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

## **User Manual**



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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<sup>1</sup>. It gives agencies the ability to investigate areas where they can improve.

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 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.

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: <a href="https://www.fhwa.dot.gov/pavement/lcatool/">https://www.fhwa.dot.gov/pavement/lcatool/</a>

## **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.

<sup>&</sup>lt;sup>1</sup>Pavement Life Cycle Assessment Framework - <u>https://www.fhwa.dot.gov/pavement/sustainability/hif16014.pdf</u>

• 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<sup>2</sup>. 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 projectlevel design studies.

<sup>&</sup>lt;sup>2</sup> 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<sup>®</sup> Windows 10 Operating System.
- Microsoft<sup>®</sup> Excel<sup>®</sup> 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.

Tools JD blick or		
Macro Settings		
Indicate Jubishers       Macro Settings         Trusted Locations       Disable all macros without notification         Trusted Add-in Catalogs       Disable all macros without notification         Add-ins       Disable all macros except digitally signed macros         Add-ins       Enable all macros (not recommended; potentially dangerous code can run)         ActiveX Settings       Developer Macro Settings         Protected View       Massage Bar         External Content       File Block Settings         Privacy Options       Trust access to the ⊻BA project object model		

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.

Excel Macro Settings Not Properly Configured X The Excel macro settings are not currently configured to allow this workbook to run. For this tool to run properly, the Excel 'Developer Macro Settings' must be configured to 'Trust access to the VBA project object model. For more specific instructions on how to make changes to the Excel options, please refer to the 'Initial Setup' portion of the User Manual document.

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.

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.	

Table 3	5-1.	Tool	libra	ries.
100100				

#### 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).

Analysis Session Details	(Step 1 of 3)			×
Analysis Sess	sion Details		<u>B</u> ack	Ne <u>x</u> t
Use the controls below	w to define the details of the current analysis ses	sion.		
<u>Analysis Details</u>	e: Compare Treatment Cycles or Pavement De	sign Life-Cycle Options	]	
Descriptio	n: Used to compare 1) pavement treatment sequences design life-cycle options. Note: this analysis of a chosen analysis period.	iences applied to an existing paven bjective option requires the user to	nent structure, or 2) paven model a series of activitie	nent es over
<u>G</u> eneral Inputs				
Session Name:	Beta Test HMA Project			
Route:	Beta-99			
Location:	Phoenix, AZ			
Project Limits:	Elm St to Washington Ave			
Analyzed By:	John Doe			
Comments:	Comparison between two HMA design options t mixtures.	hat uses two different HMA		
Design Alternatives       Number of Design Alternatives:     2				

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.

Results (Step 3 of 3)	×			
Results Use the controls on this page to select impact indicators of interest and view re	elated outputs.			
Setup:         Results Setup         Summary Results:         Overall Summary         Tree	e Comparison By Category			
Output Setup				
Use the controls below to choose a functional unit and select the impact indicators you want to include in your results. Note some functional unit choices are dependent on the user-defined analysis period, computed lane-miles, and computed total area for each alternative.				
Eunctional Unit: Total (Entire Project)				
Life-Cycle Inventory (LCI) Results	Life-Cycle Impact Assessment (LCIA) Results			
$\overline{{\bf arsigma}}$ Use of renewable energy primary energy, excluding renewable	✓ Acidification			
$\overline{\mathbf{arsigma}}$ Use of renewable primary energy resources used as raw materials	F Ecotoxicity			
I Total use of renewable primary resources	Eutrophication			
✓ Use of nonrenewable primary energy, excluding nonrenewable	Fossil Fuel Depletion			
✓ Use of nonrenewable primary energy used as raw materials	Global Warming			
✓ Total use of nonrenewable primary energy resources	✓ Human Health - Cancer			
Recycled Material Usage	Human Health - NonCancer			
V Disposed Non-Hazardous Waste	🔽 Human Health Effects -			
Disposed Hazardous Waste	✓ Ozone Depletion			
V Disposed Radio-Active Waste	Smog Formation			
Vet Use of Fresh Water				
Supplementary Cementitious Material Usage				
Select <u>A</u> ll Deselect All				

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.

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

ALT + L

LCA PAVE (Version 1.01.03)				
<b>CASPAVE</b> Pavement Life-Cycle Assessment Tool A tool for determining environmental impacts of pavement systems.				
Control Panel				
<b>Conduct Analysis</b> Click the "Conduct Analysis" button and follow the step-by-step procedures provided to setup and analyze your specific analysis objective. Setup steps include defining the analysis session details, defining up to five different design alternatives to analyze, and choosing desired outputs.				
Library To aid in the building of useful project analyses, many of the needed project building blocks can be named and stored in the library for use in future project analyses. Click the "Library" button below to view, add, and edit library items.				
Additional Information				
The tabs below contain disclaimer and general tool information, and a summary of tool applications and limitations.				
Disclaimer General Applications and Limitations				
As used in this Tool, "definition" and "Design Alternative Definition" do not refer to Federal regulatory definitions or legally binding requirements. Instead, "definition" is commonly used or referenced in Life Cycle Assessment to instruct a user to describe the term with greater detail to shape the analysis (e.g., when modeling design alternatives).				
U.S. Department of Transportation Federal Highway Administration Exit Tool Exit Tool				

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.

Librar	~
Library	^
Library Use the controls below to define library items that will be available for use when conducting an analysis session.  Library Selection	Cl <u>o</u> se
Materials         Equipment         Waste         Transport         Mix Designs         Activities	
Library Collection: 'Materials'	
Admixture/Additive         - Aggregate         - Asphalt Binder         - Cementitous         - Electricity         - Element         - Fuel         - Other         - Recycled, Co-Product, or Waste Material         - Steel	ated details.
Copy     Add New     Edit       Paste     Delete	

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).

Library	×
Library Use the controls below to define library items that will be available for Library Selection <u>Materials Equipment Waste Transport Mix Designs</u>	Close Close
Library Collection: 'Materials'	n Details: 'Material' Item
EