0 (SP6)*").
2. Look in the references list described earlier in this section and determine the name of the file associated with the missing reference.
3. Locate the missing file (identified in step 2), in the "Reference Files" provided with the tool.
4. If desired, copy the missing reference file to a location under the C:\Windows directory. Note: most needed Excel reference files are typically stored somewhere within the C:\Windows directory.
5. Open the Excel application without opening a workbook.
6. Click the "Developer" tab and click the "Visual Basic" button to open the *Visual Basic Editor* window. Note: the *Visual Basic Editor* may also be opened by using the ALT+F11 key combination at any time when Excel is opened.

8. Click the "Browse" button to open the *Add Reference* dialog box.
9. Use the provided controls to browse to the location of the needed reference file.
10. Select the needed file and click the "Open" button to add it to Excel's list of "Available References."
11. Close the *Visual Basic Editor* window.

CHAPTER 3. TOOL STRUCTURE

3.0 INTRODUCTION

This chapter provides a high-level overview of the tool's structure and the process flows. The tool consists of two primary components:

1. **Data Libraries**: Database containing both default and user-developed building blocks items that are used to model different design alternatives. Environmental impact data are specified for the unit library items.
2. **Analysis Session**: User interface used to model design alternatives using library items, run an analysis to compare design alternatives, and produce and display results.

3.1 DATA LIBRARIES

The tool consists of six data libraries—Materials, Equipment, Waste, Transport, Mix Designs, and Activities. Table 3-1 provides brief descriptions; Chapter 4 presents a more detailed look into each of the libraries.

Table 3-1. Tool libraries.

Library	Details
Materials	Database of pavement materials (e.g., aggregates, cement, asphalt binder, etc.) and associated environmental impact indicator data, metadata, and data quality assessment ratings. This database also includes data on fuels and electricity.
Equipment	Database of pavement construction equipment and associated environmental impact indicator data, metadata, and data quality assessment ratings.
Waste	Database of environmental impacts associated with four categories of waste management options for pavement materials—landfill, onsite recycling, offsite recycling, and reuse.
Transport	Database of environmental impacts associated with transportation equipment categorized under three modes—water, rail, and road vehicles.
Mix Designs	User-developed database of asphalt and concrete mix designs developed using the items from the Materials, Equipment, Waste, and Transport libraries.
Activities	User-developed database of pavement life-cycle activities (e.g., 4-inch asphalt surface layer, 6-inch concrete pavement, diamond grinding, asphalt mill and inlay, etc.) that can include items from all other libraries shown above.

Data Commentary

The tool has been populated with national average data (or closest equivalent) from publicly available sources. All data in the initial database include a data quality assessment and other metadata following a data quality matrix adapted from other federal agency efforts. The tool has gaps in its database because of the constraint to use publicly available data. Gaps in background data critical to all pavement LCA studies have been filled with other available data. Some of the publicly available data do not completely reflect practices in the United States, while other subsets of publicly available data are out of date and not fully consistent with current technology and practice. The data were selected to reflect national averages and do not reflect regional variations in practice. Additional information on the data used in the tool is available in the *Methodology and Assumptions* report (Meijer et al. 2021).

3.2 ANALYSIS SESSION

The analysis session guides the user through a three-step procedure to set up and conduct analysis:

- **Step 1. Analysis Session Details**. This is the interface where the user provides general inputs for the analysis (see figure 3-1).

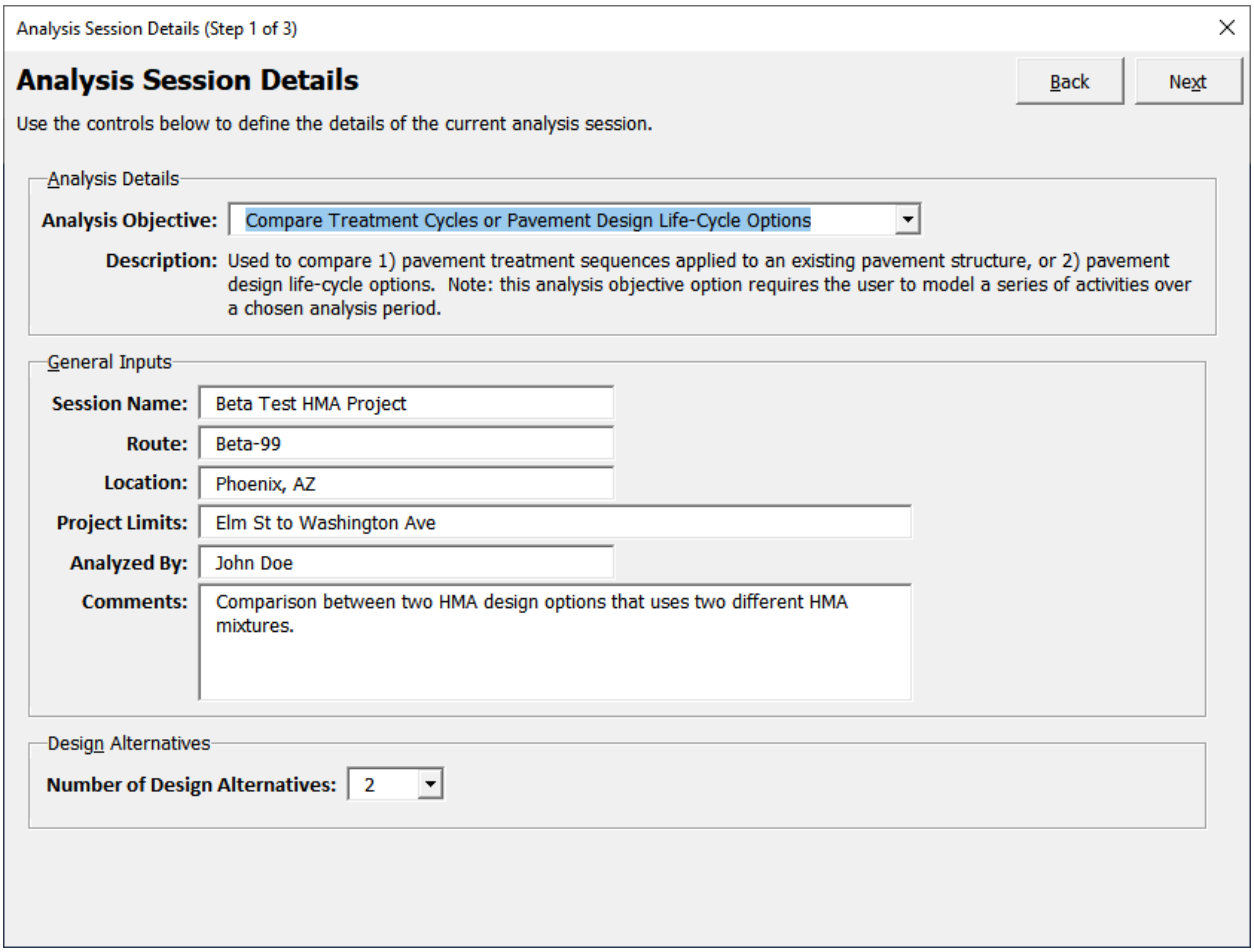


Figure 3-1. Analysis session details interface (Step 1).

- **Step 2. Design Alternative Definition**. In this interface, the user establishes the alternatives to be modeled and compared. The interface makes use of a "tree structure" to model a pavement system. The various levels are discussed below and illustrated in figure 3-2.
  - **Level 1: Alternative**: The design alternative modeled by the user for the selected analysis objective.
  - **Level 2: Pavement**: Details on the pavement facility modeled by the user (e.g., pavement type—mainline, shoulder, ramp etc., number of lanes, length, width etc.).
  - **Level 3: Pavement life-cycle stage:** Pavement life-cycle stage (e.g., initial construction, maintenance and preservation, rehabilitation, reconstruction, and removal) under which various activities are modeled.

- **Level 4: Activities**: User-set pavement activities (e.g., chip seal, 6-inch concrete layer, 4-inch asphalt layer, 1-inch mill and overlay, 0.25-inch diamond grinding, etc.) established under each pavement life-cycle stage.
- **Level 5: Processes**: Items from the tool's libraries used to model each activity.

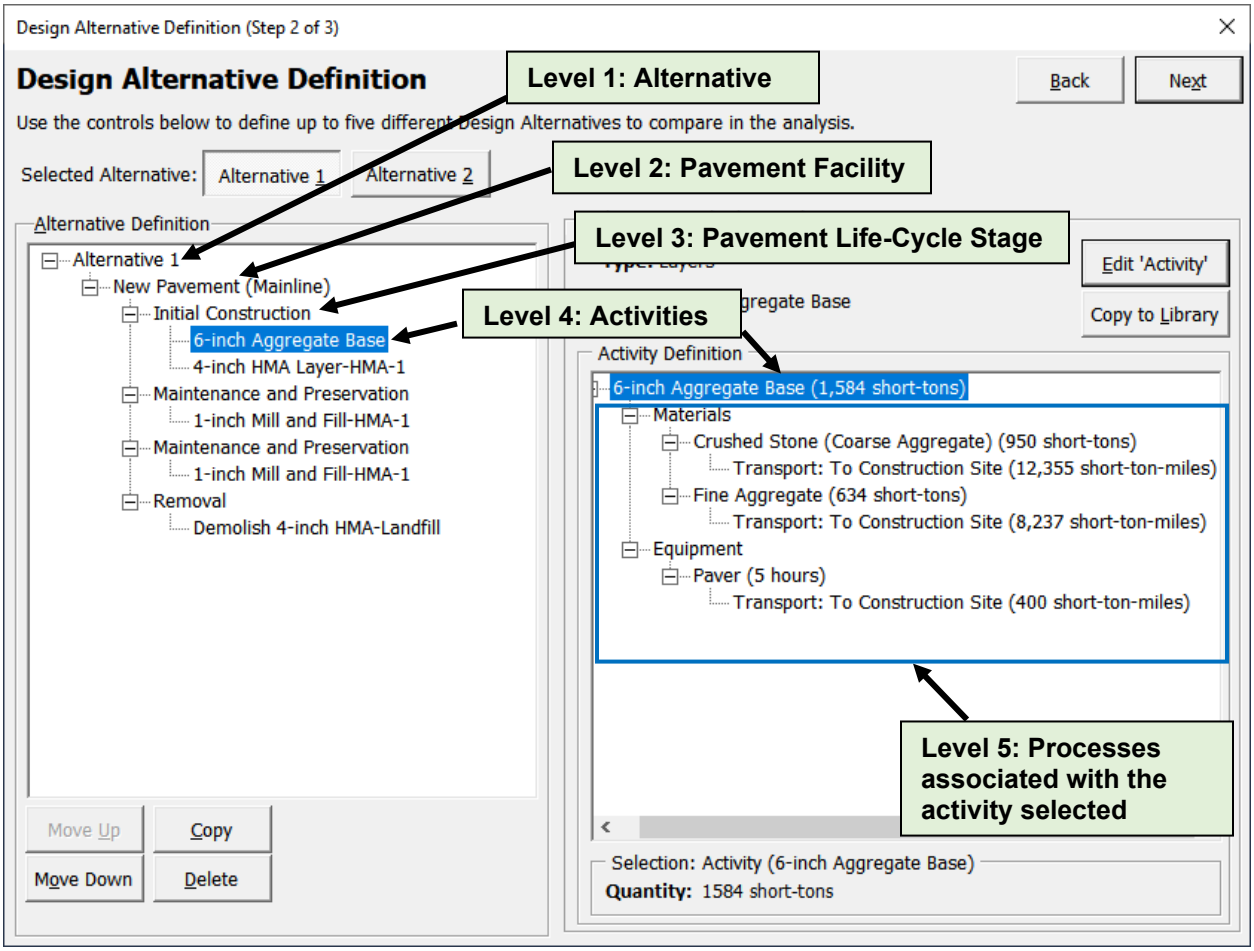


Figure 3-2. Design Alternative Definition interface (Step 2).

- **Step 3. Results**. The results interface (see figure 3-3) consists of:
  - Results Setup: The interface where the user specifies the parameters and customizes the outputs.
  - Summary Results: Summary result views available within the tool's user interface.
  - Detailed Output: Excel workbook containing detailed results.

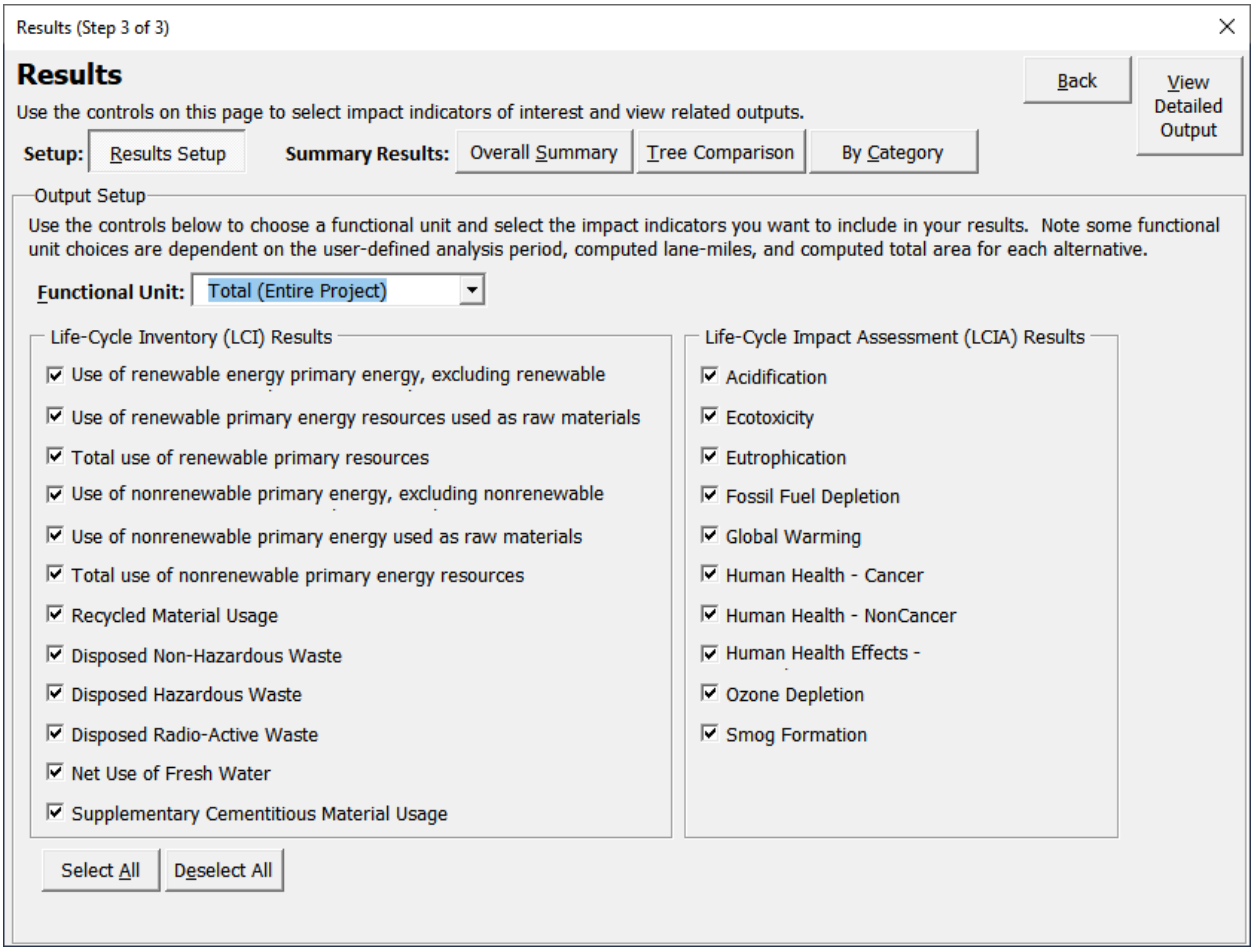


Figure 3-3. Results interface (Step 3).

Chapter 5 presents a more detailed look at the Analysis Session options.

CHAPTER 4. DATA LIBRARIES

4.0 INTRODUCTION

This chapter provides more information about each data library and shows how the user can view, add, delete, and edit data.

Keyboard shortcut to open tool Library from home screen:

ALT + L

To view the data libraries, launch the tool and click "Library" on the tool's home screen (see figure 4-1).

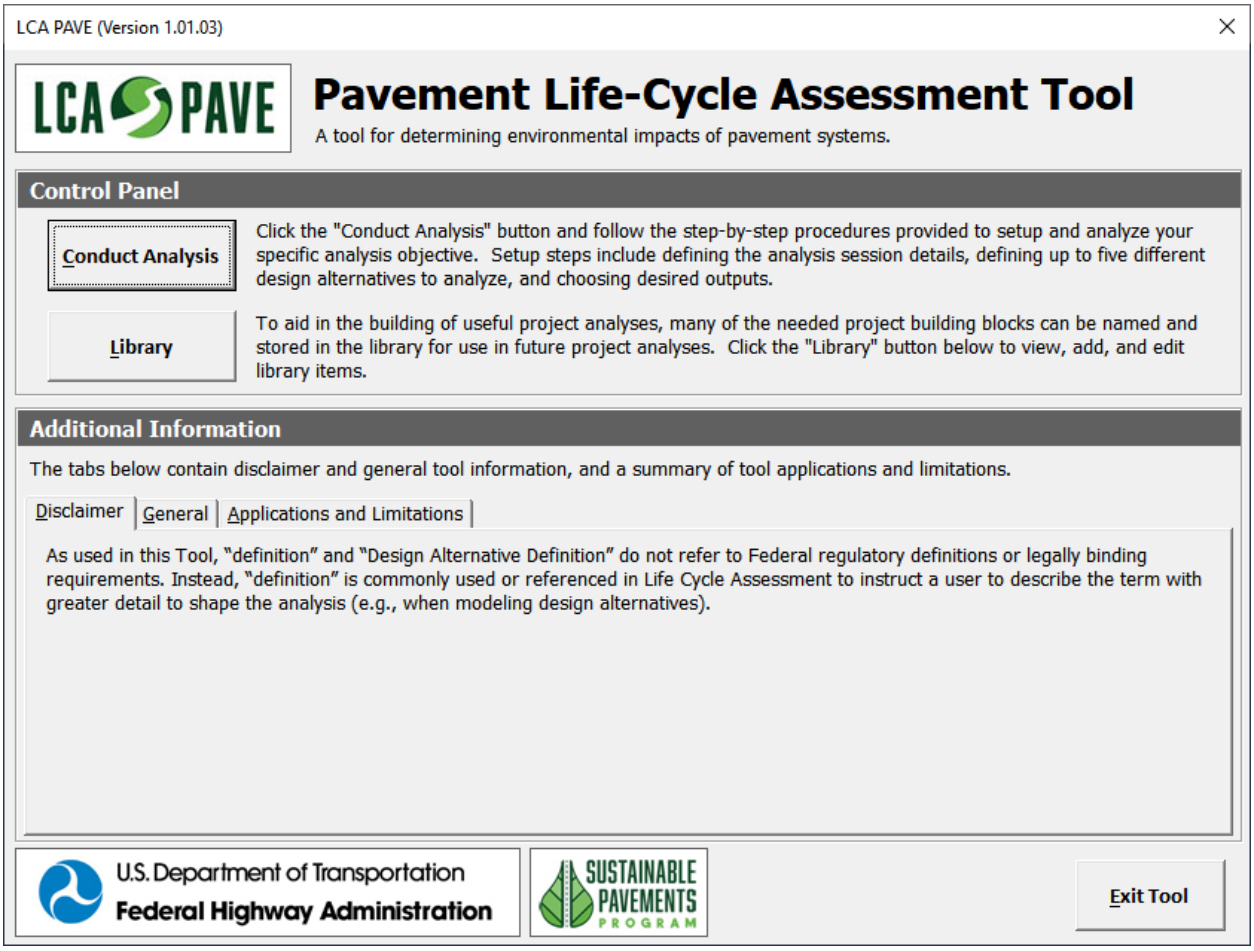


Figure 4-1. Tool home screen.

Once the "Library" button on the home screen is clicked, the user should be able to view the library selection tree interface (see figure 4-2).

Suggested Approach for Using Tool Libraries

Before using the tool for conducting analyses, users may consider populating the data libraries with items that are expected to be commonly used in the analyses. This approach will help streamline the overall analysis process.

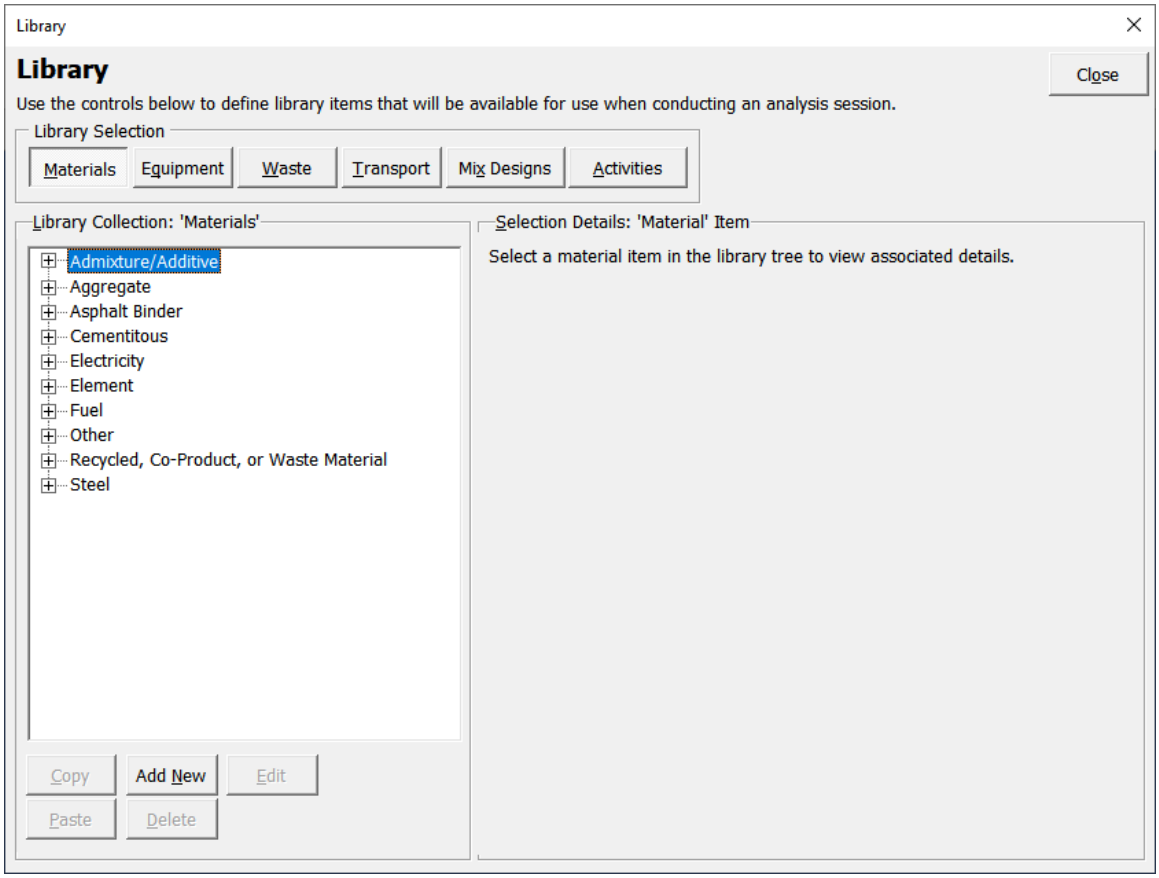


Figure 4-2. Tool libraries.

4.1 MATERIALS LIBRARY

The materials library is a database of materials used in pavement construction (e.g., aggregates, cement, asphalt binder, etc.) and associated environmental impact indicator data, metadata, and data quality assessment ratings. It also includes fuels and electricity data.

Keyboard shortcut to open Materials library within the library interface

ALT + M

4.1.1 Viewing Existing Data

- Once the Library interface is open, click the "Materials" button.
- Select material item of interest (in the example screen shot shown in figure 4-3, "Steel, reinforcing" is the material selected).

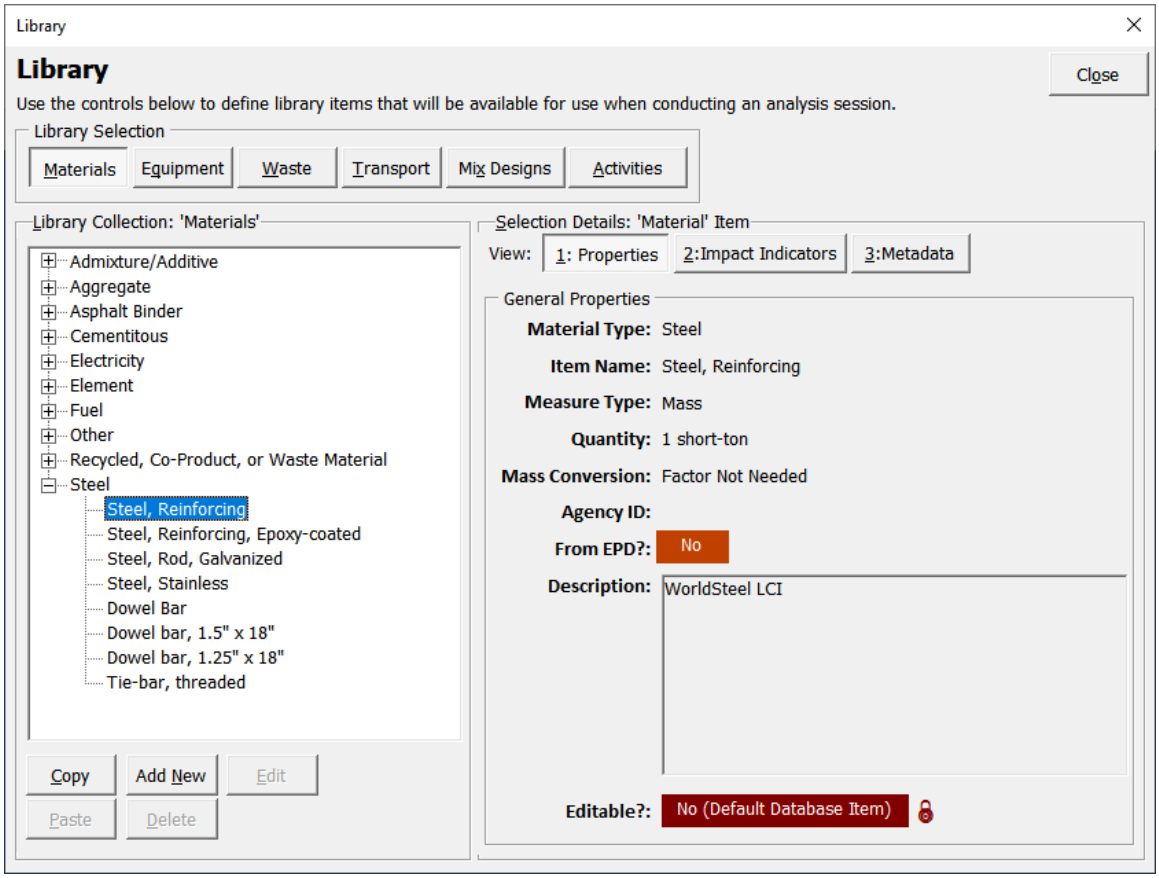


Figure 4-3. Example material properties screenshot.

- To view material properties for the selected item, click the "1: Properties" button. The following properties are displayed:

  Keyboard shortcut to open Properties interface within the Materials library

  ALT + 1

  - **Material Type**: Material category as indicated in the tree structure shown on the left side of the screen (see figure 4-3). In the example selected, the material category selected is "Steel."
  - **Item Name**: Name of the item as stored in the database.
  - **Measure Type**: Unit of measurement used. Note: applicable measure types for material library items include Length, Area, Volume, Mass, Count, and Electricity. However, note that the applicable list is specific to the library item's "Material Type" property.
  - **Quantity**: Quantity of the selected item for which environmental impact indicator data are stored in the database.
  - **Mass Conversion**: If the measure type is not in units of mass, the Mass Conversion property is the conversion factor used to convert the measure type to mass units.
  - **Agency ID**: Agency identification code for the selected item (optional).
  - **From EPD?**: Indicates whether the data are from an environmental product declaration (EPD). If the value is "Yes," the data are from an EPD; if the value is "No," the data are not from an EPD source.

- **Description:** Brief description of the selected item.
- **Editable?**: Indicates whether the information associated with the item is editable by the user. "Yes" indicates that the item is created by the user and can be edited; "No" indicates that the item is a default database item and cannot be edited by the user.

- To view impact indicator data for the selected item, click the "2: Impact Indicators" button. The following tabs are displayed:
  - **Life-Cycle Inventory**: Shows data for the life-cycle inventory flows (see figure 4-4).

Keyboard shortcut to open Impact Indicator interface within the Materials library:

ALT + 2

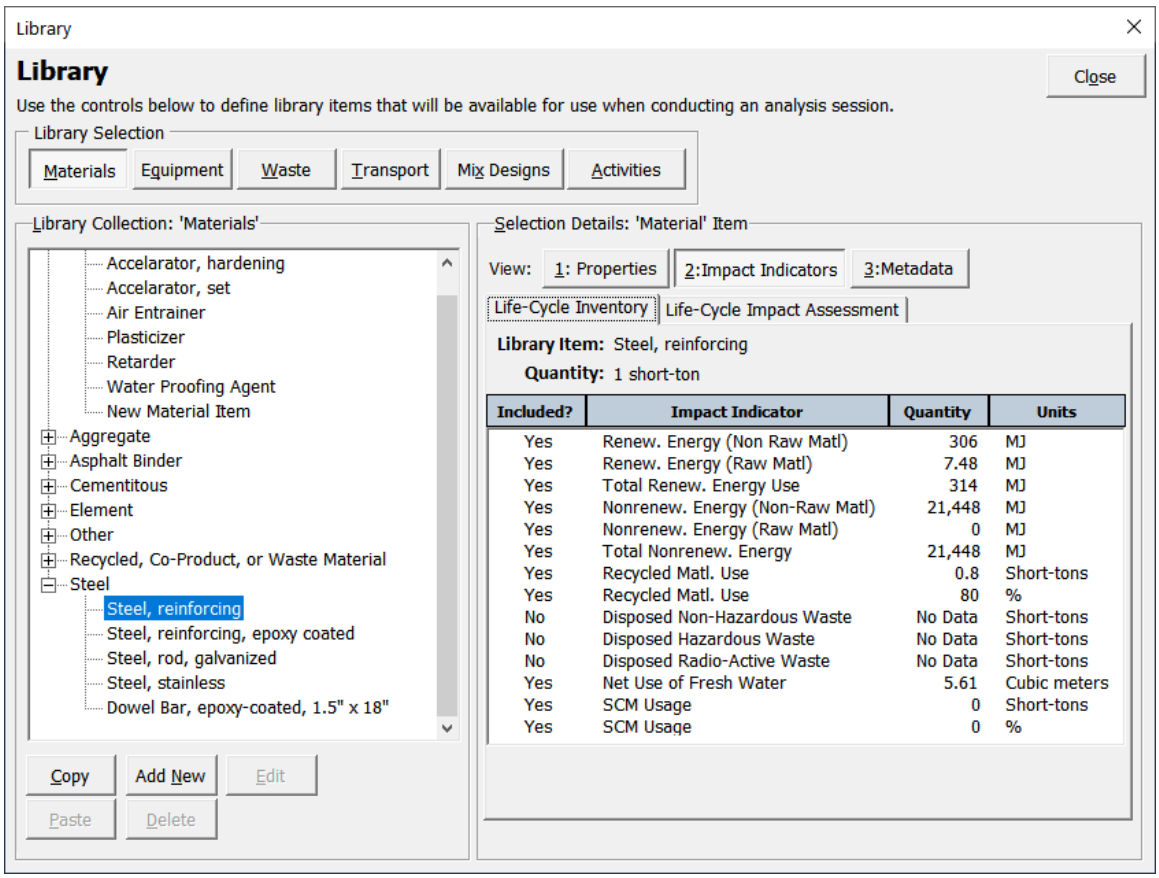


Figure 4-4. Life-Cycle Inventory impact indictor data.

- **Life-Cycle Impact Assessment:** Shows data for the US EPA TRACI life-cycle impact assessment indicators (see figure 4-5).

Bare (2012) provides details on the TRACI impact indicators. Details on the impact assessment methodology in the tool is documented the *Methodology and Assumptions Report* (Meijer et al. 2021).

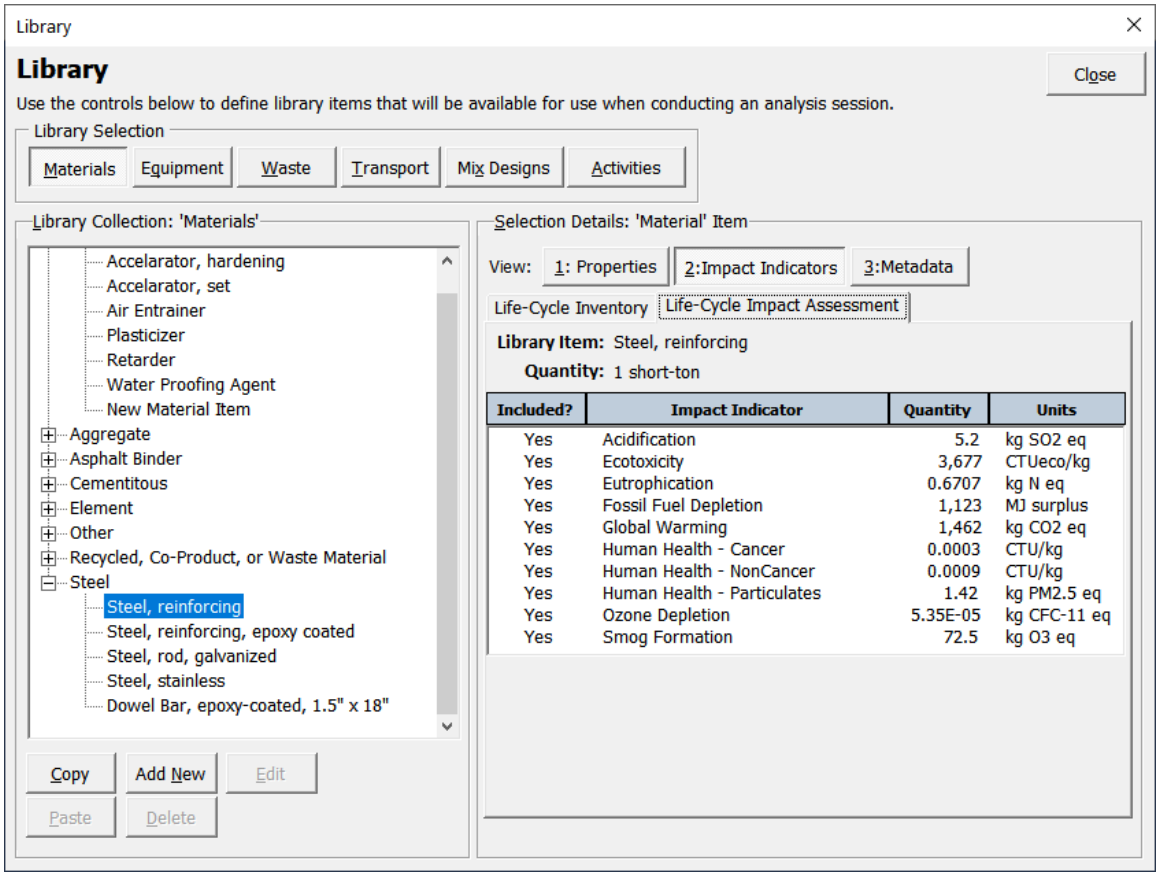


Figure 4-5. Life-Cycle Impact Assessment impact indicator data.

- To view metadata for the selected item, click the "3: Metadata" button. The following tabs are displayed:
  - **General**: Shows general metadata information recorded for the selected library item (see figure 4-6). The following fields are listed:
    - Person recording data.
    - Source of data/model calculations.
    - Data produced/published year.
    - Data accessed/recorded date.
    - Flow type/description/name.
    - Location where data are produced.
    - Other properties.

Keyboard shortcut to open Metadata interface within the Materials library

ALT + 3

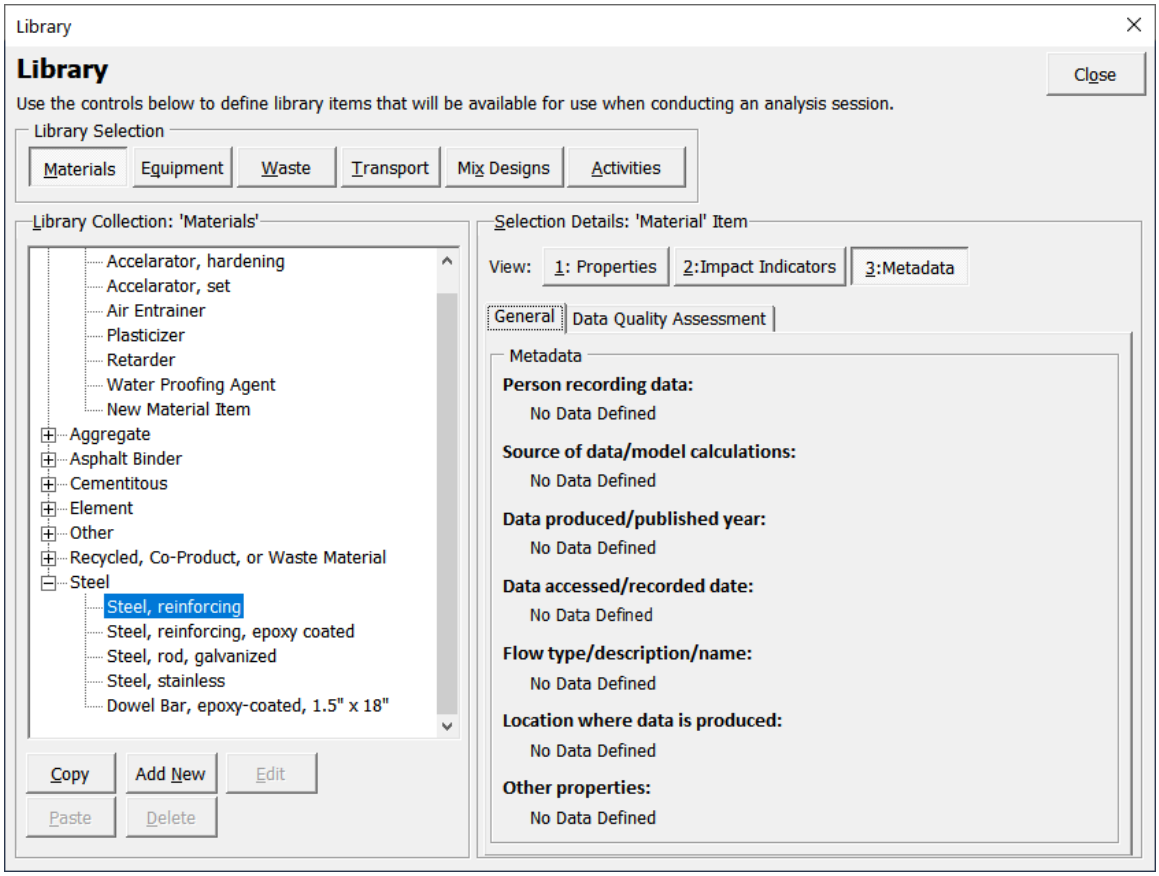


Figure 4-6. Metadata—general properties.

- **Data Quality Assessment**: Shows the data quality assessment ratings recorded for the following categories (see figure 4-7):
  - Reliability: Data Checks.
  - Reliability: Data Ownership.
  - Reliability: Data Updates and Statistics.
  - Collection: Representativeness.
  - Collection: TRACI Compatibility.
  - Time Period: Data Age.
  - Time Period: Seasonal Variations
  - Geography.
  - Technology: Materials.
  - Technology: Manufacturing.
  - Process Review.
  - Process Completeness.

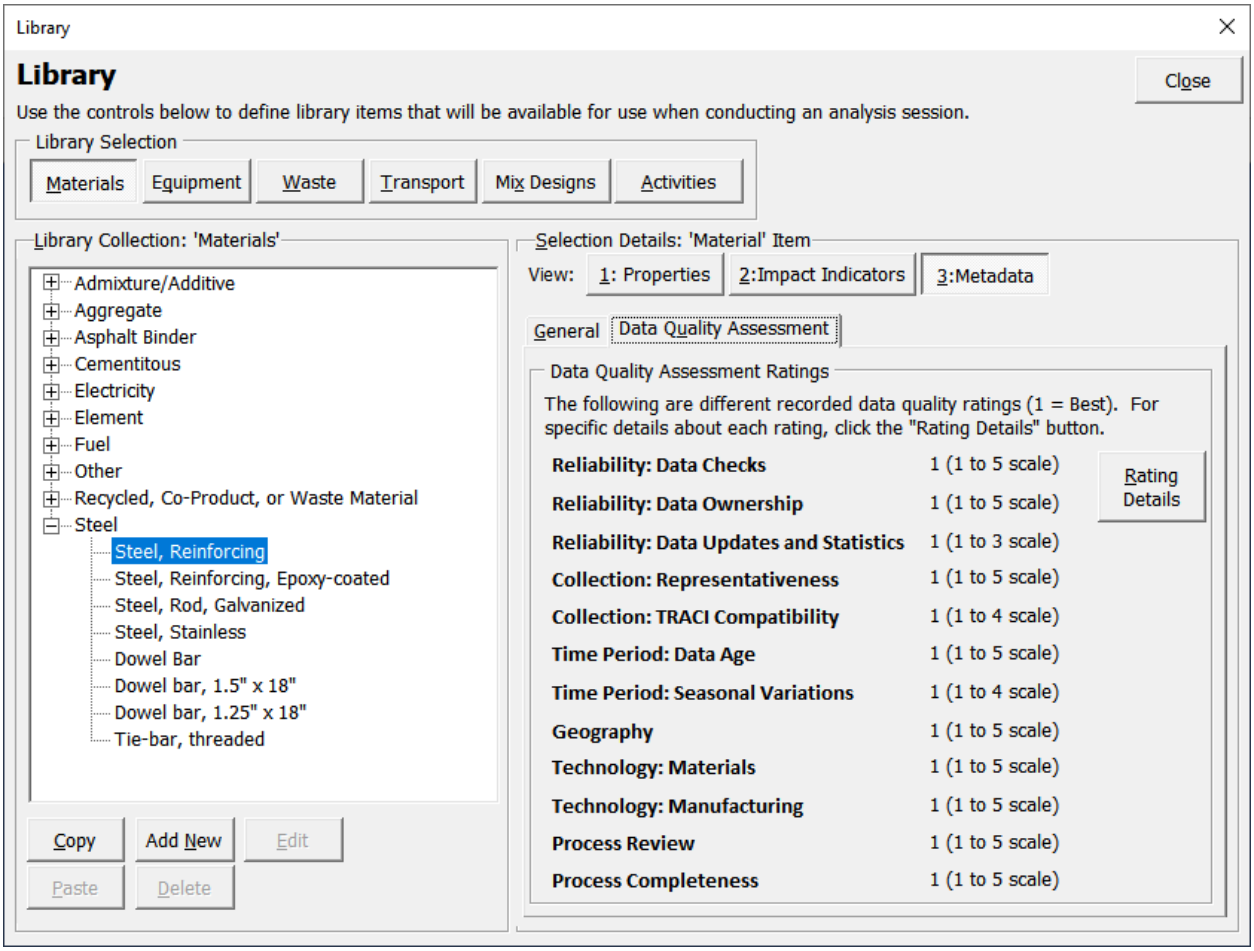


Figure 4-7. Metadata—data quality assessment ratings.

Details on the data quality assessment ratings is accessible within the tool by clicking on the "Rating Details" button shown in figure 4-7. Additional information on the metadata and data quality assessment ratings is available in the *Methodology and Assumptions* report (Meijer et al. 2021).

4.1.2 Adding Data

To add a new material library item, click the "Add New" button and follow these steps (figure 4-8):

Keyboard shortcut for Add New:
ALT + N

- Choose desired "Material Type" from the dropdown list.
- Specify "Item Name."
- Choose "Measure Type" from the dropdown list. If measure type selected is not in units of mass, specify a conversion factor to convert the measure type unit to mass units. For example, if the measure type is specified as "Volume" and the unit is specified as "cubic yards," the mass conversion factor would need to be specified in lb/yd^3 for the tool to be able to calculate the material quantity in units of mass. The call-out box on the next page provides additional information on the measurement units used in the tool.

- Input quantity of the material item for which the environmental impact indicators are to be input into the tool's database.
- Input Agency ID for the material (if available).
- Indicate whether the data are from an EPD.
- Provide a brief description of the material item being input.

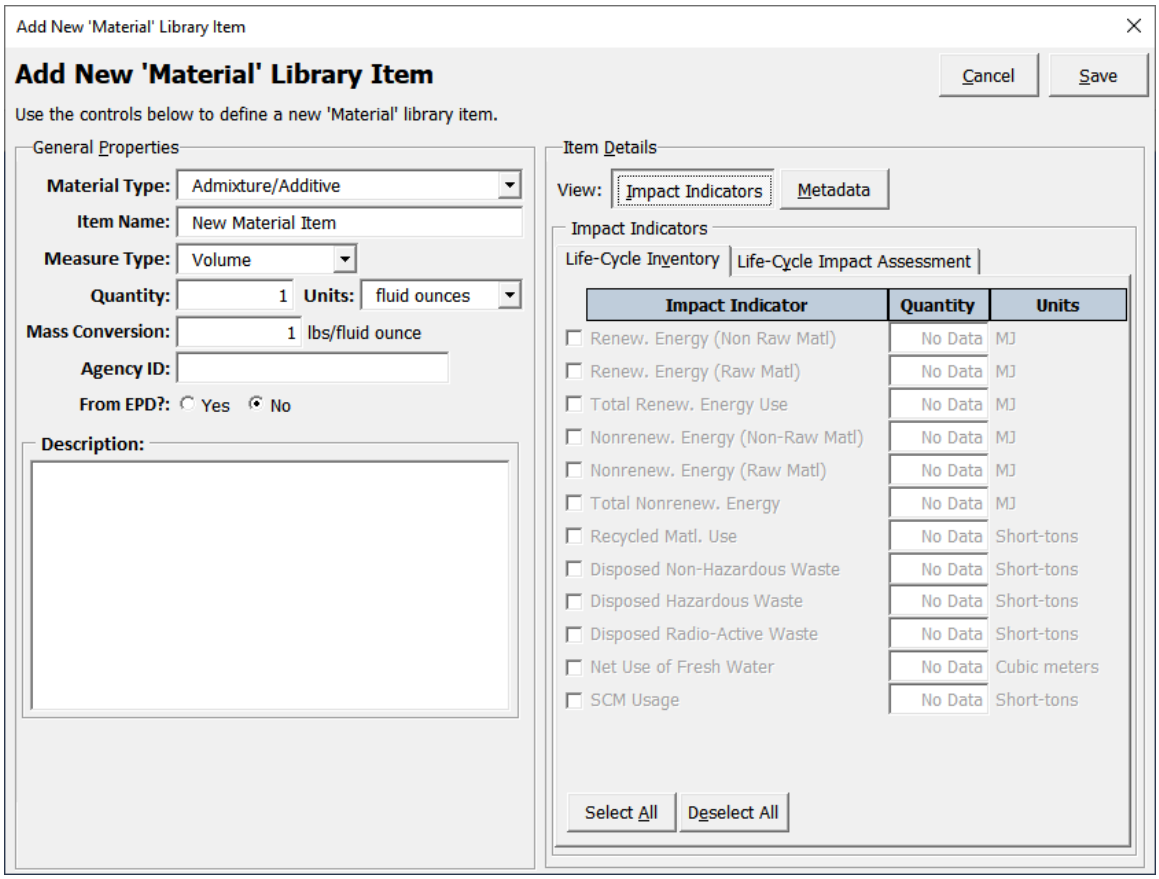


Figure 4-8. User interface for adding new materials library item.

Measurement Units

The tool can handle only certain types of measurement units. If the units for items that the user wants to include in the library are different from what the tool can support, the user would need to convert those units to the ones that are compatible with the tool before the data can be added. For example, metric ton is not supported by the tool. The user would need to convert that to other units of mass compatible with the tool (e.g., short-ton, lbs. etc.) before adding the data to the library. The tool mainly handles English/imperial units; however, some outputs are in metric units.

Once the general properties have been input into the tool, follow these steps to add impact indicator data.

Keyboard Shortcuts in the Impact Indicator Interface

Impact Indicators: **ALT + I**

Life-Cycle Inventory tab: **ALT + V**

Life-Cycle Impact Assessment tab: **ALT + Y**

Select All: **ALT + A**

Deselect All: **ALT + E**

- Click the "Impact Indicators" button.
- Select the "Life-Cycle Inventory" tab.
- Click on checkboxes for which the impact indicator data are available and input impact indicator data in the text boxes shown next to the impact indicators selected.
- To select or deselect all impact indicators, use the "Select All" or "Deselect All" buttons at the bottom of the page.
- Follow the same process for the "Life-Cycle Impact Assessment" tab.

To add metadata and data quality assessment ratings, click the "Metadata" button (see figure 4-9) and follow these steps:

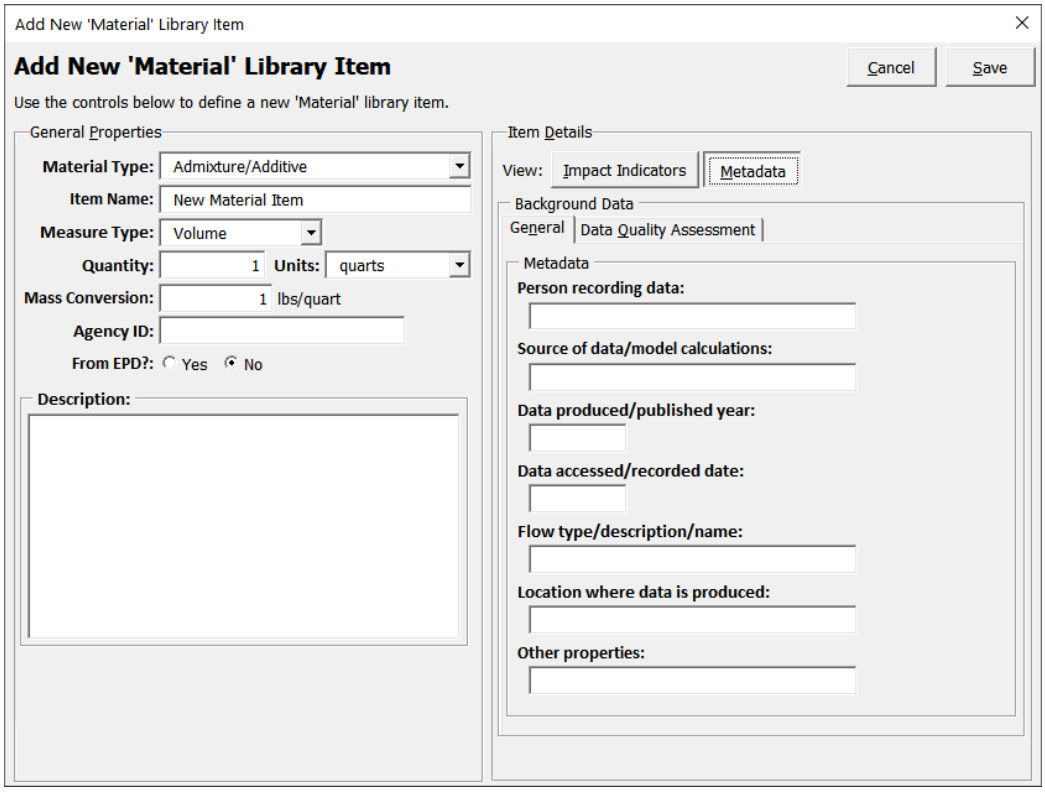


Figure 4-9. User interface for adding metadata.

- Click on the "General" tab and enter data for following fields shown in figure 4-9.

- Click on the "Data Quality Assessment" tab and enter ratings for the fields shown in figure 4-10).

Keyboard Shortcuts in the Metadata Interface:

General tab: **ALT + N**

Data Quality Assessment tab: **ALT + Q**

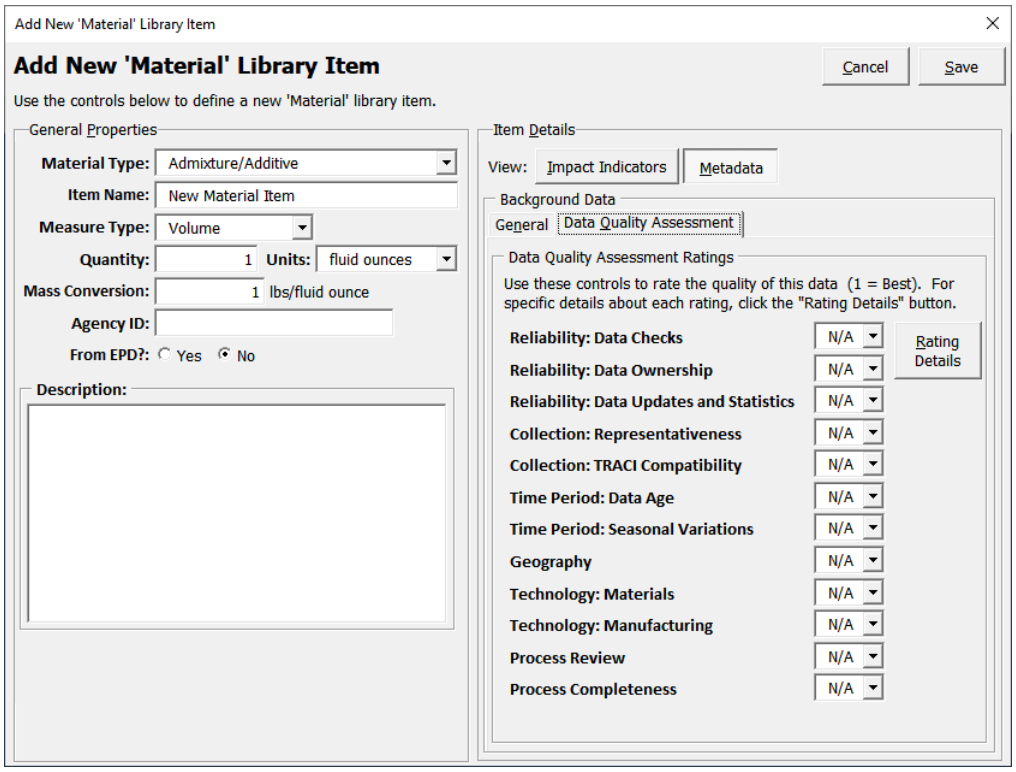


Figure 4-10. User interface for adding data quality assessment ratings.

- Click the "Ratings Details" button to view the rating scale used for the data quality assessment ratings.

4.1.3 Considerations for Adding Data from EPDs

When creating a material item that comes from an EPD, the data source should be indicated in the tool by setting the "From EPD?" property to "Yes" (see figure 4-11). Once that selection is made, the basic process for incorporating data from EPDs into the tool is the same as the process discussed under Section 4.1.2.

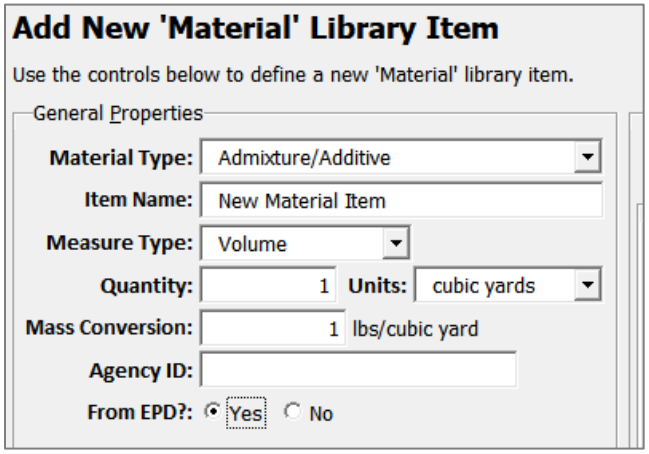


Figure 4-11. Adding EPD data to the tool.

Table 4-1 provides a list of key items for users to consider in an EPD before the data can be input into the tool.

Table 4-1. Considerations for incorporating EPD data into the tool.

Questions to Consider	***….To Answer***
• Who developed the EPD?	*How relevant is the industry or manufacturer to the industry or manufacturers of the material to be used in the pavement in the study?*
• What material(s) does the EPD cover?	*Is the material, its specification, and manufacturing technology fit for the purpose intended in the study?*
• What PCR is used to develop the EPD?	*Is the PCR within its validity period or is it expired (out of date), and does it follow best practices for harmonization?*
• What is the functional or declared unit?	*What is the unit/amount of product that is used to present all the result of the EPD ("this amount or environmental result per this amount of product") and how does that translate to the use in the project being studied?*
• What are the system boundaries?	*What is included in the results and what is not? Are the life cycle stages, full set of materials, manufacturing processes, etc. consistent with the intended material to be used by the agency or in the pavement being studied?*
• What year(s) are the data from?	*Looking at the data used to produce the EPD, are they consistent with the processes and materials used for the agency or project being studies?*
• What are some key assumptions stated?	*Look for key assumptions to see if the EPD is a good fit for the project or agency*
• What is the environmental impact assessment methodology used and what impact indicators are reported?	*Does the EPD show TRACI 2.0 impact categories (discussed in Chapter 5)? Does it include a full list when looking at the FHWA LCA Framework or not, if not, is that still appropriate, or, does it cover the impact categories that the agency is interested in? Note that there are different calculation methods for the same impact category between different impact category systems, such as between TRACI 2.0 and CML.*

Caution: EPD Use in Tool

When inputting EPD data into the tool, the declared unit on the EPD might be different from the default units that the tool supports. In such situations, the user should convert the declared units on the EPD into a unit available in the tool.

Example: If the declared Unit on the EPD = 1 metric-ton, the user converts this into units of mass that is supported by the tool (short-tons, pounds, or ounces). If the user desires to use short-tons as the unit within the tool, the "Quantity" must be entered as 1.102 (1 metric ton = 1.102 short-ton).

Additional information on using EPD data with the tool is available in the *Methodology and Assumptions Report* (Meijer et al. 2021). Appendix C provides an example on incorporating data from an existing EPD into the tool.

4.1.4 Copying Existing Data

Keyboard Shortcuts

Copy: **ALT + C**

Paste: **ALT + P**

- Select an existing item in the library.
- Click the "Copy" button and then then click the "Paste" button.
- When copying existing database items, the user will be prompted to indicate whether the metadata associated with item copied is to be carried forward to new item created (see figure 4-12).

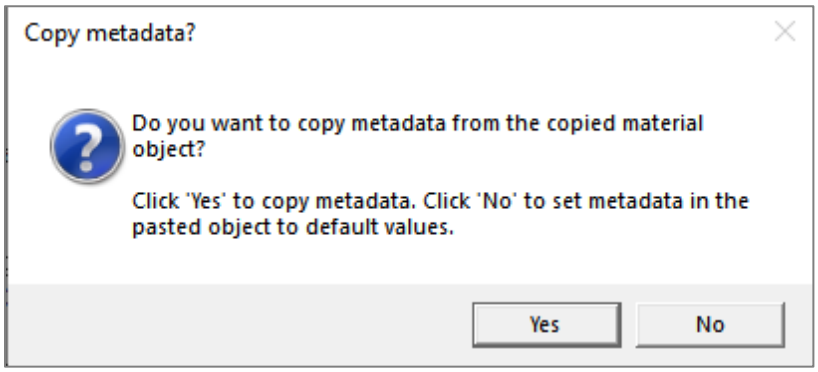


Figure 4-12. Tool prompt for user decision on copying metadata.

- A new database item with the same name as the item copied along with the suffix "(Copy)" is created (see figure 4-13).

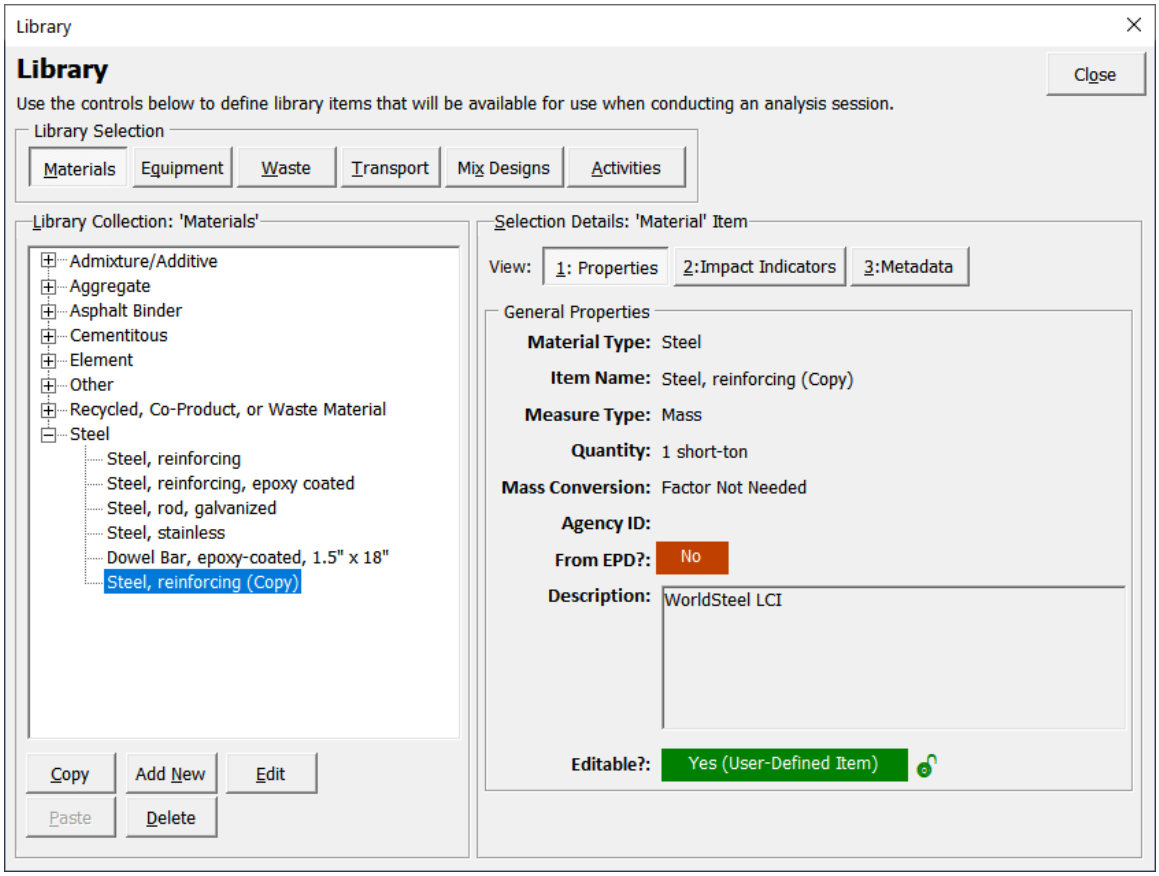


Figure 4-13. Copying existing items from the library.

4.1.5 Edit Existing Data

Keyboard Shortcuts

Delete: **ALT + D**

Edit: **ALT + E**

- Select an existing material item in the library.
- Click the "Edit" button. This action will open the "Edit 'Material' Library Item" dialog box. Note that the "Edit 'Material' Library Item" interface is the same as the "Add New 'Material' Library Item" interface discussed under section 4.1.2.

Copying, Editing, Deleting Existing Data.

The process for copying, editing, and deleting existing data is the same for all the libraries and hence these sections are **not repeated** in Sections 4.2 through 4.6.

4.1.6 Deleting Existing Data

- Select an existing material item in the library.
- Click the "Delete" button.

Managing Default Library Items

The user cannot edit or delete default library items. These options are available only for user-developed items.

When a default database item is copied and pasted into the library, the item becomes editable. This feature becomes particularly useful when users want to modify or customize existing library items.

4.2 EQUIPMENT LIBRARY

The equipment library is a database of pavement construction equipment along with associated environmental impact indicator data, metadata, and data quality assessment ratings.

Keyboard shortcut to open Equipment library within the Library interface:

ALT + Q

Equipment Library Commentary—"Generic Construction Equipment"

Environmental impacts associated with construction equipment use are primarily tied to the fuel type and the equipment's horsepower. A listing of generic construction equipment and associated environmental impacts organized by horsepower range and fuel type has been included in the tool's database under the "Generic Construction Equipment" category. Items from this equipment category may be used by the user to model other types of construction equipment.

The tool's database includes impacts associated with generic construction equipment using two measure types: (a) units of time. i.e., number of hours of equipment use, and (b) units of volume, i.e., number of gallons of fuel use. Users can select the appropriate measure type to be used in the analysis based on available data.

4.2.1 Viewing Existing Data

- Once the Library interface is open, click the "Equipment" button.
- Select equipment item of interest (in the example screen shot shown in figure 4-14, "Cement/Mortar Mixer (50 to 75 hp, Diesel)" is selected).
- To view equipment properties for the selected item, click the "1: Properties" button. The following properties are displayed:
  - **Equipment Type**: Equipment category as indicated in the tree structure shown on the left side of the screen (see figure 4-14). In the example selected, the equipment category selected is "Cement and Mortar Mixers."
  - **Item Name**: Name of the item as stored in the database.
  - **Measure Type**: Unit of measurement used. Note: applicable measure types for equipment library items include Volume, Mass, and Time.
  - **Quantity**: The quantity for which the impact indicator data are available.
  - **Fuel Type**: Type of fuel used by the equipment.
  - **Horsepower Range**: Horsepower range for the equipment.
  - **Agency ID**: Agency identification code for the selected item (optional).
  - **Description:** Brief description of the selected item.
  - **Editable?**: Indicates whether the data associated with the item are editable by the user. "Yes" indicates that the item is created by the user and can be edited; "No" indicates that the item is a default database item and cannot be edited by the user.

Keyboard Shortcuts Within Equipment Library

Properties interface: **ALT + 1**

Impact Indicators: **ALT + 2**

Metadata interface: **ALT + 3**

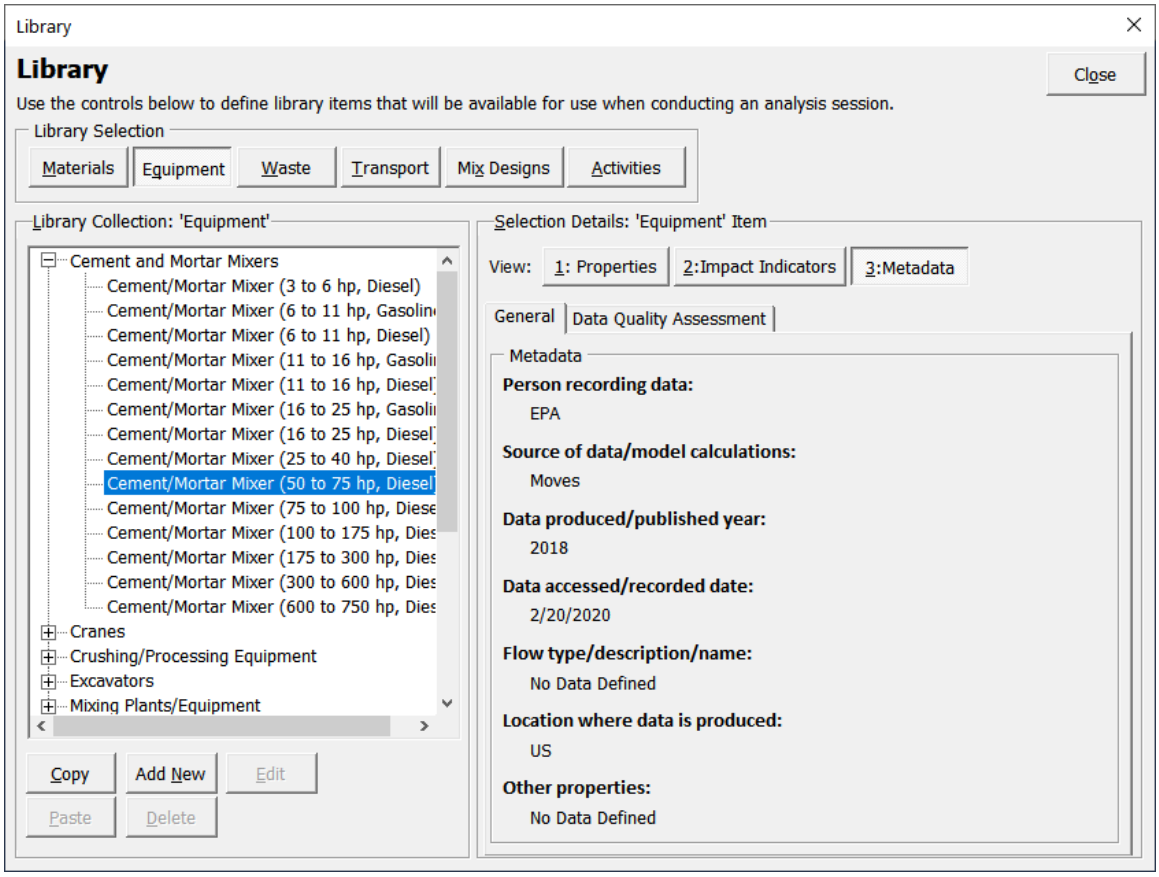


Figure 4-14. Example equipment properties screenshot.

- To view impact indicator data for the selected item, click the "2: Impact Indicators" button.
- To view metadata for the selected item, click the "3: Metadata" button.

Note: The process used to view the impact indicator data, metadata, and data quality assessment ratings are the same as described under Section 4.1.1.

4.2.2 Adding Data

Click the "Add New" button and follow these steps in the window that appears (figure 4-15).

Keyboard shortcut for Add New:
ALT + N

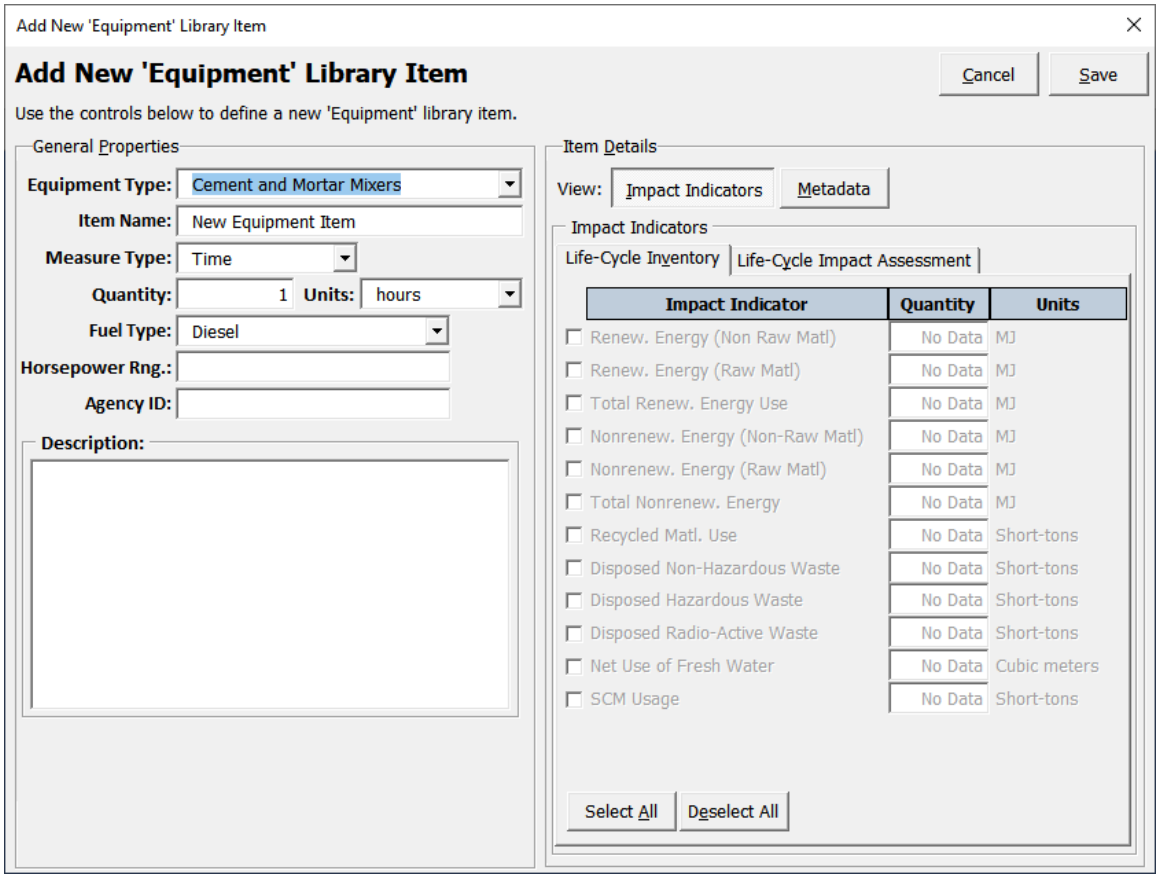


Figure 4-15. User interface for adding new equipment library item.

- Choose desired "Equipment Type" from the dropdown list.
- Specify "Item Name."
- Choose "Measure Type" from the dropdown list. Three options are available for equipment—Volume, Mass, and Time. The user can choose the appropriate type based on the equipment type and available data.
- Input quantity of the item for which the environmental impact indicators are available.
- Choose fuel type used by the equipment from the dropdown list.
- Input horsepower range for equipment.
- Input Agency ID for the equipment (if available).
- Provide a brief description of the item being input.

Keyboard Shortcuts in the Impact Indicator Interface

Impact Indicators: **ALT + I**

Life-Cycle Inventory tab: **ALT + V**

Life-Cycle Impact Assessment tab: **ALT + Y**

Select All: **ALT +A**

Deselect All: **ALT + E**

Then follow these steps to add impact indicator data.

Keyboard Shortcuts in the Metadata Interface:

General Tab: **ALT + N**

Data Quality Assessment Tab: **ALT + Q**

- Click the "Impact Indicators" button.
- Select the "Life-Cycle Inventory" tab.
- Click on checkboxes for which the impact indicator data are available and enter data in the text boxes available beside the selected impact indicators.
- To select or deselect all impact indicators, use the "Select All" or "Deselect All" buttons at the bottom of the page.
- Follow the same process for the "Life-Cycle Impact Assessment" tab.

Note: The process used to add the impact indicator data, metadata, and data quality assessment ratings is the same as described under Section 4.1.2.

4.3 WASTE LIBRARY

The waste library is a database that houses environmental impact data associated with four categories of waste management options for pavement materials—landfill, onsite recycling, offsite recycling, and reuse.

Keyboard shortcut to launch Waste library within the Library interface:

ALT + W

4.3.1 Viewing Existing Data

- Once the Library interface is open, click the "Waste" button.
- Select the waste management item of interest (in the example screen shot shown in figure 4-16, "Landfill-Aggregate" is selected).
- To view properties for the selected item, click the "1: Properties" button. The following properties are displayed:
  - **Treatment Type**: Treatment category as indicated in the tree structure shown on the left side of the screen (see figure 4-16). In the example selected, the waste category selected is "Landfill."
  - **Material Type**: Indicates material type for the selected waste treatment type.
  - **Measure Type**: Unit of measurement used. Note: applicable measure types for waste library items include Volume and Mass.
  - **Quantity**: The quantity for which the impact indicator data are available.
  - **Mass Conversion**: If the measure type is not in units of mass, the conversion factor used to convert the measure type to mass units.
  - **Agency ID**: Agency identification code for the selected item (optional).

- **Description:** Brief description of the selected item.
- **Editable?**: Indicates whether the data associated with the item are editable by the user. "Yes" indicates that the item is developed by the user and can be edited; "No" indicates that the item is a default database item and cannot be edited by the user.

Keyboard Shortcuts Within Waste Library

Properties interface: **ALT + 1**

Impact Indicators: **ALT + 2**

Metadata interface: **ALT + 3**

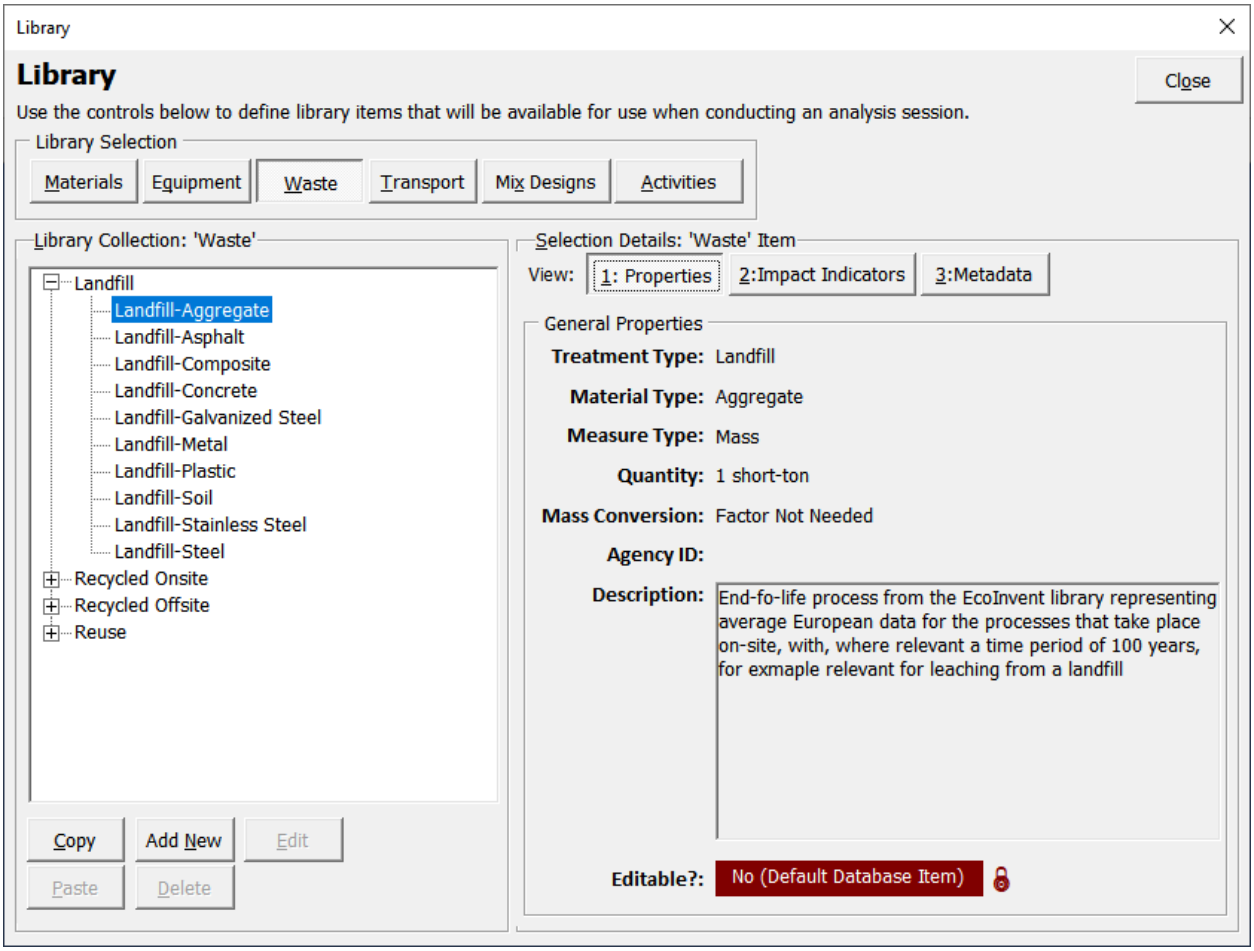


Figure 4-16. Example waste item properties screenshot.

- To view impact indicator data for the selected item, click the "2: Impact Indicators."
- To view metadata for the selected item, click the "3: Metadata" button.

Note: The process used to view the impact indicator data, metadata, and data quality assessment ratings are the same as described under Section 4.1.1.

4.3.2 Adding Data

To add a new waste library item, click the "Add New" button and follow these steps in the window that appears (figure 4-17) to add general properties.

Keyboard Shortcut for Add New: **ALT + N**

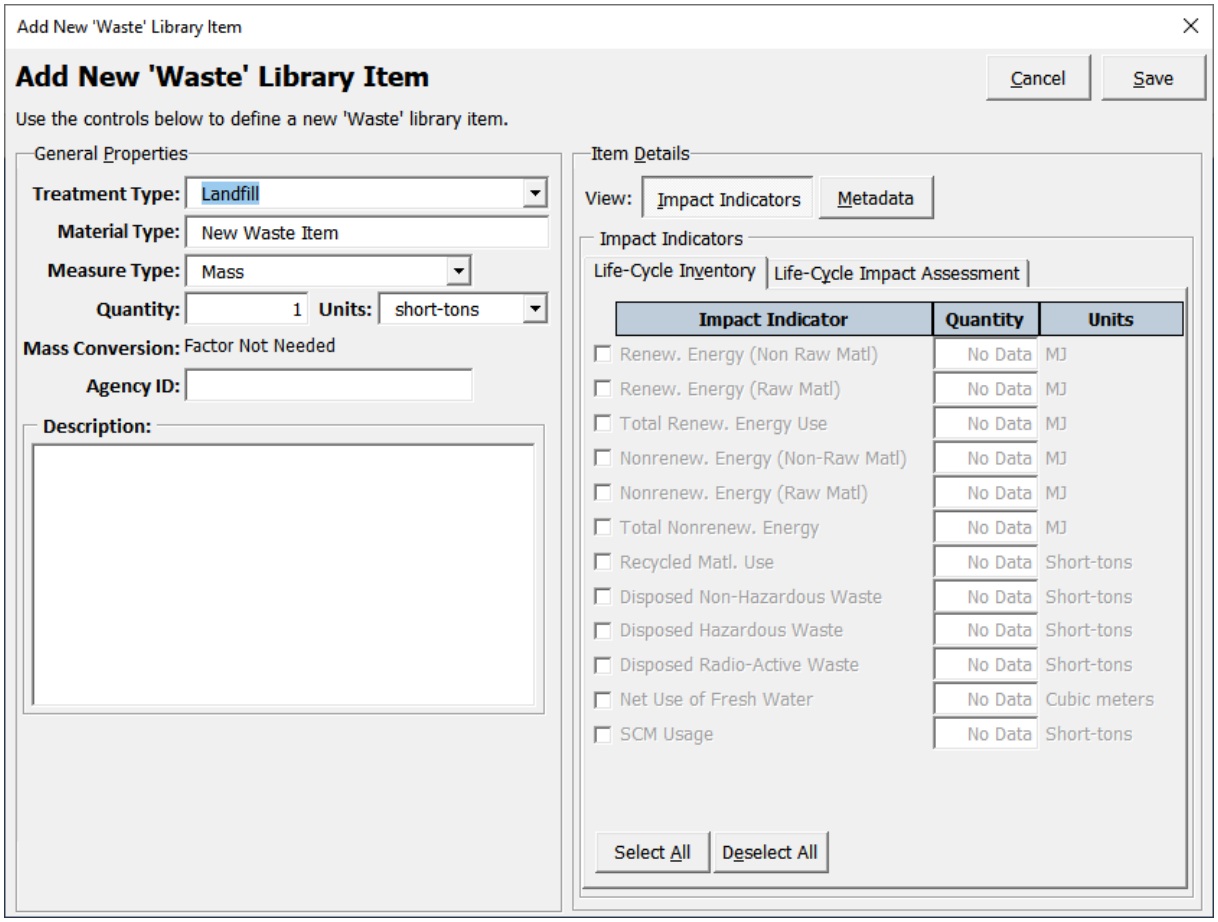


Figure 4-17. User interface for adding new waste library item.

- Choose desired "Treatment Type" from the dropdown list. The options available are Landfill, Recycled Onsite, Recycled Offsite, and Reuse.
- Specify the "Material Type."
- Choose "Measure Type" from the dropdown list. Two options are available for waste items—Mass and Volume..
- Input quantity of the item for which the environmental impact indicators are available.
- Input Agency ID for the waste item (if available).
- Provide a brief description of the item being input.

Keyboard Shortcuts in the Impact Indicator Interface

Impact Indicators: **ALT + I**

Life-Cycle Inventory tab: **ALT + V**

Life-Cycle Impact Assessment tab: **ALT + Y**

Select All: **ALT + A**

Deselect All: **ALT + E**

Keyboard Shortcuts in the Metadata Interface:

General Tab: **ALT + N**

Data Quality Assessment Tab: **ALT + Q**

Once the general properties have been input, follow these steps to add impact indicator data.

- Click the "Impact Indicators" button.

- Select the "Life-Cycle Inventory" tab.
- Click on checkboxes for which the impact indicator data is available and enter the data.
- To select or deselect all impact indicators, use the "Select All" or "Deselect All" buttons at the bottom of the page.
- Follow the same process for the "Life-Cycle Impact Assessment" tab.

Note: The process used to add the impact indicator data, metadata, and data quality assessment ratings are the same as described under Section 4.1.2.

4.4 TRANSPORT LIBRARY

The transport library houses environmental impact data associated with equipment categorized under three modes—water, rail, and road vehicles.

Keyboard shortcut to launch Transport library within the Library interface:

ALT + T

4.4.1 Viewing Existing Data

- Once the Library interface is open, click the "Transport" button.
- Select the transport item of interest (in the example screen shot shown in figure 4-18, "Barge" is selected).

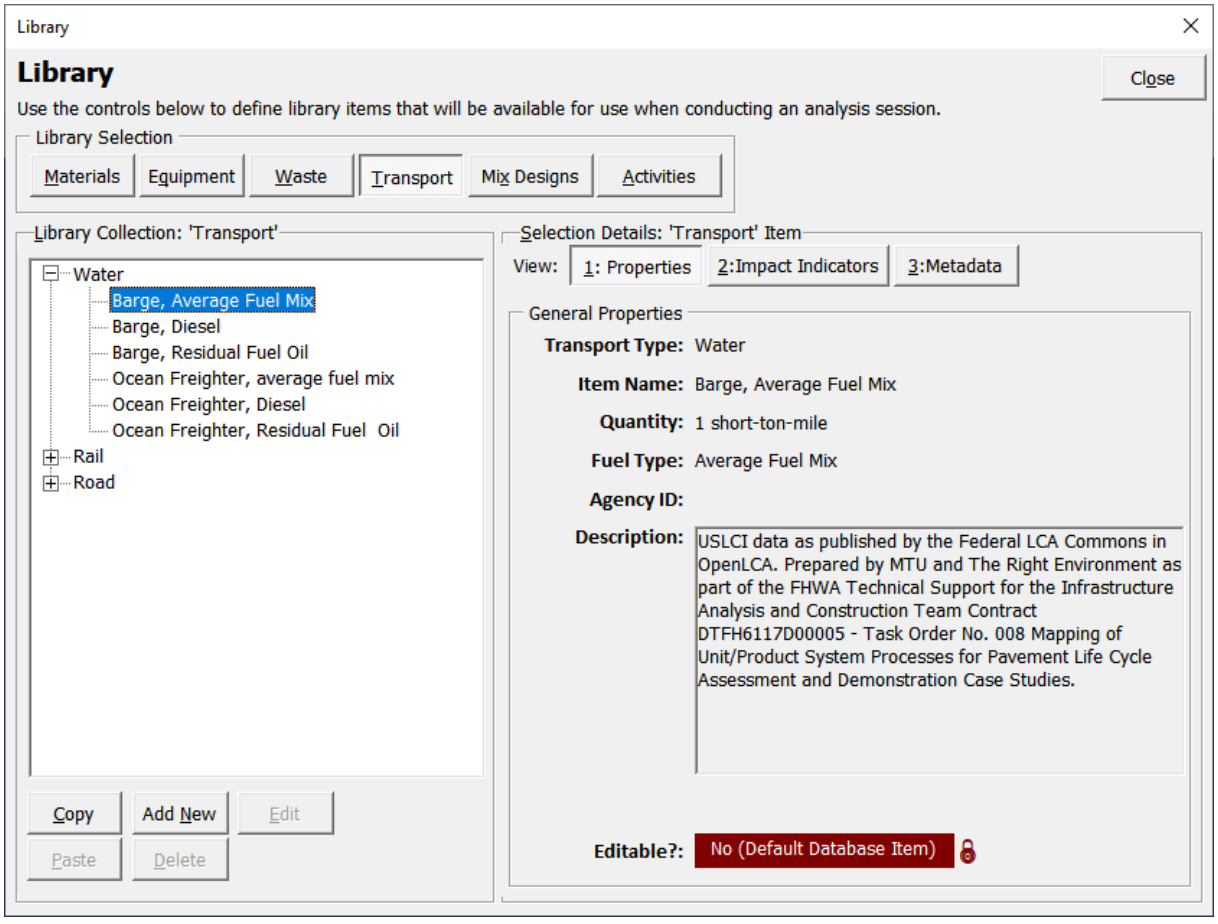


Figure 4-18. Example transport item properties screenshot.

- To view properties for the selected item, click the "1: Properties" button. The following properties are displayed:
  - **Transport Type**: Transport category as indicated in the tree structure shown on the left side of the screen (see figure 4-18). In the example selected, the category selected is "Water."
  - **Item Name**: Indicates the name of the selected transport item.
  - **Quantity**: The quantity for which the impact indicator data are available.
  - **Fuel Type**: Fuel used by the transport item.
  - **Agency ID**: Agency identification code for the selected item (optional).
  - **Description:** Brief description of the selected item.
  - **Editable?**: Indicates whether the data associated with the item are editable by the user. "Yes" indicates that the item is developed by the user and can be edited; "No" indicates that the item is a default database item and cannot be edited by the user.
- To view impact indicator data for the selected item, click the "2: Impact Indicators" button.
- To view metadata for the selected item, click the "3: Metadata" button.

Keyboard Shortcuts Within Transport Library

Properties interface: **ALT + 1**

Impact Indicators: **ALT + 2**

Metadata interface: **ALT + 3**

Note: The process used to view the impact indicator data, metadata, and data quality assessment ratings are the same as described under Section 4.1.1.

4.4.2 Adding Data

To add a new transport library item, click the "Add New" button and follow these steps in the window that appears (figure 4-19) to add general properties:

Keyboard shortcut for Add New: **ALT + N**

- Choose a "Transport Type" from the dropdown list. The options are Water, Rail, and Road.
- Specify the "Item Name."
- Input quantity of the item for which the environmental impact indicators are available. Note that the units are locked to "short ton-mile" for all Transport items. Impact data expressed using a different declared unit should be converted to short ton-mile before it is input into the tool.
- Select "Fuel Type".
- Input Agency ID (if available).

Keyboard Shortcuts in the Impact Indicator Interface

Impact Indicators: **ALT + I**

Life-Cycle Inventory tab: **ALT + V**

Life-Cycle Impact Assessment tab: **ALT + Y**

Select All: **ALT + A**

Deselect All: **ALT + E**

- Provide a brief description of the item being input.

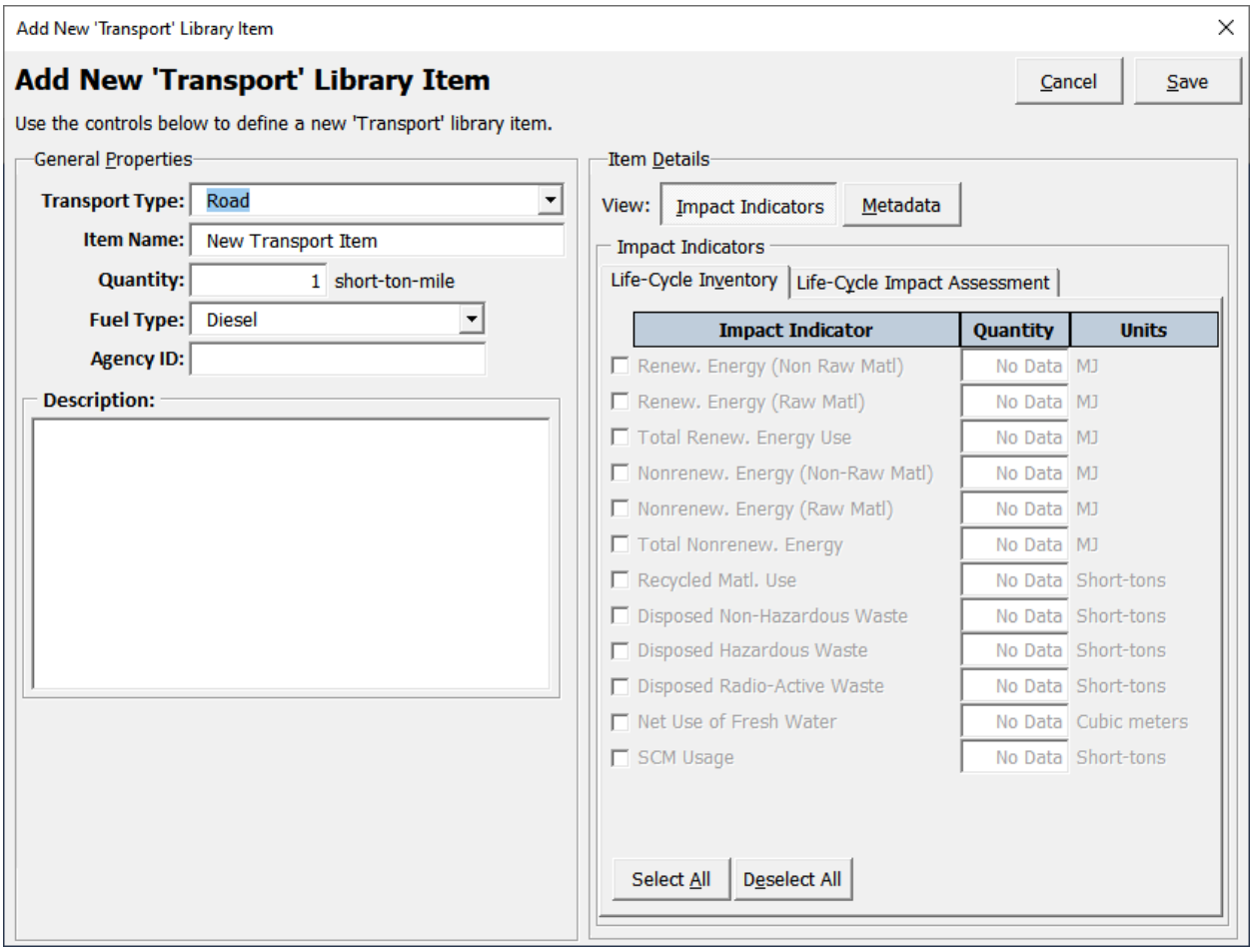


Figure 4-19. User interface for adding new transport library item.

Once the general properties have been input into the tool, follow these steps to add impact indicator data:

- Click the "Impact Indicators" button.
- Select the "Life-Cycle Inventory" Tab.
- Click on checkboxes for which the impact indicator data are available and enter data.

Keyboard Shortcuts in the Metadata Interface:

General tab: **ALT + N**

Data Quality Assessment tab: **ALT + Q**

- To select or deselect all impact indicators, use the "Select All" or "Deselect All" buttons.
- Follow the same process for the "Life-Cycle Impact Assessment" tab.

Note: The process for adding impact indicator data, metadata, and data quality assessment ratings is the same as above.

4.5 MIX DESIGNS LIBRARY

The user develops the mix designs library database of asphalt and concrete mix designs by using items from the Materials, Equipment, Waste, and Transport libraries. The user can also add EPD-based mix design data into the database.

Keyboard shortcut to launch Mix Designs library within the Library interface:

ALT + X

4.5.1 Viewing Existing Data

- Once the Library interface is open, click the "Mix Designs" button. A listing of pre-loaded mix design items will appear (see figure 4-20).

  Note: that the tool comes pre-loaded with a number of default mix design items that cannot be edited.

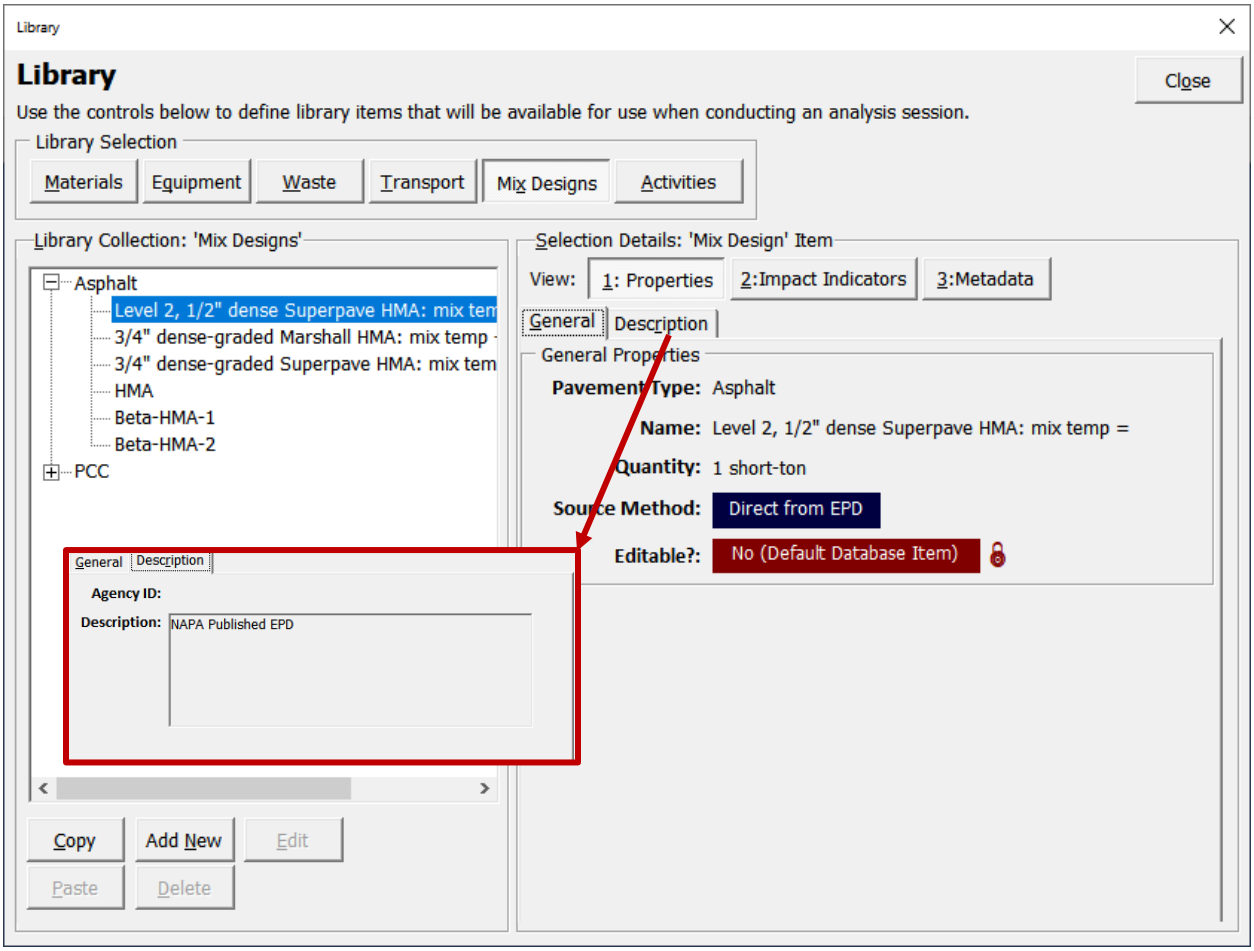


Figure 4-20. Mix design library interface to view existing data for EPD items.

- Select the item of interest from the tree interface. The general properties will be displayed in the "Selection Details" frame on the right side of the screen.
  - If the selected mix design item is based on EPD data (as shown in figure 4-20), the "General Properties" displayed:
    - **Pavement Type**: Pavement type for which the selected mix design is applicable (i.e., Asphalt, PCC, or Other).

- **Name**: Name provided for the mix design.
- **Quantity**: Quantity of mix design item for which the environmental impacts are stored in the database.
- **Source Method**: Indicator of the source of the mix design information. "Direct from EPD" indicates that the data source is from an EPD.
- **Editable?**: Indicates whether the data associated with the item are editable by the user. "Yes" indicates that the item is developed by the user and can be edited; "No" indicates that the item is a default database item and cannot be edited by the user.

– Clicking on the "Description" tab will display the "Agency ID" and "Description" fields.

– If the mix design item selected was developed using items from the tool's libraries, the "General Properties" are displayed (see figure 4-21):

- **Pavement Type**: Pavement type for which the selected mix design is applicable (i.e., Asphalt, PCC, or Other).
- **Name**: Name provided for the mix design.
- **Quantity**: Quantity of mix design item for which the environmental impacts have been stored in the database.
- **Source Method**: Indicator of the source of the mix design information. "Built from Library Items"—indicates that the mix design is modeled as a collection of other material, equipment, waste, and transport library items.
- **Editable?**: Indicates whether the data associated with the item are editable by the user. "Yes" indicates that the item is developed by the user and can be edited; "No" indicates that the item is a default database item and cannot be edited by the user.

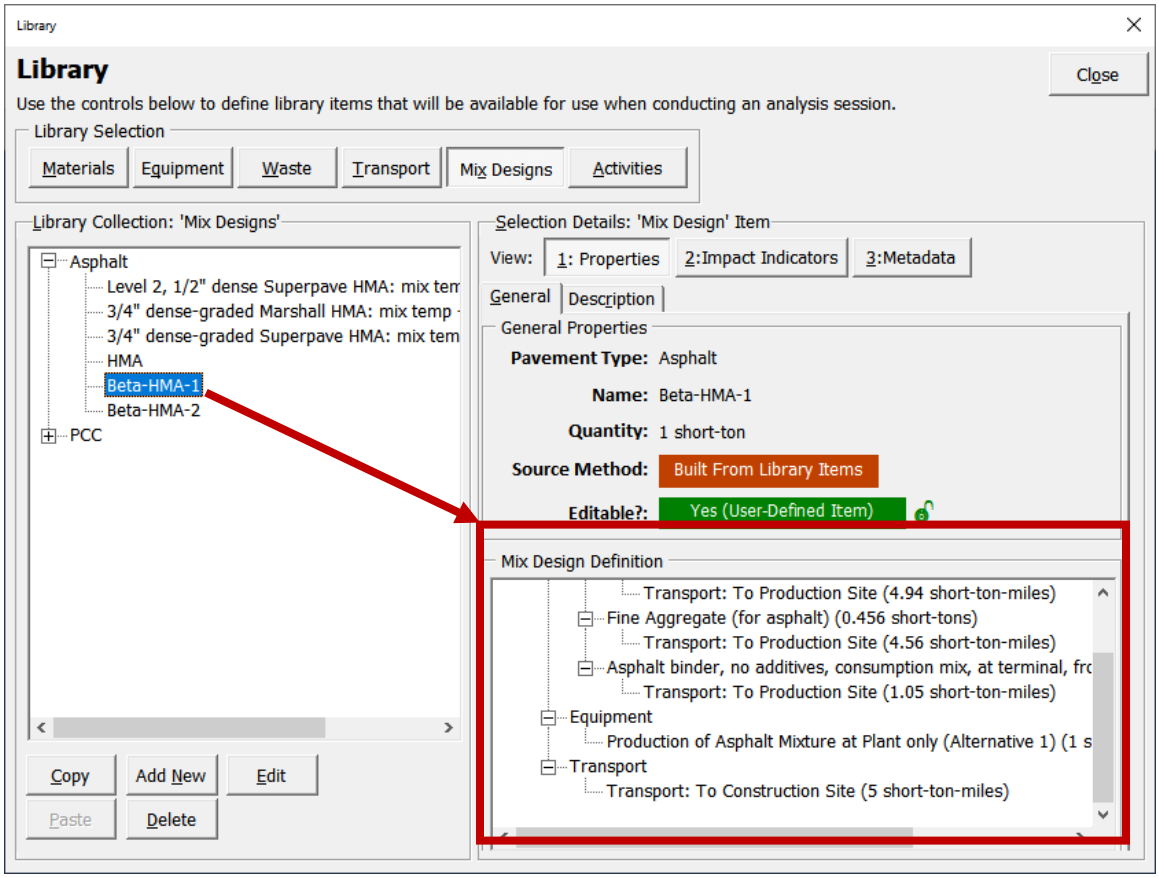


Figure 4-21. Interface to view existing data for mix designs built using library items.

Figure 4-21 shows the mix design details for an example mix design modeled by the user using items from the tool's libraries.

The impact indicator data, metadata, and data quality assessment ratings are displayed similar to the other libraries (Sections 4.1, 4.2, 4.3, and 4.4).

Impact Indicator Data for Mix Designs

For mix designs developed using library items, the impact indicator information is computed based on the sum of environmental impacts of all components included in the mix design modeled by the user. It is up to the user to determine data quality assessment rating for user-developed mix designs. EPDs typically include metadata and data quality assessment information that can be used for related mix design data.

4.5.2 Adding Mix Designs (From Library Items)

To add a mix design to the library, click the "Add New" button and follow these steps (figure 4-22):

Keyboard shortcut for Add New:
ALT + N

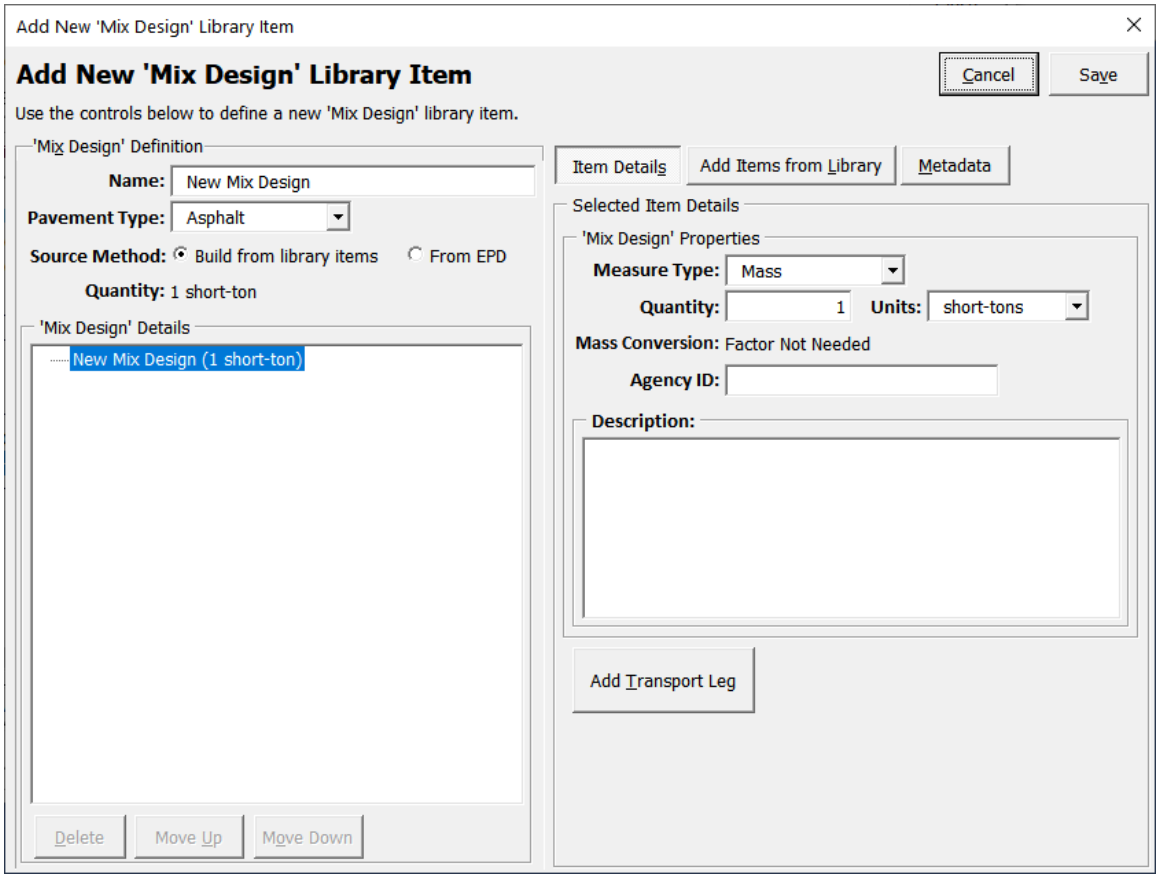


Figure 4-22. Interface to add new mix design data.

Developing Mix Designs

When developing mix designs using library items, the user is responsible for computing the mass and/or volume for the mix design components. The tool does not perform any calculation checks.

- In the "Mix Design Definition" frame, input:
  - **Name:** Name of mix design.
  - **Pavement Type:** Select pavement type from the dropdown menu. Available options are Asphalt, PCC, and Other.
  - **Source Method:** To build mix design from library items, select "Build from library items." (Adding mix design data from EPDs is discussed in the Section 4.5.3.)

Keyboard shortcut within the Add New Mix Design interface:

Item Details: **ALT + S**

Add Items from Library: **ALT + L**

Metadata: **ALT + M**

Add Transport Leg: **ALT + T**

- Click the "Item Details" button to input the following:
  - **Measure Type:** Indicate whether the mix design is based on units of mass or volume.
  - **Quantity:** Input quantity of mix design and select the appropriate units.
  - **Mass Conversion:** If the measure type selected is volume, the user will have to input a "Mass Conversion" factor to convert the volume of mix design into units of mass.

- **Agency ID:** Input agency ID for the mix design (if available).
- **Description:** provide a brief description on the mix design.
- Once a mix design has been developed, the user clicks c on the "Add Transport Leg" button. With the mix design item selected in the tree at the left, clicking this button will add a transport leg to the mix design object, and display the "Transport Details" interface shown in figure 4-23.

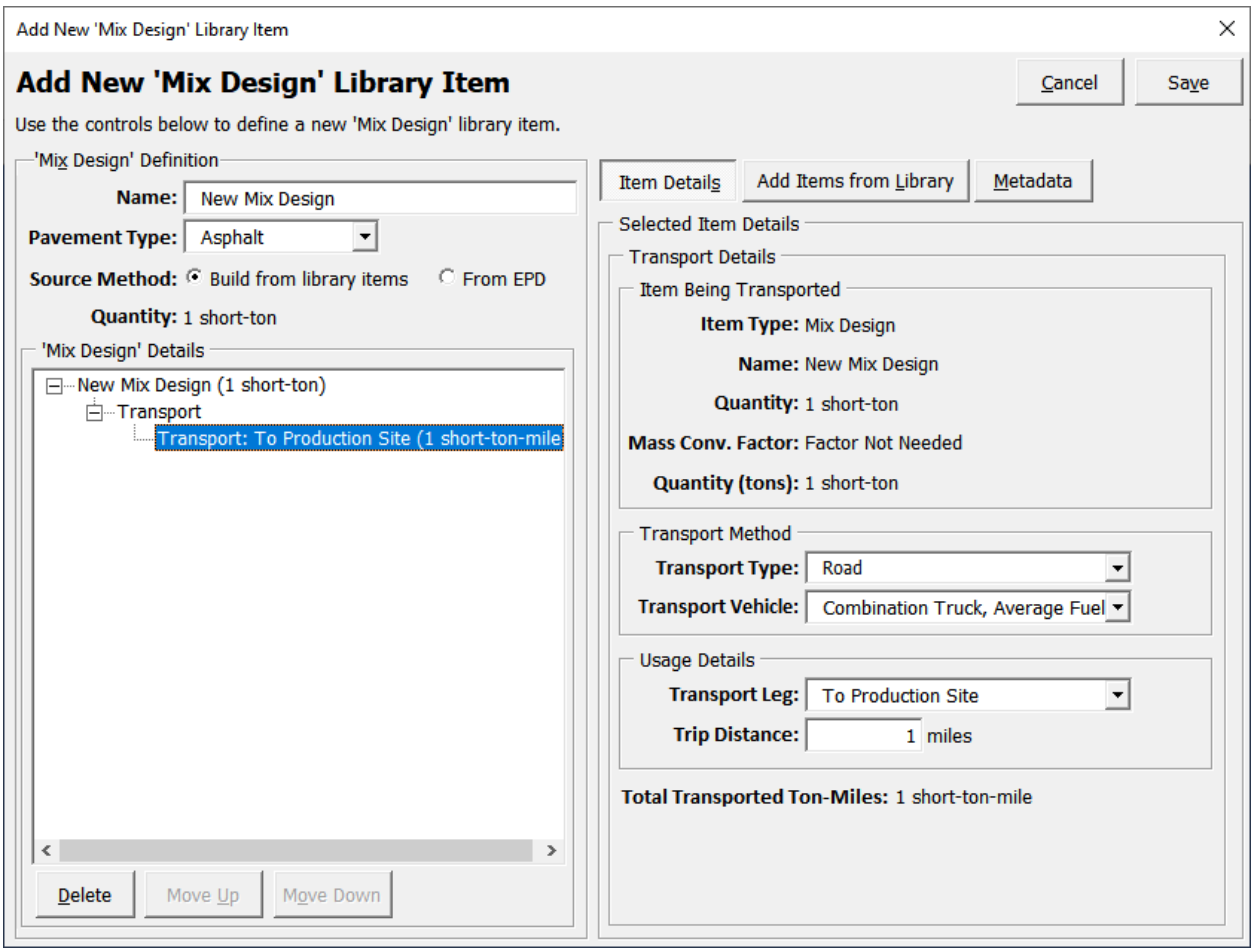


Figure 4-23. Transport leg interface.

- **"Item Being Transported" frame**—When the user adds a transport leg for an item, all associated information is shown in the "Item Being Transported" frame on the right side (see Figure 4-23).
- **"Transport Method" frame**—The controls in the "Transport Method" frame allow the user to determine how the item is transported.
  - **Transport Type**: Select a general transportation type category. Available options in this dropdown menu include Water, Rail, and Vehicles.
  - **Transport Vehicle**: Select the specific transportation "vehicle".
- **"Usage Details" frame**—The controls in the "Usage Details" frame allow the user to provide specific details about the transport leg.

  - **Transport Leg**: This field is used to describe the specific purpose of the transport leg (e.g., To Production Site). The user can select the options pre-loaded into the dropdown menu or manually input information by editing the text.
  - **Trip Distance:** This input provides the distance (in miles) between the place of origin of the item being transported and the intended destination.
- Note: The user can specify more than one transport leg for each item being transported.

- Click the "Add Items from Library" button add library items to the current mix design. The user can add items from the "Materials," "Equipment," and "Waste" libraries (see figure 4-24).
- With the "Add Items from Library" option selected, click the "Materials" button to add materials to the mix design.
  - In the tree interface that shows up on the screen, the user can select the desired materials and then click on "Add to Mix Design" button. Once an item is added, it will show up in the tree interface on the left side of the screen. In the example shown in figure 4-24, "Fine Aggregate" from the Materials library has been added to the current mix design.

Keyboard Shortcut for "Add to Mix Design":

ALT + A

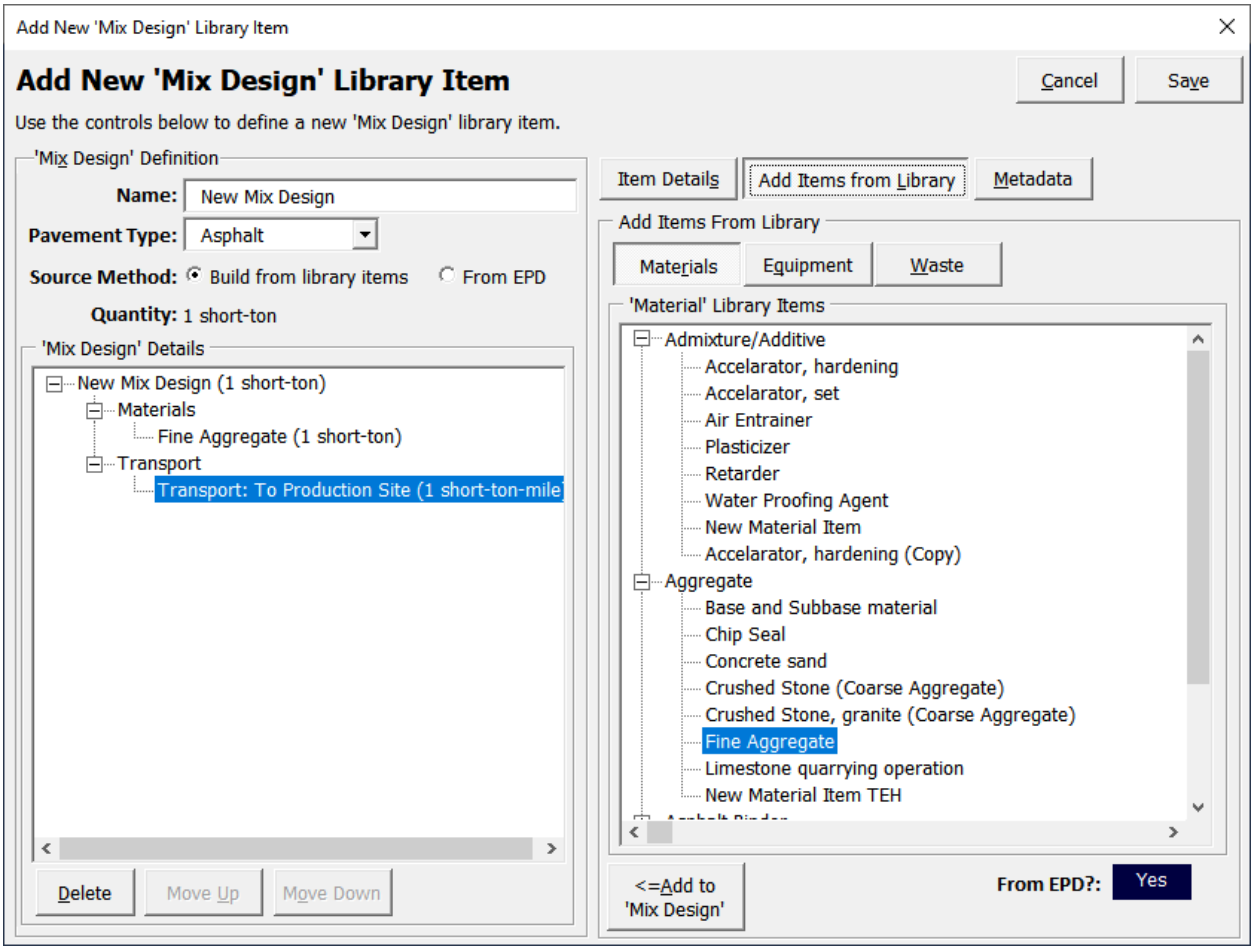


Figure 4-24. Adding materials to a mix design.

- To update the quantity of the material added to the mix design, the user can click the material item added in the tree, ("Fine Aggregate" in the example shown in figure 4-24) and update the quantity of the material item (see figure 4-25). Note that the units for the quantities are based on the units that have been specified in the materials library for the selected item. The same interface also indicates whether the data for the added item is based on an EPD.
- The user can add the transport legs associated with each material added to the mix design, similar to the process discussed earlier in this section.

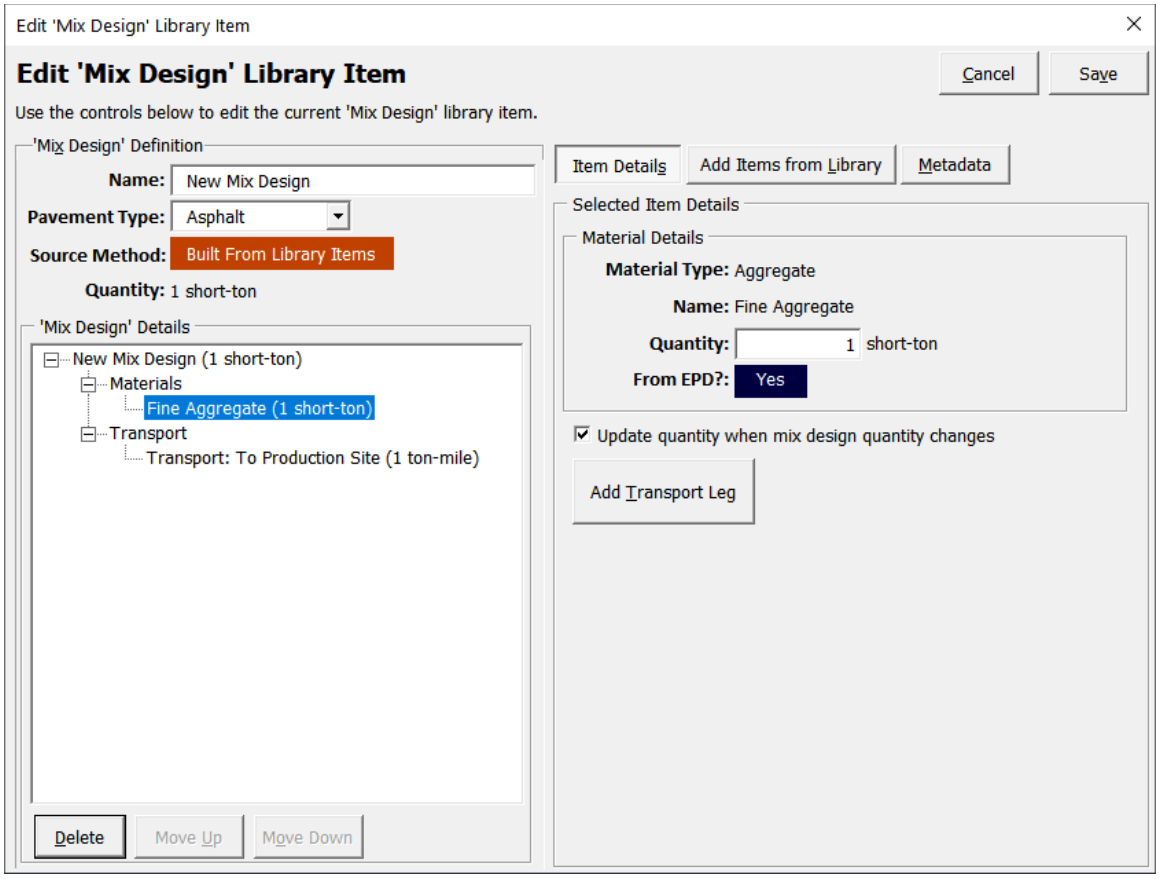


Figure 4-25. Updating quantities for materials added to mix design.

- The check box titled "Update quantity when mix design quantity changes" (just above the "Add Transport Leg" button, see figure 4-25) can be used to indicate whether the quantity of the selected item should scale based on the mix design quantity. If the checkbox is checked, the quantity of the item will scale linearly based when the mix design quantity is changed.
- To add equipment and waste library items the user can follow the same approach described for adding the materials. Some specific notes on each of these different item types:
  - To add items from the Equipment library, click the "Equipment" button, select the item, and click the "Add to Mix Design" button. Note: the only type of equipment that can be added to a mix design is "Mixing Plants/Equipment."

  - To add items from the Waste library, click the "Waste" button, select the item, and click the "Add to Mix Design" button.
  - Transport leg information can be added to the waste and equipment library items using the same process discussed earlier in this section.

- To add metadata for the mix design, click the "Metadata" button and input the information. The process used to add metadata and data quality assessment ratings are the same as described under Section 4.1.2.

Understanding Transportation Impacts

For material items based on EPD data, the user should note that the transportation impacts for moving the material from the original source (e.g., limestone quarry) to the material processing facility (e.g., aggregate processing facility) is already accounted for in the EPD. The user would only need to include the transportation legs for the material from the material processing facility to the mixing plant.

Examples on developing mix designs using the tool are provided in Chapter 6.

4.5.3 Adding Mix Designs (From EPDs)

To add mix design data from EPDs, the user sets the "Source Method" to "From EPD" in the "Add New 'Mix Design' Library Item" dialog box (see figure 4-26). The user interface then replaces the "Add Items from Library" button with the "Impact Indicators" button on the right side of the dialog box. Since the data for the mix design are coming from an EPD, the user can input the impact indicators associated with the quantity of the mix design directly into the tool. The user can select appropriate impact indicators in the tool (based on what is reported in the EPD) and input the data.

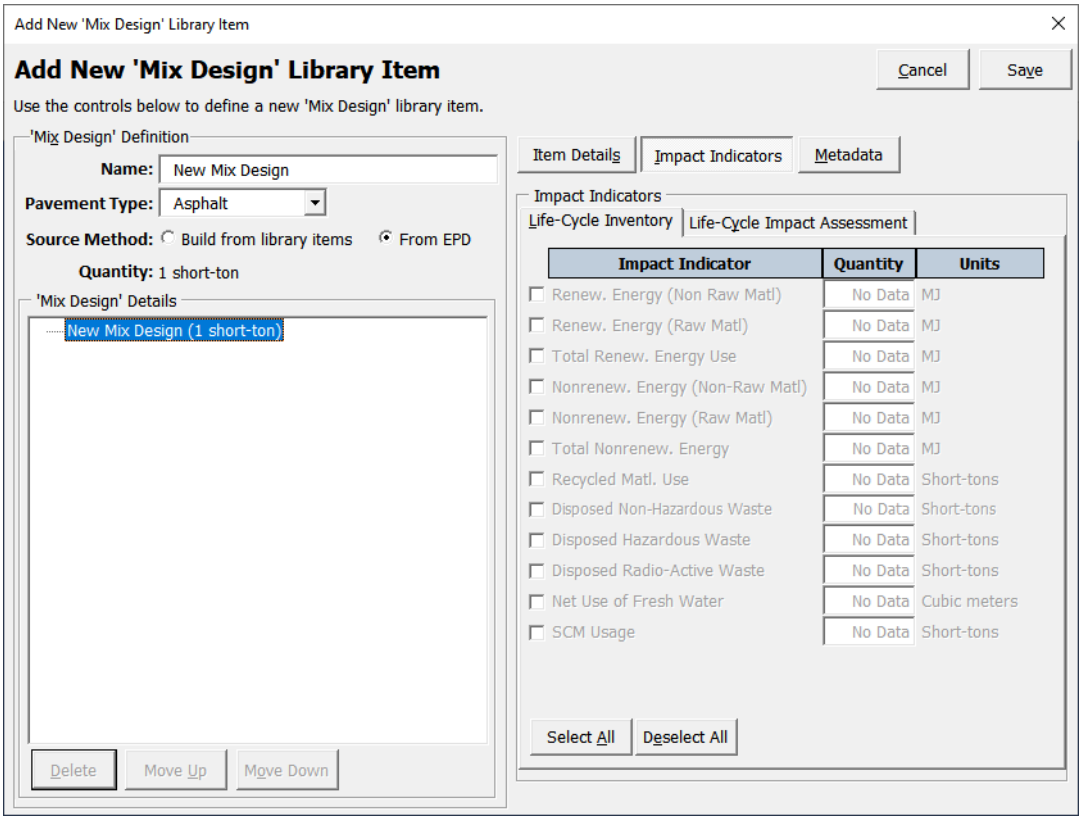


Figure 4-26. Interface to add new mix designs data.

Caution: Declared Units

When inputting EPD data into the tool, the declared unit on the EPD might be different from the default units that the tool supports. In such situations, the user should convert the declared units on the EPD into a unit available in the tool.

Example: If the declared Unit on the EPD = 1 metric-ton, the user converts this into units of mass that is supported by the tool (short-tons, pounds, or ounces). If the user desires to use short-tons as the unit within the tool, the "Quantity" must be entered as 1.102 (1 metric ton = 1.102 short-ton).

Additional information on using EPD data with the tool is available in the *Methodology and Assumptions Report* (Meijer et al. 2021). Appendix C provides an example on incorporating data from an existing EPD into the tool.

4.6 ACTIVITIES LIBRARY

The activities library (see figure 4-27) is a user-developed database of pavement life-cycle activities (e.g., 4-inch asphalt surface layer, 6-inch concrete pavement, diamond grinding, asphalt mill and inlay, etc.). activities can include items from all other libraries.

Keyboard Shortcut to Launch Mix Designs Library within the Library Interface:

ALT + A

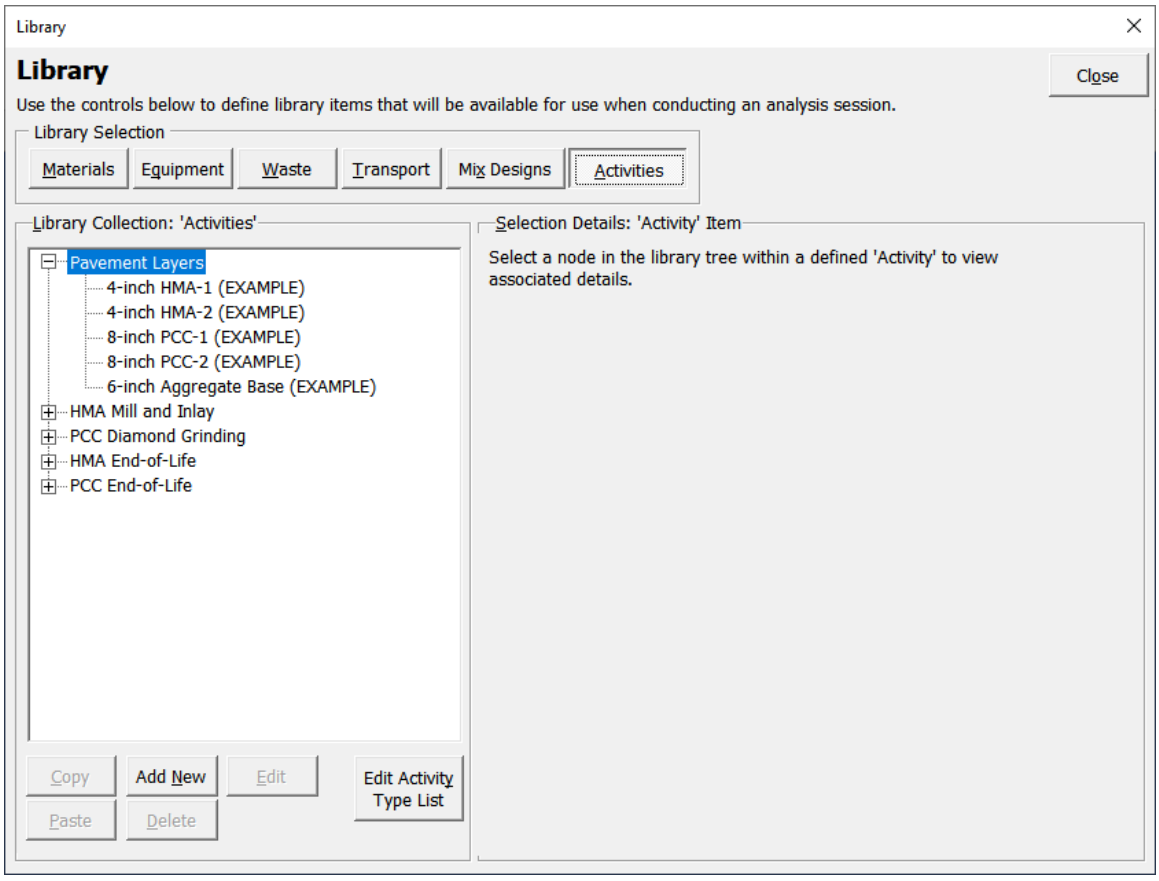


Figure 4-27. Activities library.

4.6.1 Categorizing Activities

The user can set up to 10 activity types.

Keyboard Shortcut for "Edit Activity Type List":

ALT + Y

- Click the "Edit Activity Type List" button. In the popup "Category List Editor" window that appears (see figure 4-28), the category names are displayed.
- To edit a category name, select any item from the list. Toward the bottom of the window, under the frame titled "Selection Item Details," two controls are provided.
  - A check box to determine whether the selected category name is to be displayed in the user interface shown in figure 4-28.
  - A text box field to input the category name.

Keyboard Shortcut in the Category List Editor Window:

Save: **ALT + S**

Move Up: **ALT + U**

Move Down: **ALT + D**

- The "Move Up" and "Move Down" controls can be used to organize the categories.
- Once all edits have been made, click the "Save" button.

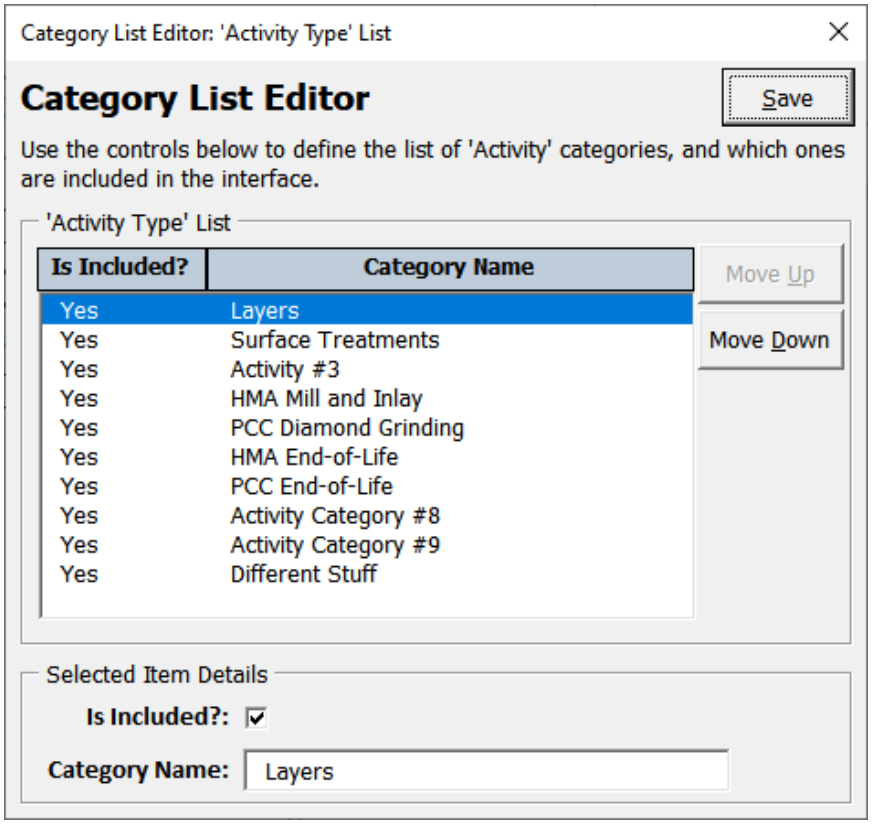


Figure 4-28. Category list editor.

4.6.2 Viewing Existing Data

Select an Activity item in the tree interface.

- To the right of the screen, the "Activity Definition" tree structure provides details on various items included in the activity modeled by the user. For example, as shown in figure 4-29, the materials, equipment, and transport items included in the "4-inch HMA Layer-HMA-2" activity are displayed in the "Activity Definition" tree structure.

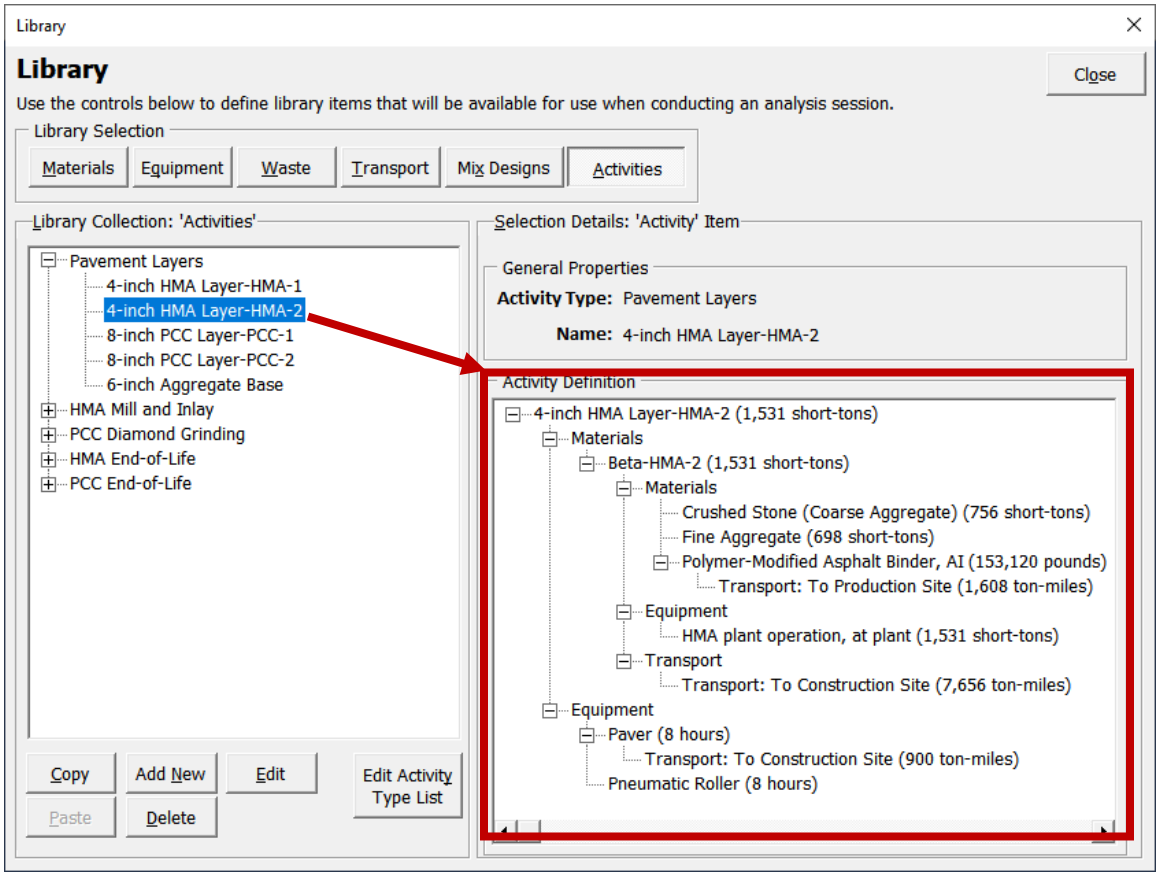


Figure 4-29. Activity properties.

4.6.3 Model New Activity

- Click the "Add New" button.
- Click the "Item Details" button and input the general properties of the activity being modeled (see figure 4-30).

Keyboard Shortcut for "Add New":

ALT + N

  - **Activity Type**: Select the activity type from the dropdown list. The list of activity types shown are the ones developed previously by the user (see Section 4.6.1).
  - **Activity Name**: Provide a name for the activity being created (e.g., 2-inch asphalt surface layer, 6-inch concrete layer, etc.).
  - **Measure Type**: Select the units of measurement for the activity from the dropdown menu.
  - **Quantity**: Input the quantity for which the activity is being modeled.

Tip: Quantity Calculations

The user calculates the quantities for the activity being modeled outside the tool. For example, if the user wants to model a 4-inch thick pavement layer that is 1-mile long and 12-ft wide, the user calculates the quantities for that activity. The user also calculates the quantities of other items included in the activity, such as quantities of mix design used in the pavement layer, hours of equipment use, etc.

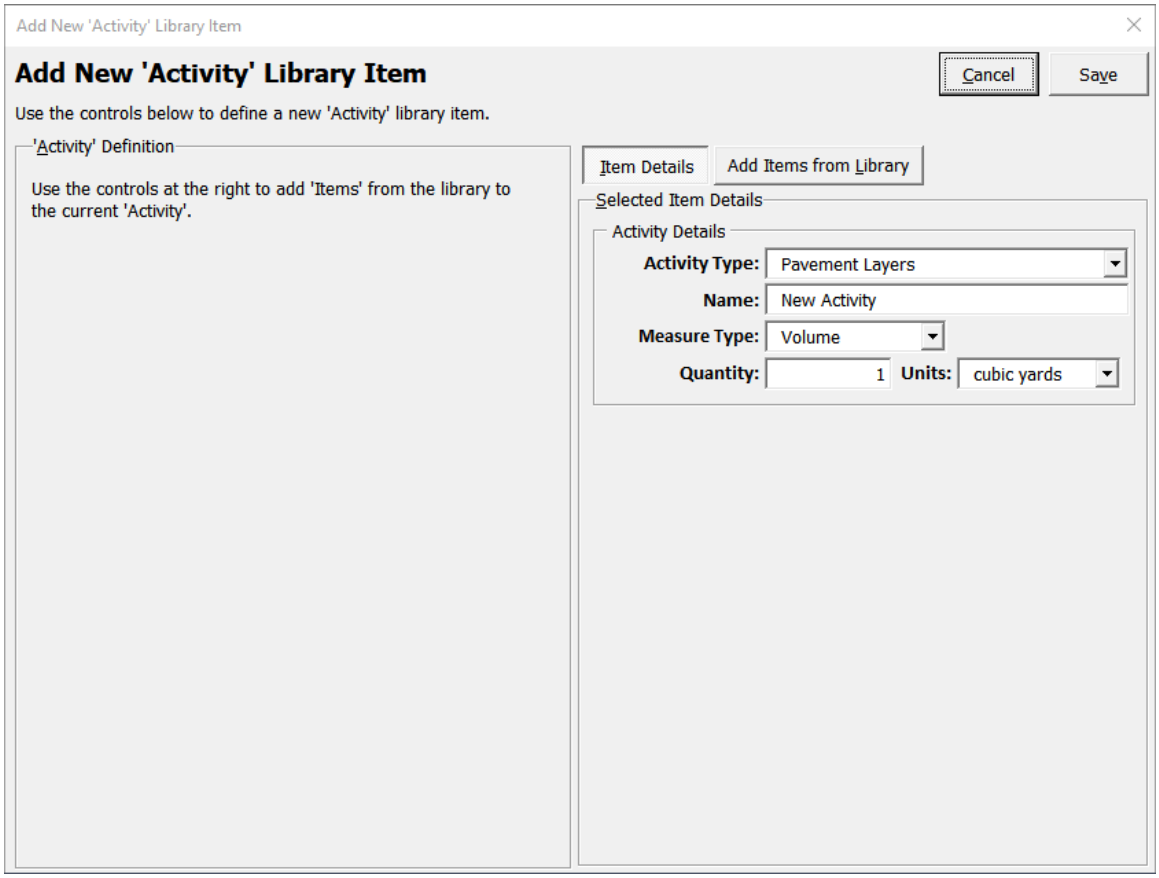


Figure 4-30. Add new activity interface.

- Once the general properties for the activity are entered, the next step is to include relevant items from the library. Click the "Add Items from Library" button a:
  - Select an item from the materials, equipment, waste, or mix design library. Click the "Add to Activity" button.
  - Once an item is added to the activity, it is displayed in the tree interface. Select the created item in the treeview and update the quantity of the added library item (see figure 4-31).

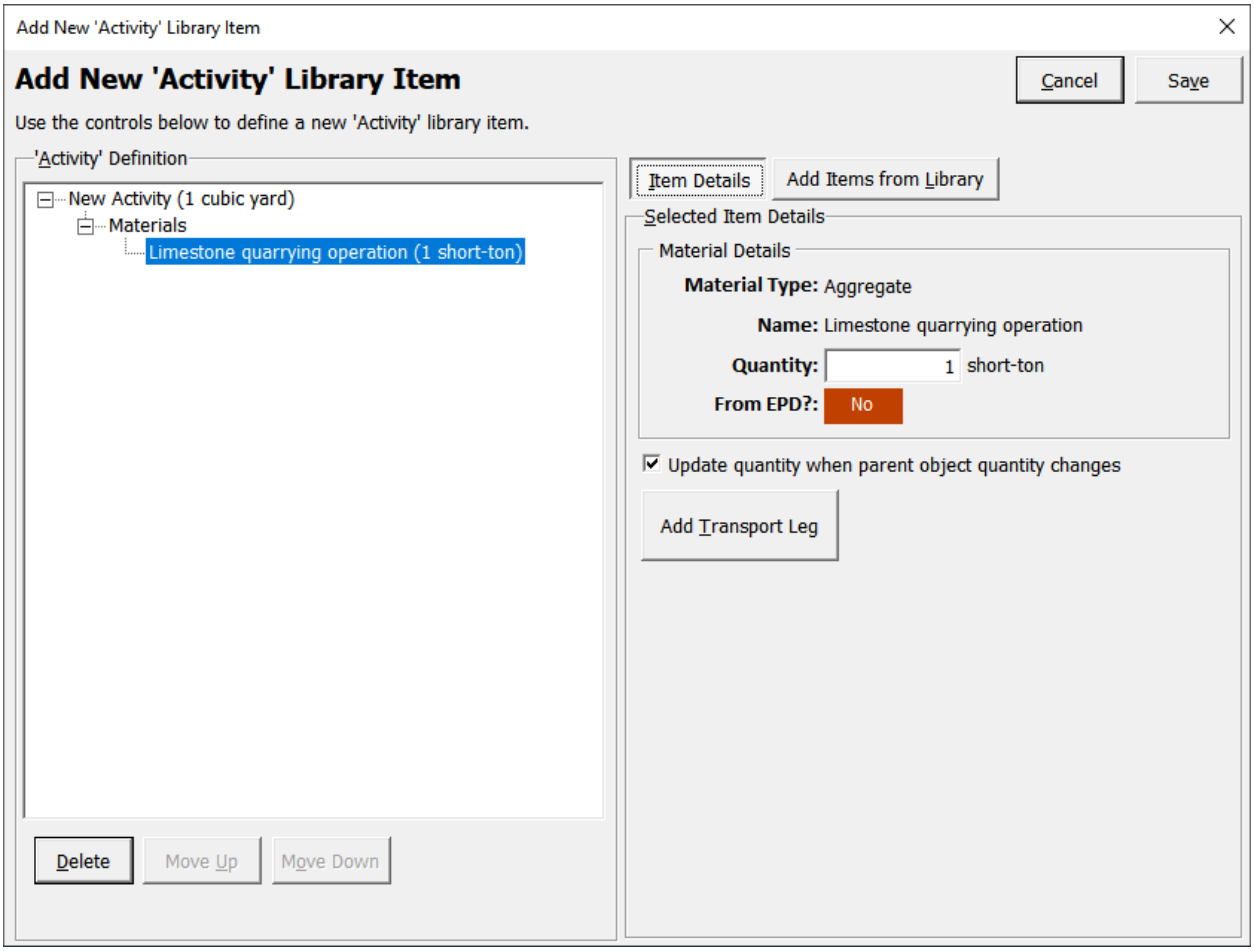


Figure 4-31. Adding items to an activity.

- The check box "Update quantity when parent object quantity changes" can be used to indicate whether the quantity of the item should be scaled based on the quantity of the activity item.
- The user can also add transportation details for each item. click that item in the "'Activity' Definition" treeview and then click the "Add Transport Leg" button (follow same process as discussed under Section 4.5.2).
- Repeat the steps above to add each desired library item t.
- Click on "Save" after the activity has been modeled.

See Chapter 6 for examples on modeling activities.

CHAPTER 5. ANALYSIS SESSION

5.0 INTRODUCTION

To begin an analysis, launch the tool and click the "Conduct Analysis" button on the tool's home screen (see figure 5-1).

Keyboard shortcut for the Conduct Analysis button from home screen:

ALT + C

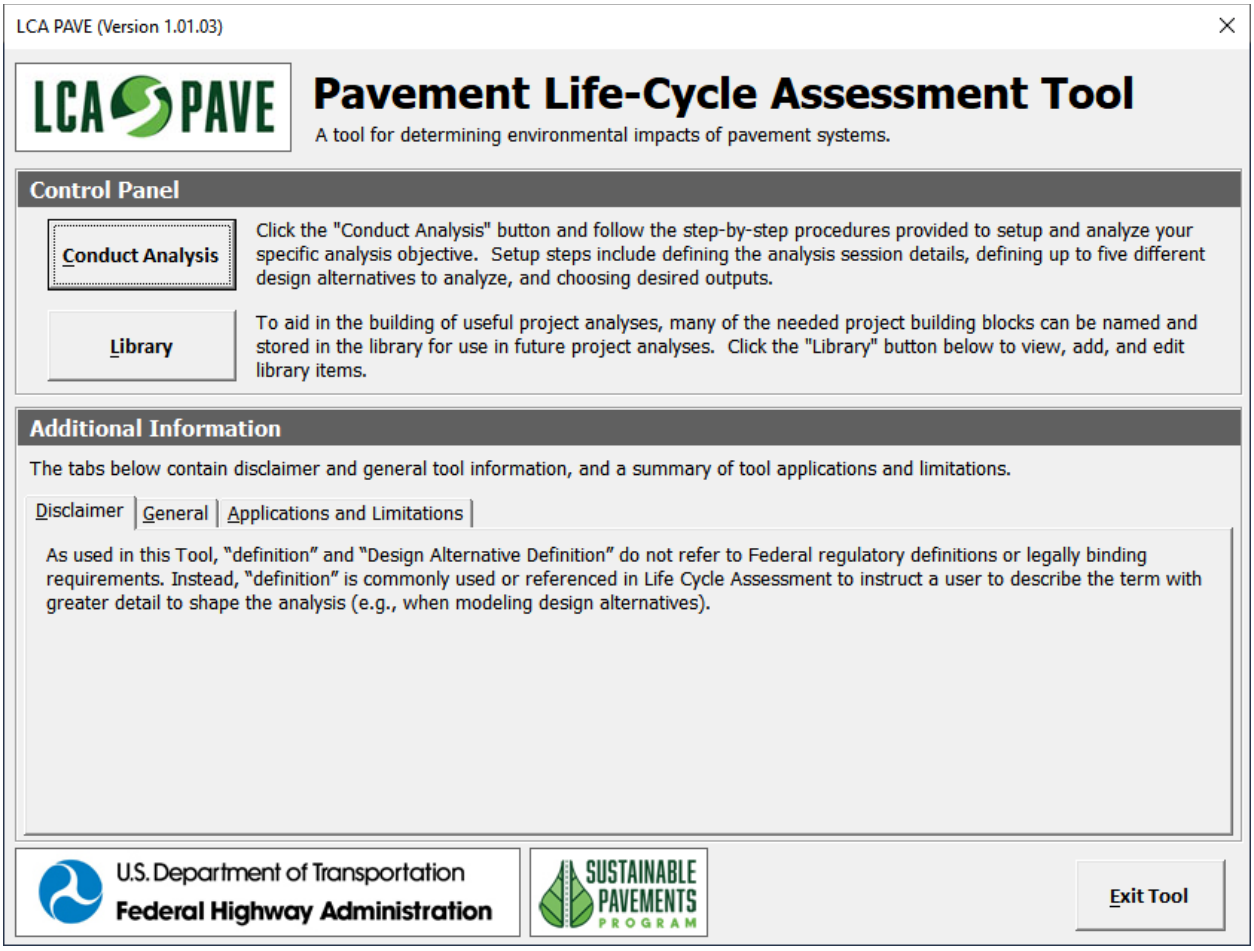


Figure 5-1. Tool home screen.

5.1 STEP 1: ANALYSIS SESSION DETAILS

The "Analysis Session Details" dialog box will be displayed (see figure 5-2).

The user can set the following details on the analysis being conducted:

- **Analysis Details**:
  - **Analysis Objective:** Use the "Analysis Objective" dropdown box to select the type of analysis d. The two options are:

Keyboard Shortcuts

Back: **ALT + B**

Next: **ALT + X**

- **Compare Materials (Use Cases #1 and #2 mentioned under Section 1.3)**: Select this option if the goal is to compare different types of materials for the same purpose in a pavement application (e.g., hot-mix asphalt vs. warm-mix asphalt; concrete mixtures with different amount of cement content, etc.). The user does not have to input an analysis period for the alternatives being modeled.
- **Compare Treatment Cycles or Pavement Design Life-Cycle Options (Use Case #3 mentioned under Section 1.3)**: This option is selected if the goal is to compare: (a) different treatment sequences applied to an existing pavement structure or (b) pavement design life-cycle options. The user will then model a series of activities over a selected analysis period.

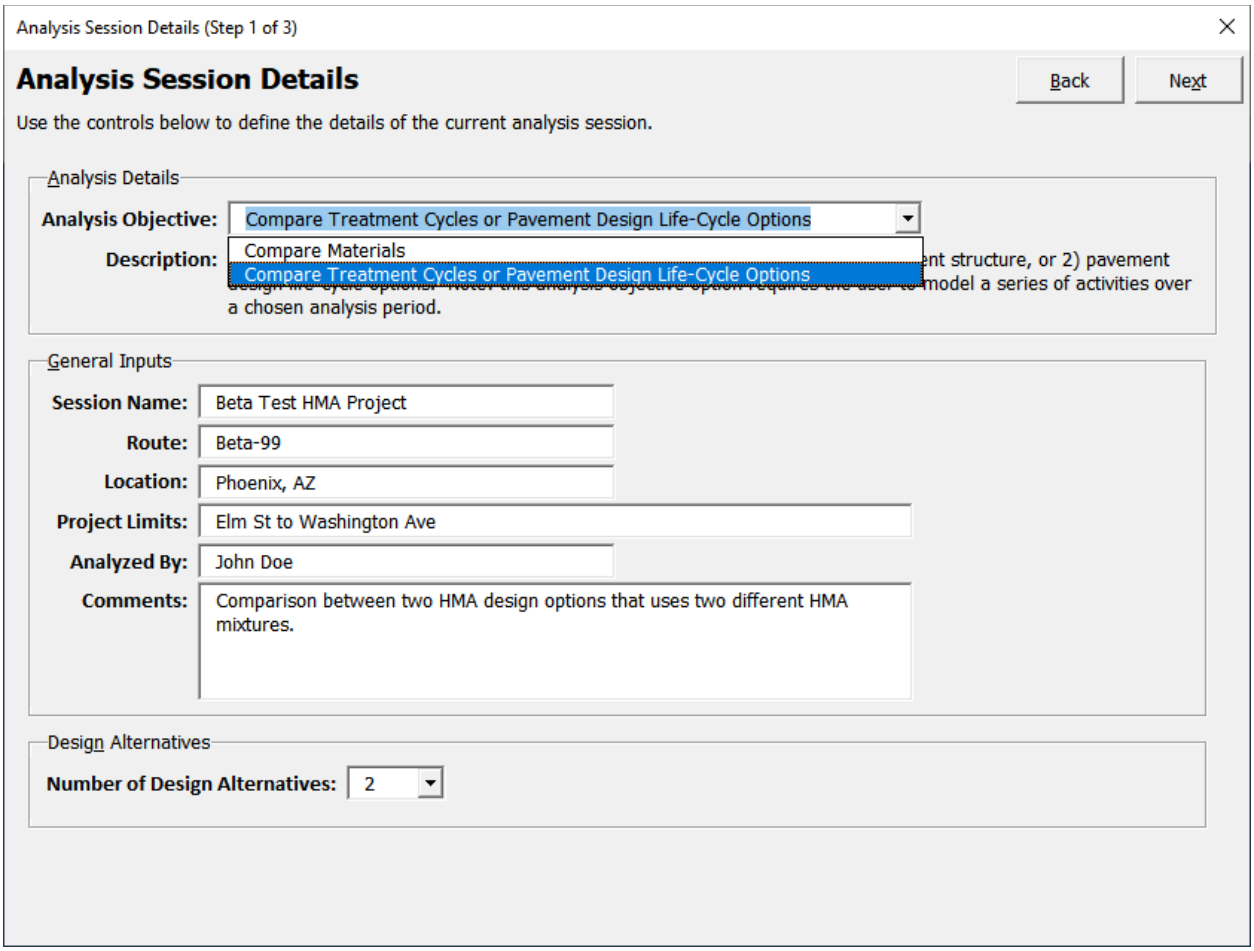


Figure 5-2. Analysis session details interface.

Caution: Compare Materials Option

The "Compare Materials" option is used to compare materials that: (a) are intended to be used for the same purpose in a given pavement system, and (b) exhibit similar performance. For example, the user can use this option to compare the environmental impacts of using of 1 short-ton of a hot-mix asphalt mixture to 1 short-ton of a warm-mix asphalt mixture intended for use in the same pavement application.

It is not appropriate to use this option to compare the environmental impacts of materials that are functionally different. For example, the user should not be comparing 1 short-ton of hot-mix asphalt to 1 short-ton of a concrete mixture. The tool does not check for inappropriate comparisons and will not provide warning messages. The tool will still provide results for any analyses set up by the user, however, the results may be inaccurate or misleading. The onus is on the user to ensure that appropriate comparisons are being made.

- **General Inputs**:
  - **Session Name:** Provide a name for the analysis session.
  - **Route:** Provide information on the facility for which the analysis is being conducted.
  - **Location:** Input location information for the facility being analyzed.
  - **Beginning MP:** Input beginning mile point of the roadway facility being analyzed.
  - **End MP:** Input end mile point of the roadway facility being analyzed.
  - **Analyzed By:** Input name of person/agency conducting the analysis
  - **Comments:** Provide a brief description of the analysis being performed.
- **Design Alternatives**:
  - **Number of Design Alternatives:** Use this dropdown box to indicate the number of design alternatives being compared (up to 5).

Once the analysis session details have been input, click "Next" to advance to Step 2: Design Alternative Definition.

5.2 STEP 2: DESIGN ALTERNATIVE DEFINITION

The "Design Alternative Definition" dialog box (see figure 5-3) is used to model the problem being investigated. The first level is the "Alternative Level." since the number of alternatives selected was "2" in Step 1, Buttons for "Alternative 1" and "Alternative 2" are shown in figure 5-3.

Note: The Analysis Period dropdown menu is available only when the analysis objective selected under Step 1 is "Compare Treatment Cycles or Pavement Design Life-Cycle Options."

Keyboard shortcuts for Alternative buttons

Alternative 1: **ALT + 1**

Alternative 2: **ALT + 2**

Alternative 3: **ALT + 3**

Alternative 4: **ALT + 4**

Alternative 5: **ALT + 5**

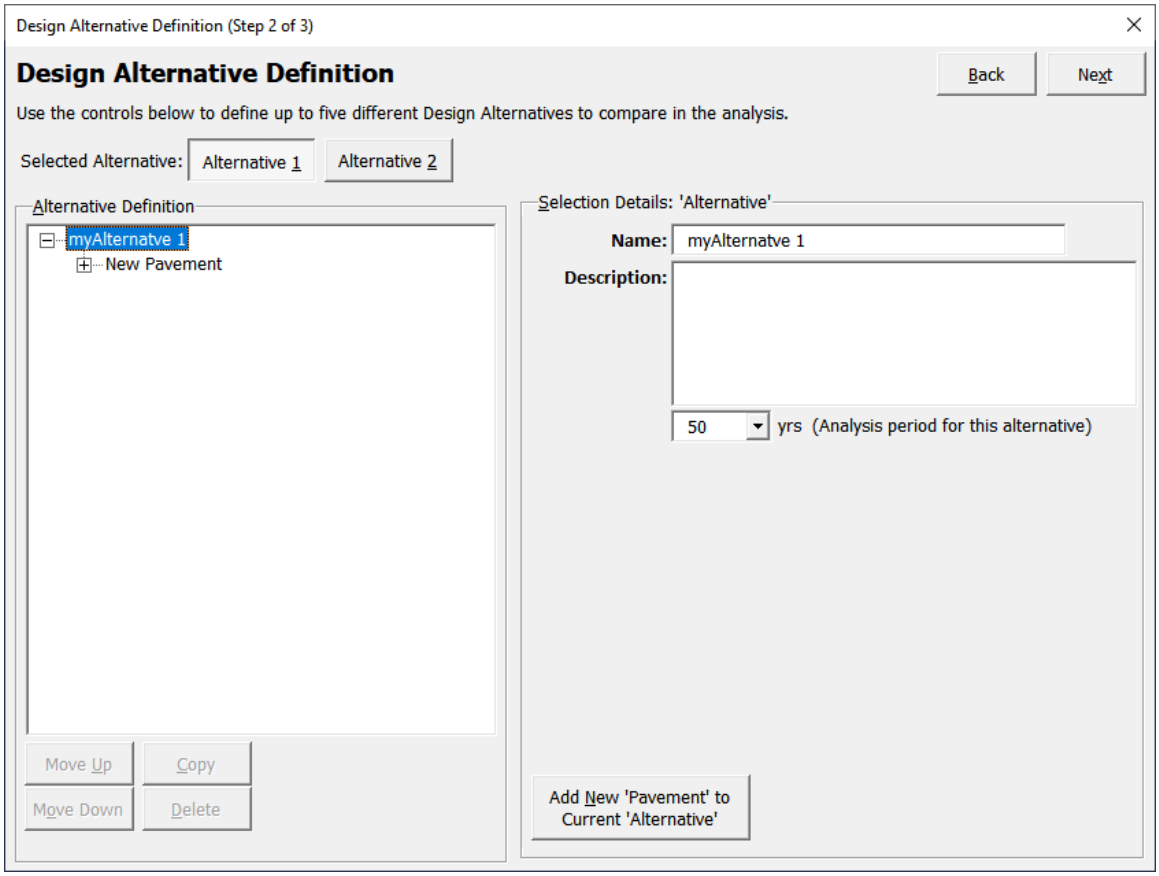


Figure 5-3. Design alternative definition interface.

Use the following steps to model the tree structure for each alternative:

Keyboard shortcuts for "Add New Pavement to Current Alternative":

ALT + N

- Click the alternative node in the treeview (i.e., the top node in the tree).
- In the "Selection Details" frame on the right, provide a name for the alternative, a brief description, and set the analysis period (only when user selects "Compare Treatment Cycles or Pavement Design Life-Cycle Options" as the analysis objective) (seen in figure 5-3).
- Click on the "Add New 'Pavement' to Current Alternative" to add a new Pavement Facility object to the current alternative object. The newly added pavement facility will show up as a "child" object under the alternative object in the treeview.
- Click on the pavement facility node in the treeview to view the object's properties. Use the following controls in the "Selection Details" frame to set the facility properties (see figure 5-4):
  - **Type:** Select from options available in the dropdown list (Mainline, Shoulder, Ramp, and Other).
  - **Name:** Provide a name for the pavement facility.
  - **Description:** Input a brief description of the facility.

- **Num. Lanes:** Input the number of lanes in this facility.
- **Length:** Input the length of the pavement facility in units of feet.
- **Width:** Input pavement width (total width of all lanes) in units of feet

Modeling Pavement Facilities

The tool calculates the total number of lane-miles and surface area for the pavement facility added by the user and the results are displayed in the user interface (see figure 5-4). At the bottom of the screen, the "Include this pavement's lane-miles and area in the functional unit calculations for this alternative" checkbox can be used indicate whether the lane-miles and surface area are to be included in the functional unit calculations. This checkbox is checked by default.

The user can add more than one pavement facility to a design alternative (e.g., mainline, ramp, shoulders etc.). When more than one pavement facility is added, the user determines which facilities are to be included in the functional unit calculations under Step 3 (see Section 5.3). By default, the tool assumes that the lane-miles and area of ALL pavement facilities will be included in the functional unit calculations. The tool will add the number of lanes and area for each pavement facility to perform the functional unit calculations.

For example, consider a design alternative that includes two pavement facilities: a mainline and a shoulder. Assume that each of these facilities is 5,280 ft long and 12 ft wide with one lane each. By default, the tool will assume that the total number of lane-miles = 2 and the total area = 126,720 ft^2 (2 x 5280 x 12). If the user decides to exclude the shoulder by unchecking the checkbox, the following data is used for the functional unit calculations: total lane-miles = 1; total area = 63,360 ft^2.

This functional unit aspect of the tool is explained in detail in Section 5.3.

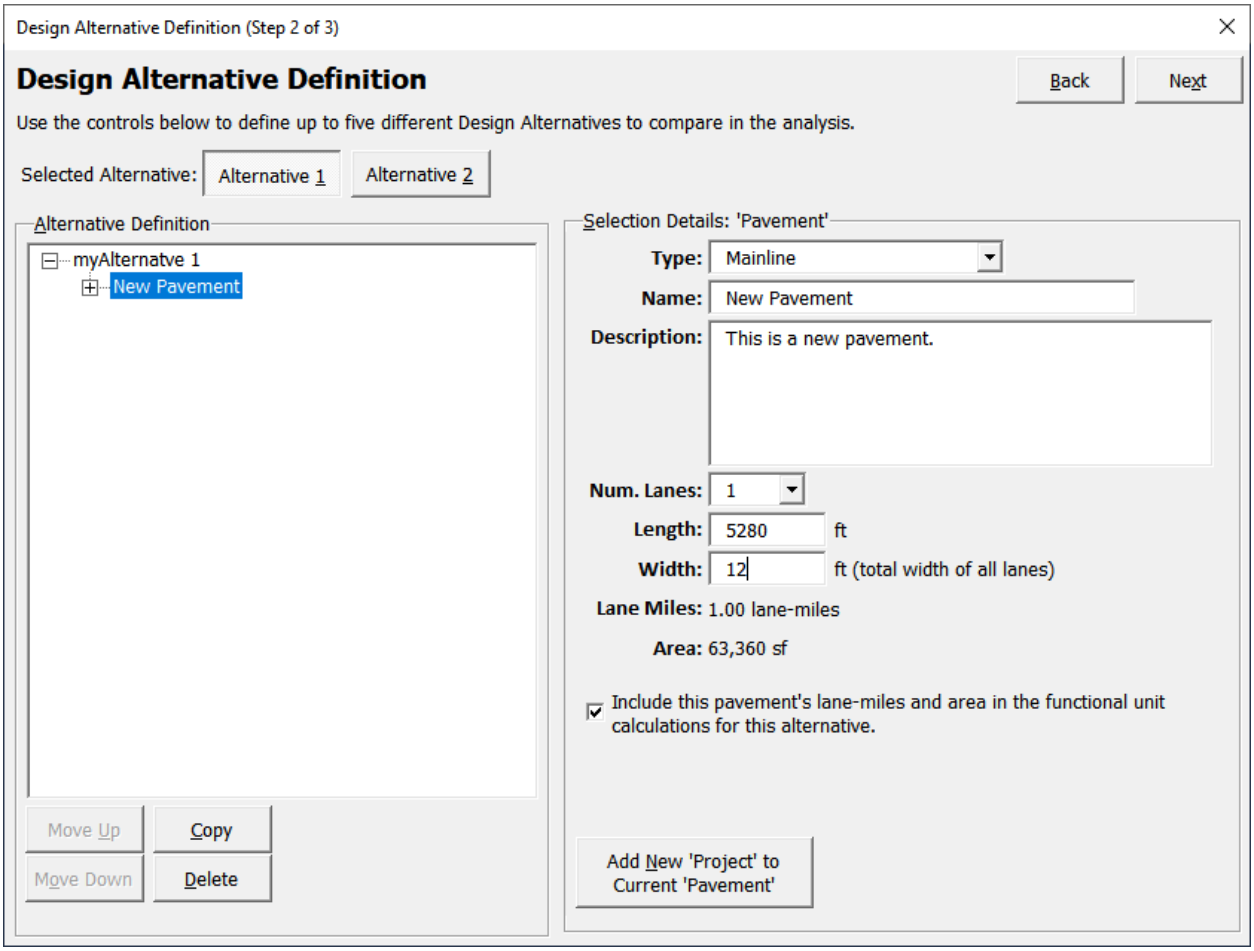


Figure 5-4. Specifying pavement details for the design alternative.

- Click the "Add New 'Project' to Current 'Pavement'" button to add a new project object to the current pavement facility object. The newly added project will show up as a 'child' object under the pavement facility object in the treeview.

Keyboard shortcut for "Add New Project to Current Pavement":

ALT + N

- Click on the project node in the treeview to view the object's properties. Use the following controls in the "Selection Details" frame to set the properties (see figure 5-5):
  - **Type:** Select type of project from the dropdown menu (Initial Construction, Maintenance and Preservation, Rehabilitation, Reconstruction, and Removal).
  - **Application Age:** Input age of the pavement at which the project is performed.

    Note: The Application Age dropdown menu is available only when the analysis objective selected under Step 1 is "Compare Treatment Cycles or Pavement Design Life-Cycle Options."

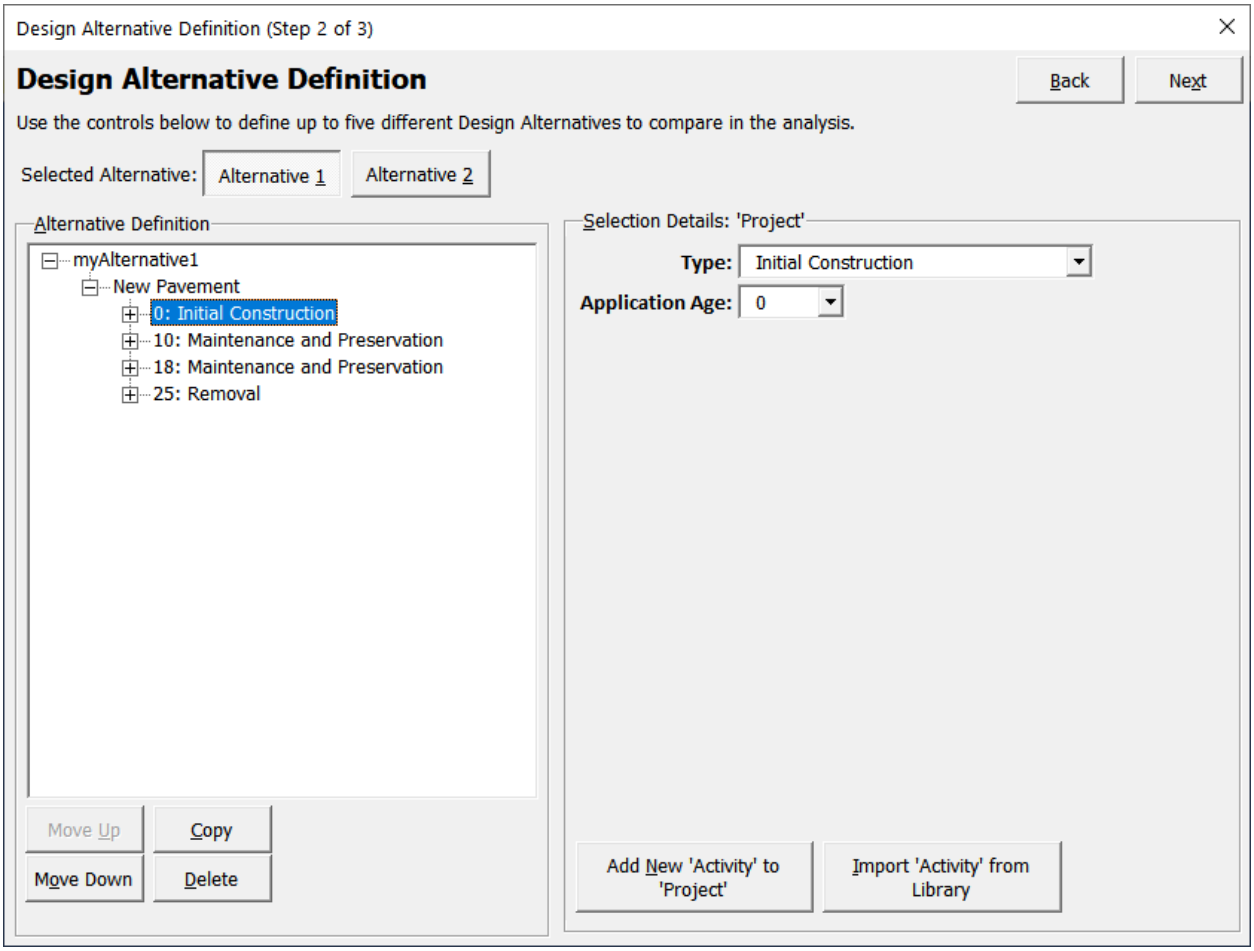


Figure 5-5. Adding activities to projects.

- To add an activity object to an existing project object, first click that project node in the treeview. With a project object selected in the treeview, two buttons will be displayed at the bottom of the "Selection Details" frame on the right: "Add New 'Activity' to 'Project'" and "Import 'Activity' from Library." These two options are described in detail below:
  - **Option #1: Add New 'Activity' to 'Project'**—This option is used when the user would like to create a new activity within the analysis session. the interface that is shown on the screen is the same interface used to model a new activity (see Section 4.6.3).

Keyboard Shortcuts:

Add New Activity to Project: **ALT + N**

Import Activity from Library: **ALT + I**

  - **Option #2: Import 'Activity' from Library**—This option is used when the user has already modeled activities and they are stored in the library for use in the analysis session. When this option is selected, the activity library window appears and shows the list of available activities in the library (see figure 5-6). The user can select activities and click on "Add to Project" to include them under the project being modeled.

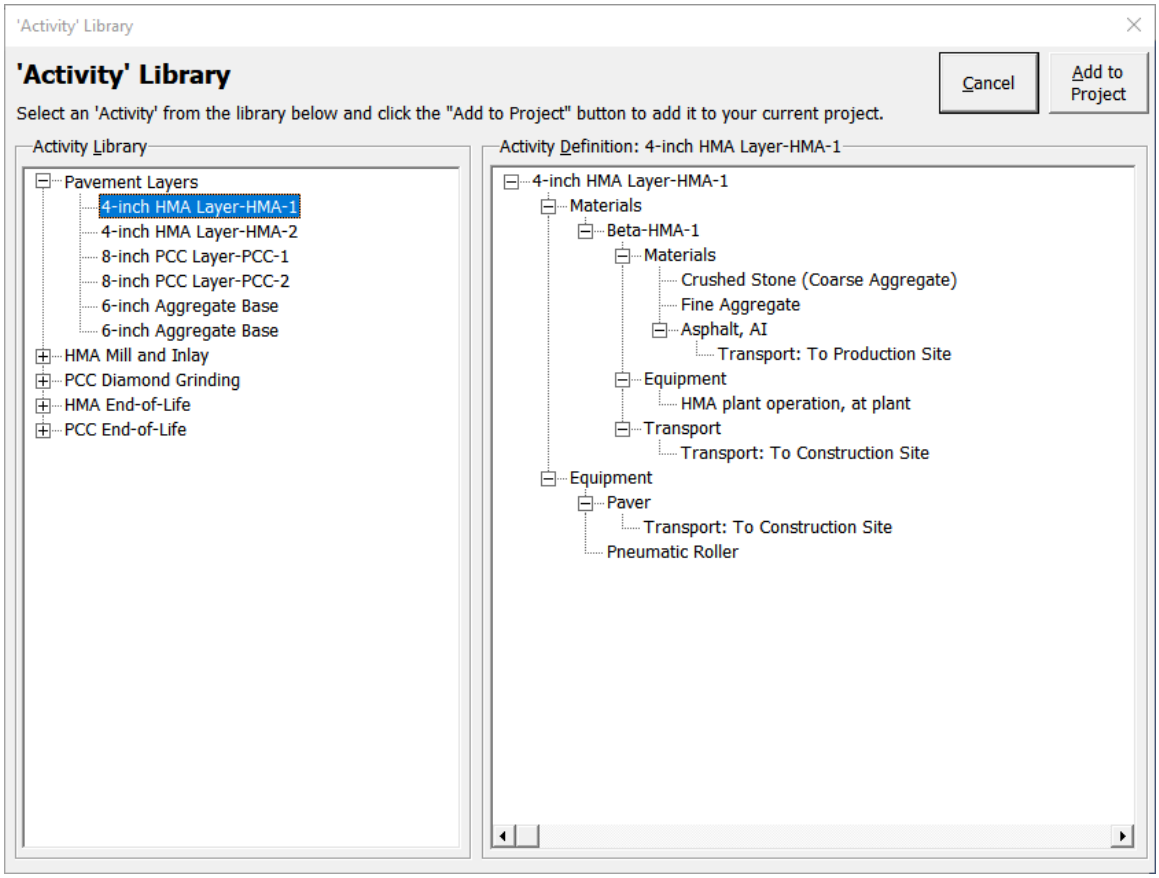


Figure 5-6. Importing activities from library to the analysis session.

- Once activities have been included under a project, they can be edited by clicking on the "Edit Activity" button (see figure 5-7). Note: when editing an activity, the interface is the same as adding a new activity, discussed under Section 4.6.3.
- An activity shown in the Alternative Definition treeview can also be copied to the library so it is available for future use. To copy an existing *activity* object, click on the activity object node in the treeview and click the "Copy to Library" button (see figure 5-7).

Keyboard Shortcuts (Figure 5-6):

Cancel: **ALT + C**

Add to Project: **ALT + A**

Keyboard Shortcuts (Figure 5-6):

Edit Activity: **ALT + E**

Copy to Library: **ALT + L**

- The same process described above can be used to add multiple activities to a *project*. Multiple *projects* can be added at various years over the analysis period to model a pavement life cycle.
- The same process described in this section can be used to model the various pavement alternatives that the user desires to compare in the analysis.

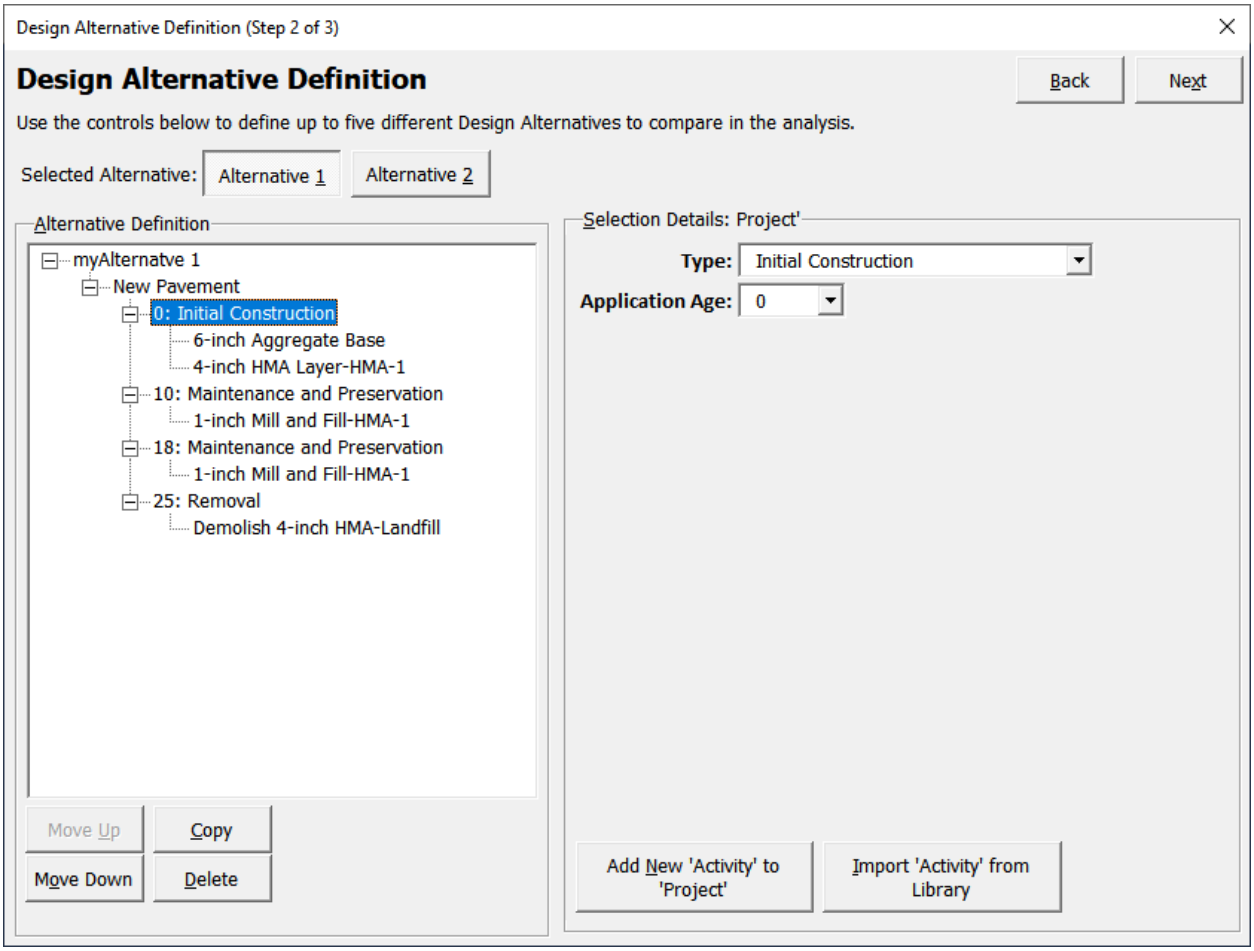


Figure 5-7. Details on activities included in the analysis session.

5.3 STEP 3: RESULTS

To view the results interface (see figure 5-8), click the "Next" button after the modeling all the alternatives to be compared in the analysis.

Keyboard Shortcuts (Figure 5-8):

Results Setup: **ALT + R**

Overall Summary: **ALT + S**

Tree Comparison: **ALT + T**

By Category: **ALT + C**

Select All: **ALT + A**

Deselect All: **ALT + E**

View Detailed Output: **ALT + V**

5.3.1 Results Setup

The first step is to select the functional unit for comparing the modeled design alternatives. The options available are:

- Total (Entire Project).
- Per Year.
- Per Lane-Mile.
- Per Lane-Mile Per Year.
- Per Square Foot.
- Per Square Foot Per Year.

In this example, the information on the lane-miles and the pavement area (in sq. ft.) used in the functional unit calculations is obtained from Step 2 (see Section 5.2). Once the functional unit is chosen, the next step is to select the impact indicators.

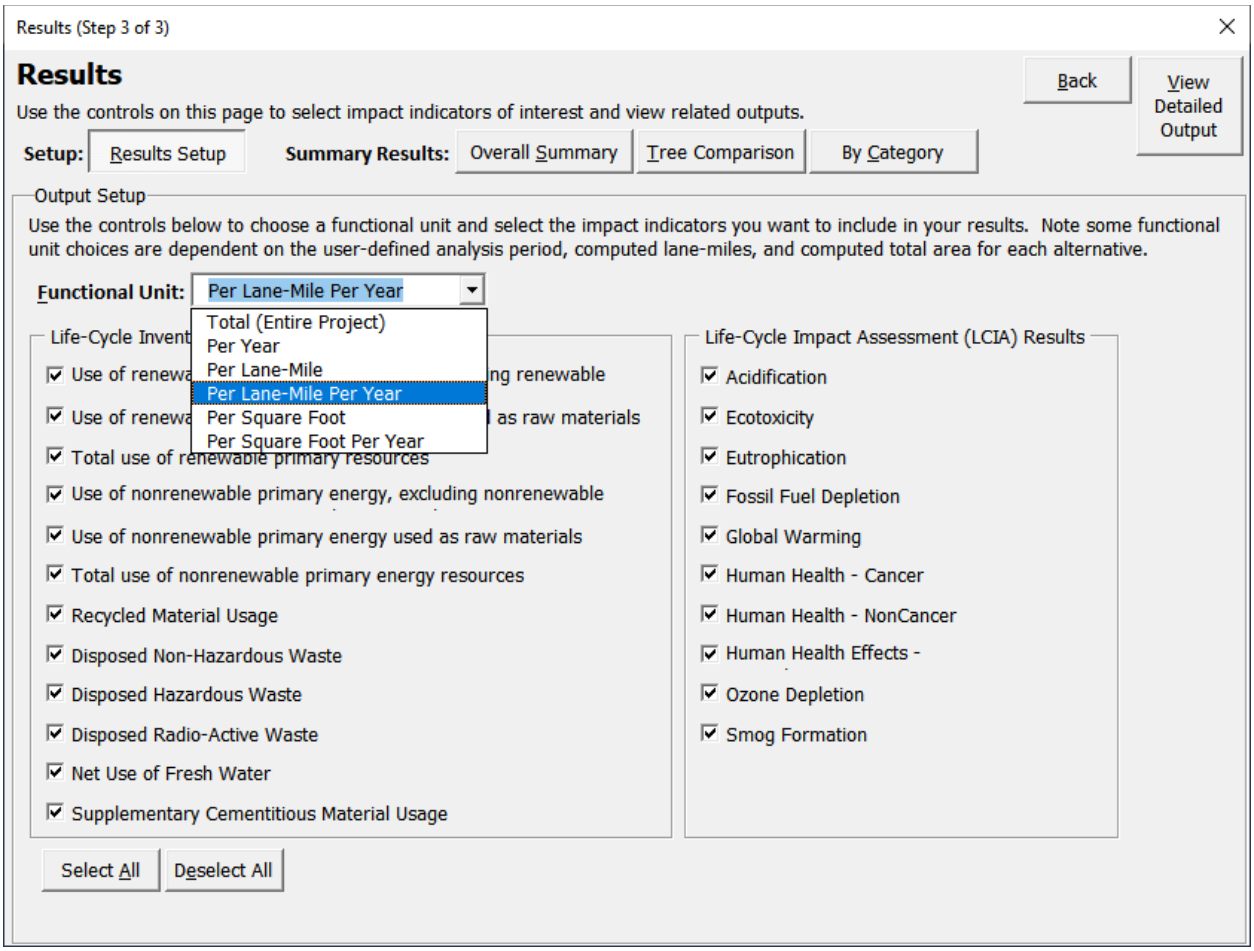


Figure 5-8. Results setup interface.

Caution: Functional Units

The tool does not assess the validity of the analysis being conducted as the user controls the selection of the functional unit. The tool is built with the assumption that the functional unit for each alternative is the same.

Whenever the goal of the study is the comparison of alternatives, there should be equivalence of the definitions of the functional units or the alternatives. It is the user's responsibility to select the appropriate functional unit when comparing design alternatives.

5.3.2 Viewing Summary Results

Three types of summary result views are available—(a) overall summary, (b) tree comparison, and (c) categorized summaries. The results in each of these result views are shown based on the functional unit selected in the "Results Setup" interface (see figure 5-8). Each result view also provides details on the analysis period, total lane-miles, and total area for each design alternative modeled by the user. The total lane-miles and total area used in the calculation of the results (based on the chosen functional unit) are determined based on the input provided by the user in Step 2 (see Section 5.2).

Keyboard Shortcuts

Results Setup: **ALT + R**

Overall Summary: **ALT + S**

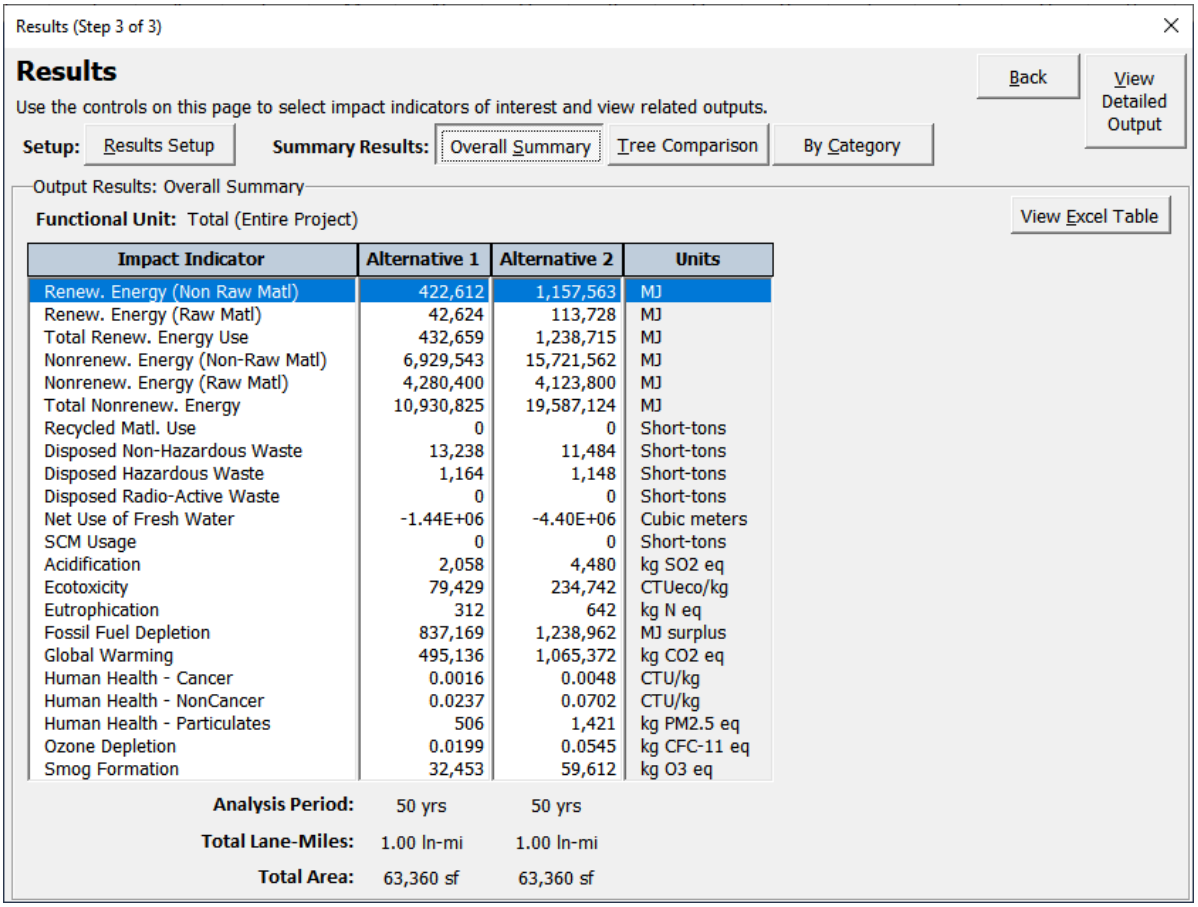
Tree Comparison: **ALT + T**

By Category**: ALT + C**

"View Excel Table": **ALT + E**

- **Overall Summary**: Click the "Overall Summary" button (see figure 5-9). This shows the calculated values for each impact indicator selected for each alternative. The results are displayed using the functional unit selected in the "Results Setup" interface.

  For accessibility reasons, the user may view this same summary data in an Excel worksheet by clicking on the "View Excel Table" button.



Impact Indicator	Alternative 1	Alternative 2	Units
Renew. Energy (Non Raw Matl)	422,612	1,157,563	MJ
Renew. Energy (Raw Matl)	42,624	113,728	MJ
Total Renew. Energy Use	432,659	1,238,715	MJ
Nonrenew. Energy (Non-Raw Matl)	6,929,543	15,721,562	MJ
Nonrenew. Energy (Raw Matl)	4,280,400	4,123,800	MJ
Total Nonrenew. Energy	10,930,825	19,587,124	MJ
Recycled Matl. Use	0	0	Short-tons
Disposed Non-Hazardous Waste	13,238	11,484	Short-tons
Disposed Hazardous Waste	1,164	1,148	Short-tons
Disposed Radio-Active Waste	0	0	Short-tons
Net Use of Fresh Water	-1.44E+06	-4.40E+06	Cubic meters
SCM Usage	0	0	Short-tons
Acidification	2,058	4,480	kg SO2 eq
Ecotoxicity	79,429	234,742	CTUeco/kg
Eutrophication	312	642	kg N eq
Fossil Fuel Depletion	837,169	1,238,962	MJ surplus
Global Warming	495,136	1,065,372	kg CO2 eq
Human Health - Cancer	0.0016	0.0048	CTU/kg
Human Health - NonCancer	0.0237	0.0702	CTU/kg
Human Health - Particulates	506	1,421	kg PM2.5 eq
Ozone Depletion	0.0199	0.0545	kg CFC-11 eq
Smog Formation	32,453	59,612	kg O3 eq
Analysis Period:	50 yrs	50 yrs	
Total Lane-Miles:	1.00 ln-mi	1.00 ln-mi	
Total Area:	63,360 sf	63,360 sf	

Figure 5-9. Summary results—overall summary.

- **Tree Comparison**: To compare the results between two alternatives in treeview form, click the "Tree Comparison" button (see figure 5-10). The results are displayed using the

functional unit selected by the user in the "Results Setup" interface. The following controls can be used to customize the result views.

- **Impact Indicator**: Select the impact indicator for which the results are to be displayed.
- **Hide Units**: The user can use the check box to hide the units associated impact indicator.
- **Selection 1**: Use this dropdown menu to select the first alternative to be compared.
- **Selection 2**: Use this dropdown menu to select the second alternative to be compared.

The impact indicator results are displayed in parentheses at the end of each line item (see figure 5-10). This result view also provides details on the analysis period, total lane-miles, and total area for each design alternative modeled by the user.

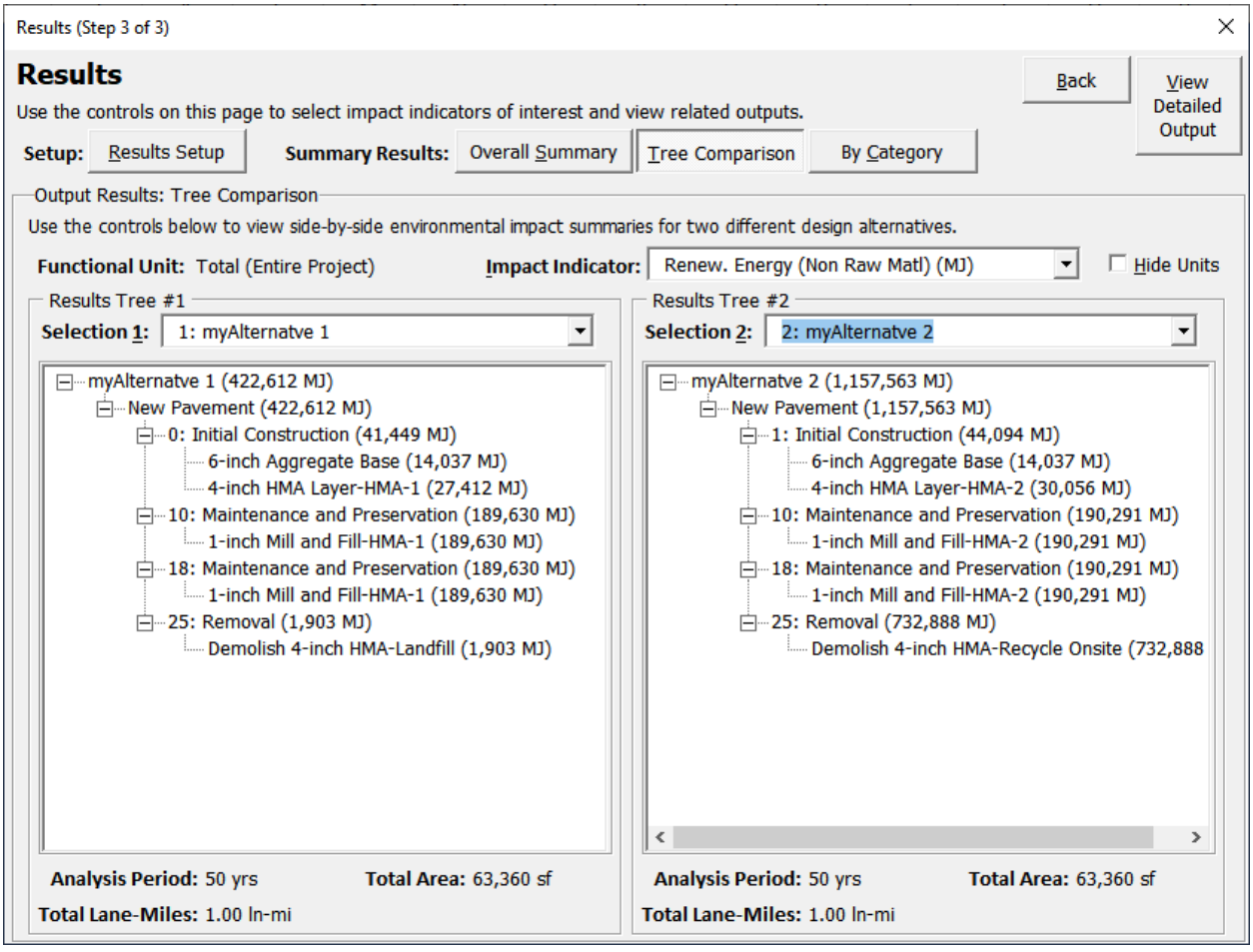


Figure 5-10. Summary results—tree comparison.

- **By Category**: To view results by various categories specified in the tool, click the "By Category" button (see figure 5-11). The results are displayed using the functional unit selected in the "Results Setup" interface. The following on-screen controls can be used to customize the results:
  - **Impact Indicator**: Select the impact indicator f.

- **Category**: These category options are available:
  - **Facility Type**: View results by facility type (mainline, shoulder, ramp, other).
  - **Life-Cycle Stage**: View results by pavement life-cycle stage (initial construction, maintenance, and preservation, rehabilitation, reconstruction, removal) indicated when the alternatives were modeled.
  - **Activity Type**: View results by activity type categories specified by the user.
  - **Process Type**: View results by the following process types: material, equipment, waste, and transport.
  - **Application Age**: View results by project application age (as specified for each alternative). Note: this option is not available if the analysis type selected in Step 1 is "Compare Materials."

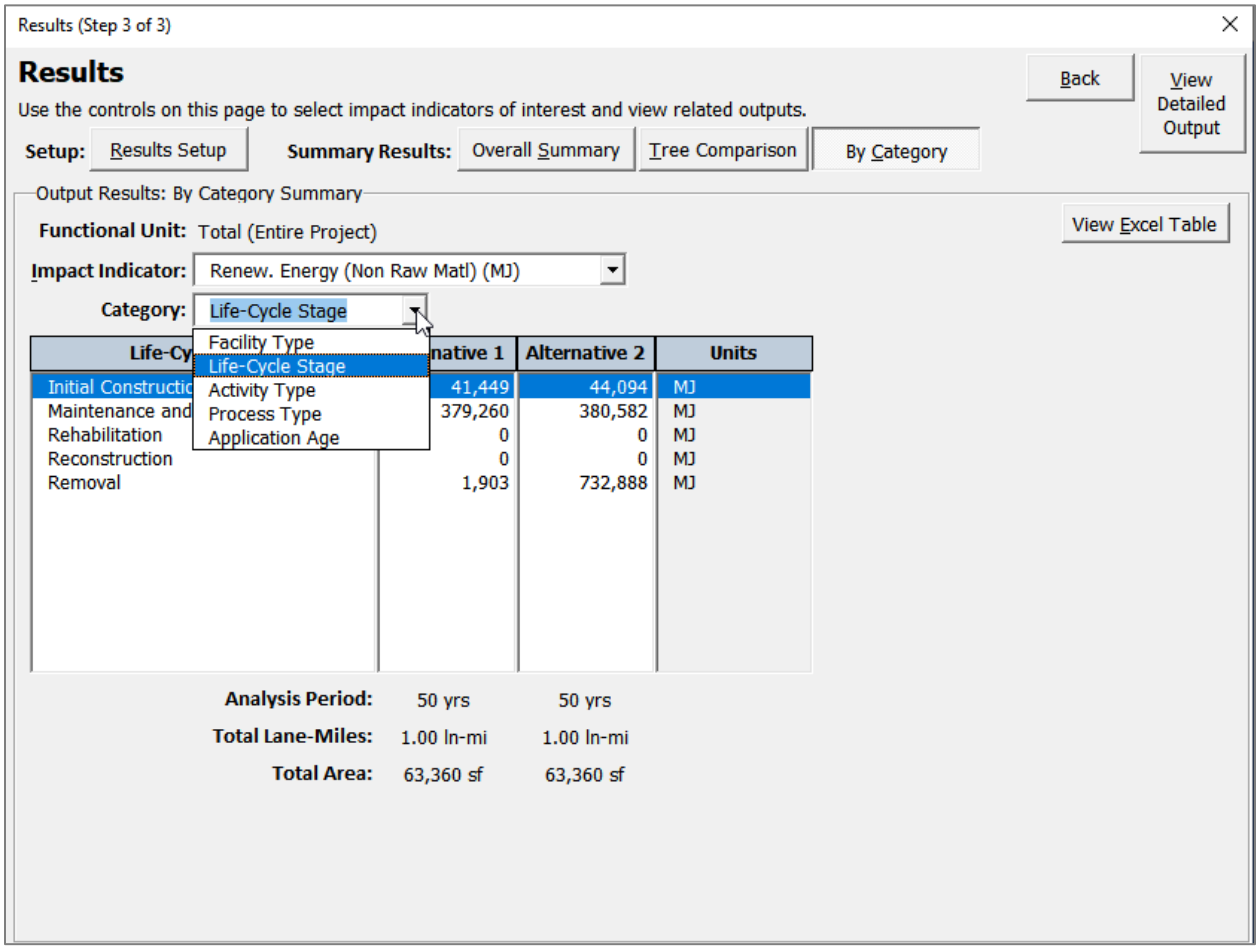


Figure 5-11. Summary results—by category.

5.3.3 Viewing Detailed Outputs

In addition to the summary results views discussed in Section 5.3.2, the user can view detailed outputs by clicking on the "View Detailed Output" button in the top right corner of the Results window (see figure 5-11). Once this button is clicked, the tool generates several worksheets that contain output tables and charts (see figure 5-12). Each of the generated output worksheets is described in more detail in the following sections.

Tip: View Detailed Output

When generating detailed outputs, the functional units used are the same as the functional units selected by the user in the Results Setup interface. The functional unit is indicated in the "Session Summary" worksheet.

5.3.3.1. Output Control Panel

The Output Control Panel worksheet provides a summary of all the output worksheets generated by the tool (see figure 5-12). A brief description of each output worksheet is also included.

Detailed LCA Output

Return to Session

Export Output to New Workbook

Overall and alternative-specific output associated with your current analysis session is provided in the visible worksheet tabs below. To aid in the navigation ot specific output of interest, a list of hyperlinks to the different worksheet tabs is also provided below. Note, you can also use CTRL+PgDn and CTRL+PgUp to navigate between output tabs.

Click the 'Return to Session' button to return to your current analysis session.

Summary of Output Worksheets

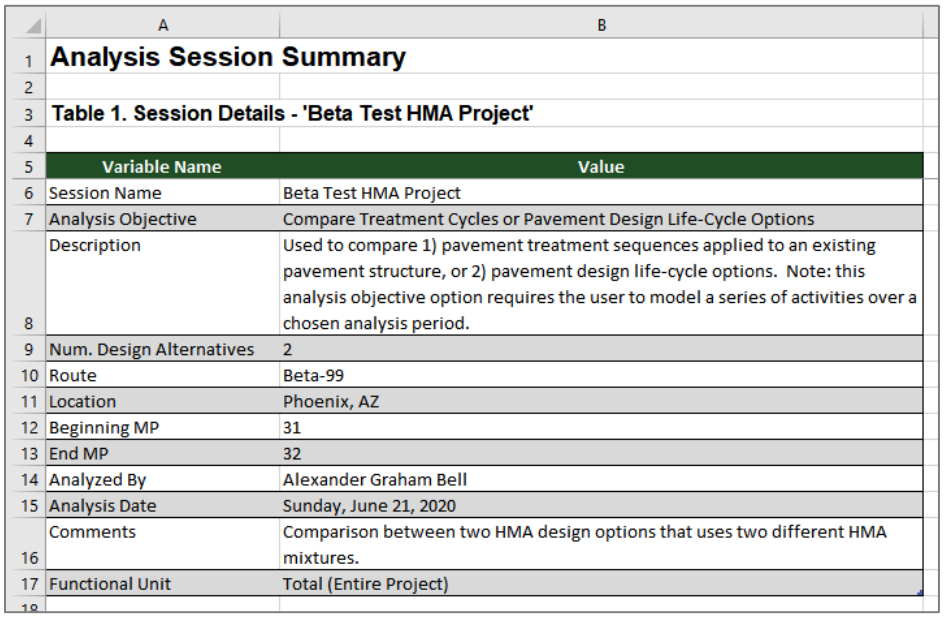
Tab Name	Tab Description
Session Summary	Summary of general analysis session attributes.
Alternative Comparison Summary	Comparison of included impact indicators for all included Design Alternatives.
Alternative 1 Definition	General description of the Alternative 1 object and all of its components.
Alternative 1 Definition 508	508-compliant version of the table shown on tab 'Alternative 1 Definition'.
Alternative 1 Details	Summary of the environmental impacts for each component in Alternative 1, for each included impact indicator.
Alternative 1 Details 508	508-compliant version of the table shown on tab 'Alternative 1 Details'.
Alternative 1 By Category Data	Summary of the by category environmental impacts for each component in Alternative 1, for each included impact indicator.
Alternative 1 Pct of Catg Data	Summary of the by category environmental impact percentages for each component in Alternative 1, for each included impact indicator.
Alternative 1 Summary Charts	Series of by category environmental impact charts for Alternative 1.
Alternative 2 Definition	General description of the Alternative 2 object and all of its components.
Alternative 2 Definition 508	508-compliant version of the table shown on tab 'Alternative 2 Definition'.
Alternative 2 Details	Summary of the environmental impacts for each component in Alternative 2, for each included impact indicator.
Alternative 2 Details 508	508-compliant version of the table shown on tab 'Alternative 2 Details'.
Alternative 2 By Category Data	Summary of the by category environmental impacts for each component in Alternative 2, for each included impact indicator.
Alternative 2 Pct of Catg Data	Summary of the by category environmental impact percentages for each component in Alternative 2, for each included impact indicator.
Alternative 2 Summary Charts	Series of by category environmental impact charts for Alternative 2.

Output Control Panel | Session Summary | Alternative Comparison Summary | Alternative 1 Definition | Alternative 1 Definition 508

Figure 5-12. Output control panel.

5.3.3.2 Session Summary Worksheet

The session summary worksheet provides details on the analysis session (see figure 5-13), as specified by the user under Step 1 of the analysis (see section 5.1). The functional unit used to display the results is also shown in this worksheet.



	A	B
1	**Analysis Session Summary**	
2		
3	**Table 1. Session Details - 'Beta Test HMA Project'**	
4		
5	**Variable Name**	**Value**
6	Session Name	Beta Test HMA Project
7	Analysis Objective	Compare Treatment Cycles or Pavement Design Life-Cycle Options
8	Description	Used to compare 1) pavement treatment sequences applied to an existing pavement structure, or 2) pavement design life-cycle options. Note: this analysis objective option requires the user to model a series of activities over a chosen analysis period.
9	Num. Design Alternatives	2
10	Route	Beta-99
11	Location	Phoenix, AZ
12	Beginning MP	31
13	End MP	32
14	Analyzed By	Alexander Graham Bell
15	Analysis Date	Sunday, June 21, 2020
16	Comments	Comparison between two HMA design options that uses two different HMA mixtures.
17	Functional Unit	Total (Entire Project)

Figure 5-13. Session summary worksheet.

5.3.3.3 Alternative Comparison Summary

The alternative comparison summary worksheet presents a comparison of the environmental impact results (for impact indicators selected by the user) for all included design alternatives based on the functional unit. The results are also normalized by setting the impact indicator with the highest value among the alternatives modeled to 100 percent. The values for the same impact indicator for the other alternatives modeled are then normalized based on the highest value. The results are presented in both tabular (see table 5-1) and chart formats (see figure 5-14).

Table 5-1. Example output comparing impact indicator data for alternatives modeled.

Impact Indicator	Alternative 1 Value (Total)	Alternative 1 Normalized Value, %	Alternative 2 Value (Total)	Alternative 2 Normalized Value, %
Acidification (kg SO2 eq)	2,058	46%	4,480	100%
Ecotoxicity (CTUeco/kg)	79,429	34%	234,742	100%
Eutrophication (kg N eq)	312	49%	642	100%
Fossil Fuel Depletion (MJ surplus)	837,169	68%	1,238,962	100%
Global Warming (kg CO2 eq)	495,136	46%	1,065,372	100%
Human Health - Cancer (CTU/kg)	0.0016	34%	0.0048	100%
Human Health - NonCancer (CTU/kg)	0.0237	34%	0.0702	100%
Human Health Effects - Particulates (kg PM2.5 eq)	506	36%	1,421	100%
Ozone Depletion (kg CFC-11 eq)	0.0199	37%	0.0545	100%
Smog Formation (kg O3 eq)	32,453	54%	59,612	100%

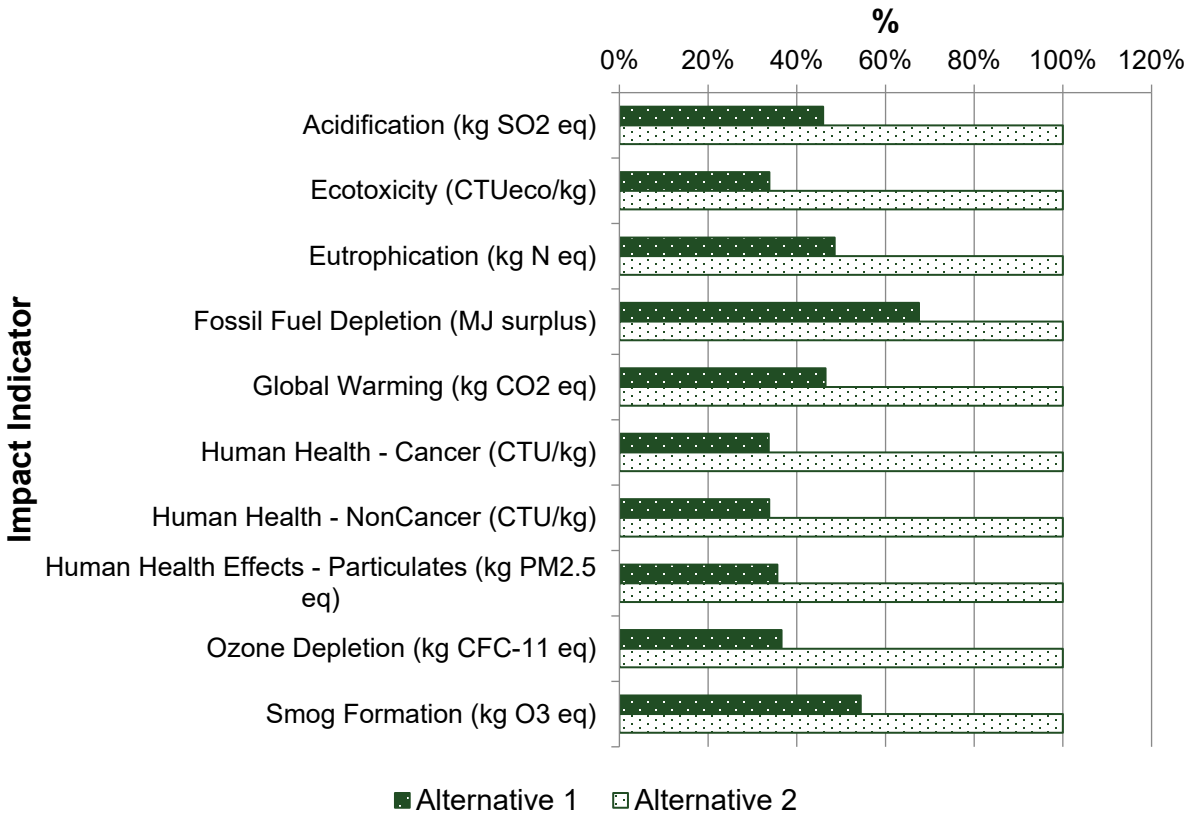


Figure 5-14. Example chart output comparing normalized impact indicator values for alternatives modeled.

5.3.3.4 Alternative Definition Worksheet

The alternative definition worksheet (see figure 5-15) includes a general description of the various analysis objects (items from tool libraries), quantities, and properties for each alternative. (separate worksheets are generated for each alternative modeled). This worksheet also identifies whether the object used in the analysis is a default database item or a user-developed item. This worksheet documents all the information from the tree structure for each alternative modeled by the user.

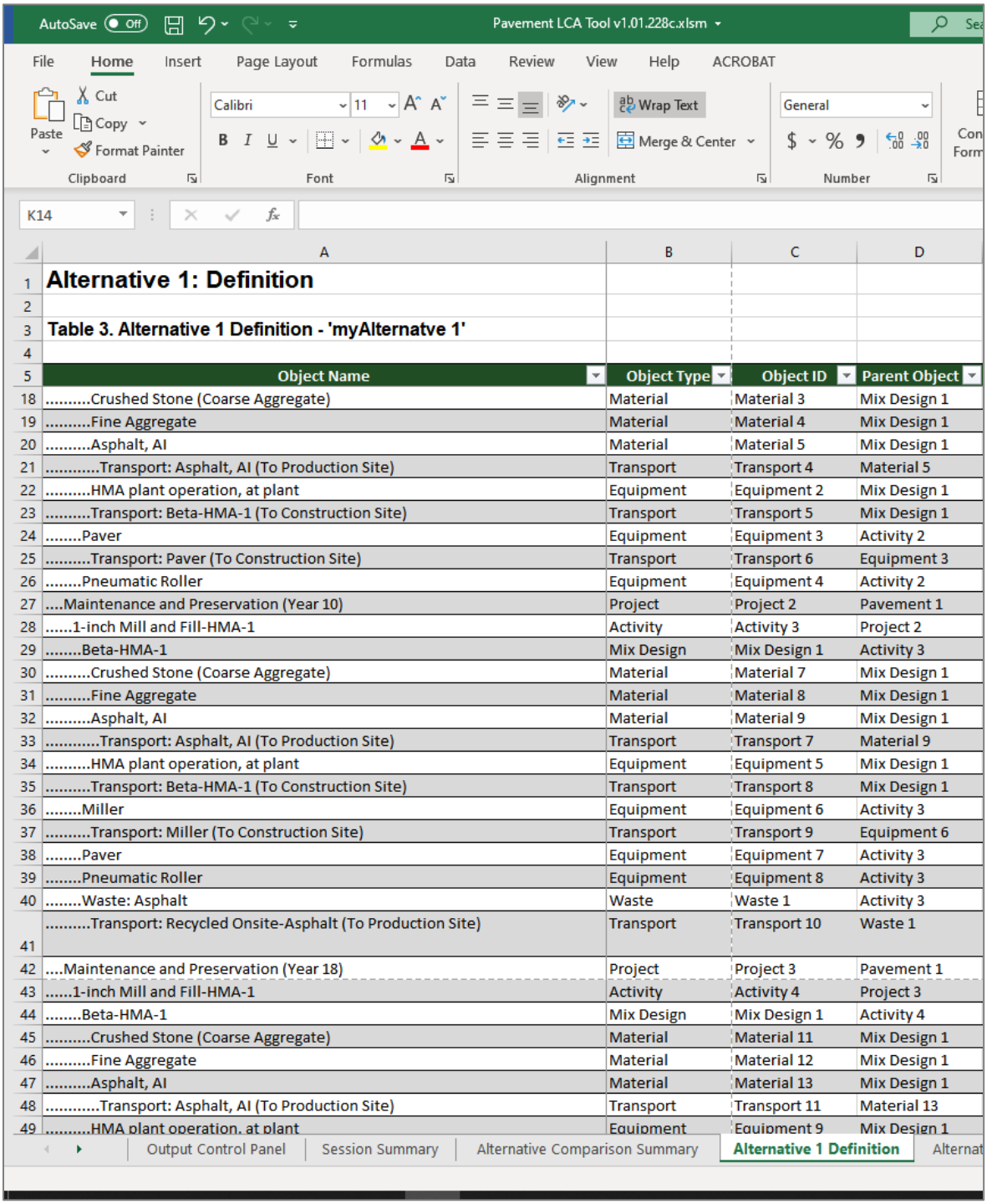
The same data are also presented in a Section 508 conformant worksheet (indicated with the suffix "508").

5.3.3.5 Alternative Details Worksheet

The alternative details worksheet (see figure 5-16) presents the environmental impact data (for impact indicators selected under Results Setup) for each analysis object as modeled by the user using the tree interface under Step 2 (see section 5.2). Separate worksheets are generated for each alternative modeled. The outputs also indicate the "status" of the results associated with each impact indicator. If the status is "Complete," the data set used to calculate the impact indicator does not have any gaps. An "Incomplete" status indicates that the data set used to calculate the impact indicator has some gaps. The results were computed assuming zero values

where gaps were present. The status "All Missing" indicates that no data were available to calculate the results for the impact indicator.

The same data are also presented in a Section 508 compliant worksheet (indicated with the suffix "508").

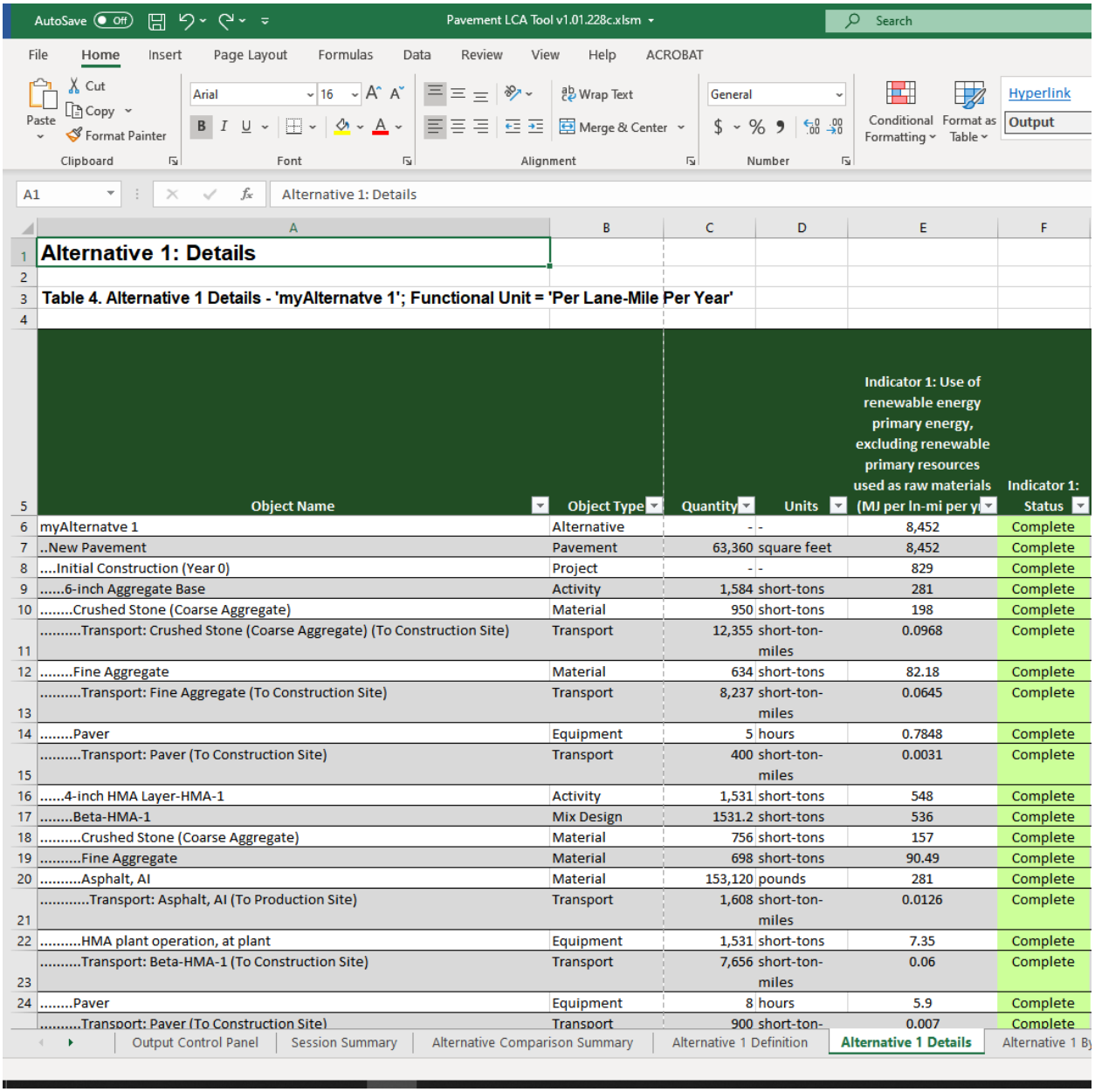


Alternative 1: Definition

Table 3. Alternative 1 Definition - 'myAlternatve 1'

Object Name	Object Type	Object ID	Parent Object
.....Crushed Stone (Coarse Aggregate)	Material	Material 3	Mix Design 1
.....Fine Aggregate	Material	Material 4	Mix Design 1
.....Asphalt, AI	Material	Material 5	Mix Design 1
.....Transport: Asphalt, AI (To Production Site)	Transport	Transport 4	Material 5
.....HMA plant operation, at plant	Equipment	Equipment 2	Mix Design 1
.....Transport: Beta-HMA-1 (To Construction Site)	Transport	Transport 5	Mix Design 1
.....Paver	Equipment	Equipment 3	Activity 2
.....Transport: Paver (To Construction Site)	Transport	Transport 6	Equipment 3
.....Pneumatic Roller	Equipment	Equipment 4	Activity 2
....Maintenance and Preservation (Year 10)	Project	Project 2	Pavement 1
.....1-inch Mill and Fill-HMA-1	Activity	Activity 3	Project 2
.....Beta-HMA-1	Mix Design	Mix Design 1	Activity 3
.....Crushed Stone (Coarse Aggregate)	Material	Material 7	Mix Design 1
.....Fine Aggregate	Material	Material 8	Mix Design 1
.....Asphalt, AI	Material	Material 9	Mix Design 1
.....Transport: Asphalt, AI (To Production Site)	Transport	Transport 7	Material 9
.....HMA plant operation, at plant	Equipment	Equipment 5	Mix Design 1
.....Transport: Beta-HMA-1 (To Construction Site)	Transport	Transport 8	Mix Design 1
.....Miller	Equipment	Equipment 6	Activity 3
.....Transport: Miller (To Construction Site)	Transport	Transport 9	Equipment 6
.....Paver	Equipment	Equipment 7	Activity 3
.....Pneumatic Roller	Equipment	Equipment 8	Activity 3
.....Waste: Asphalt	Waste	Waste 1	Activity 3
.....Transport: Recycled Onsite-Asphalt (To Production Site)	Transport	Transport 10	Waste 1
....Maintenance and Preservation (Year 18)	Project	Project 3	Pavement 1
.....1-inch Mill and Fill-HMA-1	Activity	Activity 4	Project 3
.....Beta-HMA-1	Mix Design	Mix Design 1	Activity 4
.....Crushed Stone (Coarse Aggregate)	Material	Material 11	Mix Design 1
.....Fine Aggregate	Material	Material 12	Mix Design 1
.....Asphalt, AI	Material	Material 13	Mix Design 1
.....Transport: Asphalt, AI (To Production Site)	Transport	Transport 11	Material 13
.....HMA plant operation, at plant	Equipment	Equipment 9	Mix Design 1

Figure 5-15. Alternative definition worksheet.



Alternative 1: Details

Table 4. Alternative 1 Details - 'myAlternatve 1'; Functional Unit = 'Per Lane-Mile Per Year'

Object Name	Object Type	Quantity	Units	Indicator 1: Use of renewable energy primary energy, excluding renewable primary resources used as raw materials (MJ per ln-mi per yr	Indicator 1: Status
myAlternatve 1	Alternative	-	-	8,452	Complete
..New Pavement	Pavement	63,360	square feet	8,452	Complete
....Initial Construction (Year 0)	Project	-	-	829	Complete
......6-inch Aggregate Base	Activity	1,584	short-tons	281	Complete
........Crushed Stone (Coarse Aggregate)	Material	950	short-tons	198	Complete
..........Transport: Crushed Stone (Coarse Aggregate) (To Construction Site)	Transport	12,355	short-ton-miles	0.0968	Complete
........Fine Aggregate	Material	634	short-tons	82.18	Complete
..........Transport: Fine Aggregate (To Construction Site)	Transport	8,237	short-ton-miles	0.0645	Complete
........Paver	Equipment	5	hours	0.7848	Complete
..........Transport: Paver (To Construction Site)	Transport	400	short-ton-miles	0.0031	Complete
......4-inch HMA Layer-HMA-1	Activity	1,531	short-tons	548	Complete
........Beta-HMA-1	Mix Design	1531.2	short-tons	536	Complete
..........Crushed Stone (Coarse Aggregate)	Material	756	short-tons	157	Complete
..........Fine Aggregate	Material	698	short-tons	90.49	Complete
..........Asphalt, AI	Material	153,120	pounds	281	Complete
............Transport: Asphalt, AI (To Production Site)	Transport	1,608	short-ton-miles	0.0126	Complete
..........HMA plant operation, at plant	Equipment	1,531	short-tons	7.35	Complete
..........Transport: Beta-HMA-1 (To Construction Site)	Transport	7,656	short-ton-miles	0.06	Complete
........Paver	Equipment	8	hours	5.9	Complete
..........Transport: Paver (To Construction Site)	Transport	900	short-ton-	0.007	Complete

Figure 5-16. Alternative details worksheet.

5.3.3.6 Alternative by Category

The alternative by category worksheet (see figure 5-17) presents the environmental impact data by category (e.g., pavement facility, life-cycle stage, etc.) for impact indicator selected. Separate worksheets are generated for each alternative modeled. The outputs also indicate the "status" of the results associated with each impact indicator. If the status is "Complete," the data set used does not have any gaps. An "Incomplete" status indicates that the data set used t has gaps. The results are computed assuming zero values where gaps were present. The status "All Missing" indicates that no data were available t

Note: Application age is not available if the analysis type selected in Step 1 is "Compare Materials."

5.3.3.7 Alternative by Percent of Category

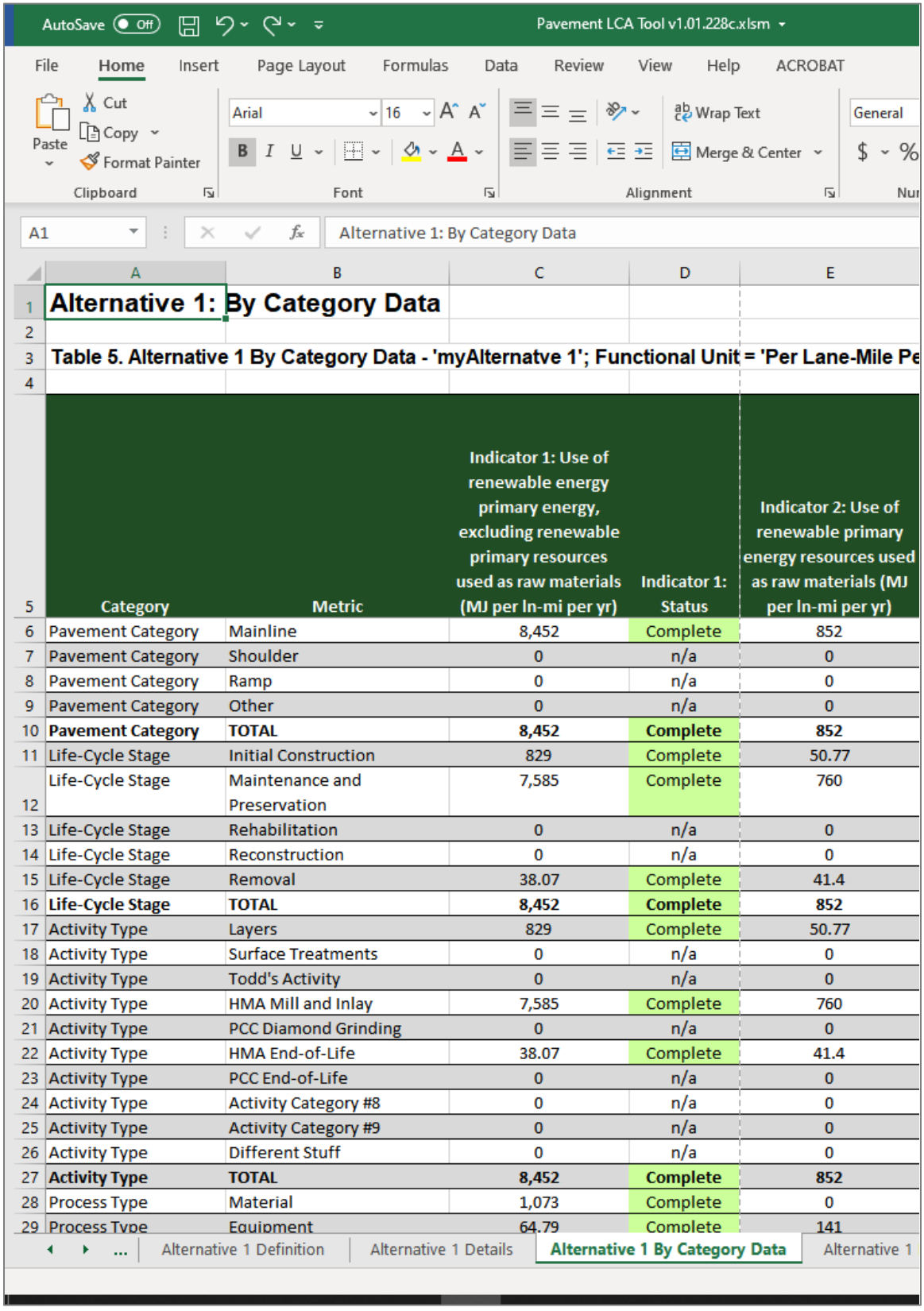
This worksheet (see figure 5-18) shows the percent contribution of each object under each category. The same data shown in the "Alternative by Category Data" worksheet are used to generate the environmental impact percentages by category. Separate worksheets are generated for each alternative modeled.

Note: Application age is not available if the analysis type selected in Step 1 is "Compare Materials."

5.3.3.8 Summary Charts

The following summary charts are generated for each alternative modeled (separate worksheets are generated for each alternative).

- **By Pavement Category Summary**: Environmental impact contributions (in percentage) by each pavement category specified by user (i.e., mainline, shoulder, ramp, etc.) (see figure 5-19).
- **By Life-Cycle Stage Summary**: Environmental impact contributions (in percentage) by pavement life-cycle stage (i.e.., initial construction, rehabilitation, removal etc.) (see figure 5-20).
- **By Activity Type Summary**: Environmental impact contribution (in percentage) by activity types specified by user (e.g., pavement layers, surface treatments etc.) (see figure 5-21).
- **By Process Type Summary:** Environmental impact contribution (in percentage) by process type (i.e., materials, equipment, waste, and transport) (see figure 5-22).
- **By Application Age Summary**: Environmental impact contribution (in percentage) by age of pavement at activity application. Note this option is not available if the analysis type selected in Step 1 is "Compare Materials" (see figure 5-23).

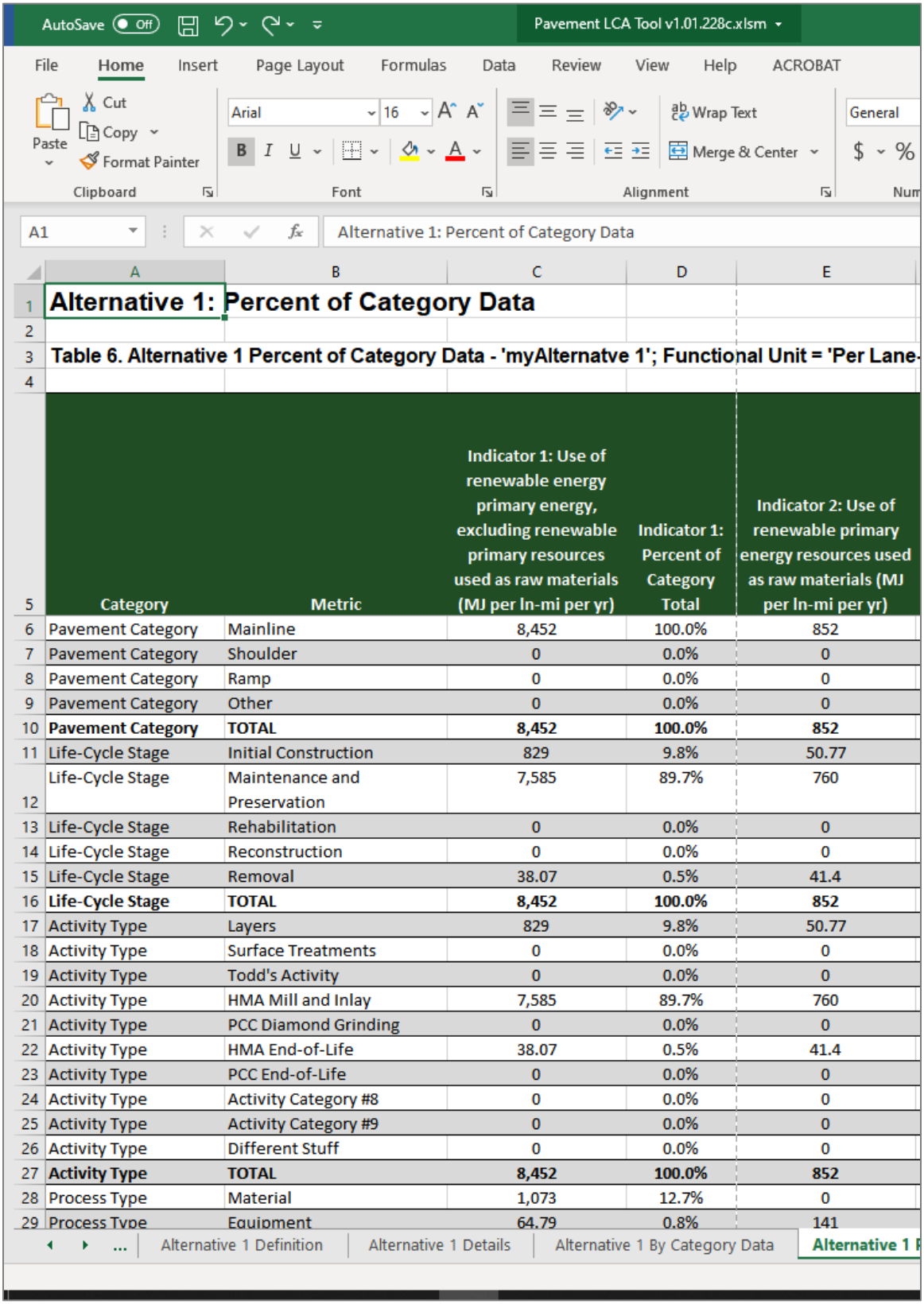


Alternative 1: By Category Data

Table 5. Alternative 1 By Category Data - 'myAlternatve 1'; Functional Unit = 'Per Lane-Mile Pe

Category	Metric	Indicator 1: Use of renewable energy primary energy, excluding renewable primary resources used as raw materials (MJ per ln-mi per yr)	Indicator 1: Status	Indicator 2: Use of renewable primary energy resources used as raw materials (MJ per ln-mi per yr)
Pavement Category	Mainline	8,452	Complete	852
Pavement Category	Shoulder	0	n/a	0
Pavement Category	Ramp	0	n/a	0
Pavement Category	Other	0	n/a	0
Pavement Category	**TOTAL**	**8,452**	**Complete**	**852**
Life-Cycle Stage	Initial Construction	829	Complete	50.77
Life-Cycle Stage	Maintenance and Preservation	7,585	Complete	760
Life-Cycle Stage	Rehabilitation	0	n/a	0
Life-Cycle Stage	Reconstruction	0	n/a	0
Life-Cycle Stage	Removal	38.07	Complete	41.4
Life-Cycle Stage	**TOTAL**	**8,452**	**Complete**	**852**
Activity Type	Layers	829	Complete	50.77
Activity Type	Surface Treatments	0	n/a	0
Activity Type	Todd's Activity	0	n/a	0
Activity Type	HMA Mill and Inlay	7,585	Complete	760
Activity Type	PCC Diamond Grinding	0	n/a	0
Activity Type	HMA End-of-Life	38.07	Complete	41.4
Activity Type	PCC End-of-Life	0	n/a	0
Activity Type	Activity Category #8	0	n/a	0
Activity Type	Activity Category #9	0	n/a	0
Activity Type	Different Stuff	0	n/a	0
Activity Type	**TOTAL**	**8,452**	**Complete**	**852**
Process Type	Material	1,073	Complete	0
Process Type	Equipment	64.79	Complete	141

Figure 5-17. Alternative by category worksheet showing example data.



Alternative 1: Percent of Category Data

Table 6. Alternative 1 Percent of Category Data - 'myAlternatve 1'; Functional Unit = 'Per Lane-

Category	Metric	Indicator 1: Use of renewable energy primary energy, excluding renewable primary resources used as raw materials (MJ per ln-mi per yr)	Indicator 1: Percent of Category Total	Indicator 2: Use of renewable primary energy resources used as raw materials (MJ per ln-mi per yr)
Pavement Category	Mainline	8,452	100.0%	852
Pavement Category	Shoulder	0	0.0%	0
Pavement Category	Ramp	0	0.0%	0
Pavement Category	Other	0	0.0%	0
Pavement Category	**TOTAL**	**8,452**	**100.0%**	**852**
Life-Cycle Stage	Initial Construction	829	9.8%	50.77
Life-Cycle Stage	Maintenance and Preservation	7,585	89.7%	760
Life-Cycle Stage	Rehabilitation	0	0.0%	0
Life-Cycle Stage	Reconstruction	0	0.0%	0
Life-Cycle Stage	Removal	38.07	0.5%	41.4
Life-Cycle Stage	**TOTAL**	**8,452**	**100.0%**	**852**
Activity Type	Layers	829	9.8%	50.77
Activity Type	Surface Treatments	0	0.0%	0
Activity Type	Todd's Activity	0	0.0%	0
Activity Type	HMA Mill and Inlay	7,585	89.7%	760
Activity Type	PCC Diamond Grinding	0	0.0%	0
Activity Type	HMA End-of-Life	38.07	0.5%	41.4
Activity Type	PCC End-of-Life	0	0.0%	0
Activity Type	Activity Category #8	0	0.0%	0
Activity Type	Activity Category #9	0	0.0%	0
Activity Type	Different Stuff	0	0.0%	0
Activity Type	**TOTAL**	**8,452**	**100.0%**	**852**
Process Type	Material	1,073	12.7%	0
Process Type	Equipment	64.79	0.8%	141

Figure 5-18. Alternative by percent of category worksheet showing example data.

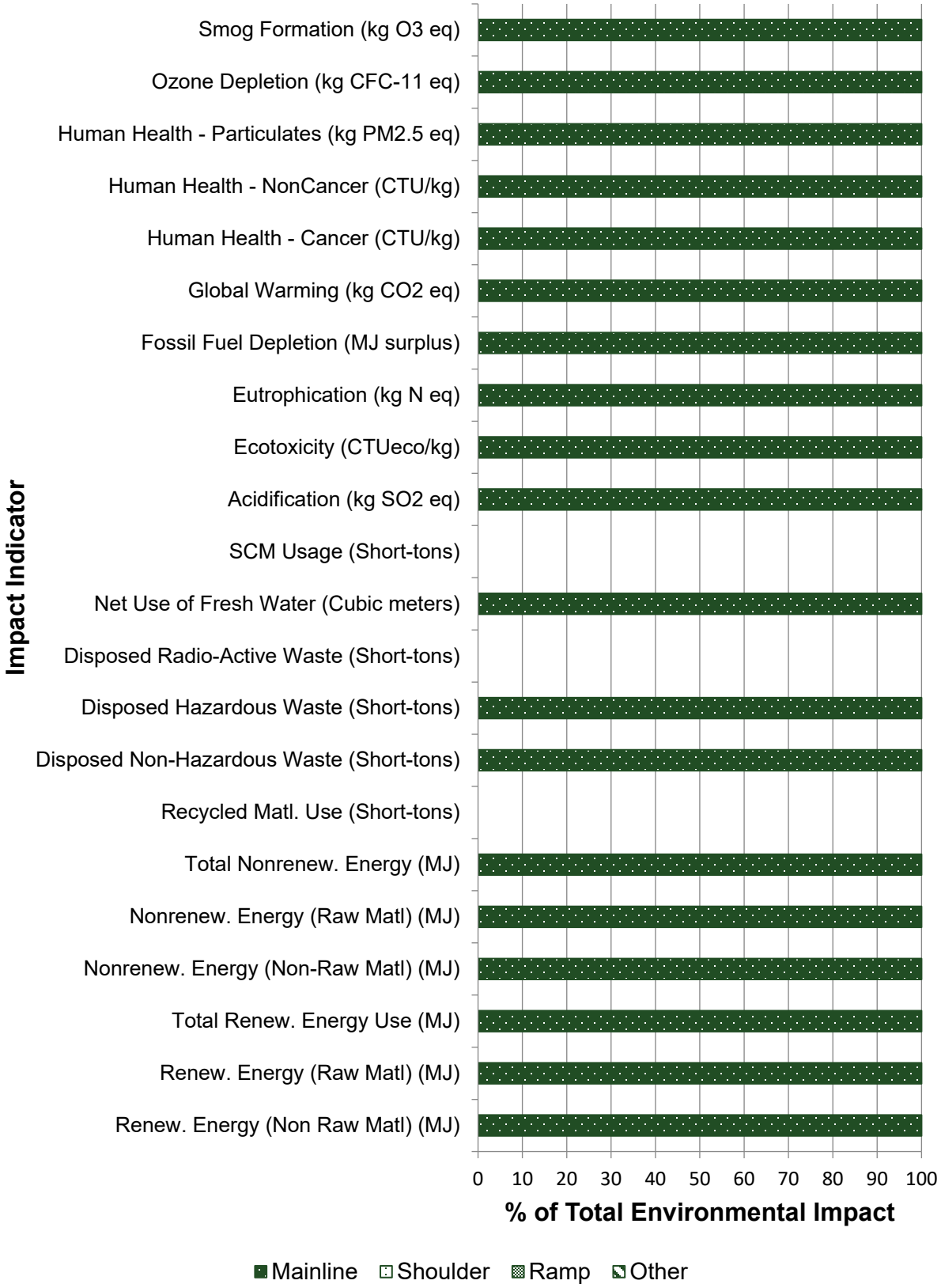


Figure 5-19. Example summary results by pavement category.

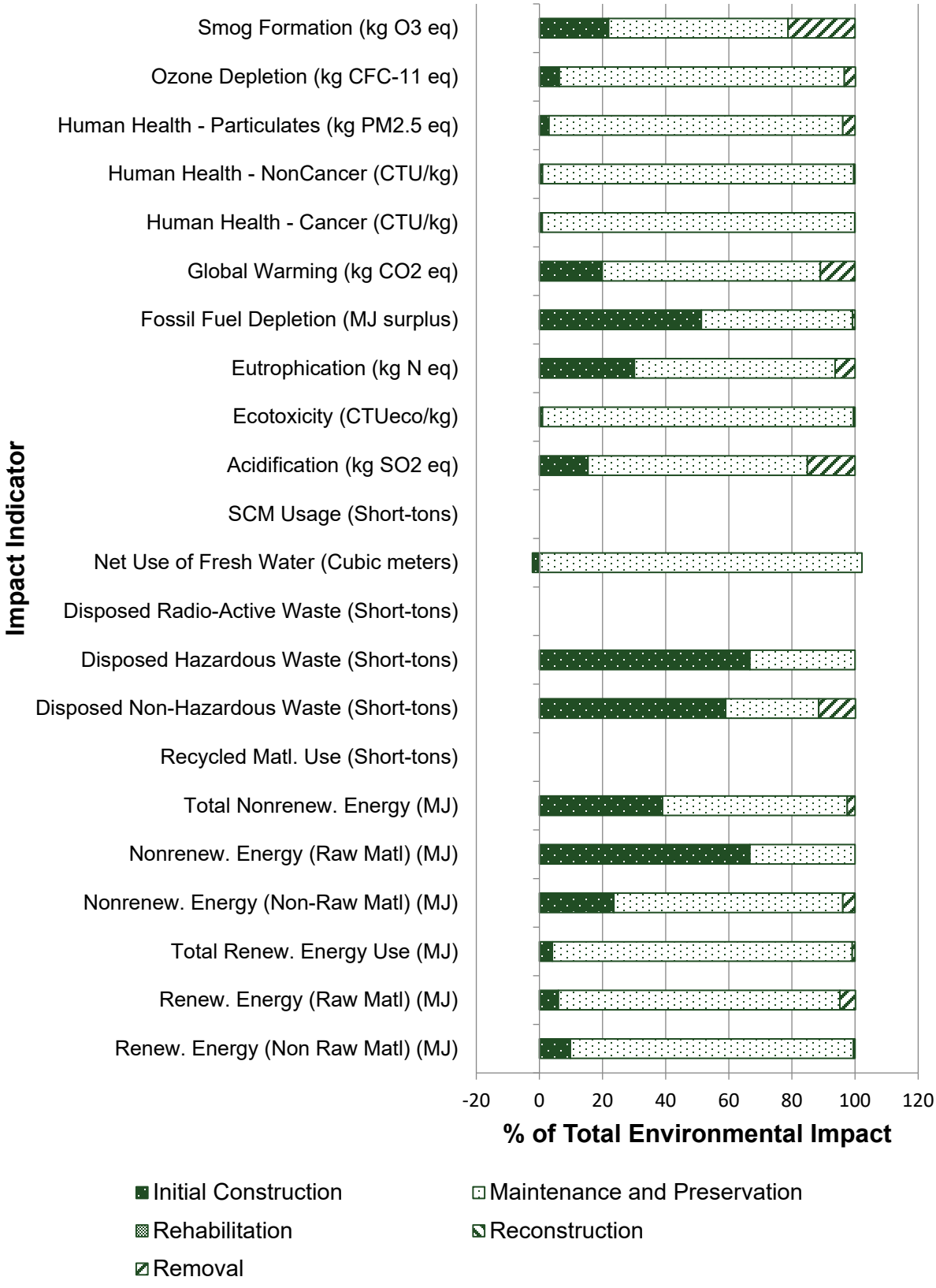


Figure 5-20. Example summary results by life-cycle stage.

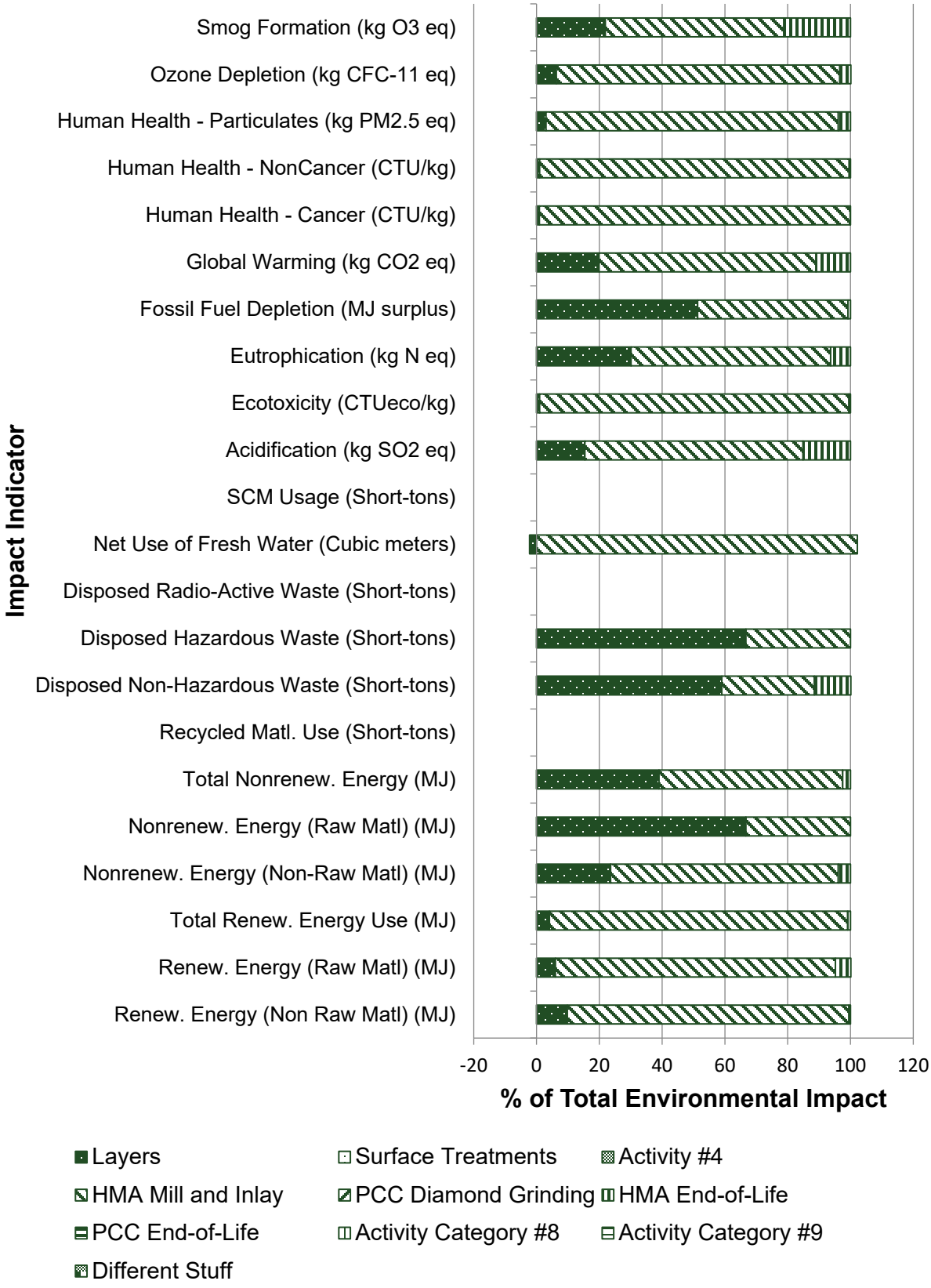


Figure 5-21. Example summary results by activity type.

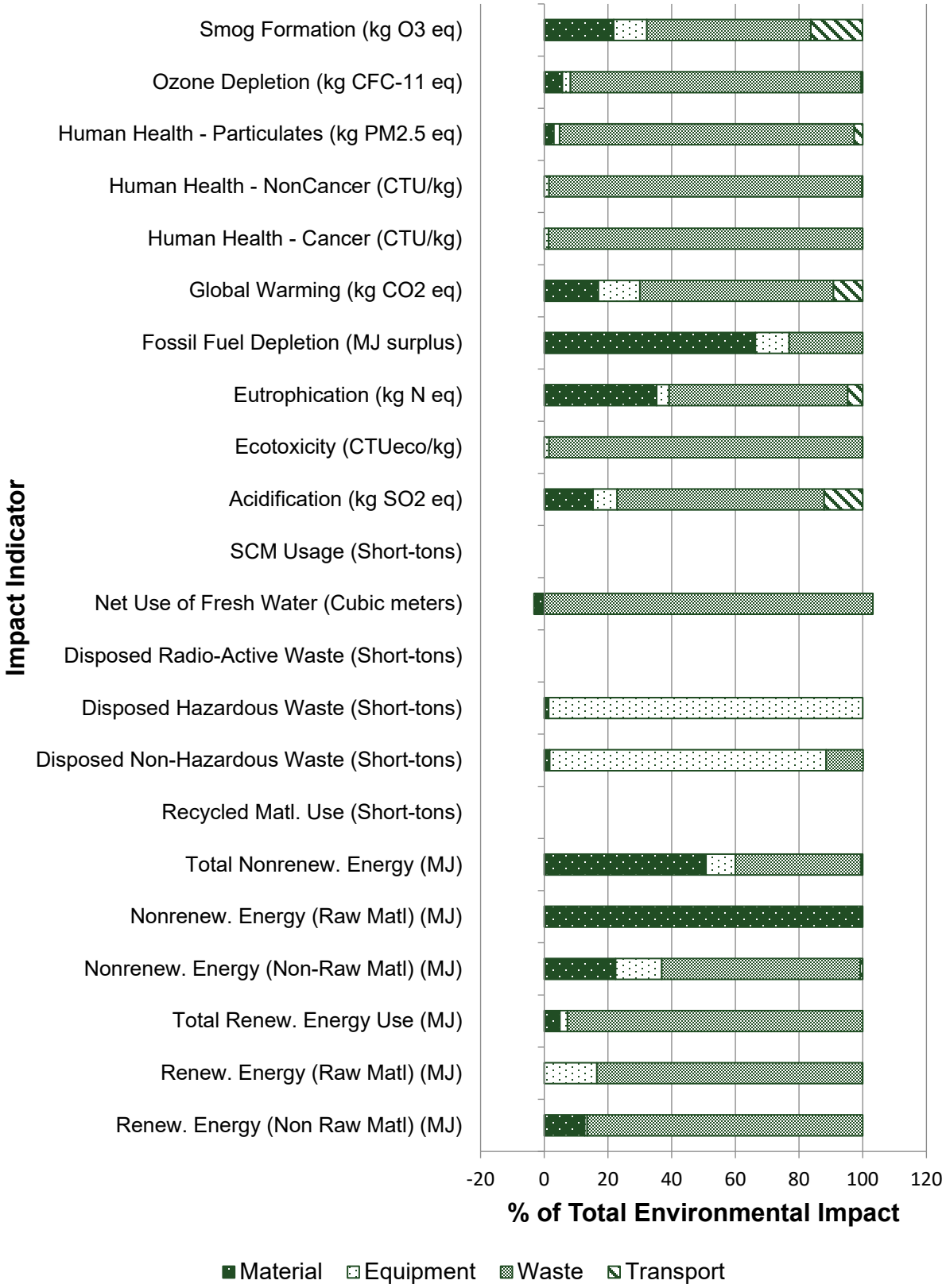


Figure 5-22. Example summary results by process type.

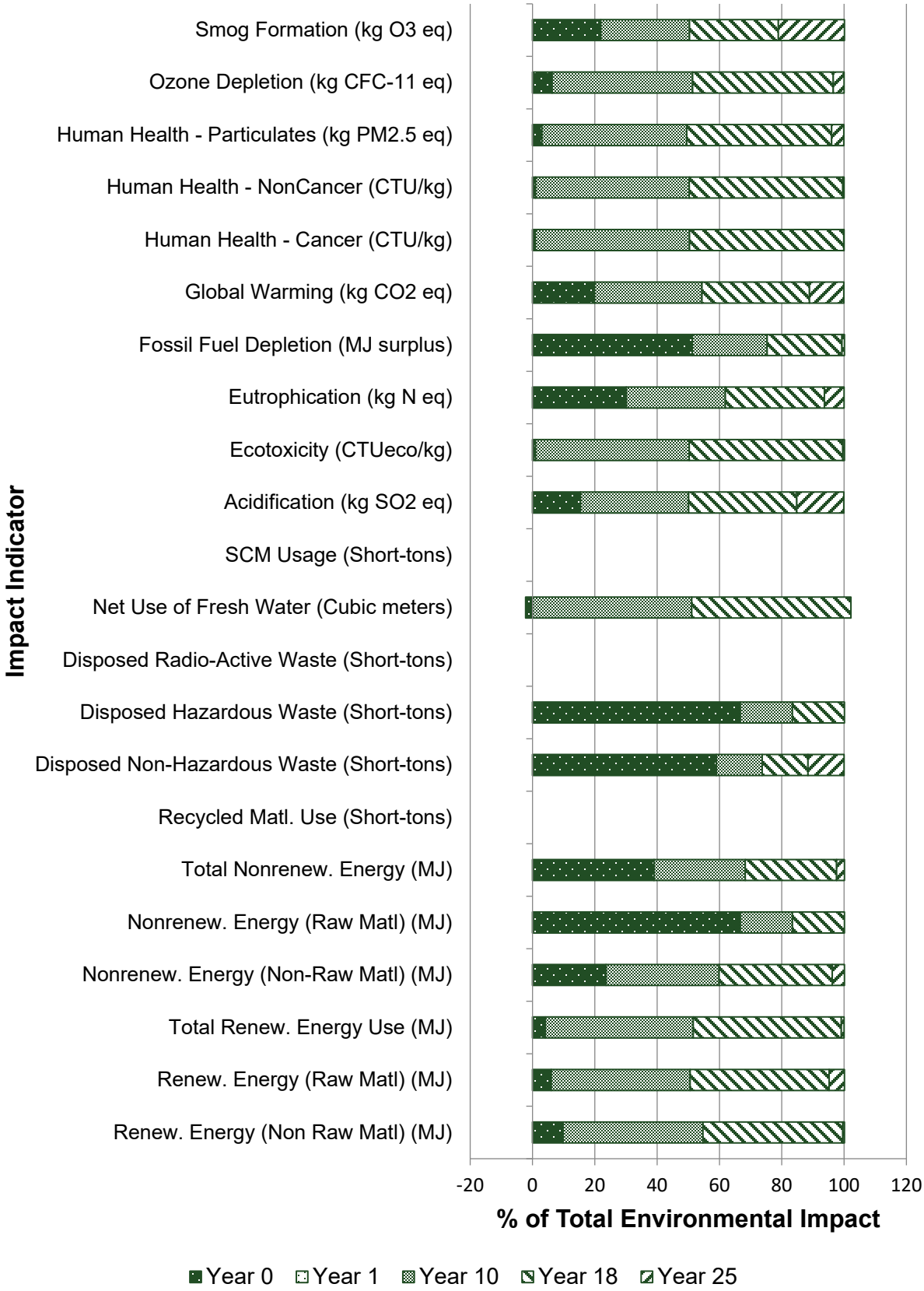


Figure 5-23. Example summary results by application age.

- The user can click the "Return to Session" button found in the "Output Control Panel" worksheet (see figure 5-24) to go back to the analysis session.

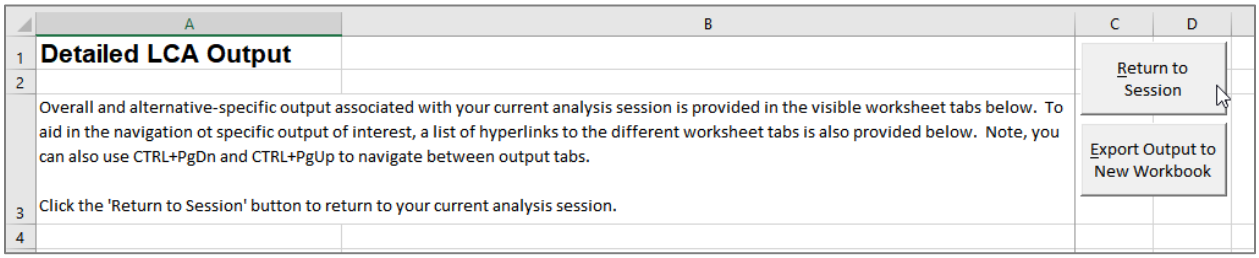


Figure 5-24. Controls available in the output interface.

- Clicking on the "Export Output to New Workbook" button (see figure 5-24) will prompt the user to provide a destination location on the computer where the detailed results file is to be saved.
- To save and exit from the tool, the user should go back to the home screen (by clicking on the various "Back" buttons) and then click the "Exit Tool" button (see figure 5-25).

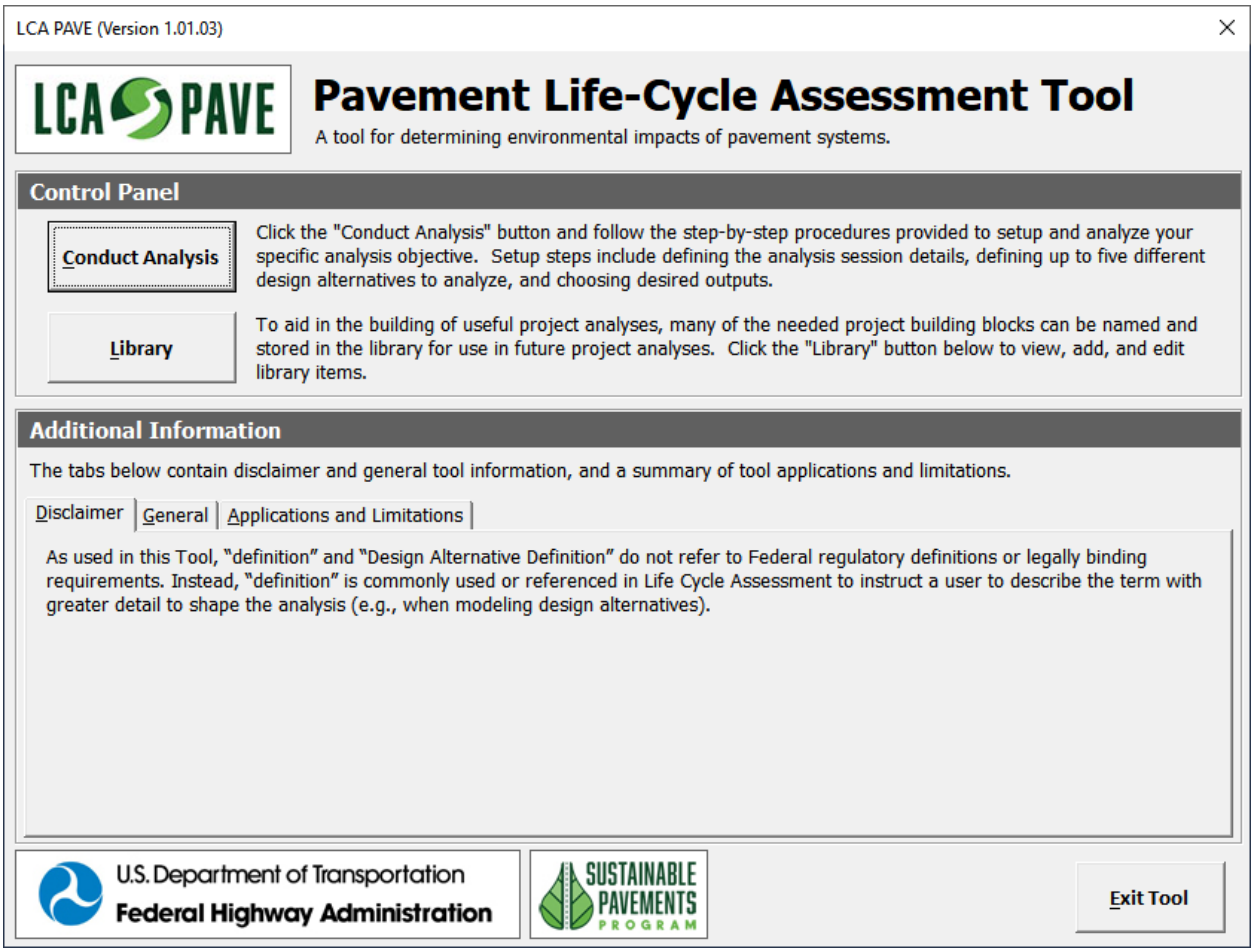


Figure 5-25. Tool's home screen.

The next chapter presents examples that illustrate tool features and analysis functionalities.

CHAPTER 6. EXAMPLES

6.0 INTRODUCTION

This chapter presents examples and step-by-step instructions on how the user can conduct an analysis, model a pavement life cycle, and view results. The examples show how the user can model asphalt and concrete pavement life-cycles (Use Case #3 noted in section 1.3) by creating the following library items:

- Asphalt and concrete mix designs.
- Asphalt and concrete pavement layers.
- Aggregate base layer.
- Asphalt mill and inlay activity.
- Diamond grinding activity
- Modeling asphalt and concrete pavement end-of-life activities.

Note: The examples presented in this chapter are not intended to be comprehensive. They illustrate tool features and functionality.

6.1 MODELING MIX DESIGNS

This section presents examples on how asphalt and concrete mix design can be modeled in the tool. Before modeling mix designs, the user should compile:

- Mix design ingredients and material quantities.
- Types of equipment and quantity of equipment use to develop desired quantity of mix design.
- Transportation legs (origin and destination of item being transported) and distances (in miles between origin and destination) associated with materials used in the mix design. If EPDs are used for certain materials in the mix design, the user should be cognizant of transportation impacts already incorporated into the EPDs and not double count them when modeling mix designs using the tool.

The tool does not calculate any material quantities. The user should perform calculations before modeling mix designs in the tool. The user should document any assumptions that go into the calculations; this information can be input into the tool description fields.

6.1.1 Asphalt Mix Designs

Example #1: Model Asphalt Mix Designs

This example models two asphalt mix designs (Beta-HMA-1 and Beta-HMA-2). All quantities are either assumed values or have been pre-calculated for the user.

6.1.1.1 Step 1: Input General Mix Design Properties

- Launch the tool and click the “Library” button.

- Select the “Mix Designs” library.
- Click the “Add New” button.
- Set the *Source Method* to “Build from library items.”
- Set the *Pavement Type* to “Asphalt.”
- Name the mix design “Beta-HMA-1.”
- Set the following mix design properties:
  - Measure Type: Mass.
  - Quantity: 1 short-tons.
  - Agency ID: “HMA-001.”

Figure 6-1 shows a screen shot of the “Add New ‘Mix Design’ Library Item” dialog box after step 1 is complete.

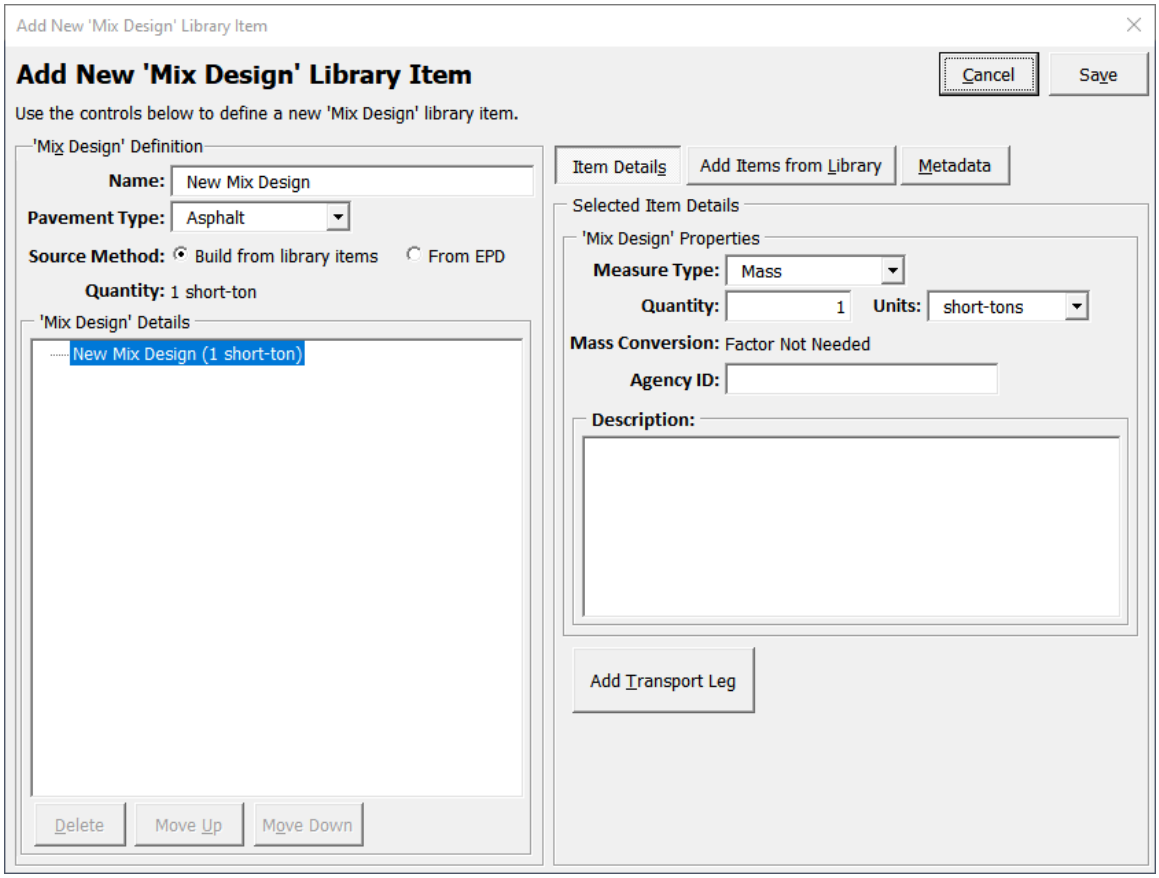


Figure 6-1. User interface to input general asphalt mix design properties.

6.1.1.2 Step 2: Populate Mix Design Ingredients

- In the “Add New ‘Mix Design’ Library Item” dialog box, click the “Add Items from Library” button.
- Select the “Materials” library.

- Select “Crushed Stone, granite (Coarse Aggregate for Asphalt)” under “Aggregate” and click the “Add to Mix Design” button.
- Select “Fine Aggregate (for asphalt)” under “Aggregate” and click the “Add to Mix Design” button.
- Select “Asphalt binder, no additives, consumption mix, at terminal, from crude oil” under “Asphalt Binder” and click the “Add to Mix Design” button.
- Select each material added to the treeview and specify the following quantities:
  - Crushed Stone: 0.494 short-ton.
  - Fine Aggregate: 0.456 short-ton.
  - Asphalt Binder: 0.05 short-ton.

Figure 6-2 shows a screen shot of the “Add New ‘Mix Design’ Library Item” dialog box after step 2 is complete.

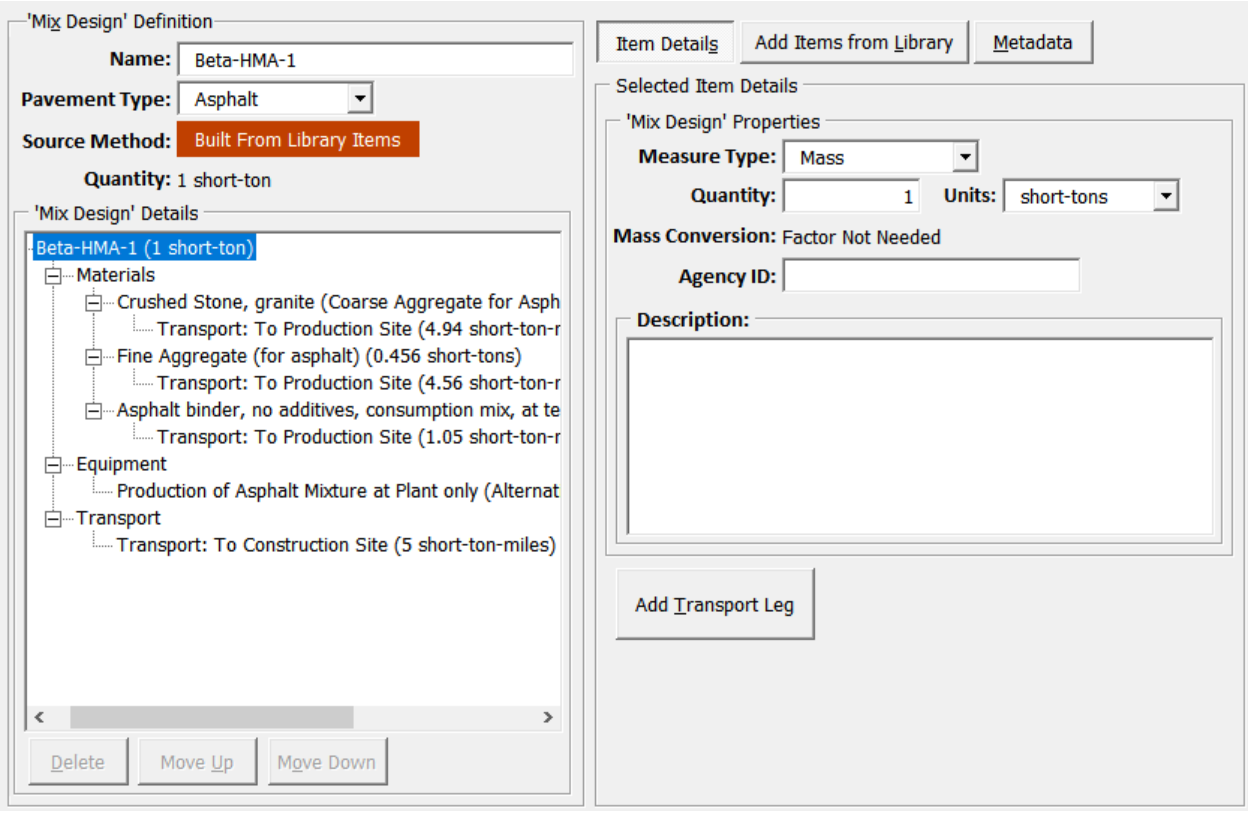


Figure 6-2. User interface to populate mix design ingredients.

6.1.1.3 Step 3: Add Equipment and Transportation

- Select “Crushed Stone” from the “‘Mix Design’ Details” treeview.
- Click the “Add Transport Leg” button and input the following details:
  - Transport Type: Road.
  - Transport Vehicle: Transfer Truck, Diesel.

  - Transport Leg: “To Production Site.”
  - Trip Distance: 10 miles.
- Select “Fine Aggregate” from the “‘Mix Design’ Details” treeview.
- Click the “Add Transport Leg” button and input the following details:
  - Transport Type: Road.
  - Transport Vehicle: Transfer Truck, Diesel.
  - Transport Leg: “To Production Site.”
  - Trip Distance: 10 miles.
- Select “Asphalt binder” from the “‘Mix Design’ Details” treeview.
- Click the “Add Transport Leg” button and input the following details:
  - Transport Type: Road.
  - Transport Vehicle: Transfer Truck, Diesel.
  - Transport Leg: “To Production Site.”
  - Trip Distance: 21 miles.
- Select “Add Items from Library,” click the “Equipment” library button, expand the tree “Mixing Operations – Asphalt,” and select “Production of Asphalt Mixture at Plant only (Alternative 1),” and click the “Add to Mix Design” button.
- Select “Beta-HMA-1” from the “‘Mix Design’ Details” treeview and click the “Add Transport Leg” button. Note: this action is used to input the transport details for the mix design itself after the mixing operations are complete. To include the mix design transport leg details, input the following details in the right side “Selected Item Details” frame:
  - Transport Type: Road.
  - Transport Vehicle: Transfer Truck, Diesel.
  - Transport Leg: “To Construction Site.”
  - Trip Distance: 5 miles.
- Click the “Save” button.

Figure 6-3 shows a screen shot of the “Add New ‘Mix Design’ Library Item” dialog box after step 3 is complete.

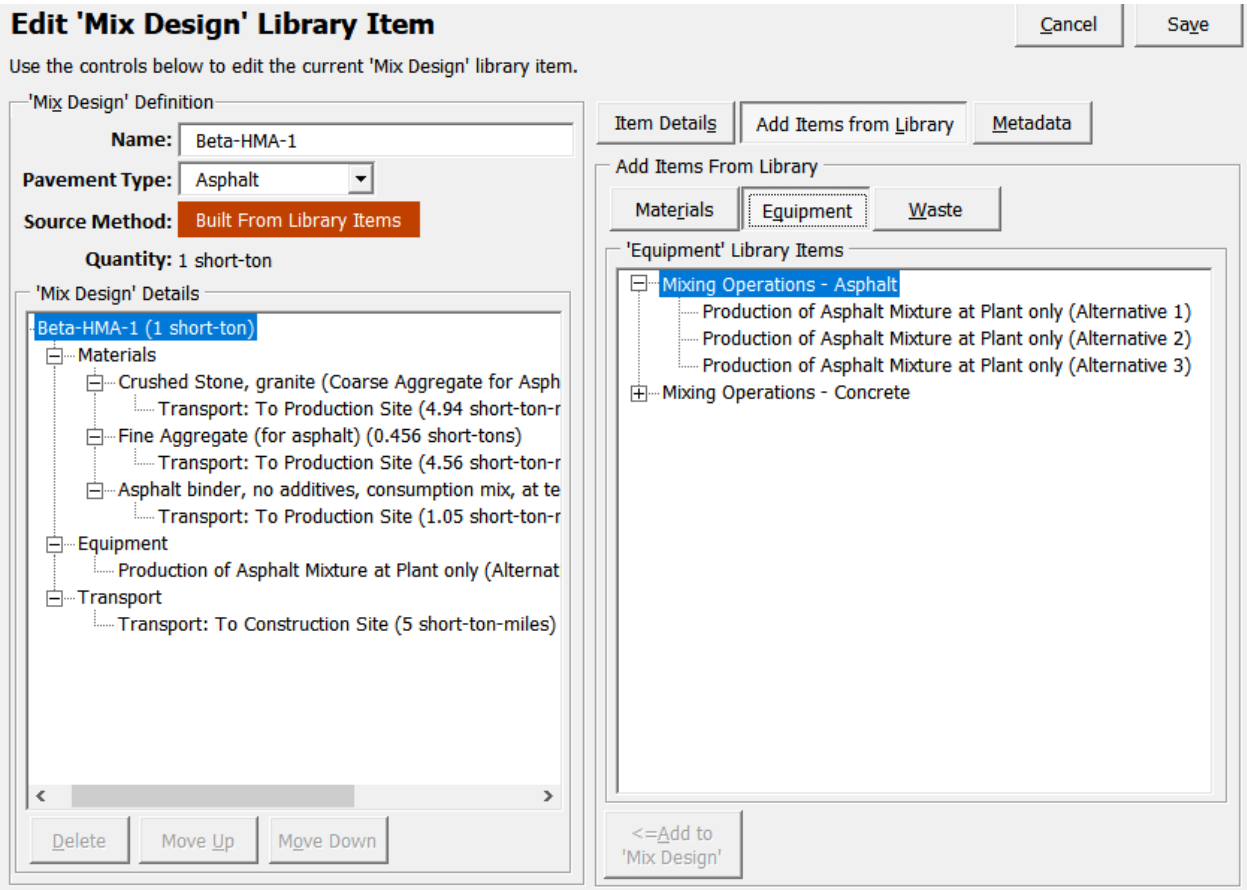


Figure 6-3. User interface to add equipment to develop mix design.

6.1.1.4 Modeling Another Mix Design

- Use the same process shown under Sections 6.1.1.1 through 6.1.1.3 to develop another mix design named "Beta-HMA-2" with the same quantities but use a different asphalt binder from the library: "Asphalt binder, 8% ground rubber tire (GRT), consumption mix, at terminal, from crude oil, 8% ground rubber tire" (see figure 6-4).
- *HINT: Use the "Copy" and "Paste" features to copy all details from "Beta-HMA-1" and then rename the mix as "Beta-HMA-2."*
  - *Note: Once the existing asphalt binder from "Beta-HMA-1" is deleted and the new binder added to "Beta-HMA-2," add the Transport details again.*
- Click the "Close" button to exit the library interface.

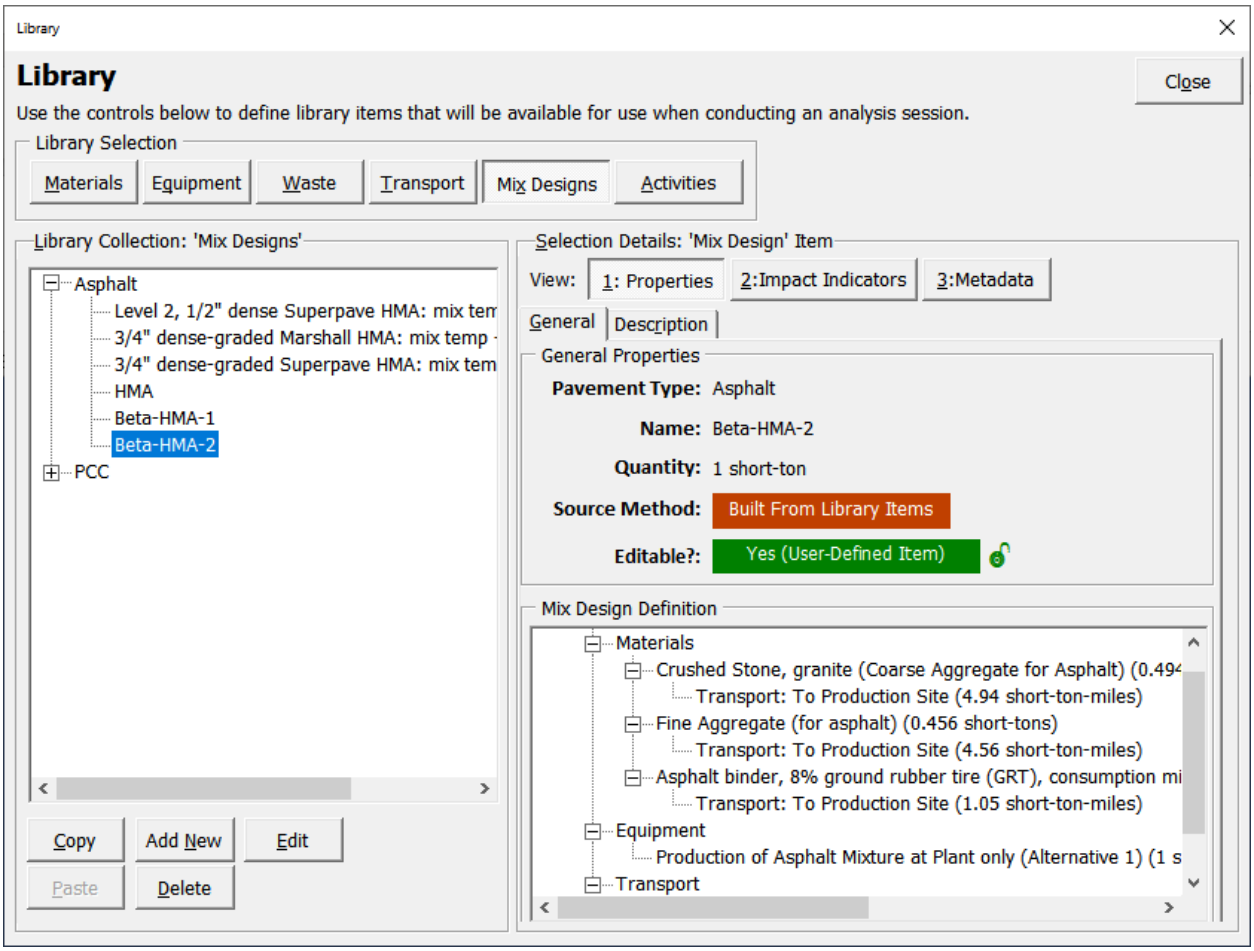


Figure 6-4. Using interface showing second asphalt mix design modeled.

6.1.2 Concrete Mix Designs

Example #2: Model Concrete Mix Designs

This example models two concrete mix designs (Beta-PCC-1 and Beta-PCC-2). All quantities used in the examples are assumed values or have been pre-calculated for the user.

6.1.2.1 Step 1: Input General Mix Design Properties

- Launch the tool and click the "Library" button.
- Select the "Mix Designs" library.
- Click on the "Add New" button.
- Set the *Source Method* to "Build from library items."
- Set the *Pavement Type* to "Concrete."
- Name the mix design "Beta-PCC-1."
- Set the following mix design properties:

- Measure Type: Volume.
- Quantity: 1 cubic yard.
- Mass Conversion: 4000 lbs. per cu. yd.
- Agency ID: “PCC-001.”

Figure 6-5 shows a screen shot of the “Add New ‘Mix Design’ Library Item” dialog box after step 1 is complete.

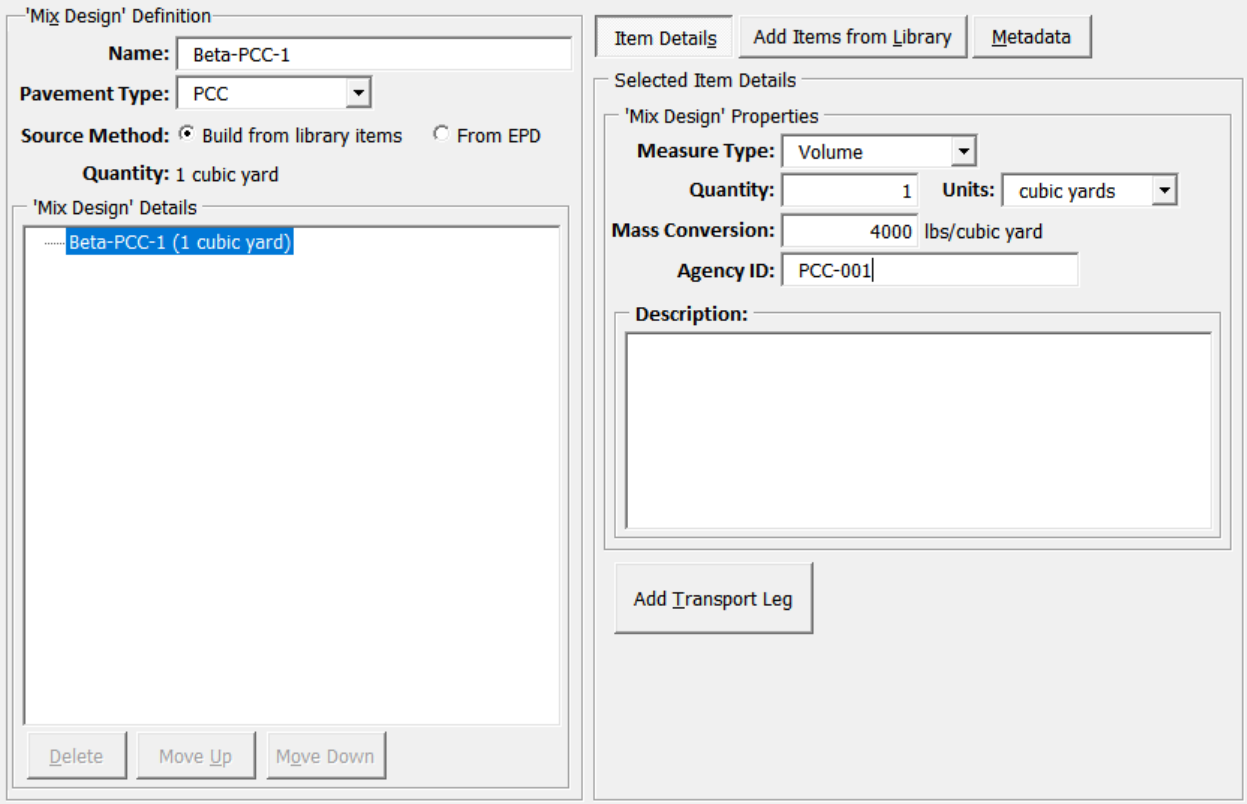


Figure 6-5. User interface to input general concrete mix design properties.

6.1.2.2 Step 2: Populate Mix Design Ingredients

- In the “Add New ‘Mix Design’ Library Item” dialog box, click the “Add Items from Library” button.
- Select the “Materials” library.
- Select “Crushed Stone (Coarse Aggregate for Concrete)” under “Aggregate” and click the “Add to Mix Design” button.
- Select “Fine Aggregate (for concrete)” under “Aggregate” and click the “Add to Mix Design” button.
- Select “Cement (Precalciner method)” under “Cementitious” and click the “Add to Mix Design” button.
- Select “Water” under Other” and click the “Add to Mix Design” button.

- Select each material added to the treeview and specify the following quantities:
  - Cement: 0.295 short-ton.
  - Coarse Aggregate: 0.8625 short-ton.
  - Fine Aggregate: 0.695 short-ton.
  - Water: 0.11 short-ton.

Figure 6-6 shows a screen shot of the "Add New 'Mix Design' Library Item" dialog box after step 2 is complete.

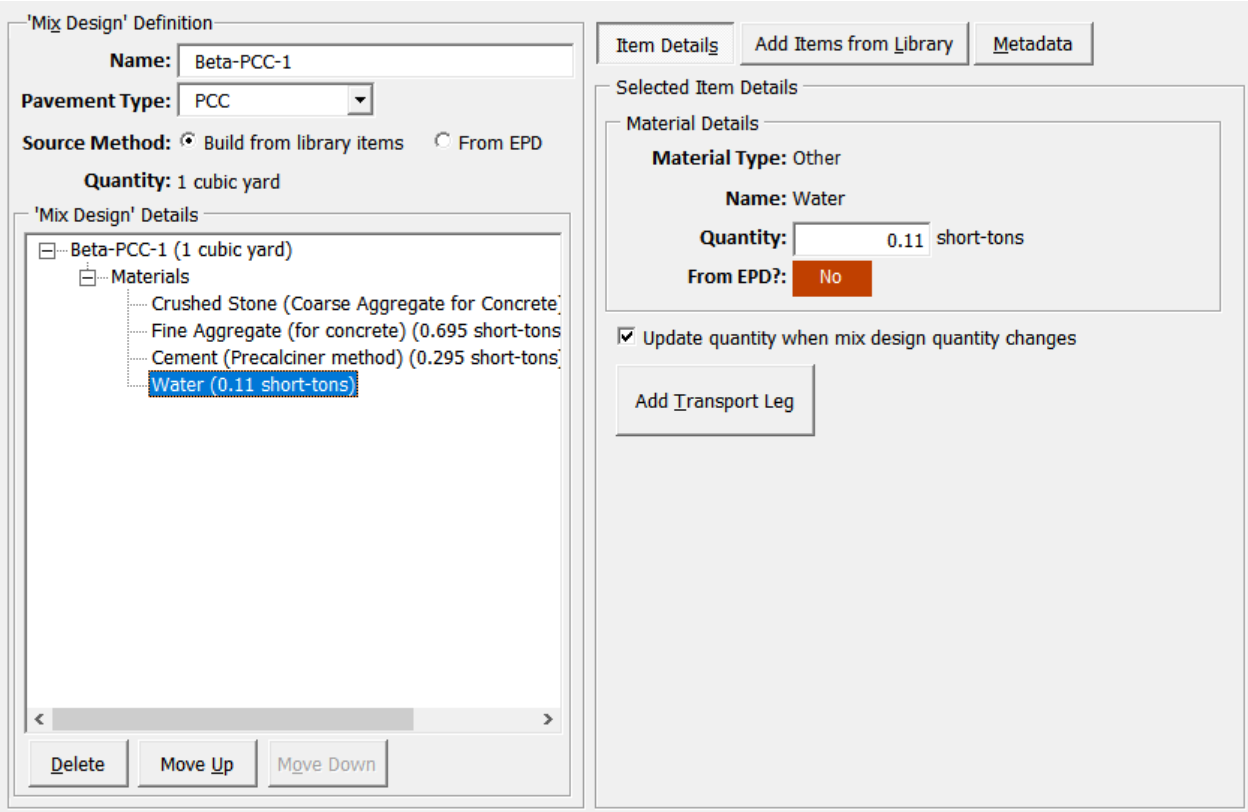


Figure 6-6. User interface to populate mix design ingredients.

6.1.2.3 Step 3: Add Equipment and Transportation

- Select "Crushed Stone" from the "'Mix Design' Details" treeview. Click the "Add Transport Leg" button and input the following details:
  - Transport Type: Road.
  - Transport Vehicle: Transfer Truck, Diesel.
  - Transport Leg: "To Production Site."
  - Trip Distance: 10 miles.
- Select "Fine Aggregate" from the "'Mix Design' Details" treeview.
- Click the "Add Transport Leg" button and input the following details:

  - Transport Type: Road.
  - Transport Vehicle: Transfer Truck, Diesel.
  - Transport Leg: "To Production Site."
  - Trip Distance: 10 miles.
- Select "Cement" from the "'Mix Design' Details" treeview.
- Click the "Add Transport Leg" button and input the following details:
  - Transport Type: Road.
  - Transport Vehicle: Transfer Truck, Diesel.
  - Transport Leg: "To Production Site."
  - Tip Distance: 14 miles.
- Select "Add Items from Library," click on "Equipment," select "Production of Concrete Mixture at Plant only (Alternative 1)," and click the "Add to Mix Design" button.
- Select "Beta-PCC-1" from "'Mix Design' Details" treeview and click the "Add Transport Leg" button. To include the mix design transport leg details, input the following details in the right side "Selected Item Details" frame:
  - Transport Type: Road.
  - Transport Vehicle: Ready Mix Concrete Truck, Diesel.
  - Transport Leg: "To Construction Site."
  - Trip Distance: 8 miles.
- Click the "Save" button.

Figure 6-7 shows a screen shot of the "Add New 'Mix Design' Library Item" dialog box after step 3 is complete.

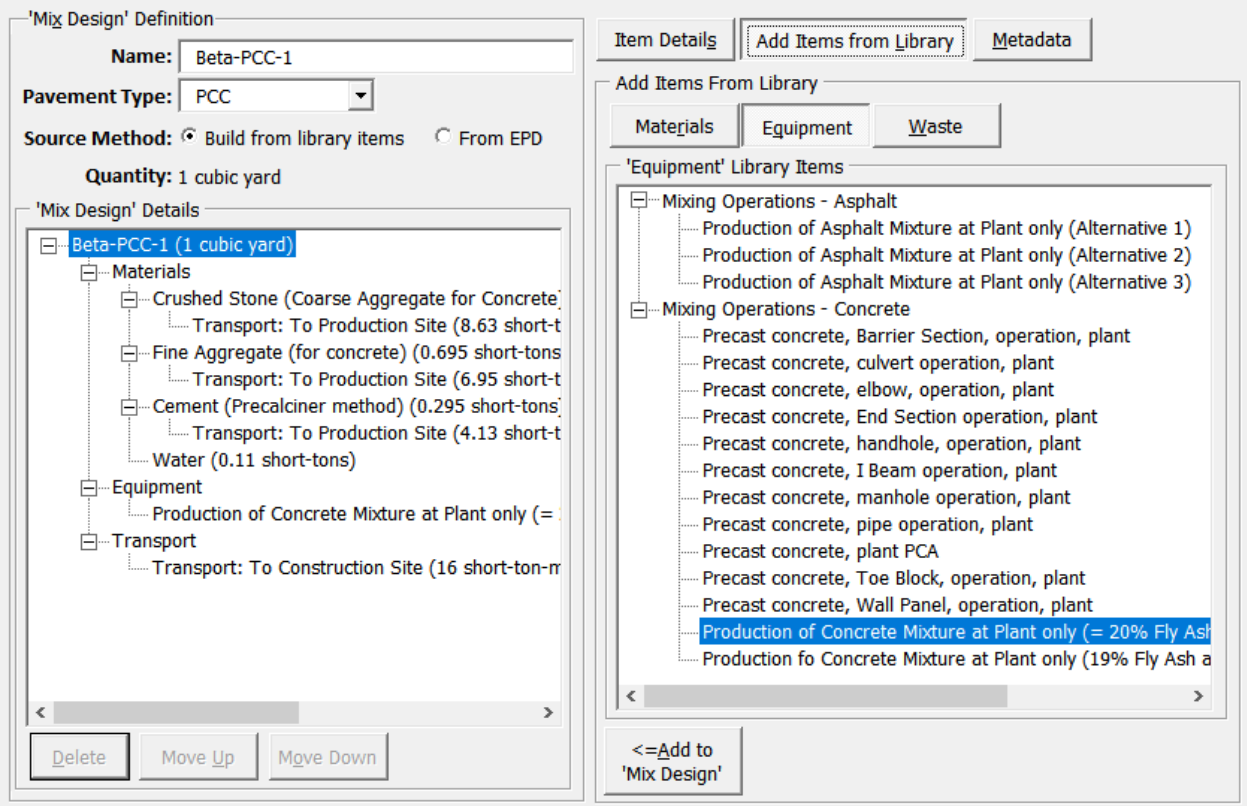


Figure 6-7. User interface to add equipment to develop mix design.

6.1.2.4 Modeling Another Mix Design

- Use the same process shown under Sections 6.1.2.1 through 6.1.2.3 to develop another mix design named “Beta-PCC-2” with the same quantities but using a different cement from the library “Cement (Blended with SCMs)” (see figure 6-8).
- *HINT: Use the “Copy” and “Paste” features to copy all details from “Beta-PCC-1” and then rename the mix as “Beta-PCC-2.”*
  - *Note: Once the existing cement is deleted from “Beta-PCC-1” and the new cement is added to “Beta-PCC-2,” add the Transport details again.*
- Click the “Close” button to exit the library interface.

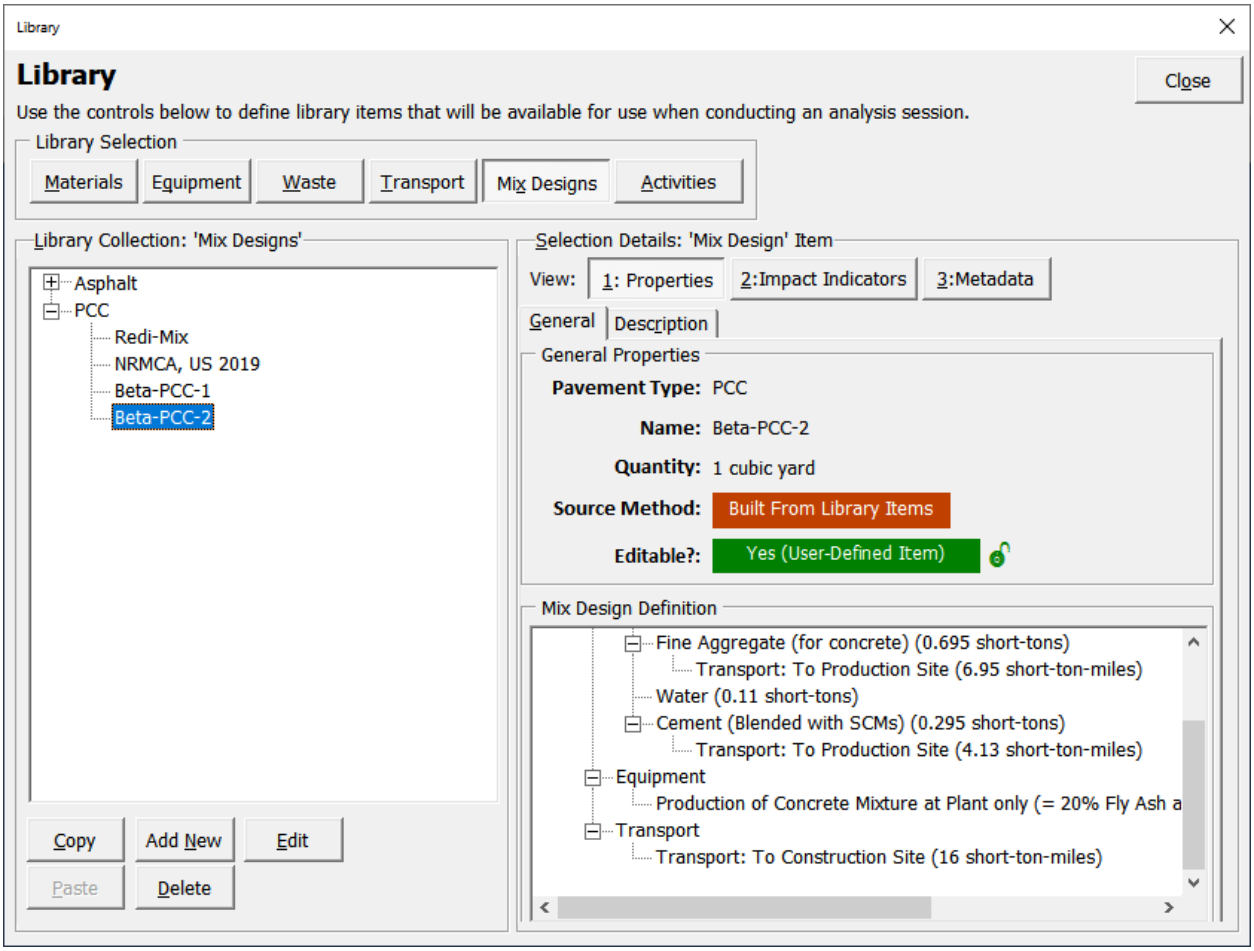


Figure 6-8. Using interface showing second concrete mix design modeled.

6.2 MODELING PAVEMENT LAYERS

Before modeling a pavement layer, the user should compile the following information:

- Geometry of pavement layer being modeled (length, width, thickness etc.) to calculate volume and/or mass of materials requirement.
- If materials quantities are based on volumes, a mass conversion factor is required to convert units of volume to units of mass.
- Pavement elements included in the layers being modeled along with material quantities (e.g., dowel bars, tie bars, reinforcing steel, geotextile layers, etc.)
- Transportation legs (origin and destination of item being transported) and distances (in miles between origin and destination) associated with materials, mix designs, and equipment required during construction.

The example layers modeled in the following sections are based on 1 lane-mile (lane length = 5280 ft, lane width = 12 ft; lane area = 63,360 ft^2).

6.2.1 Asphalt Pavement Layer

Example #3: Model Asphalt Pavement Layer

This example models two 4-inch asphalt pavement layers (length = 5280 ft, width = 12 ft); one using the mix design Beta-HMA-1 and the other using the mix design Beta-HMA-2 (discussed under Section 6.1.1). All quantities used in the examples are either assumed values or have been pre-calculated for the user.

6.2.1.1 Step 1: Input General Layer Properties and Add Mix Design

- Launch the tool and click the "Library" button.
- Select the "Activities" library.
- Click the "Edit Activity Type List" button, select "Activity Category #1" from the list, and update that activity type name to "Layers."
- Click the "Save" button to close the "Category List Editor" dialog box.
- Click the "Add New" button and enter the following details in the "Activity Details" frame on the right side of the dialog box:
  - Activity Type: Layers.
  - Name: "4-inch HMA-1."
  - Measure Type: Area.
  - Quantity: 63,360 sq. ft.

  Note: Instead of using area as the measure type to model this activity, the user can use units of length, mass, or volume.
- Click the "Add Items from Library" button.
- Click the "Mix Designs" library button.
- Select "Beta-HMA-1" from the "Asphalt" list in the Mix Design library and click the "Add to Activity" button.
- Select "Beta-HMA-1" in the "'Activity' Definition" treeview and update the mix design quantity in the "Materials Details" frame to 1531.2 short-tons.

Figure 6-9 shows a screen shot of the "Add New 'Activity' Library Item" dialog box after step 1 is complete.

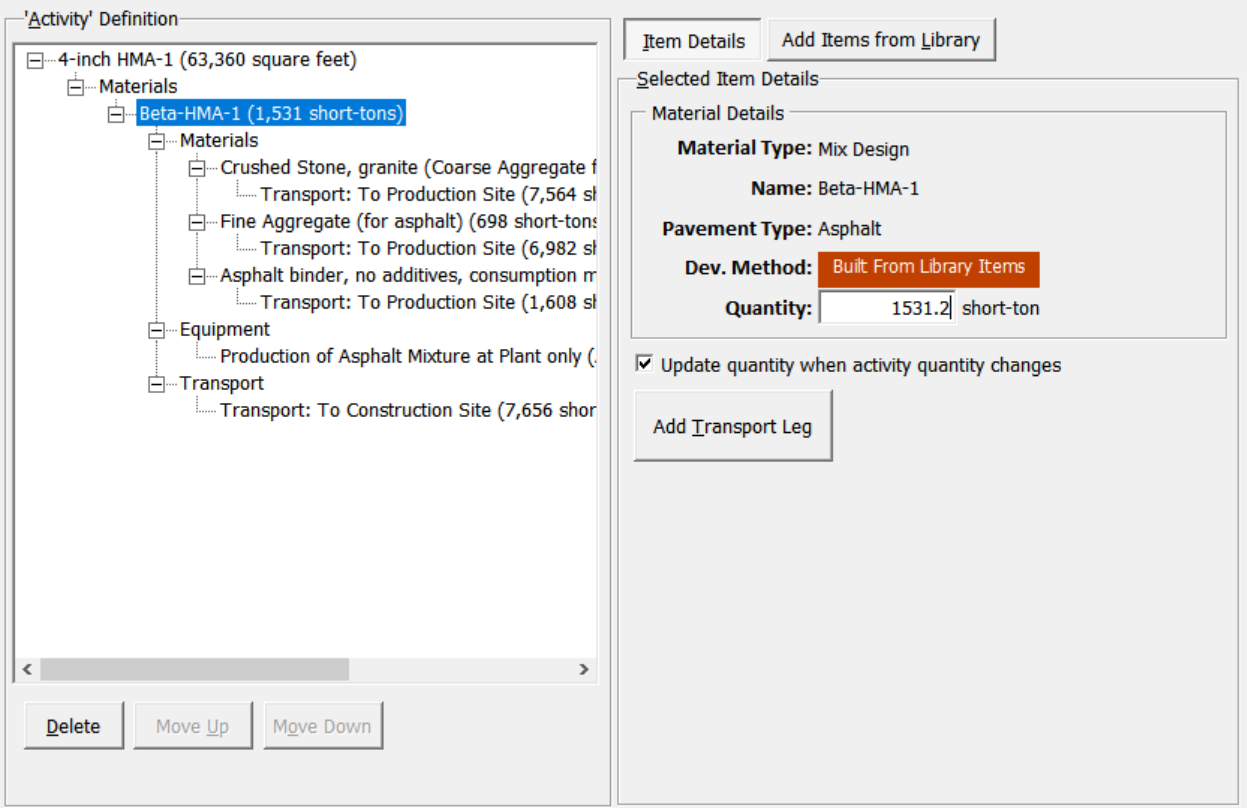


Figure 6-9. Using interface showing an asphalt mix design added to a pavement layer activity.

6.2.1.2 Step 2: Add Equipment and Transportation

- Click the "Add Items from Library" button, click on the "Equipment" library button, select "Paver, Nonroad Diesel Fuel, 300 < hp <= 600" from the "Pavers" category, and click the "Add to Mix Design" button.
- Click on the newly added paver item in the "Activity Definition" treeview and set the quantity to "8 hours" in the "Equipment Details" frame on the right side.
- Click the "Add Transport Leg" button to include details for mobilizing the paver to the construction site. Set the details of the transport leg to the following:
  - Transport Type: Road.
  - Transport Vehicle: Combination Truck, Diesel.
  - Transport Leg: "To Construction Site."
  - Trip Distance: 18 miles.
- Click the "Add Items from Library" button, click on the "Equipment" library button, select "Rollers, Nonroad Diesel Fuel, 300 < hp <=600" from the "Pneumatic Rollers" category, and click the "Add to Mix Design" button.
- Click on the newly added roller item in the "Activity Definition" treeview and set the quantity to "4 hours" in the "Equipment Details" frame on the right side.
- Click the "Save" button.

Figure 6-10 shows a screen shot of the "Add New 'Activity' Library Item" dialog box after step 2 is complete.

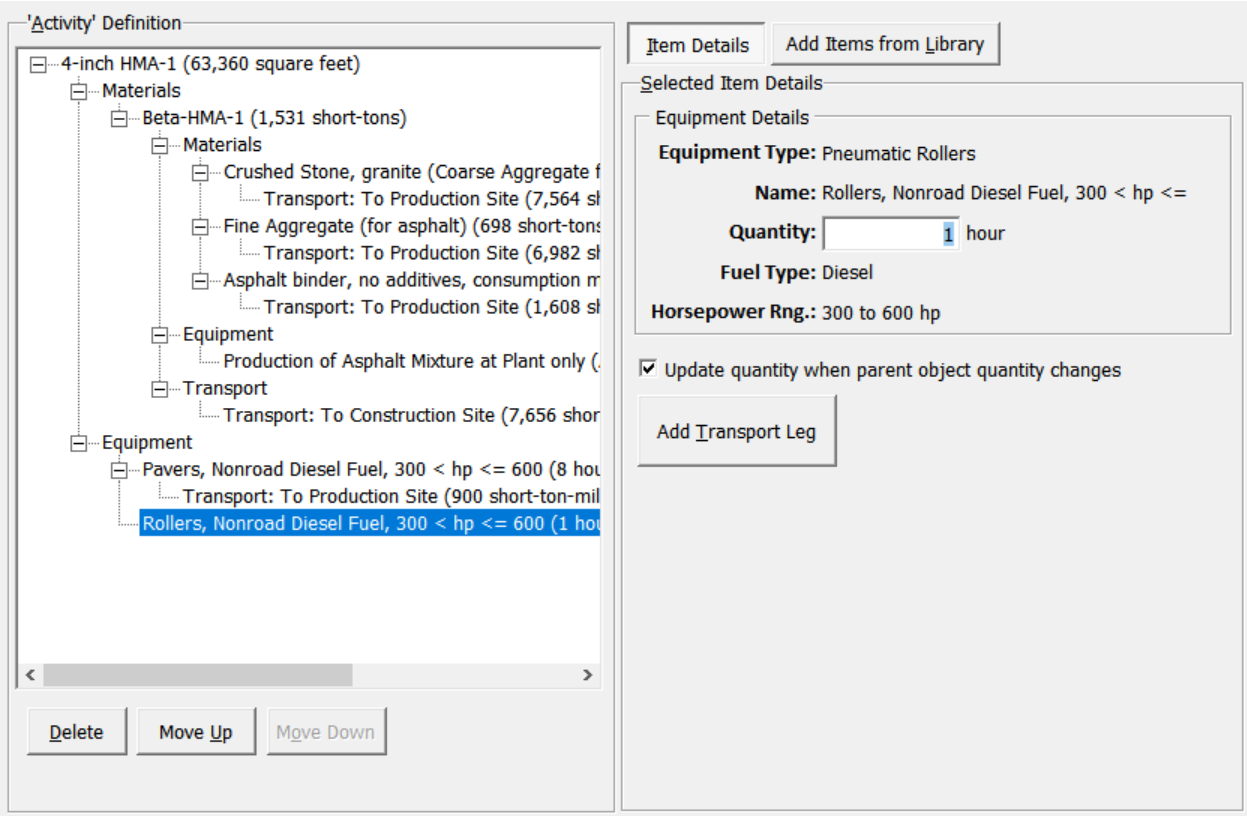


Figure 6-10. User interface showing equipment and transport details for the asphalt pavement layer activity.

6.1.2.3 Modeling Another Pavement Layer

- Use the same process shown under Sections 6.2.1.1 and 6.2.1.2 to model a 4-inch HMA layer that uses the mix design Beta-HMA-2 (developed earlier under section 6.1.1.4) and name that "4-inch HMA-2."
- *HINT: Use the "Copy" and "Paste" feature to expedite the process.*

6.2.2 Concrete Pavement Layer

Example #4: Model Concrete Pavement Layer

This example models two 8-inch concrete pavement layers (length = 5280 ft, width = 12 ft), one using the mix design Beta-PCC-1 and the other using the mix design Beta-PCC-2 (discussed under Section 6.1.2). All quantities used in the examples are assumed values or have been pre-calculated for the user.

6.2.2.1 Step 1: Input General Layer Properties and add Mix Design

- Launch the tool and click the "Library" button.
- Select the "Activities" library.
- Click the "Add New" button and enter the following details in the "Activity Details" frame on the right side of the dialog box:
  - Activity Type: Layers.
  - Name: "8-inch PCC-1."
  - Measure Type: Area.
  - Quantity: 63,360 sq. ft.

  Note: Instead of using area as the measure type to model this activity, the user can use units of length, mass, or volume.
- Click the "Add Items from Library" button.
- Click the "Mix Designs" library button.
- Select "Beta-PCC-1" from the "PCC" list in the Mix Design library and click the "Add to Activity" button.
- Select "Beta-PCC-1" in the "'Activity' Definition" treeview and update the mix design quantity in the "Materials Details" frame to 1564.4 cu. yds.
- Click the "Add Items from Library" button.
- Click the "Materials" library button.
- Select "Dowel Bar 1.5" x 18"" from the "Steel" category list in the Materials library and click the "Add to Activity" button.
- Select the dowel bar item added in the "'Activity' Definition" treeview and update the item quantity in the "Materials Details" frame to 3,900 items (the number of dowel bars used in the layer quantity being modeled is calculated manually by the user).

Figure 6-11 shows a screen shot of the "Add New 'Activity' Library Item" dialog box after step 1 is complete.

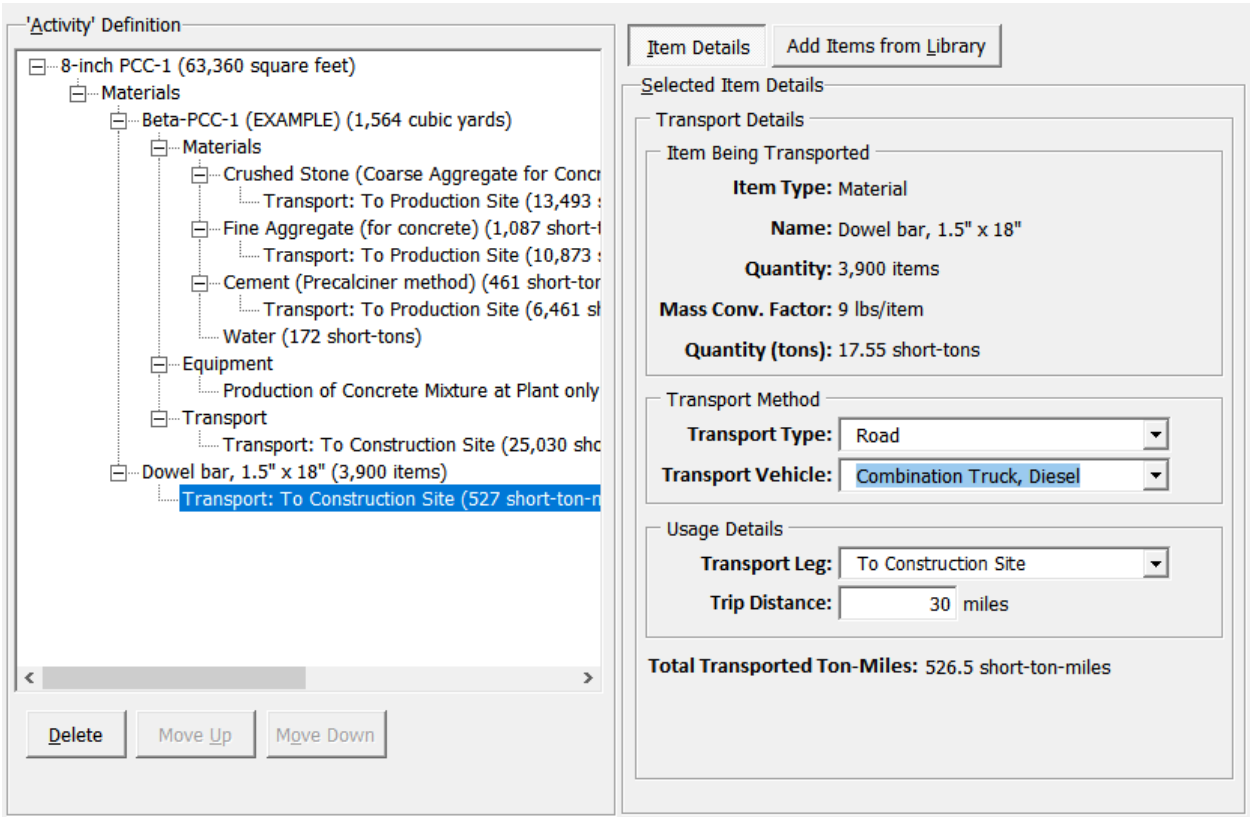


Figure 6-11. Using interface showing a concrete mix design added to a pavement layer activity.

6.2.2.2 Step 2: Add Equipment and Transportation

- Click the "Add Items from Library" button, click on the "Equipment" library button, select "Paver, Nonroad Diesel Fuel, 300 < hp <= 600" from the "Pavers" category, and click the "Add to Mix Design" button.
- Click on the newly added paver item in the "Activity Definition" treeview and set the quantity to "11 hours" in the "Equipment Details" frame on the right side.
- Click the "Add Transport Leg" button to include details for mobilizing the paver to the construction site. Set the details of the transport leg to the following:
  - Transport Type: Road.
  - Transport Vehicle: Combination Truck, Diesel.
  - Transport Leg: "To Construction Site."
  - Trip Distance: 10 miles.
- Select "Dowel bar, 1.5" x 18"" in the "'Activity' Definition" treeview.
- Click the "Add Transport Leg" button to include details for mobilizing the materials to the construction site. Set the details of the transport leg to the following:
  - Transport Type: Road.
  - Transport Vehicle: Combination Truck, Diesel.
  - Transport Leg: "To Construction Site."

- Trip Distance: 30 miles.

Example #5: Model Aggregate Base Layer

This example models a 6-inch aggregate base layer (length = 5280 ft, width = 12 ft). All quantities used in the examples are either assumed values or have been pre-calculated for the user.

- Click the "Save" button.
- Figure 6-12 shows a screen shot of the "Add New 'Activity' Library Item" dialog box after step 2 is complete.

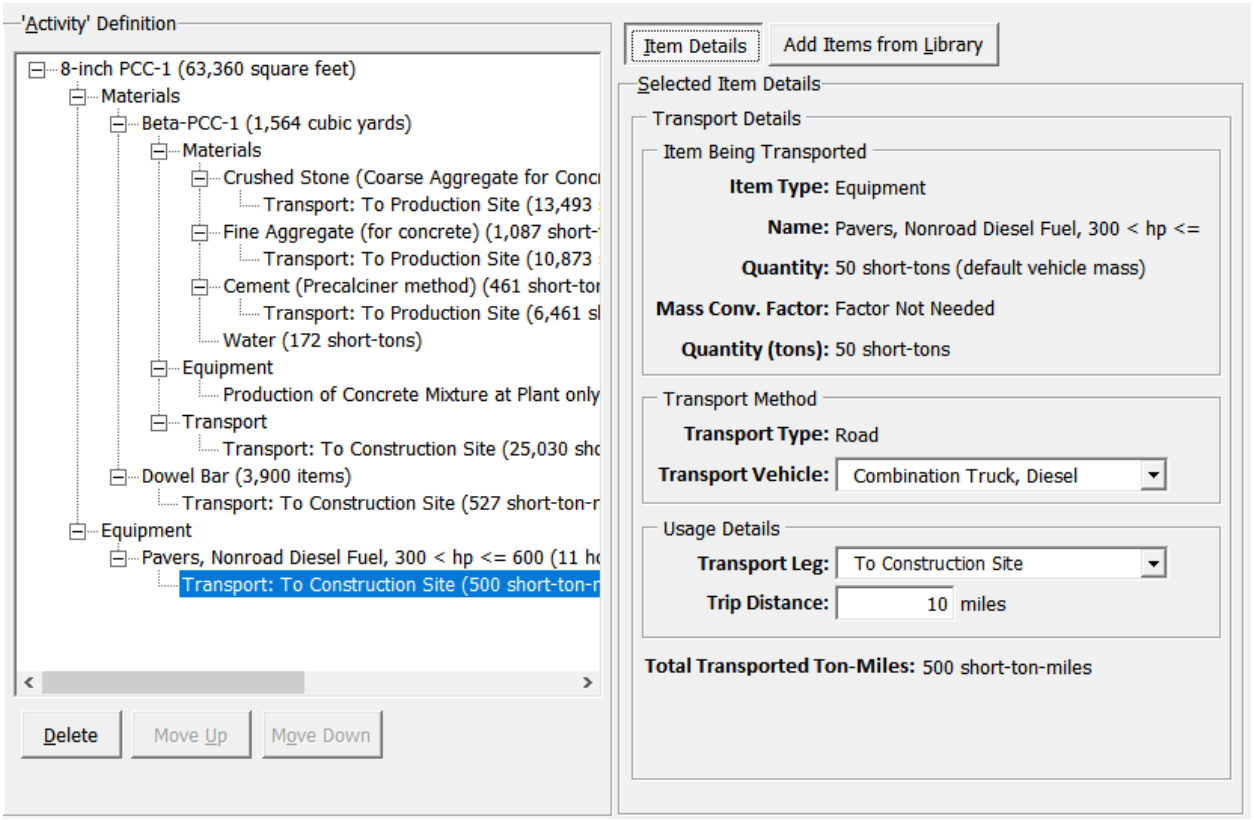


Figure 6-12. User interface showing equipment and transport details for the pavement layer activity.

6.1.2.3 Modeling Another Pavement Layer

- Use the same process shown under Sections 6.2.2.1 and 6.2.2.2 to model an 8-inch PCC layer that uses the mix design Beta-PCC-2 (developed earlier under section 6.1.2.4) and name that "8-inch PCC-2."
- *HINT: Use the "Copy" and "Paste" feature to expedite the process.*

6.2.3 Aggregate Base Layer

6.2.3.1 Step 1: Input General Layer Properties and Add Materials

- Launch the tool and click the "Library" button.
- Select the "Activities" library.
  - Click the "Add New" button and enter the following details in the "Activity Details" frame on the right side of the dialog box: Activity Type: Layers.
  - Name: 6-inch Aggregate Base.
  - Measure Type: Area.
  - Quantity: 63,360 sq. ft.

  Note: Instead of using area as the measure type to model this activity, the user can also use units of length, mass, or volume.
- Click the "Add Items from Library" button.
- Click the "Materials" library button. Add the following materials from the "Aggregate" category and update the material quantities as shown:
  - Crushed Stone (Coase Aggregate for Concrete): 950.4 short-ton.
  - Fine Aggregate (for concrete): 633.6 short-ton.

Figure 6-13 shows a screen shot of the "Add New 'Activity' Library Item" dialog box after step 1 is complete.

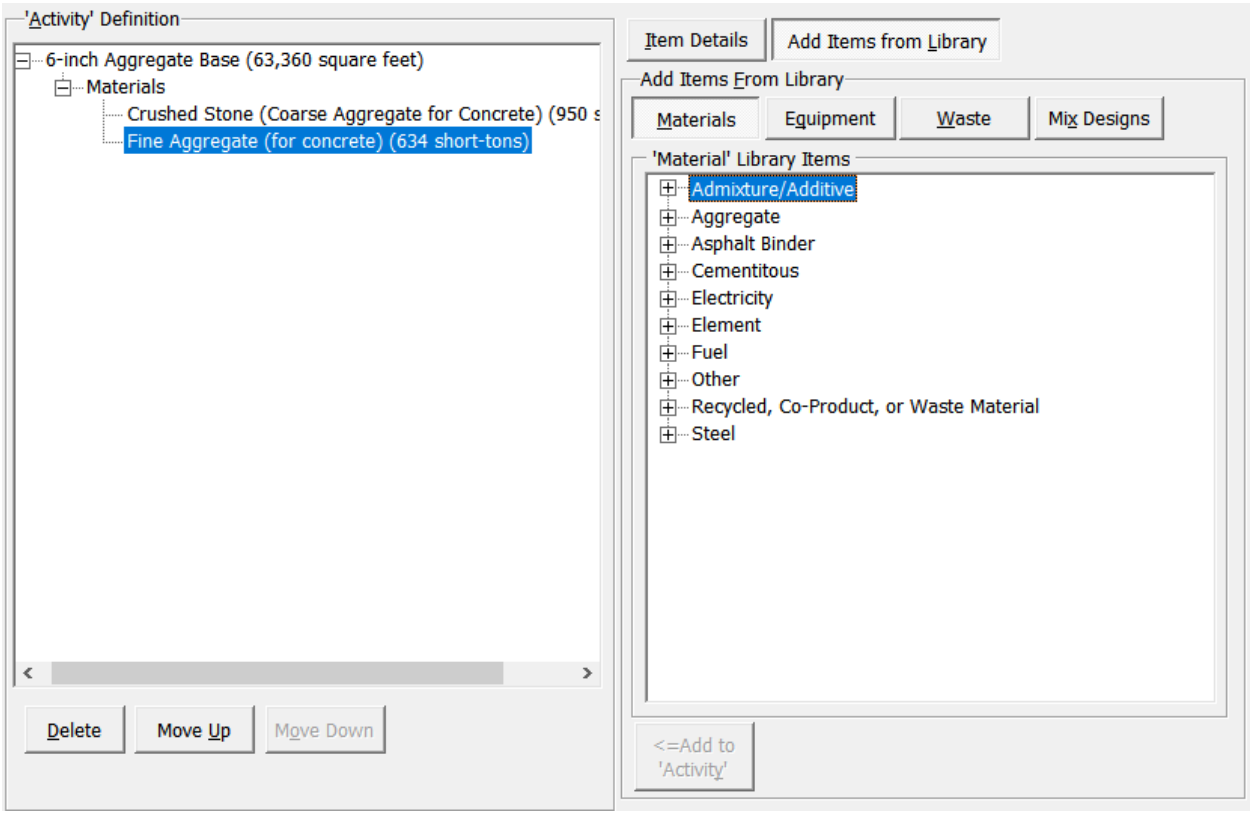


Figure 6-13. Using interface showing materials added to an aggregate base layer activity.

6.2.3.2 Step 2: Add Equipment and Transportation

- Select "Crushed Stone (Coarse Aggregate for Concrete)" in the "Activity Definition" treeview, click the "Add Transport Leg" button, and enter the following details in the "Transport Details" frame:
  - Transport Type: Road.
  - Transport Vehicle: Transfer Truck, Diesel.
  - Transport Leg: "To Production Site."
  - Trip Distance: 10 miles.
- Select "Crushed Stone (Coarse Aggregate for Concrete)" again in the "Activity Definition" treeview, click the "Add Transport Leg" button, and enter the following details in the "Transport Details" frame:
  - Transport Type: Road.
  - Transport Vehicle: Transfer Truck, Diesel.
  - Transport Leg: "To Construction Site."
  - Trip Distance: 13 miles.
- Add the same transportation details shown above for "Fine Aggregate (for concrete)."
- Click the "Add Items from Library" button, click the "Equipment" library button, select "Paver, Nonroad Diesel Fuel, 75 < hp <= 100" from the "Pavers" category, and click the "Add to Activity" button.
- Click on the newly added paver item in the "Activity Definition" treeview and set the quantity to "5 hours."
- Click the "Add Transport Leg" button to include details for mobilizing the paver to the construction site. Set the details of the transport leg to the following:
  - Transport Type: Road.
  - Transport Vehicle: Combination Truck, Diesel.
  - Transport Leg: "To Construction Site."
  - Trip Distance: 8 miles.
- Click the "Save" button.

Figure 6-14 shows a screen shot of the "Add New 'Activity' Library Item" dialog box after step 2 is complete.

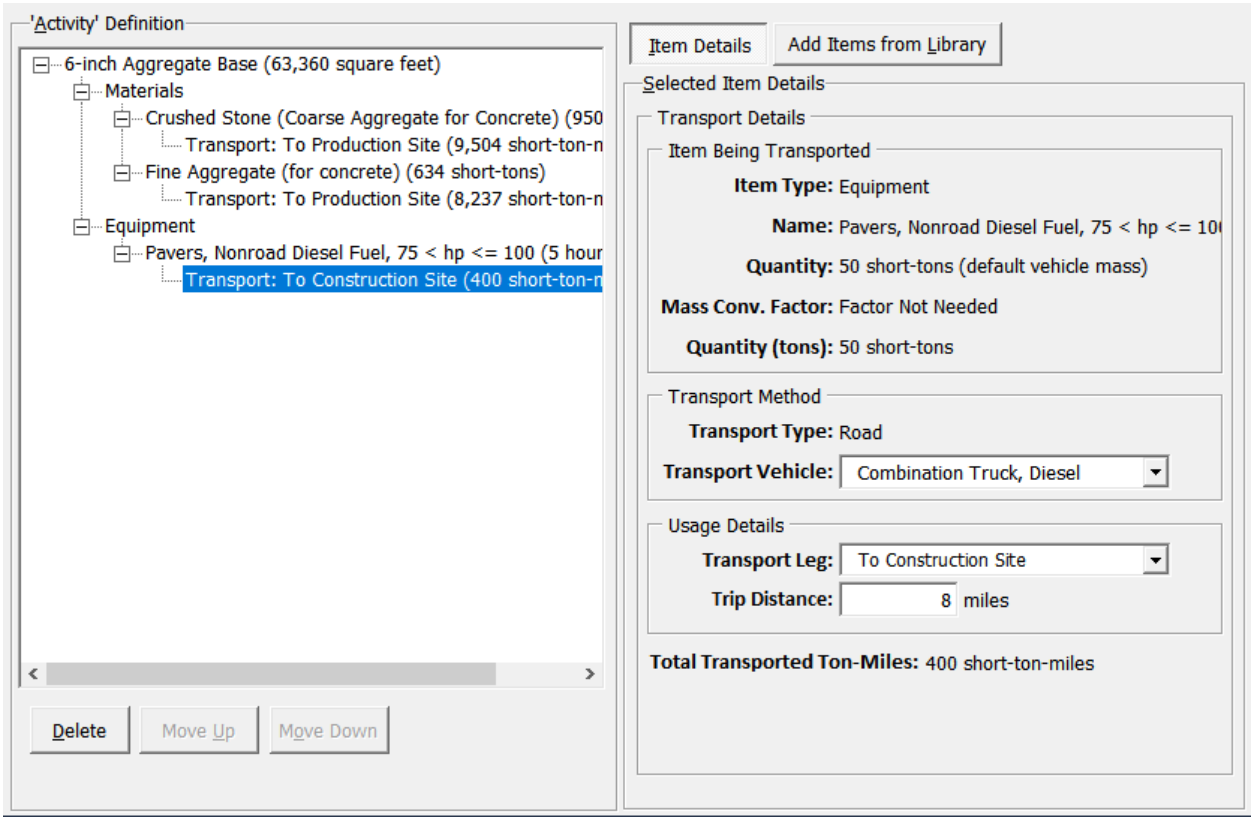


Figure 6-14. User interface showing equipment and transport details for the aggregate layer activity.

6.3 MODELING PAVEMENT TREATMENT ACTIVITIES

This section presents examples on how the user can model pavement treatment activities. Some key considerations are summarized below:

- Does the activity involve removal of material from the existing pavement surface? If yes, how much material is being is removed and how will the waste material generated be handled (landfilled, on-site recycling, off-site recycling, reuse, etc.)?
- If materials quantities are based on volume, a mass conversion factor is required to convert units of volume to units of mass.
- What equipment is needed for the activity being modeled?
- What are the transportation modes and distances associated with the movement of various materials and equipment used in the activity modeled?

6.3.1 Asphalt Mill and Inlay

Example #6: Model 1-inch Mill and Inlay Activity

This example models a 1-inch mill and inlay activity (length = 5280 ft, width = 12 ft) using each mix design developed under Section 6.1.1. for the fill activity. All quantities used in the examples are assumed values or have been pre-calculated.

- Launch the tool and click the "Library" button.
- Select the "Activities" library.
- Click the "Edit Activity Type List" button, select "Activity Category #3" from the list, and update that activity type name to "HMA Mill and Inlay."
- Click the "Save" button to close the "Category List Editor" dialog box.

6.3.1.1 Model 1-inch Mill Component

- In the "Activities" library, click the "Add New" button and enter the following details in the "Activity Details" frame on the right side of the dialog box:
  - Activity Type: HMA Mill and Inlay.
  - Name: "1-inch Mill and Fill-1."
  - Measure Type: Mass.
  - Quantity: 382.8 short-tons.
- Click the "Add Items from Library" button.
- Click the "Equipment" library button.
- Select "Milling Machine, Nonroad Diesel Fuel, 50 < hp <= 75" from the "Milling Machines" list in the Equipment library and click the "Add to Activity" button. Select the item added in the "'Activity' Definition" treeview and update the quantity to 4 hours.
- Click the "Add Transport Leg" button to include details for mobilizing the milling equipment to the construction site. Set the details of the transport leg to the following:
  - Transport Type: Road.
  - Transport Vehicle: Combination Truck, Diesel.
  - Transport Leg: "To Construction Site."
  - Trip Distance: 7 miles.
- Click the "Add Items from Library" button.
- Click the "Waste" library button.
- Select "Recycled Onsite-Asphalt" from the Waste library and click the "Add to Activity" button. Update the quantity of the newly added item to 382.8 short-tons.
- Click the "Add Transport Leg" button and set the details of the transport leg to the following:

- Transport Type: Road.
- Transport Vehicle: Transfer Truck, Diesel.
- Transport Leg: “From Construction Site.”
- Trip Distance: 10 miles.

Figure 6-15 shows a screen shot of the “Add New ‘Activity’ Library Item” dialog box after the modeled mill component is complete.

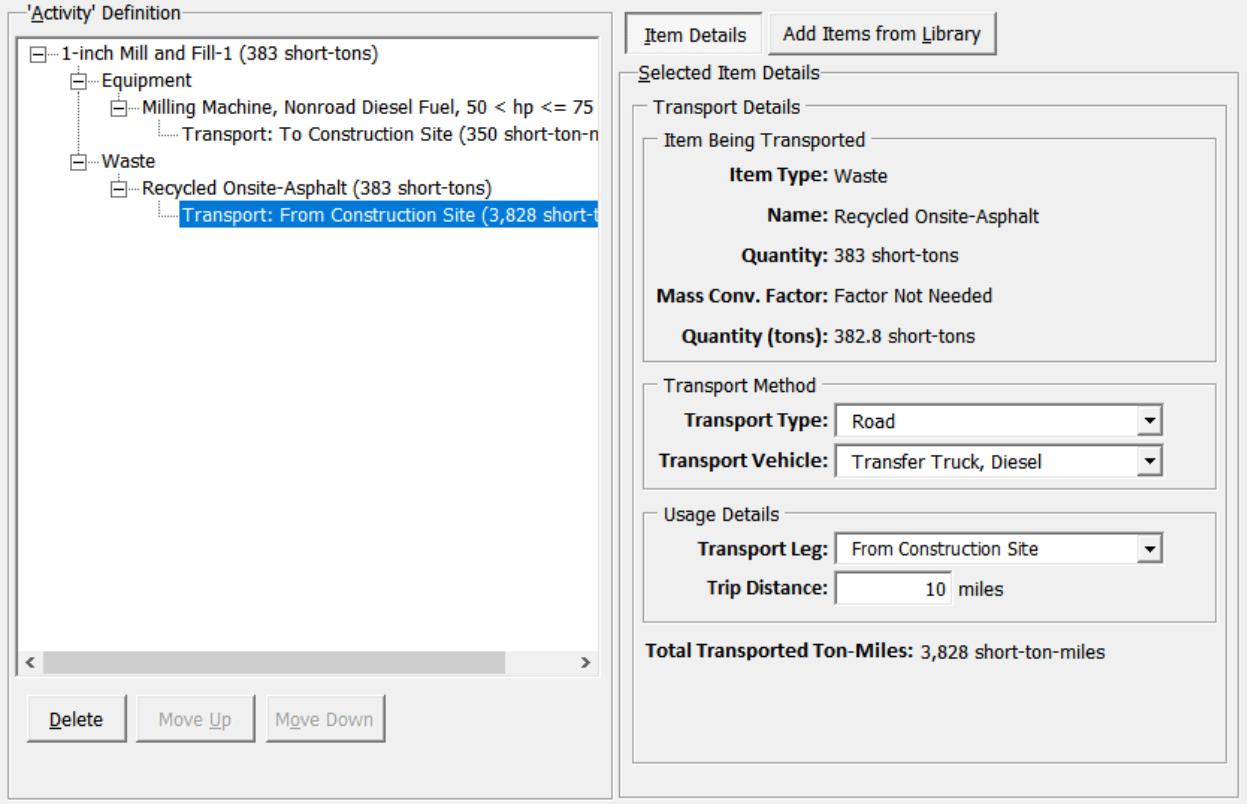


Figure 6-15. User interface showing the mill component modeled.

6.3.1.2 Model 1-inch Fill Component

- Click the “Add Items from Library” button.
- Click the “Mix Designs” library button.
- Select “Beta-HMA-1” from the “Asphalt” list in the Mix Design library and click the “Add to Activity” button.
- Select “Beta-HMA-1” in the “‘Activity’ Definition” treeview and update the quantity to 382.8 short tons.
- Click the “Add Items from Library” button.
- Click the “Equipment” library button.
- Select “Paver, Nonroad Diesel Fuel, 175 < hp <= 300” from the “Pavers” category in the Equipment library and click the “Add to Activity” button.

- Select paver item added in the "'Activity' Definition" treeview and update the quantity to 4 hours.
- Click the "Add Items from Library" button.
- Click the "Equipment" library button.
- Select "Pneumatic Roller, Nonroad Diesel Fuel, 100 < hp <= 175" from the "Rollers" category in the Equipment library and click the "Add to Activity" button.
- Select the roller item added in the "'Activity' Definition" treeview and update the quantity to 2 hours.
- Click the "Save" button.

Figure 6-16 shows a screen shot of the "Add New 'Activity' Library Item" dialog box after the modeled 1-inch fill component activity is complete.

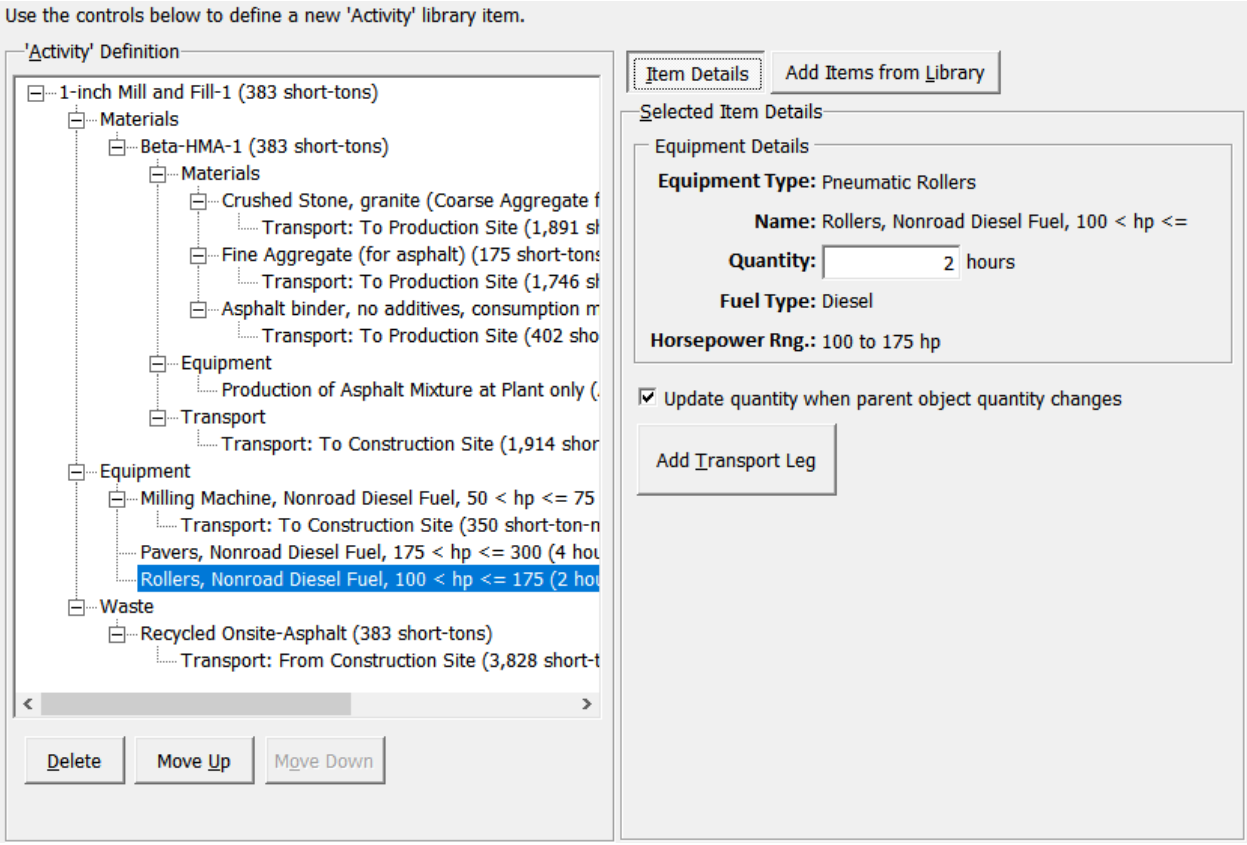


Figure 6-16. User interface showing the modeled 1-inch mill and fill activity.

- Use the same process shown in Sections 6.3.1.1 and 6.3.1.2 to model another 1-inch Mill and Fill activity using the asphalt mix: "Beta-HMA-2" and name that activity as "1-inch Mill and Fill-HMA-2."
- *HINT: Use the "Copy" and "Paste" features to expedite the process.*

6.3.2 Diamond Grinding

Example #7: Model 0.25-inch Concrete Pavement Diamond Grinding Activity

This example models a 0.25-inch diamond grinding activity (length = 5280 ft, width = 12 ft). All quantities used are assumed values or have been pre-calculated for the user.

- Launch the tool and click the "Library" button.
- Select the "Activities" library.
- Click the "Edit Activity Type List" button, select "Activity Category #5" from the list, and update that activity type name to "PCC Diamond Grinding."
- Click the "Save" button to close the "Category List Editor" dialog box.

6.3.2.1 Model 0.25-inch Diamond Grinding Activity

- In the "Activities" library, click the "Add New" button and enter the following details in the "Activity Details" frame on the right side of the dialog box:
  - Activity Type: PCC Diamond Grinding.
  - Name: "0.25-inch Diamond Grinding."
  - Measure Type: Area.
  - Quantity: 63,360 sq. ft.
- Click the "Add Items from Library" button.
- Click the "Equipment" library button.
- Select "equipment operation, >750 hp and < 1200 hp" from the "Generic Construction Equipment" list in the Equipment library and click the "Add to Activity" button.
- Select equipment item added in the "'Activity' Definition" treeview and update the quantity to 6 hours.
- Click the "Add Transport Leg" button to include details for mobilizing the milling equipment to the construction site. Set the details of the transport leg to the following:
  - Transport Type: Road.
  - Transport Vehicle: Combination Truck, Diesel.
  - Transport Leg: "To Construction Site."
  - Trip Distance: 11 miles.
- Click the "Add Items from Library" button.
- Click the "Waste" library button.
- Select "Landfill-Concrete" from the Waste library and click the "Add to Activity" button. Update the quantity of the newly added item to 95.7 short-tons.
- Click the "Add Transport Leg" button and set the details of the transport leg to the following:

  - Transport Type: Road.
  - Transport Vehicle: Combination Truck, Diesel.
  - Transport Leg: "From Construction Site."
  - Trip Distance: 20 miles.
- Click the "Save" button.

Figure 6-17 shows a screen shot of the "Add New 'Activity' Library Item" dialog box after the modeled diamond grinding activity is complete.

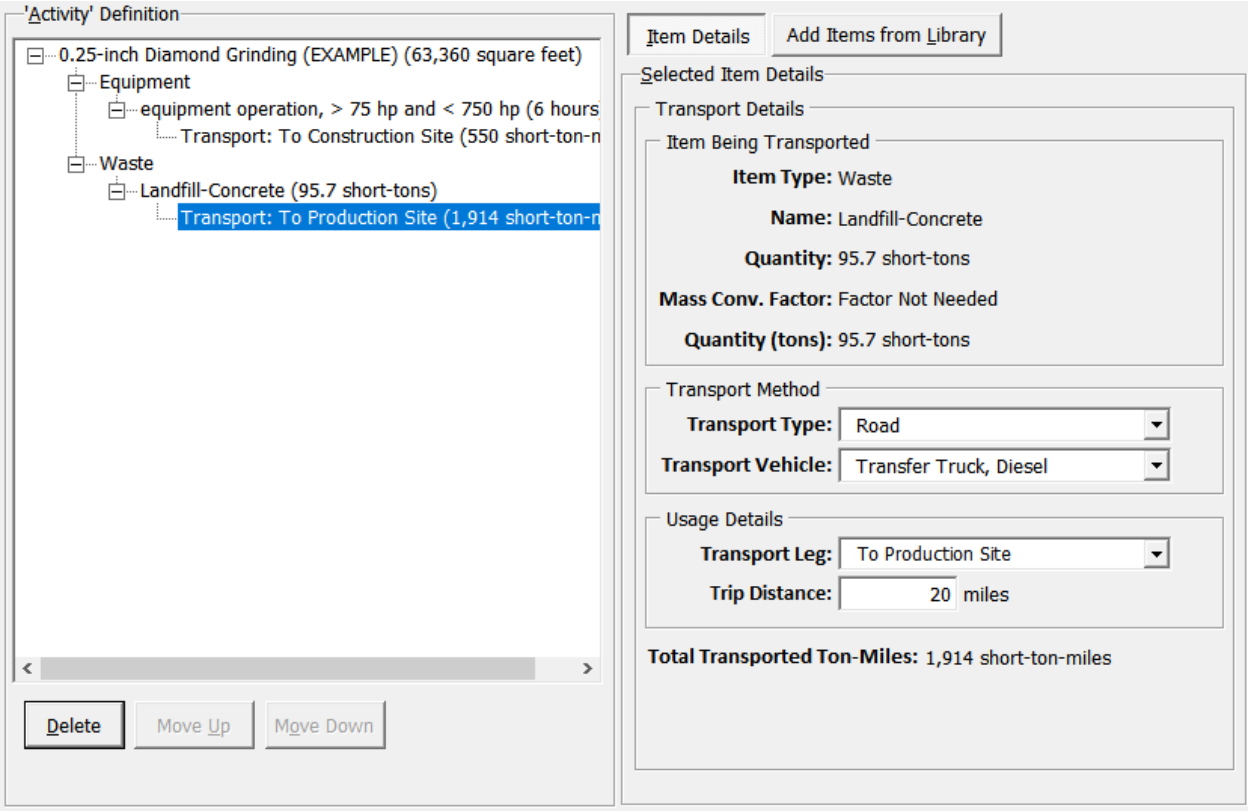


Figure 6-17. User interface showing the diamond grinding modeled.

6.3.3 Asphalt Pavement End-of-Life Activities

Example #8: Model Asphalt Pavement End-of-Life Activities

This example models two asphalt pavement end-of-life activities: (a) demolition and landfilling, and (b) demolition and on-site recycling. All quantities used in the examples are assumed values or have been pre-calculated for the user.

- Launch the tool and click the "Library" button.
- Select the "Activities" library.

- Click the "Edit Activity Type List" button, select "Activity Category #6" from the list, and update that activity type name to "HMA End-of-Life."
- Click the "Save" button to close the "Category List Editor" dialog box.

6.3.3.1 Model Pavement Demolition and Landfilling Activity

- In the "Activities" library, click the "Add New" button and enter the following details in the "Activity Details" frame on the right side of the dialog box:
  - Activity Type: HMA End-of-Life.
  - Activity Name: "Demolish 4-inch HMA-Landfill."
  - Measure Type: Mass.
  - Quantity: 1531.2 short-tons.
- Click the "Add Items from Library" button.
- Click the "Equipment" library button.
- Select "equipment operation, >750 hp and < 1200 hp" from the "Generic Construction Equipment" list in the Equipment library and click the "Add to Activity" button (the generic construction equipment is used for the demolition activity).
- Select equipment item added in the "'Activity' Definition" treeview and update the quantity to 8 hours.
- Click the "Add Transport Leg" button to include details for mobilizing the demolition equipment to the construction site. Set the details of the transport leg to the following:
  - Transport Type: Road.
  - Transport Vehicle: Combination Truck, Diesel.
  - Transport Leg: "To Construction Site."
  - Trip Distance: 15 miles.
- Click the "Add Items from Library" button.
- Click the "Waste" library button.
- Select "Landfill-Asphalt" from the Waste library and click the "Add to Activity" button. Update the quantity of the newly added item to 1531.2 short-tons.
- Click the "Add Transport Leg" button and set the details of the transport leg to the following:
  - Transport Type: Road.
  - Transport Vehicle: Transfer Truck, Diesel.
  - Transport Leg: "From Construction Site."
  - Trip Distance: 20 miles.
- Click the "Save" button.

Figure 6-18 shows a screen shot of the "Add New 'Activity' Library Item" dialog box after the modeled pavement demolition and landfilling activity is complete.

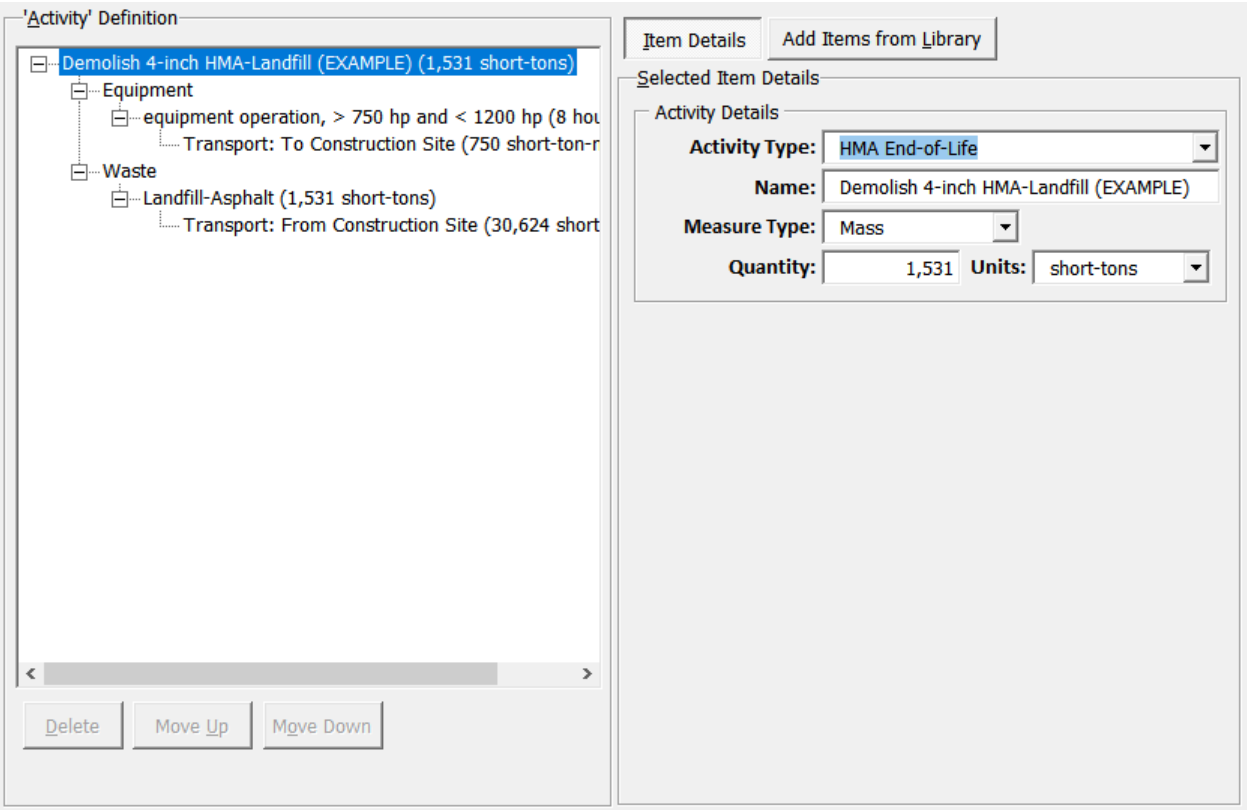


Figure 6-18. User interface showing the modeled asphalt pavement demolition and landfilling activity.

6.3.3.2 Model Pavement Demolition and Onsite Recycling Activity

- Follow the same steps as shown under Section 6.3.3.1 to model a pavement demolition and onsite recycling activity named "Demolish 4-inch HMA-Recycle Onsite." Instead of selecting "Landfill-Asphalt" from the "Waste" library (as shown under Section 6.3.3.1), select "Recycled Onsite-Asphalt" and use the following Transport details:
  - Transport Type: Road.
  - Transport Vehicle: Transfer Truck, Diesel.
  - Transport Leg: "From Construction Site."
  - Trip Distance: 10 miles.

Figure 6-19 shows a screen shot of the "Add New 'Activity' Library Item" dialog box after the modeled pavement demolition and on-site recycling activity is complete.

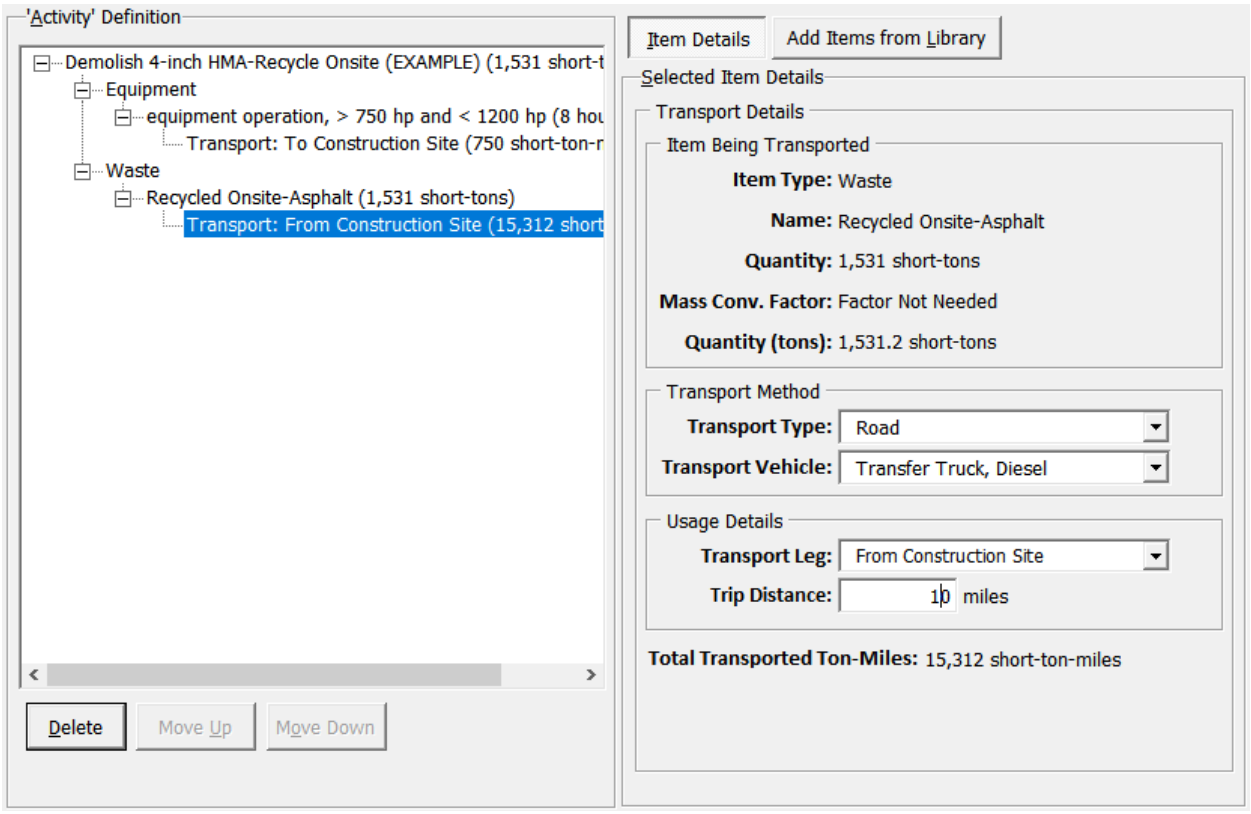


Figure 6-19. User interface showing the modeled asphalt pavement demolition and on-site recycling activity.

6.3.4 Concrete Pavement End-of-Life Activities

Example #9: Model Concrete Pavement End-of-Life Activities

This example models demolition and landfilling, and demolition and on-site recycling. All quantities used in the examples are assumed values or have been pre-calculated for the user.

- Launch the tool and click the "Library" button.
- Select the "Activities" library.
- Click the "Edit Activity Type List" button, select "Activity Category #7" from the list, and update that activity type name to "PCC End-of-Life."
- Click the "Save" button to close the "Category List Editor" dialog box.

6.3.4.1 Model Pavement Demolition and Landfilling Activity

- In the "Activities" library, click the "Add New" button and enter the following details in the "Activity Details" frame on the right side of the dialog box:
  - Activity Type: PCC End-of-Life.
  - Activity Name: "Demolish 8-inch PCC-Landfill."
  - Measure Type: Mass.

  - Quantity: 3062.4 short-tons.
- Click the "Add Items from Library" button.
- Click the "Equipment" library button.
- Select "equipment operation, >750 hp and < 1200 hp" from the "Generic Construction Equipment" list in the Equipment library and click the "Add to Activity" button.
- Select equipment item added in the "'Activity' Definition" treeview and update the quantity to 12 hours.
- Click the "Add Transport Leg" button to include details for mobilizing the guillotine equipment to the construction site. Set the details of the transport leg to the following:
  - Transport Type: Road.
  - Transport Vehicle: Combination Truck, Diesel.
  - Transport Leg: "To Construction Site."
  - Trip Distance: 15 miles.
- Click the "Add Items from Library" button.
- Click the "Waste" library button.
- Select "Landfill-Concrete" from the Waste library and click the "Add to Activity" button. Update the quantity of the newly added item to 3062.4 short-tons.
- Click the "Add Transport Leg" button and set the details of the transport leg to the following:
  - Transport Type: Road.
  - Transport Vehicle: Transfer Truck, Diesel.
  - Transport Leg: "From Construction Site."
  - Trip Distance: 20 miles.
- Click the "Add Items from Library" button.
- Click the "Waste" library button.
- Select "Recycled-Offsite-Steel" from the "Recycled Offsite" category in the Waste library and click the "Add to Activity" button. Update the quantity of the newly added item to 17.5 short-tons.
- Click the "Add Transport Leg" button and set the details of the transport leg to the following:
  - Transport Type: Road.
  - Transport Vehicle: Transfer Truck, Diesel.
  - Transport Leg: "From Construction Site'.
  - Trip Distance: 88 miles.
- Click the "Save" button.

Figure 6-20 shows a screen shot of the "Add New 'Activity' Library Item" dialog box after the modeled concrete pavement demolition and landfilling activity is complete.

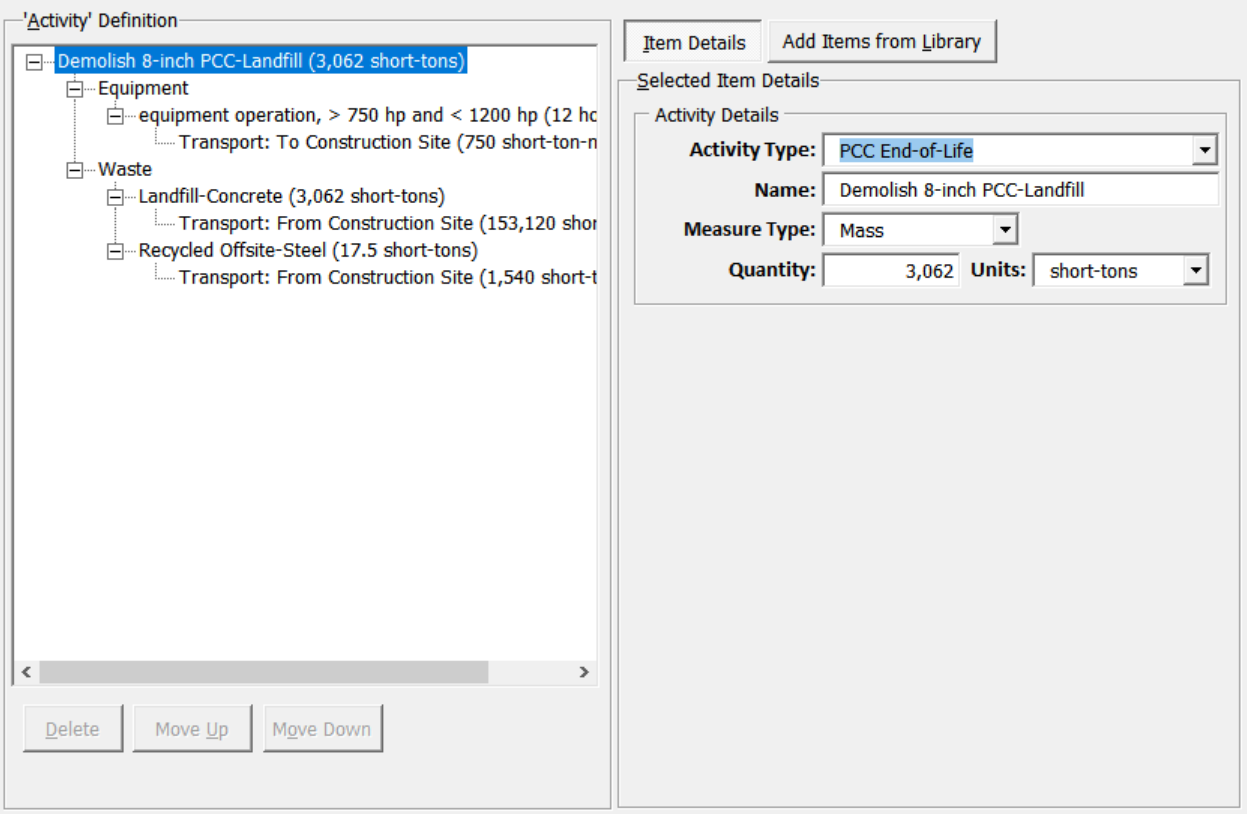


Figure 6-20. User interface showing the modeled concrete pavement demolition and landfilling activity.

6.3.3.2 Model Pavement Demolition and On-Site Recycling Activity

- Follow the same steps as shown under Section 6.3.4.1 to model a pavement demolition and onsite recycling activity named "Demolish 4-inch PCC-Recycle Onsite." Instead of selecting "Landfill-Concrete" from the "Waste" library (as shown under Section 6.3.4.1), select "Recycled Onsite-Concrete" and use the following Transport details:
  - Transport Type: Road.
  - Transport Vehicle: Transfer Truck, Diesel.
  - Transport Leg: "From Construction Site."
  - Trip Distance: 10 miles.

Figure 6-21 shows a screen shot of the "Add New 'Activity' Library Item" dialog box after the modeled pavement demolition and on-site recycling activity is complete.

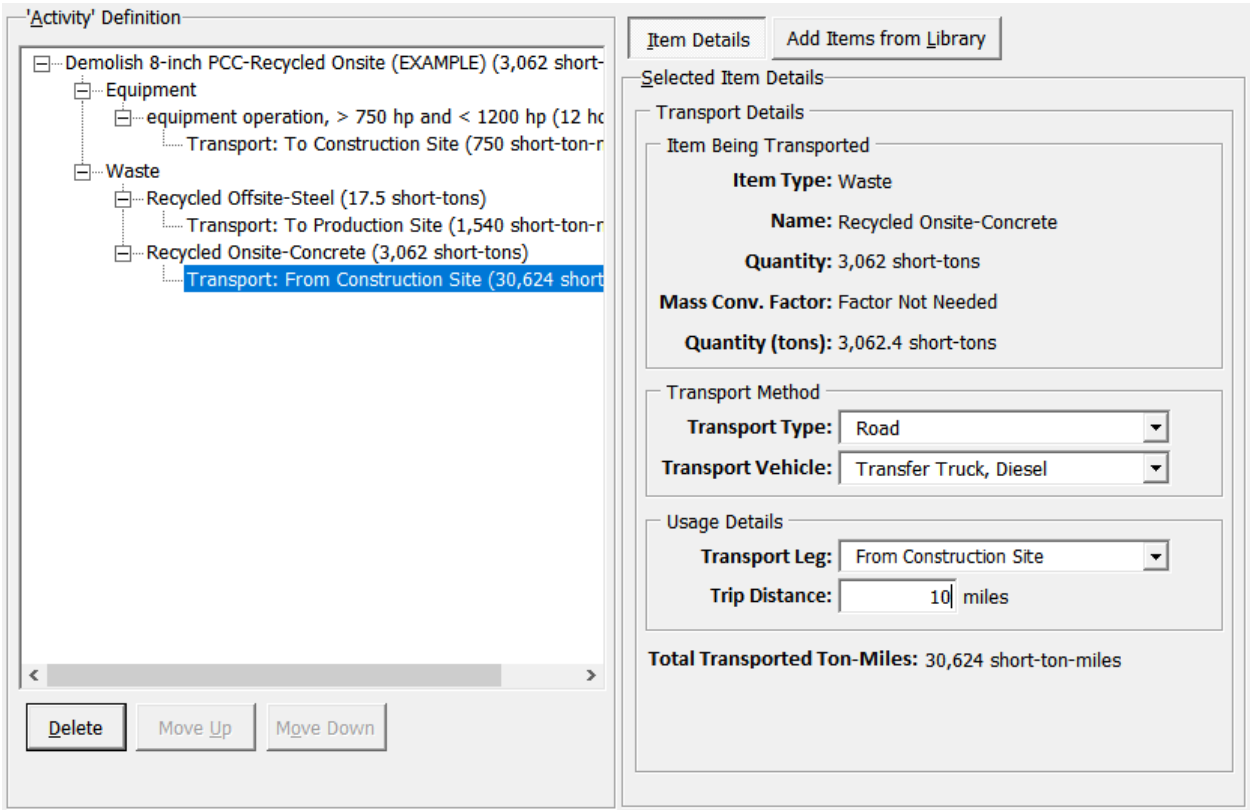


Figure 6-21. User interface showing the modeled pavement demolition and on-site recycling activity.

TIP

Before proceeding to the next section, the user should:

- Save the file and exit the tool.
- Copy file and save two additional versions—one to model the asphalt pavement example and the other for the concrete pavement example.

6.4 MODELING PAVEMENT LIFE CYCLES

This section presents examples on how the user can model asphalt and concrete pavement life cycles and compare results of the analysis.

6.4.1 Model Asphalt Pavement Life Cycles

Example #10: Model Asphalt Pavement Lifecycles

This example models two pavement design life-cycle alternatives:

Alternative #1	Alternative #2
• Asphalt Mix Design: Beta-HMA-1	• Asphalt Mix Design: Beta-HMA-2
• Analysis Period: 25 years	• Analysis Period: 25 years
• Pavement Life-Cycle Activities: o Year 0: 4-inch HMA over 6-inch aggregate base o Year 10: 1-inch mill and fill o Year 18: 1-inch mill and fill o Year 25: Demolish and Landfill	• Pavement Life-Cycle Activities: o Year 0: 4-inch HMA over 6-inch aggregate base o Year 10: 1-inch mill and fill o Year 18: 1-inch mill and fill o Year 25: Demolish and Recycle On-Site

6.4.1.1 Input General Analysis Details

- Launch the tool and click the "Conduct Analysis" button on the home page *(use the file saved for asphalt pavement analysis).*
- In the "Analysis Session Details" dialog box that pops up, input the following details (see figure 6-22):
  - **Analysis Objective**: "Compare Treatment Cycles or Pavement Design Life-Cycle Options."
  - **Session Name:** Enter a name for the analysis session.
  - **Route:** Input route details.
  - **Location:** Input location info.
  - **Beginning MP:** Input beginning mile point for route being analyzed.
  - **End MP:** Input end mile point for route being analyzed.
  - **Analyzed By:** Input name of person conducting the analysis.
  - **Comments:** Add any comments regarding the analysis being conducted.
  - **Number of Design Alternatives:** Select number of design alternatives being compared (for this example, select 2).
- Click the "Next" button to advance to the "Design Alternative Definition" dialog box.

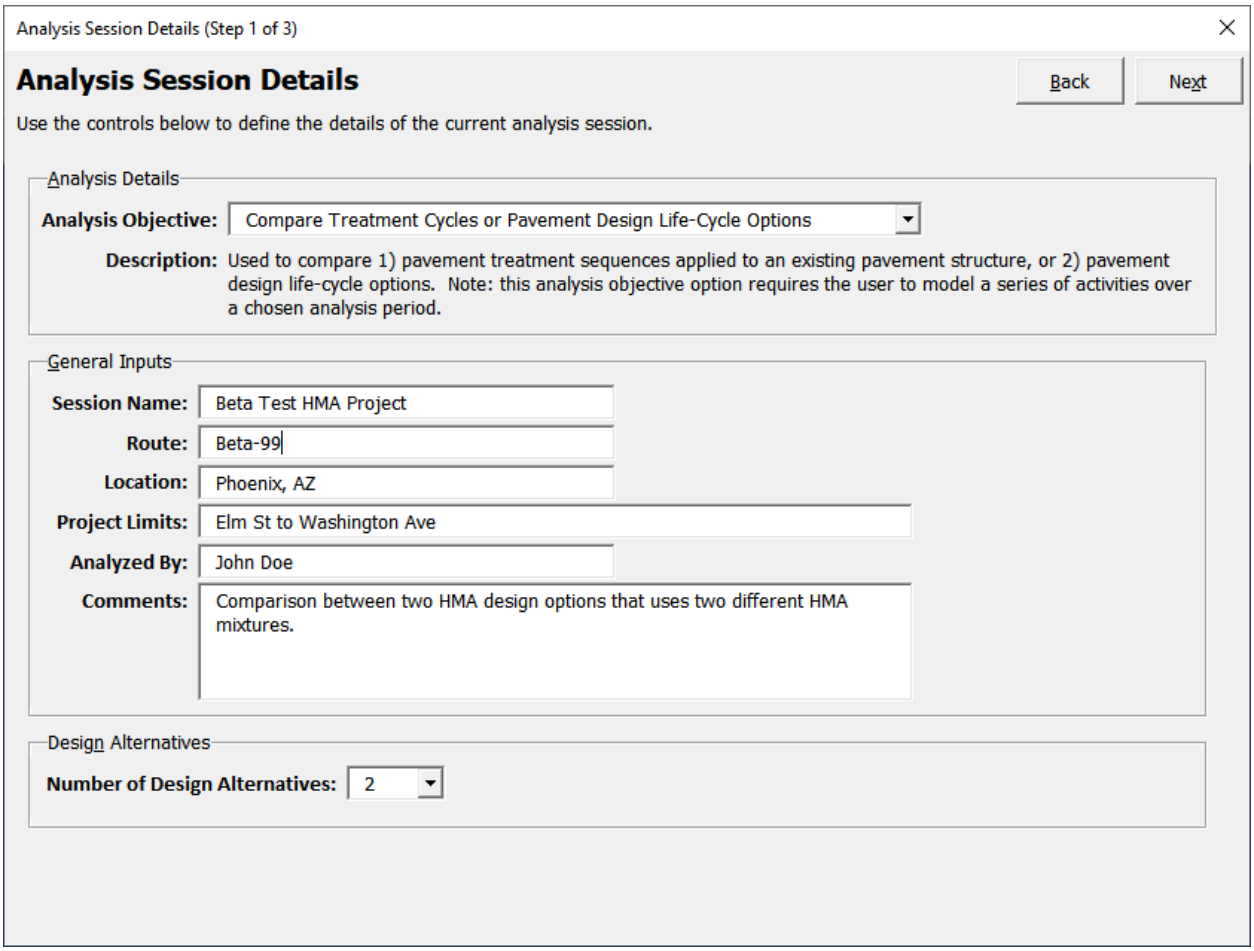


Figure 6-22. Analysis session details (asphalt pavement example).

6.4.1.2 Design Alternative #1 Definition

- Click the "Alternative 1" button.
- Input the following details in the "Section Details: 'Alternative'" frame (see figure 6-23):
  - **Name:** "HMA Design 1."
  - **Description:** "Design Using Beta-HMA-1, Landfilling at EOL."
  - **Analysis Period:** 25 years.

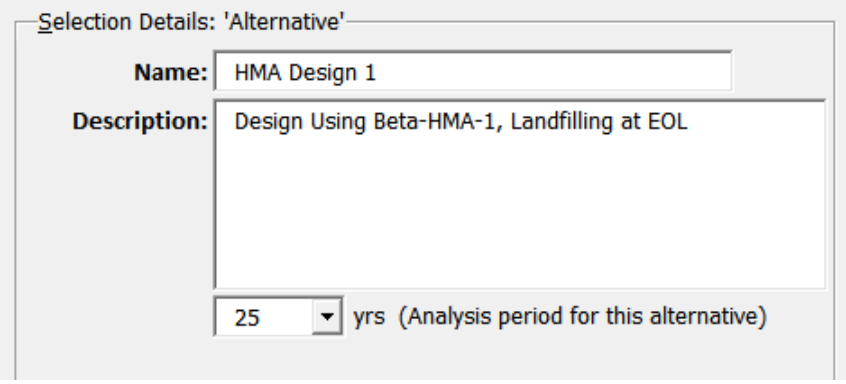


Figure 6-23. Alternative #1 general details (asphalt pavement example).

- With the alternative node selected in the "Alternative Definition" treeview, click the "Add New 'Pavement' to Current 'Alternative'" button and update the following input fields in the "Selection Details: 'Pavement'" frame (see figure 6-24):
  - **Type:** Mainline.
  - **Name:** "New Pavement."
  - **Number of Lanes:** 1.
  - **Length:** 5280 ft.
  - **Width:** 12 ft.
  - Check the "Include this pavement's lane-miles and area in the functional unit calculations for this alternative" checkbox.

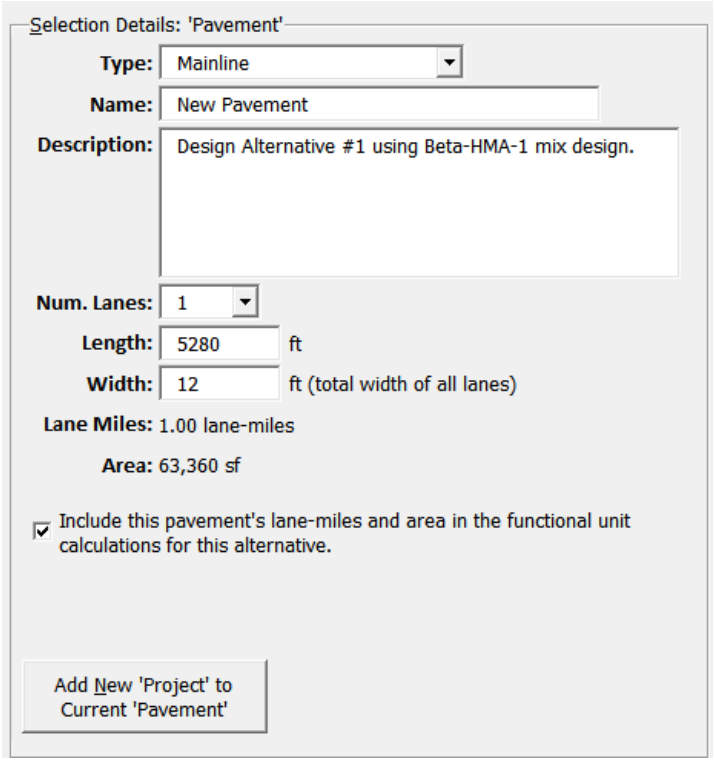


Figure 6-24. Alternative #1 pavement details (asphalt pavement example).

- Select the newly created "New Pavement" node in the "Alternative Definition" treeview and click the "Add New 'Project' to Current 'Pavement'" button. With the newly added project item selected, input the following details in the "Selection Details: 'Project'" frame:
  - **Type:** Initial Construction.
  - **Application Age:** 0.
- Select "0: Initial Construction" in the "Alternative Definition" treeview and click the "Import 'Activity' from Library" button.
- Select "6-inch Aggregate Base" from the "Layers" category of the "Activity" library and click the "Add to Project" button.
- Select "0: Initial Construction" in the "Alternative Definition" treeview and click the "Import 'Activity' from Library" button.
- Select "4-inch HMA Layer-HMA-1" from the "Layers" category of the "Activity" library and click the "Add to Project" button.
- Select "New Pavement" in the "Alternative Definition" treeview and click the "Add New 'Project' to Current Pavement" button.
- With the newly created project node selected in the "Alternative Definition" treeview, input the following details in the "Selection Details: 'Project'" frame:
  - **Type:** Maintenance and Preservation.
  - **Application Age:** 10.
- Select "10: Maintenance and Preservation" in the "Alternative Definition" treeview and click the "Import 'Activity' from Library" button.
- Select "1-inch Mill and Fill-HMA-1" from the "HMA Mill and Inlay" category of the "Activity" library and click the "Add to Project" button.
- Repeat the same step as above to add a "1-inch mill and Fill-HMA-1" to year 18.
  - *HINT: Use "Copy" and "Paste" feature to expedite the process.*
- Select "New Pavement" in the "Alternative Definition" treeview and click the "Add New 'Project' to Current 'Pavement'" button.
- With the newly created project node selected in the "Alternative Definition" treeview, input the following details in the "Selection Details: 'Project'" frame:
  - **Type:** Removal.
  - **Application Age:** 25.
- Select "25: Removal" in the "Alternative Definition" treeview and click on the "Import 'Activity' from Library" button.
- Select "Demolish 4-inch HMA-Landfill" from the "HMA End-of-Life" category of the "Activity" library and click the "Add to Project" button.

Figure 6-25 shows Alternative #1 modeled using the details specified above.

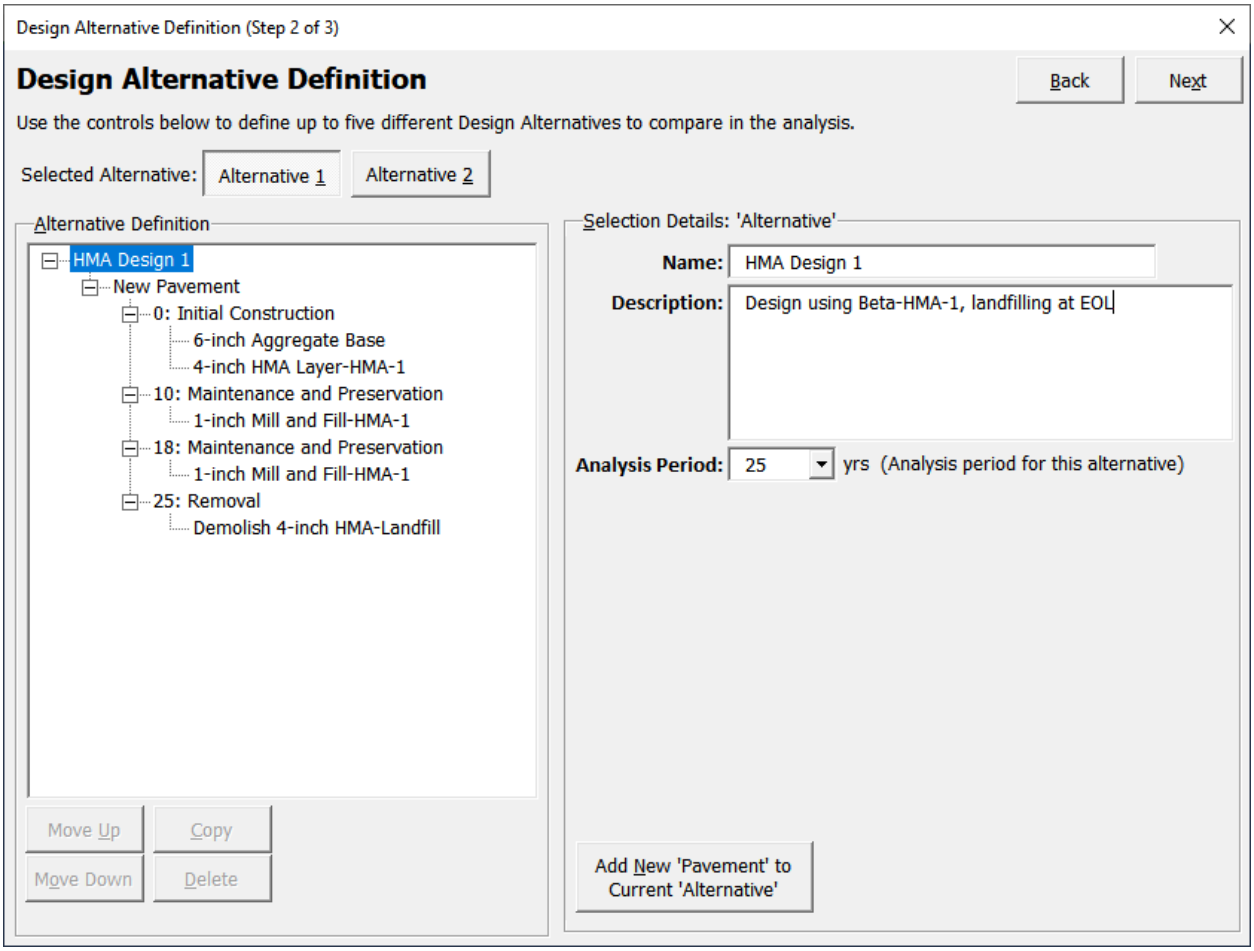


Figure 6-25. Pavement life cycle modeled for Alternative #1 (asphalt pavement example).

6.4.1.3 Design Alternative #2 Definition

Use the same process described under Section 6.4.1.2 to set Alternative #2 with the following differences:

- For Initial Construction, use "4-inch HMA Layer-HMA-2" from the activities library (see Section 6.2.1).
- For the Maintenance and Preservation stages, use "1-inch Mill and Fill-HMA-2" from the activities library (see Section 6.3.1).
- For Removal, use "Demolish 4-inch HMA-Recycle Onsite" from the activities library (see Section 6.3.3).
- *HINT: The entire tree structure from Alternative #1 can be copied and pasted into Alternative #2 and then the changes noted above can be made.*

Figure 6-26 shows Alternative #2 modeled using the details specified above.

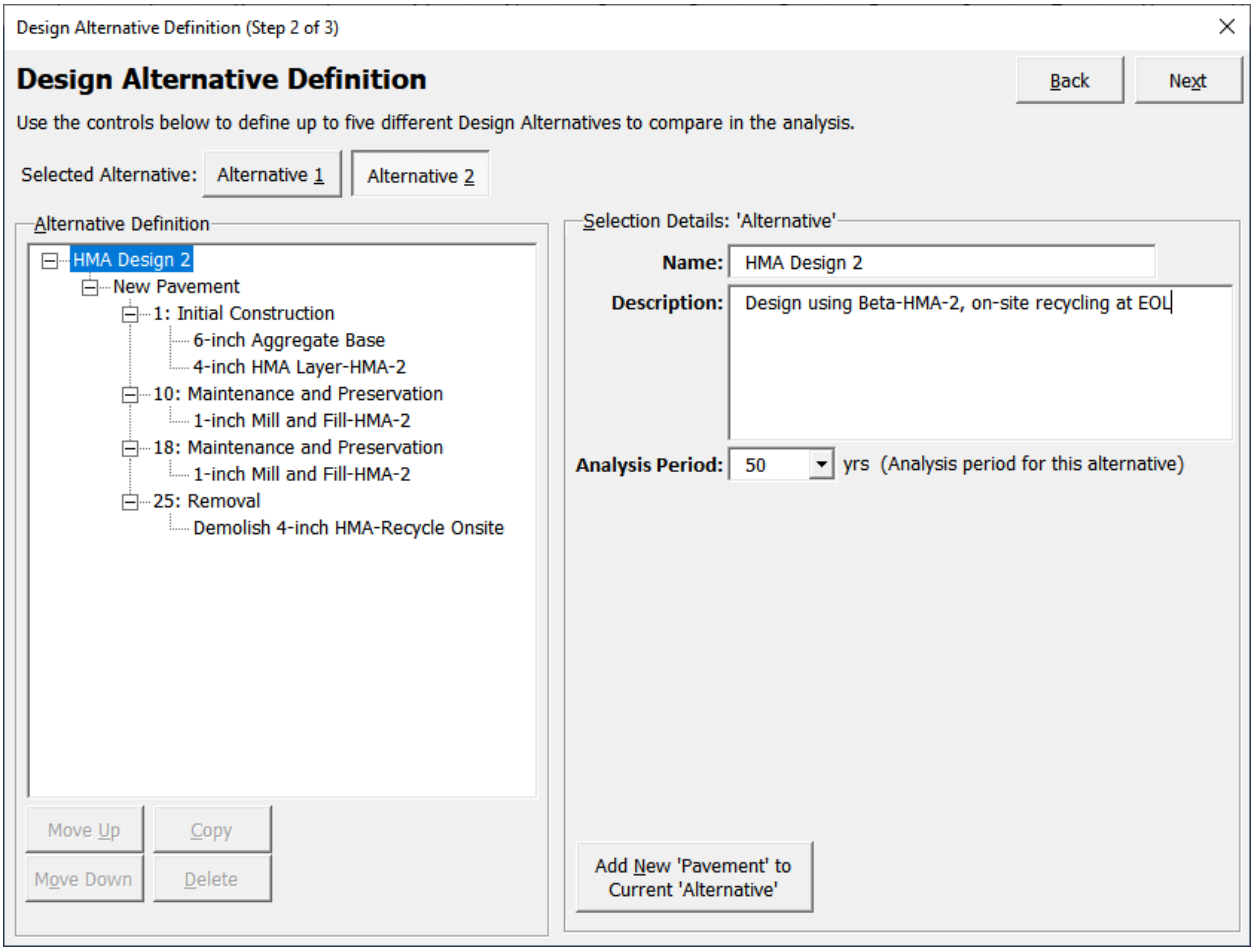


Figure 6-26. Pavement life cycle modeled for Alternative #1 (asphalt pavement example).

6.4.2 Model Concrete Pavement Life Cycles

Example #11: Model Concrete Pavement Life-Cycles

This example models two pavement design life-cycle alternatives:

Alternative #1	Alternative #2
• Asphalt Mix Design: Beta-PCC-1	• Asphalt Mix Design: Beta-PCC-2
• Analysis Period: 35 years	• Analysis Period: 35 years
• Pavement Life-Cycle Activities: ○ Year 0: 8-inch PCC over 6-inch aggregate base ○ Year 20: 0.25-inch Diamond Grinding ○ Year 35: Demolish and Landfill	• Pavement Life-Cycle Activities: ○ Year 0: 8-inch PCC over 6-inch aggregate base ○ Year 20: 0.25-inch Diamond Grinding ○ Year 35: Demolish and Landfill

6.4.2.1 Input General Analysis Details

- Launch the tool and click the "Conduct Analysis" button on the home page *(use the file saved for concrete pavement analysis)*.
- In the "Analysis Session Details" dialog box that pops up, input the following details (see figure 6-27):
  - **Analysis Objective:** "Compare Treatment Cycles or Pavement Design Life-Cycle Options."
  - **Session Name:** Enter a name for the analysis session.
  - **Route:** Input route details.
  - **Location:** Input location info.
  - **Beginning MP:** Input beginning mile point for route being analyzed.
  - **End MP:** Input end mile point for route being analyzed.
  - **Analyzed By:** Input name of person conducting the analysis.
  - **Comments:** Add any comments regarding the analysis being conducted.
  - **Number of Design Alternatives:** Select number of design alternatives being compared (for this example, select 2).
- Click the "Next" button to advance to the "Design Alternative Definition" dialog box.

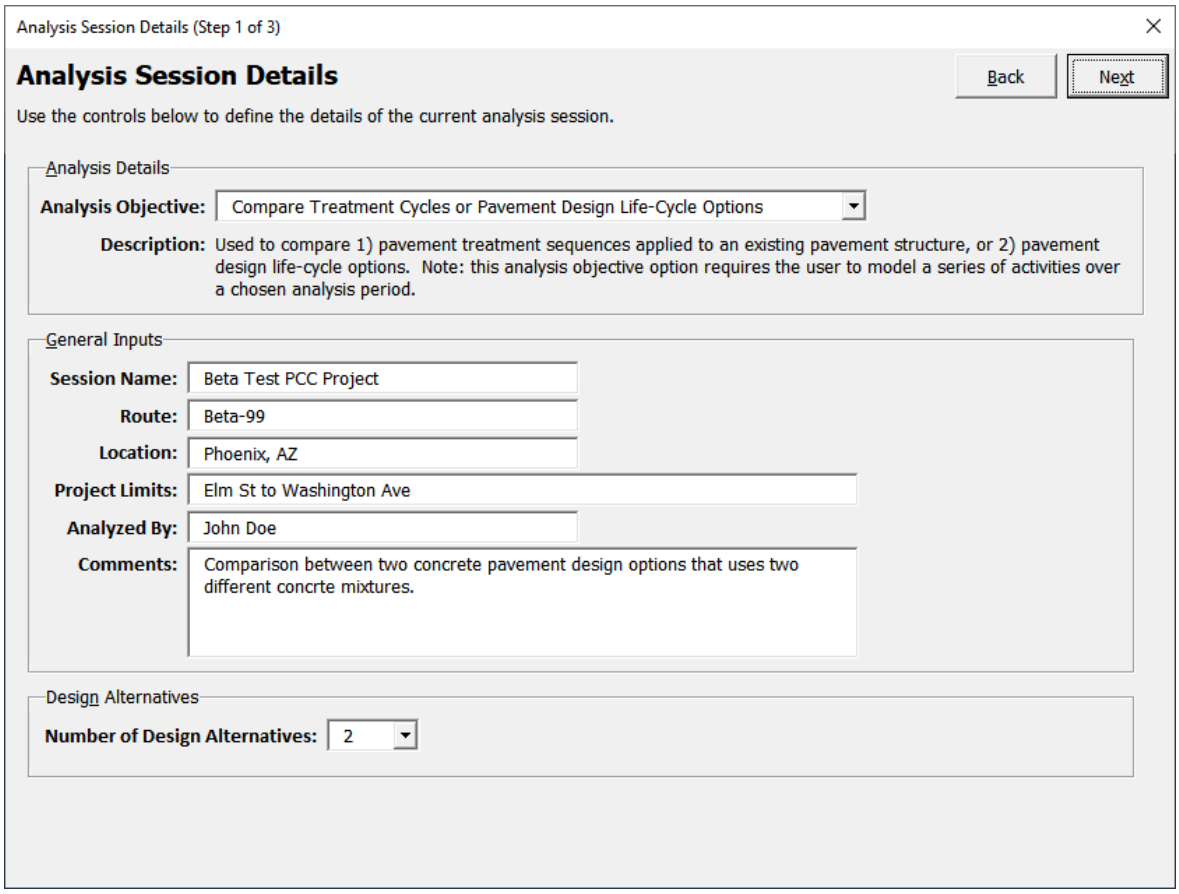


Figure 6-27. Analysis session details (concrete pavement example).

6.4.2.2 Design Alternative #1 Definition

- Click the "Alternative 1" button.
- Input the following details in the "Section Details: 'Alternative'" frame (see figure 6-28):
  - **Name:** "PCC Design 1."
  - **Description:** "Design Using Beta-PCC-1, Landfilling at EOL."
  - **Service Life:** 35 years.

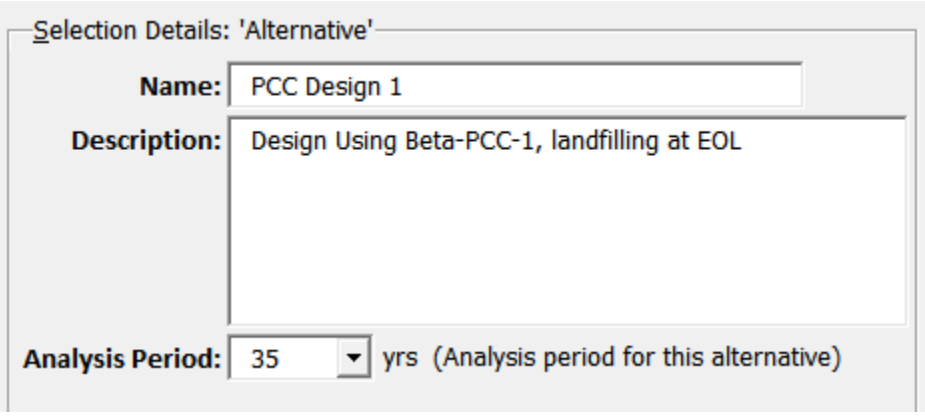


Figure 6-28. Alternative #1 general details (concrete pavement example).

- With the alternative node selected in the "Alternative Definition" treeview, click the "Add New 'Pavement' to Current 'Alternative'" button and update the following input fields in the "Selection Details: 'Pavement'" frame (see figure 6-29):
  - **Type:** Mainline.
  - **Name:** "New Pavement."
  - **Number of Lanes:** 1.
  - **Length:** 5280 ft.
  - **Width:** 12 ft.
  - Check the "Include this pavement's lane-miles and area in the functional unit calculations for this alternative" checkbox.

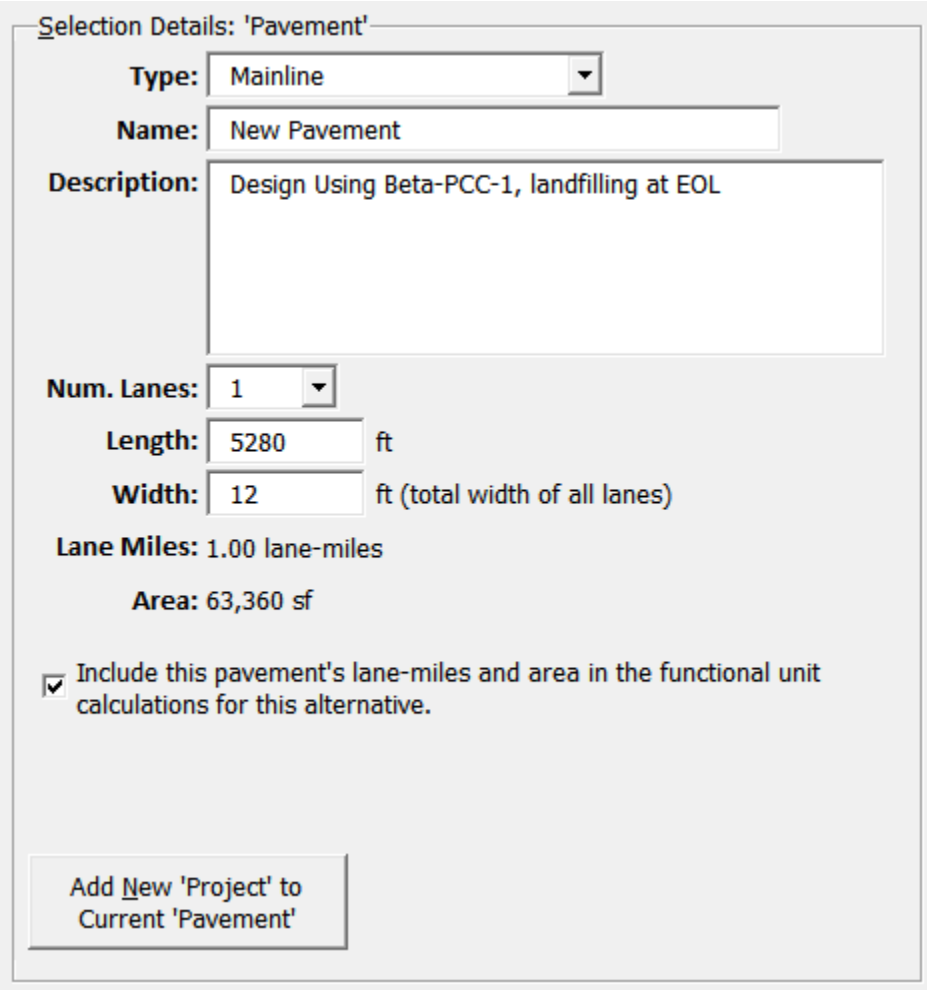


Figure 6-29. Alternative #1 pavement details (concrete pavement example).

- Select the newly created "New Pavement" node in the "Alternative Definition" treeview and click the "Add New 'Project' to Current 'Pavement'" button. With the newly added project item selected, input the following details in the "Selection Details: 'Project'" frame:
  - **Type:** Initial Construction.
  - **Application Age:** 0.
- Select "0: Initial Construction" in the "Alternative Definition" treeview and click the "Import 'Activity' from Library" button.
- Select "6-inch Aggregate Base" from the "Layers" category of the "Activity" library and click the "Add to Project" button.
- Select "0: Initial Construction" in the "Alternative Definition" treeview and click the "Import 'Activity' from Library" button.
- Select "8-inch PCC Layer-PCC-1" from the "Layers" category of the "Activity" library and click the "Add to Project" button.
- Select "New Pavement" in the "Alternative Definition" treeview and click the "Add New 'Project' to Current Pavement" button.

- With the newly created project node selected in the "Alternative Definition" treeview, input the following details in the "Selection Details: 'Project'" frame:
  - **Type:** Maintenance and Preservation.
  - **Application Age:** 20.
- Select "20: Maintenance and Preservation" in the "Alternative Definition" treeview and click the "Import 'Activity' from Library" button.
- Select "0.25-inch Diamond Grinding" from the "Diamond Grinding" category of the "Activity" library and click the "Add to Project" button.
- Select "New Pavement" in the "Alternative Definition" treeview and click the "Add New 'Project' to Current 'Pavement'" button.
- With the newly created project node selected in the "Alternative Definition" treeview, input the following details in the "Selection Details: 'Project'" frame:
  - **Type:** Removal.
  - **Application Age:** 35.
- Select "35: Removal" in the "Alternative Definition" treeview and click on the "Import 'Activity' from Library" button.
- Select "Demolish 8-inch PCC-Landfill" from the "PCC End-of-Life" category of the "Activity" library and click the "Add to Project" button.

Figure 6-30 shows Alternative #1 modeled using the details specified above.

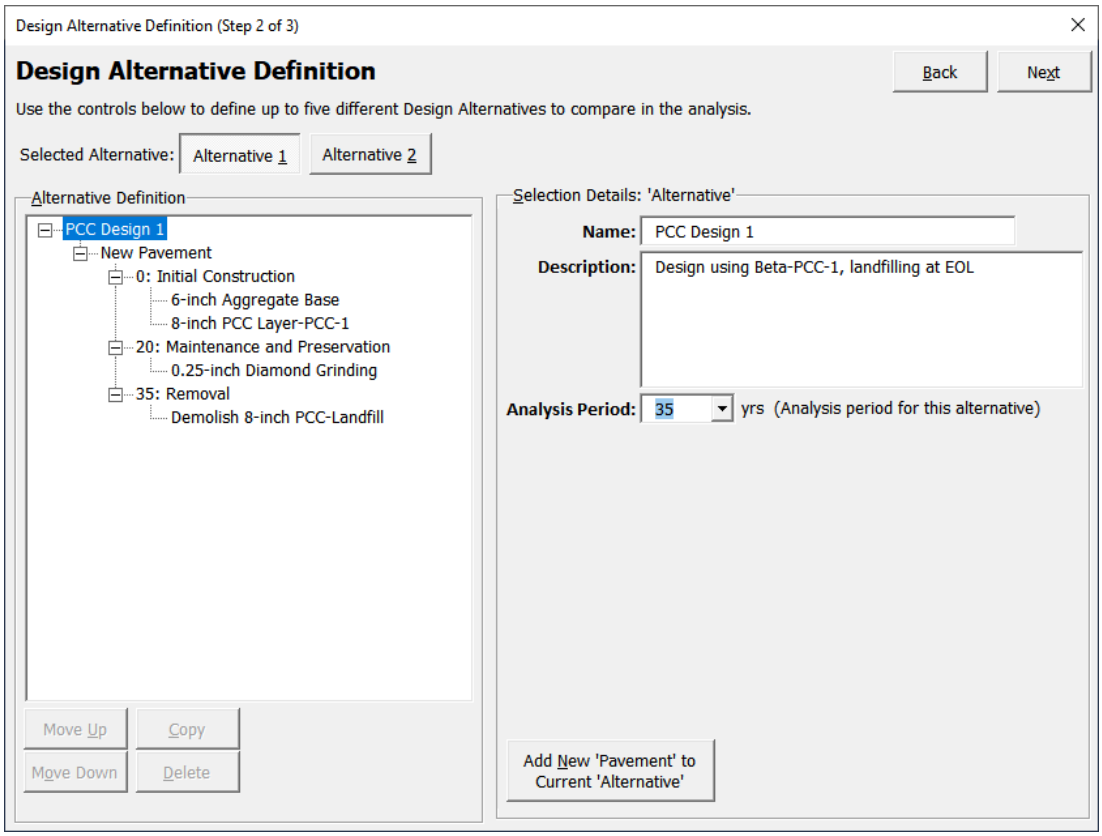


Figure 6-30. Pavement life cycle modeled for Alternative #1 (concrete pavement example).

6.4.2.3 Design Alternative #2 Definition

- Use the same process described under Section 6.4.2.2 to model Alternative #2 with the following differences:
  - For Initial Construction, Use "8-inch PCC Layer-PCC-2" from the activities library (see section 6.2.2).
  - For Removal, use "Demolish 8-inch PCC-Recycled Onsite" from the activities library (see section 6.3.4).
- *HINT: The entire tree structure from Alternative #1 can be copied and pasted into Alternative #2, and then make the changes as noted in the previous bullet.*

Figure 6-31 shows Alternative #1 modeled using the details specified above.

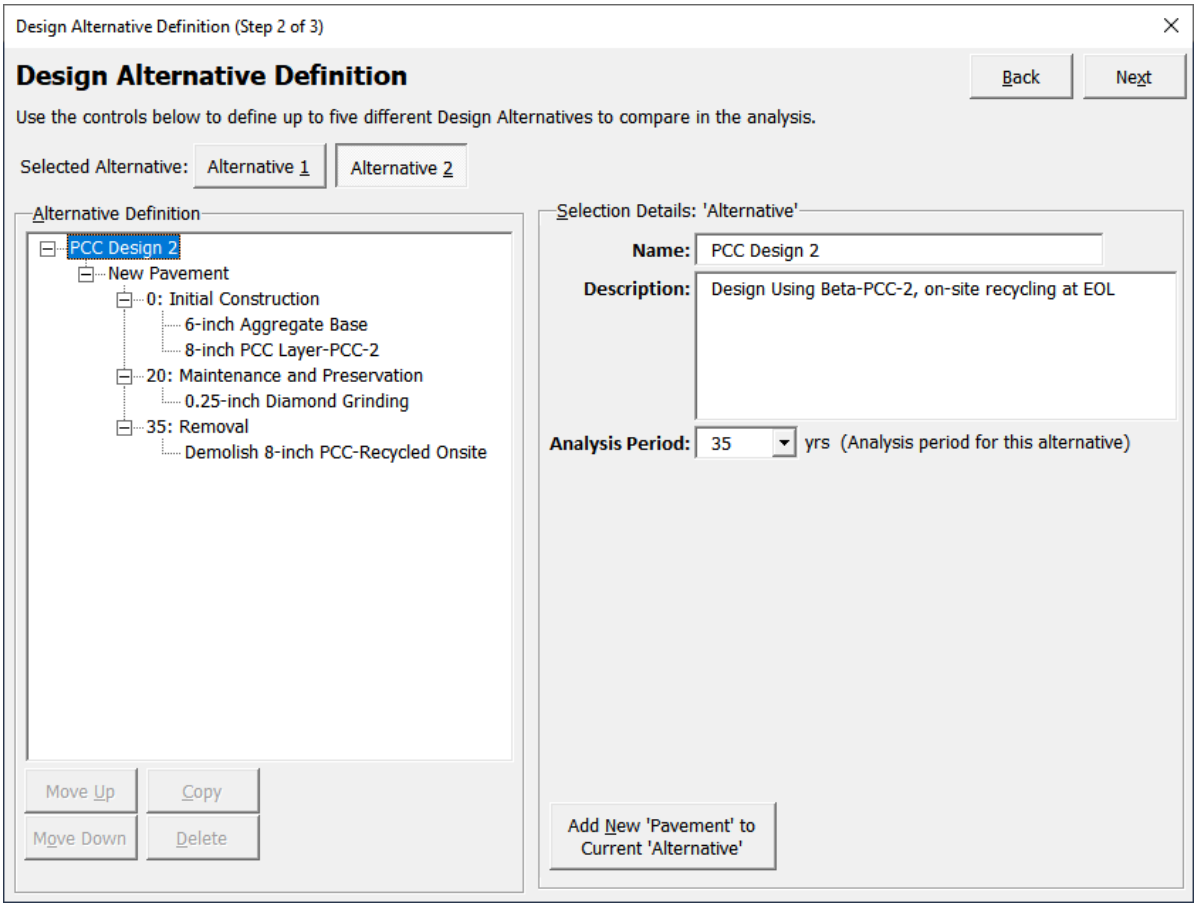


Figure 6-31. Pavement life cycle modeled for Alternative #2 (concrete pavement example).

6.5 VIEWING RESULTS

This section presents example results from an analysis that compares two design alternatives. It also provides a brief discussion on how those results can be used in the interpretation process. The example outputs discussed in this section are not exhaustive but are intended to provide a general idea as to how the results from the analysis can be used in the interpretation process. Details on how to evaluate LCA results are available in the *Methodology and Assumptions Report* (Meijer et al. 2021) and in FHWA's *LCA Framework Document* (Harvey et al. 2016).

Once the design alternatives have been modeled, the next step is to view and evaluate results. Select the functional unit desired (see Section 5.3 for details) and the list of impact indicators for which the results are to be generated. To view the detailed outputs, click on the "View Detailed Output" button available in the top right corner of the Results dialog box (see figure 6-32). Once this button is clicked, the tool generates several Excel worksheets that contain output tables and charts (discussed earlier under Section 5.3).

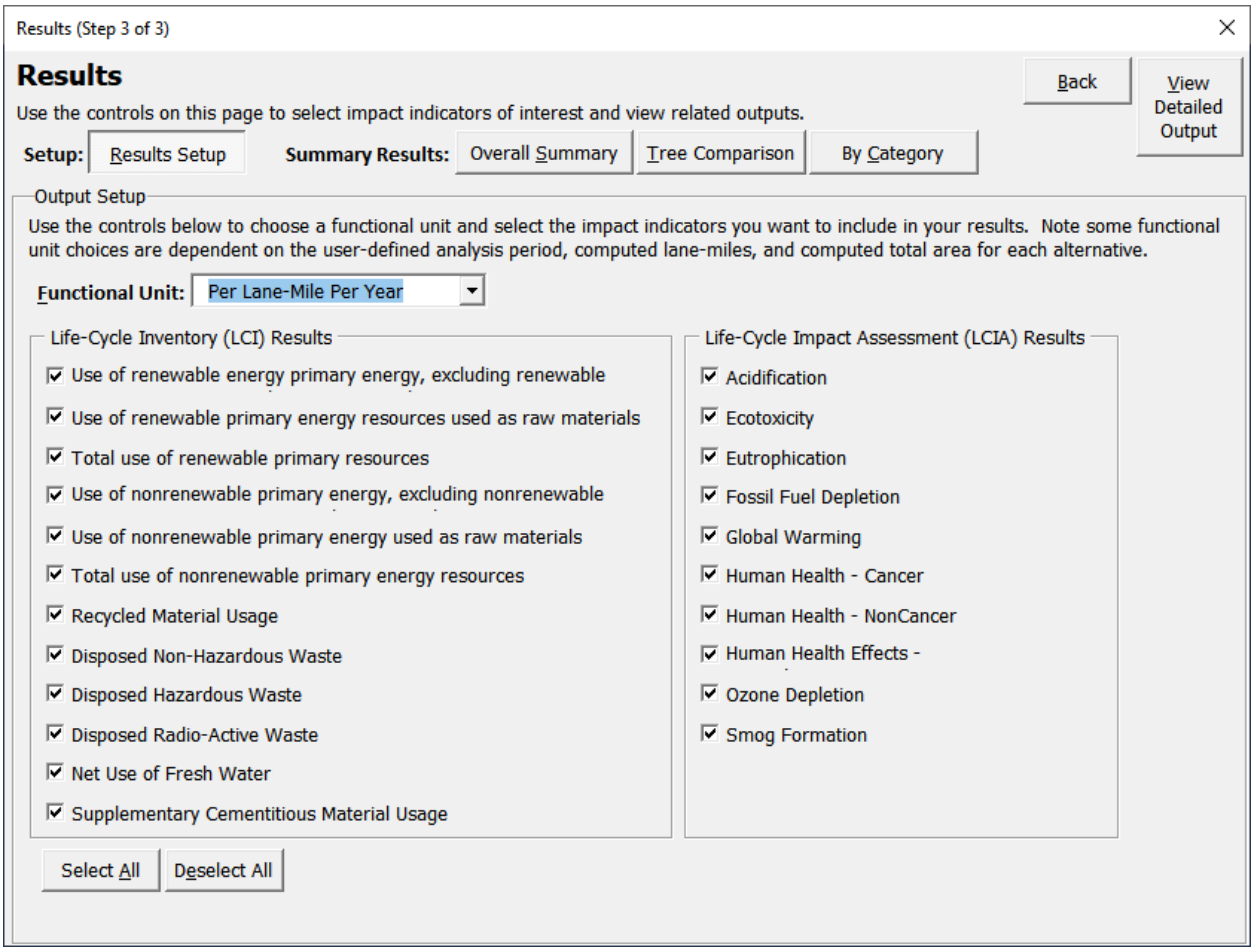


Figure 6-32. Results interface.

Figure 6-33 shows a high-level comparison between two alternatives modeled using the tool. The impact indicator with the highest value among the alternatives modeled is set to 100 percent and the other values for the same impact indicator for the other alternatives modeled are normalized based on the highest value. This chart provides quick information to the user on key differences between the environmental performance of each alternative modeled by the user. For example, based on figure 6-33, it is apparent that Alternative 2 results in higher overall environmental impacts for most of the impact indicators.

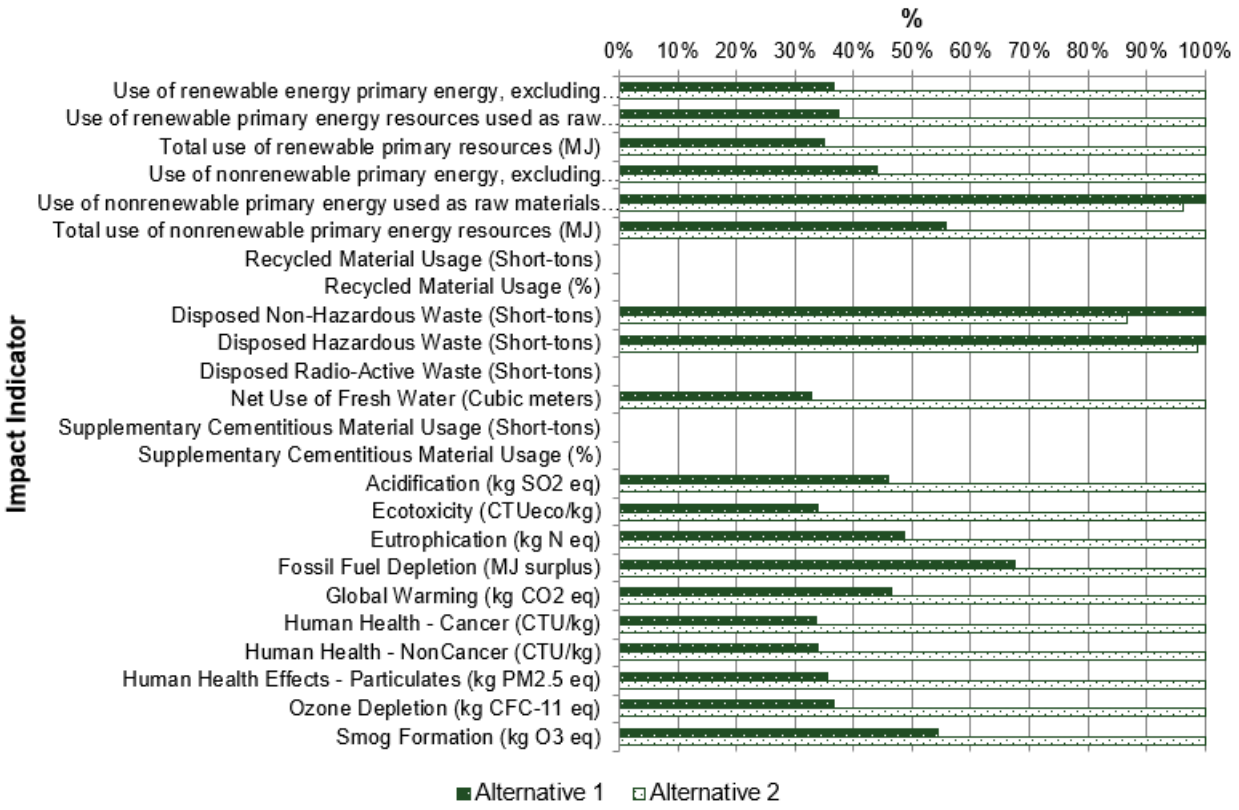


Figure 6-33. Comparison of normalized impact indicator values for each example alternative modeled.

Figure 6-34 shows the environmental impacts associated with each pavement life-cycle stage (initial construction, maintenance and preservation, rehabilitation, reconstruction, removal) for one example alternative modeled by the user. This chart can help the user visualize the life-cycle stages that have significant contributions to the overall environmental impact of the design alternative modeled. The user can then view the details on the various process included in those life-cycle stages to better understand the reasons behind the higher environmental impacts, which in turn can be used to help identify potential strategies to reduce those impacts.

Figure 6-35 shows the environmental impacts associated with each process type (materials, equipment, waste, and transport) for one alternative modeled by the user. This chart can be used by the user to determine the process type(s) that are major contributors to the overall environmental impact for each alternative modeled. The user can then focus on process types that are major contributors to the overall impacts to determine options for minimizing impacts associated with those processes. For example, if the use of a particular type of cement or asphalt binder is resulting in higher overall impacts for the materials process, the user can look into options for reducing the impacts by using a different cement type or a different type of asphalt binder.

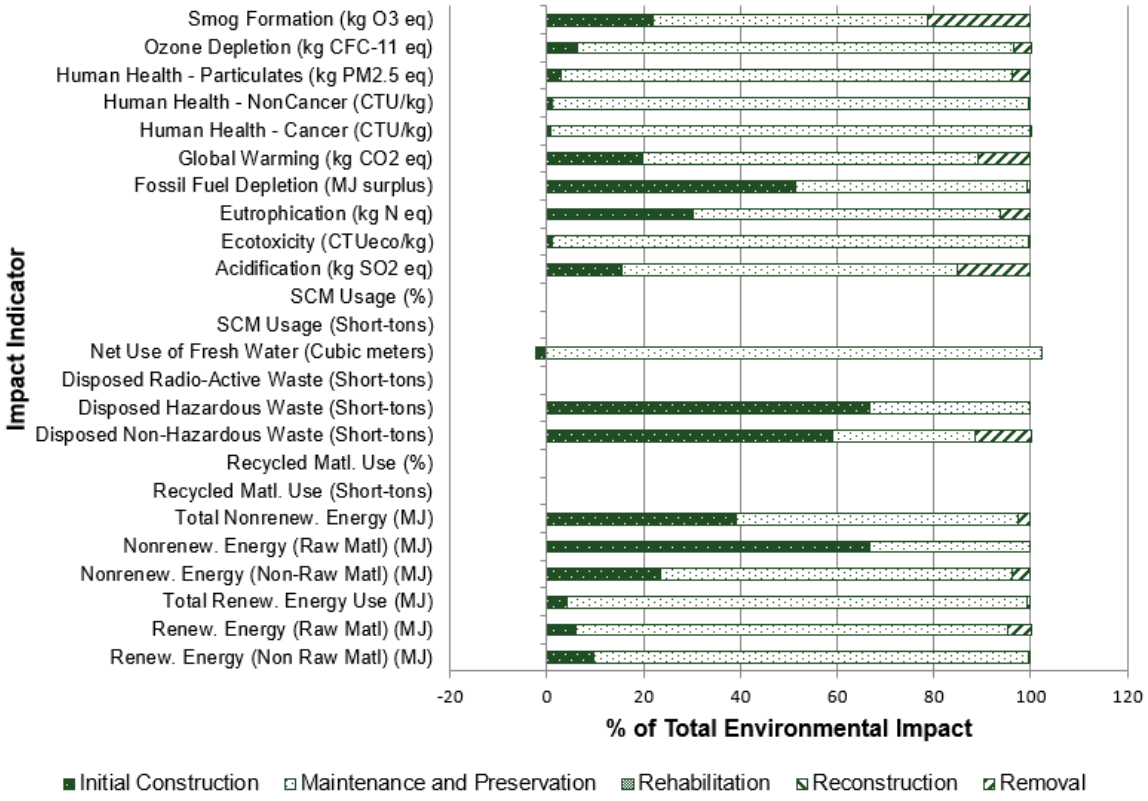


Figure 6-34. Example summary results by pavement life-cycle stage.

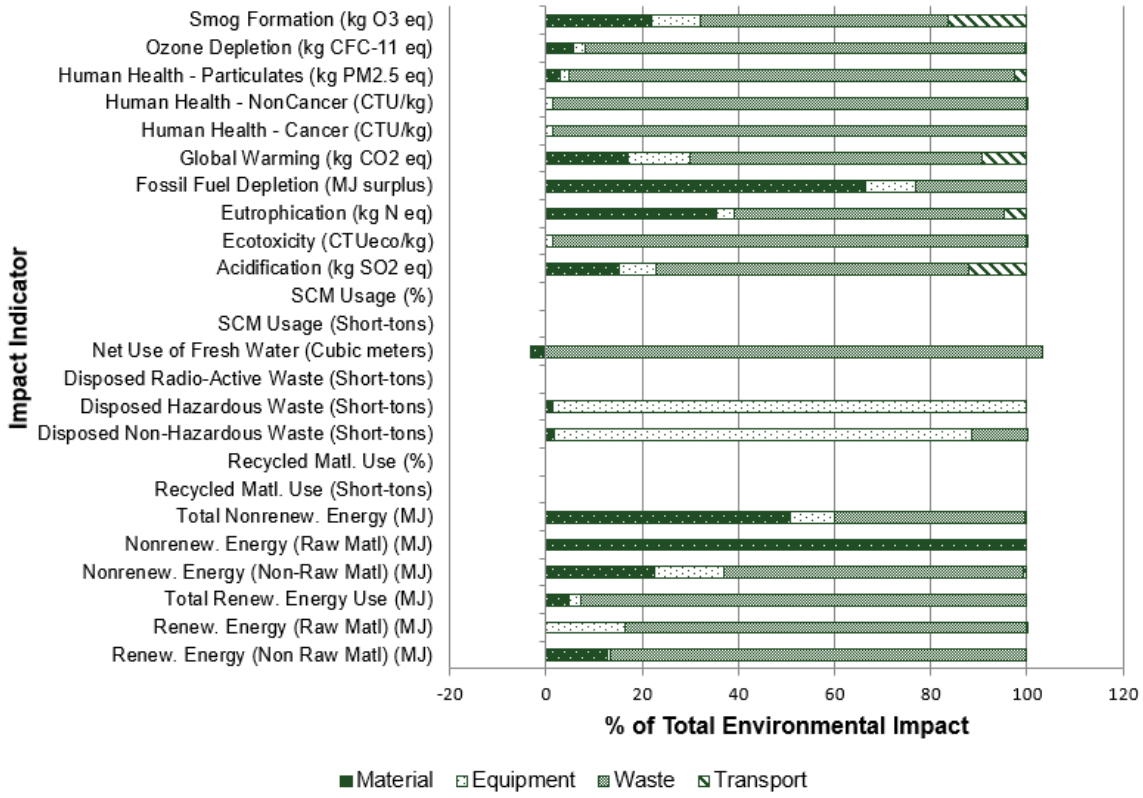


Figure 6-35. Example summary results by process type.

Figure 6-36 shows the environmental impacts by treatment/activity application age over the pavement life cycle modeled by the user. From figure 6-36 it is apparent that activities performed during years 10 and 18 are significant contributors to the overall impacts. The user can look into the activities being performed at these years to understand the reasons behind the higher overall impacts and see if other strategies can be used to reduce those effects.

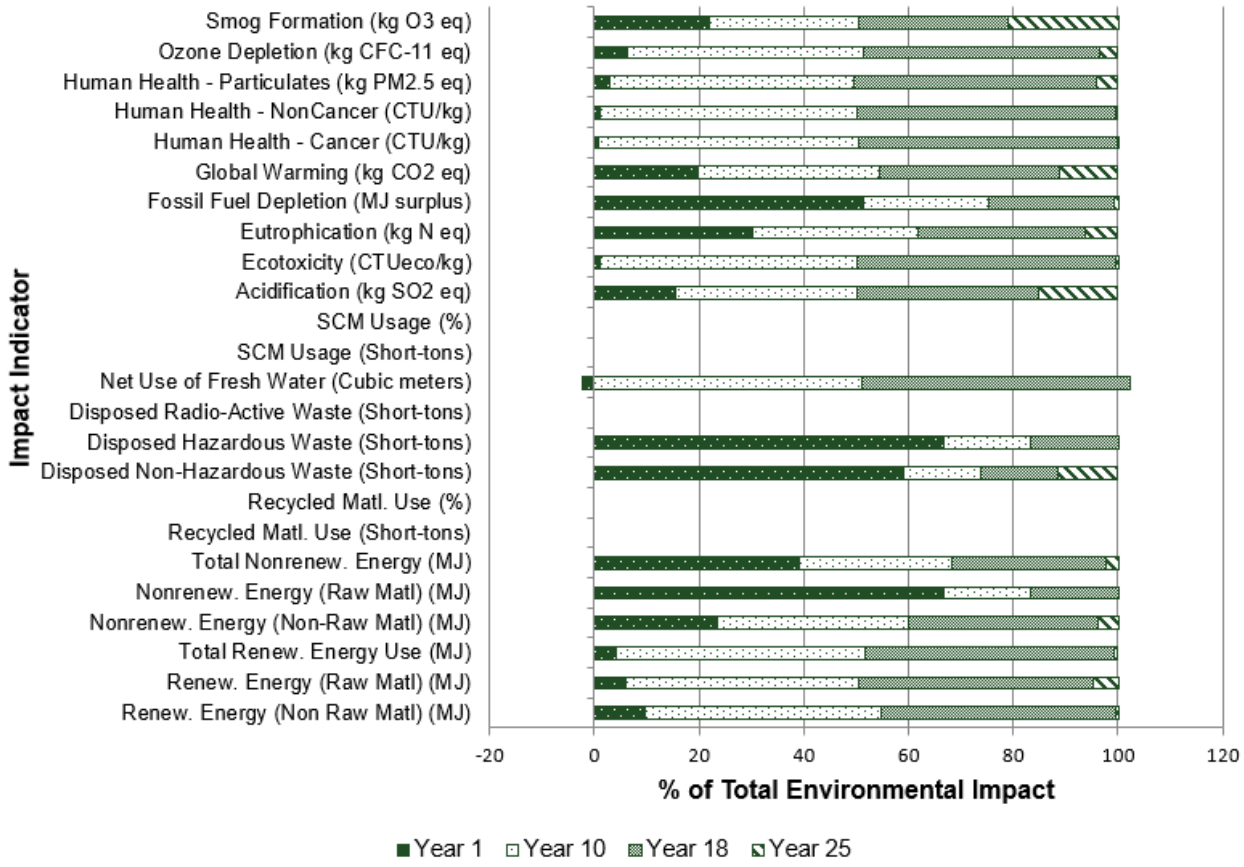


Figure 6-36. Example summary results by application age.

In addition to the summary result charts discussed in this section, the tool also provides detailed outputs from the analysis performed by the user (as discussed under section 5.3.

CHAPTER 7. SUMMARY

7.0 TOOL SUMMARY

A first version of a Microsoft Excel-based tool has been developed for conducting LCA of pavement systems. The tool has been populated with national average data (or closest equivalent) from publicly available sources. The tool is fully functional for the materials production, construction, and end-of-life stages, including transportation of materials. All data in the initial database includes data quality assessment and other metadata following a data quality matrix adapted from other Federal agency efforts.

The tool can be used to analyze and quantify the environmental impacts of materials, construction, and related transportation of various pavement mixtures and pavement designs used for new construction, reconstruction, rehabilitation, maintenance, and preservation, but it does not include the use stage. This leaves out work zone traffic flow, including work zone speed changes, delay, and diversions, changes in traffic over time, pavement vehicle interaction and related fuel use and emissions, ice and snow management, storm water runoff, heat island effects, and carbonation. The tool has been developed such that these processes can be added with the development of future modules.

7.1 TOOL MANAGEMENT

- The user should save a clean backup of the tool's original version before making customizations to the libraries and/or conducting an analysis.
- For every update made to the tool, the user should save a backup and maintain a log of changes made.
- A unique file should be used for each analysis conducted by the user. For every analysis performed, the user should maintain a log of the version of the tool used to conduct the analysis.
- Before using the tool for analysis, the user should customize the data libraries and develop a set of mix designs and pavement activities that are commonly used by the agency.

REFERENCES

Bare, J. 2012. *Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI). TRACI Version 2.1 User's Guide.* EPA/600/R-12/554. U.S. Environmental Protection Agency, Cincinnati, OH.

Harvey, J. T., J. Meijer, H. Ozer, I. L. Al-Qadi, A. Saboori, and A. Kendall. 2016. *Pavement Life-Cycle Assessment Framework*. FHWA-HIF-16-014. Federal Highway Administration, Washington, DC.

Harvey, J., J. Meijer, P. Ram, and K. Smith. 2020. *Environmental Product Declarations: Communicating Environmental Impact for Transportation Products.* FHWA-HIF-19-087. Federal Highway Administration, Washington, DC.

Meijer, J., J. T. Harvey, A. A. Butt, C. Kim, P. V. Ram, and K. D. Smith. 2021. *Sustainable Pavements Life-Cycle Assessment Tool—Underlying Methodology and Assumptions*. Federal Highway Administration, Washington, DC.

Van Dam, T. J., J. T. Harvey, S. T. Muench, K. D. Smith, M. B. Snyder, I. L. Al-Qadi, H. Ozer, J. Meijer, P. V. Ram, J. R. Roesler, and A. Kendall. 2015. *Towards Sustainable Pavement Systems: A Reference Document*. FHWA-HIF-15-002. Federal Highway Administration, Washington, DC.

APPENDIX A. GLOSSARY

Table A-1. Tool terminology.

Term	Meaning
Activity	A discrete event that changes a segment/section/area of pavement. Includes all materials, composite materials, elements, equipment, hauling, construction processes, and waste treatments associated with that change.
Alternative	A user-developed version of the model of the project making use of the line item database to create a sequence of activities. Different alternatives can be modeled and compared.
Analysis Period	The time period in years for which an alternative is modeled.
Element	Something used in the pavement structure that has a pre-formed shape before arriving at the construction site. Examples include dowels, tie bars, fabric interlayers, and pipes.
Equipment	A piece of equipment that is used for activities or pay items.
Hauling	A means of transportation that is used for bringing materials to a processing plant or bringing and hauling materials and equipment to and from the job site.
Item	A line item in the database that consists of activities, composite materials, elements, equipment, hauling, materials, pay items and waste treatments needed to model any alternative.
Material	Something used in the pavement structure that does not have a pre-formed shape before arriving at the construction site.
Mix Design	A user-developed library item developed using ingredients from the tool's libraries.
Pavement	An object with varying numbers of hard surfaced lanes, which may include an inner and outer shoulder, that can all have several layers including a base and subgrade.
Pavement Life Cycle	A series of discrete projects in time within an identified performance (and hence analysis) period. The Pavement Life Cycle considered in the scope of this study can include all or only some of these stages, and is assigned by the user within an alternative: − Initial construction. − Maintenance. − Preservation. − Rehabilitation. − Removal. − Reconstruction.
Project	A pavement project that the user wants to model, or a user-developed set of activities that are completed over a discrete period of time that are organized together in a coordinated manner to transform a segment/section or area of pavement, often within a single contract.
Treatment	Any activity performed to the pavement during any point during its life cycle (e.g., asphalt mill and overlay, diamond grinding, patching, crack sealing, etc.)
Unit Process	Smallest element considered in the life-cycle inventory analysis for which input and output data are quantified.
Waste Treatment	A process that handles a material waste flow.

APPENDIX B. LCA TOOL DATA NEEDS

The tool has been populated with national average data (or closest equivalent) from publicly available sources. Data selected for inclusion in the tool reflect national averages and do not reflect regional variation in practice. The data pre-populated in the tool includes environmental impact indicators associated with various items (materials, equipment, transport, waste treatment method) used to model a pavement system.

A summary of other information that the user should compile or compute before using the tool is presented below.

- Geometry for each pavement facility (mainline, shoulder, ramps, other) to be included in the analysis.
  - Number of lanes.
  - Length (of entire facility).
  - Width (of entire facility).
- Analysis period (in years) for each alternative to be modeled.
- Mix designs to be used in the analysis.
  - Material types and quantities included in the mass/volume of mix design modeled using the tool (if mix designs are developed using library items).
  - Relevant EPDs for materials and mix designs (if applicable).
  - Equipment used to manufacture the mix design (mixing plant or other mixing equipment from the equipment if the mix design is produced on site).
  - Transportation (transportation equipment, transportation legs, and transportation distances associated with materials and equipment used for each activity).
- Activities to be applied over the analysis period for each alternative to be modeled.
  - Quantities associated with each activity to be modeled:
    - Materials (type of materials used, mass and/or volume associated with the activity quantity).
    - Equipment (type of equipment and hours of equipment use associated with the activity quantity).
    - Transportation (transportation equipment, transportation legs, and transportation distances associated with materials and equipment used for each activity).
    - Waste treatment (methodology associated with any waste generated from an activity).
  - Service interval (years) for each activity included over the pavement life cycle.
- Impact indicators of interest to the person/agency conducting the analysis.
- Functional unit to be used for reporting (e.g., per lane mile, per lane mile per year, per square foot, per square foot per year).

APPENDIX C. USING EPD DATA

An example illustrating how to incorporate Environmental Product Declaration (EPD) data into the tool is shown here. EPD use is not required by Federal regulation or statute.

Table C-1 summarizes a list of key items to review in an EPD before inputting data.

Table C-1. Considerations for incorporating EPD data into the tool.

Ask these questions...	***…. to answer***
• Who developed the EPD?	*How relevant is the industry or manufacturers that are represented to the agency?*
• What material(s) does the EPD cover?	*Is the material, its specification and manufacturing technology fit for purpose?*
• What PCR is used to develop the EPD?	*Is the PCR up to date and does it follow best practices?*
• What is the functional or declared unit?	*What is the unit/amount of product that is used to present all the result of the EPD ("this amount or environmental result per this amount of product")?*
• What are the system boundaries?	*What is included in the results and what is not? Think about life cycle stages, ancillary materials, etc.*
• What year(s) are the data from?	*Are the data current enough for the processes and materials covered used by the agency?*
• What are some key assumptions stated?	*Look for key assumptions to see if the EPD is a good fit for the agency.*
• What is the environmental impact assessment methodology used and what impact indicators are reported?	*Does the EPD show TRACI 2.0 impact categories? Does it include a full list when looking at the FHWA LCA Framework or not? If not, is that still appropriate, or, does is cover the impact categories of interest to the agency?*

Example data for a few impact indicators for 1 metric ton (1.102 short-tons) of the material is shown in table C-2.

Table C-2. Example EPD data.

Impact Indicator	**Units**	**Results**
Global warming potential	kg CO_2 eq	6.06
Acidification potential	kg SO_2 eq	0.05
Eutrophication potential	kg N eq	0.01
Photochemical ozone creation potential	kg O_3 eq	0.73
Ozone depletion potential	kg CFC-11 eq	1.59E-07
Use of renewable primary energy	MJ	7.54
Use of non-renewable primary energy	MJ	90.7
Use of net fresh water	m^3	0.11
Non-hazardous waste disposed	kg (short-ton)	0.14 (1.54E-04)
Radioactive waste disposed	kg (short-ton)	1.20E-04 (1.32E-07)

Note: Tool user to convert all units reported in EPDs to units that are compatible with the tool.

Figures C-1 and C-2 show the EPD data after it is input into the tool.

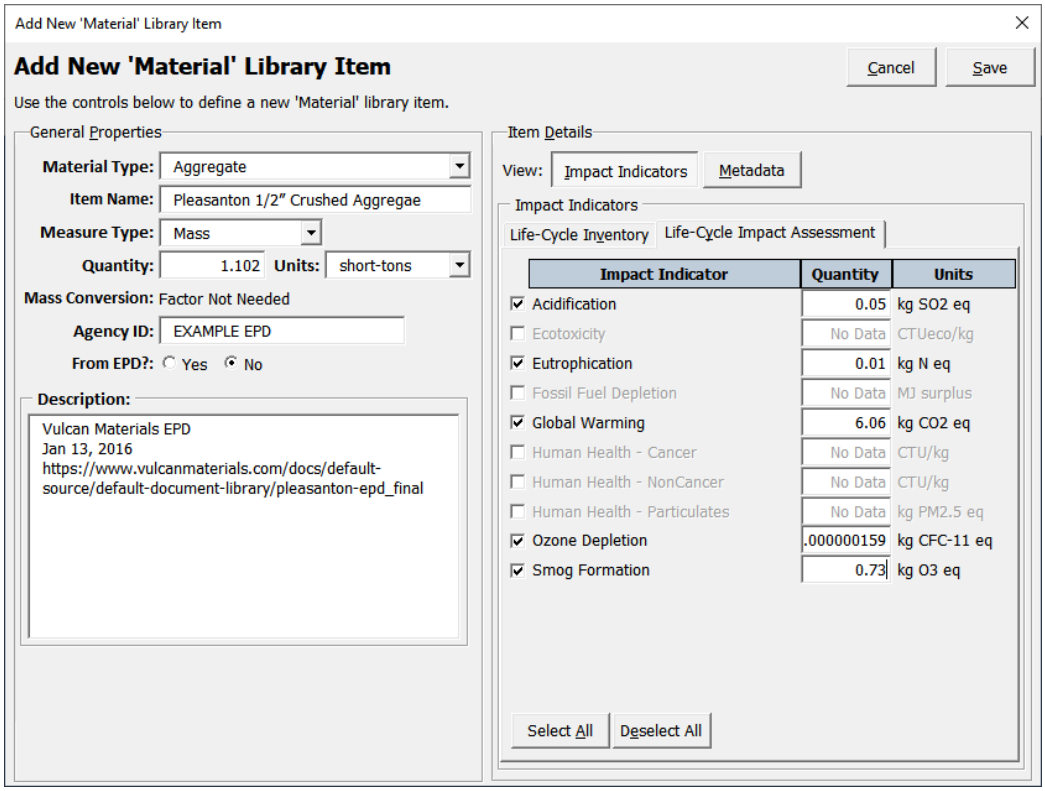


Figure C-1. Adding example EPD data to the tool—Life-Cycle Impact Assessment Indicators.

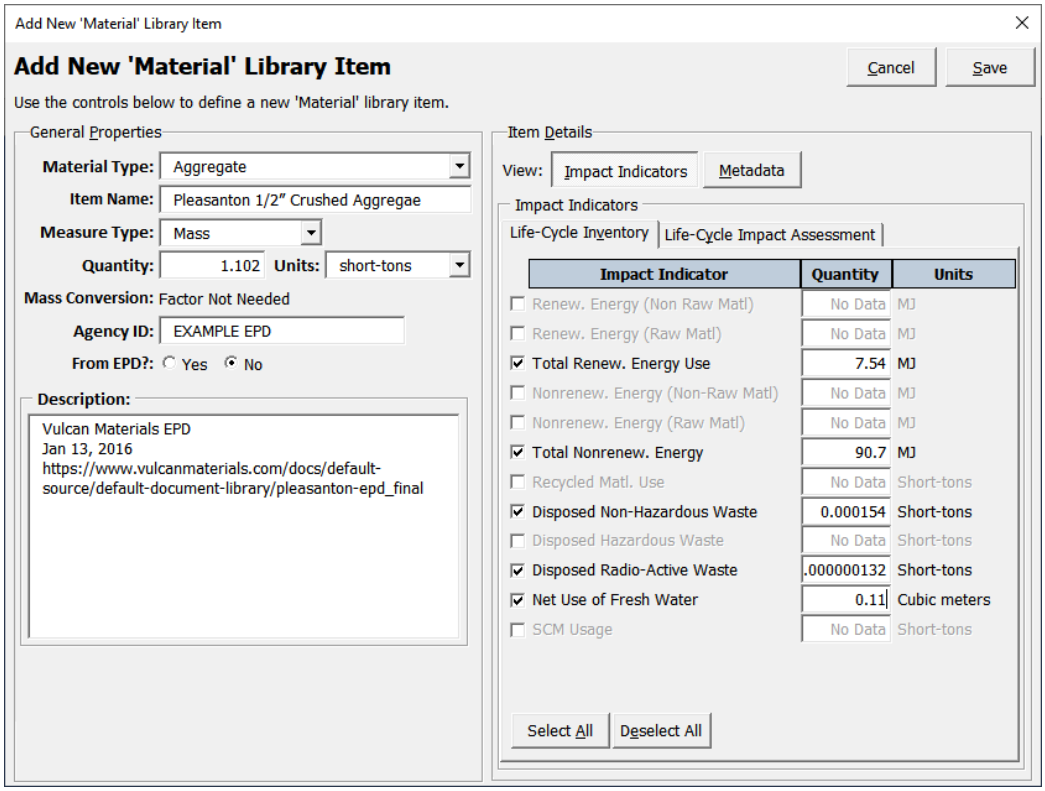


Figure C-2. Adding example EPD data to the tool—Life-Cycle Inventory Impact Indicators.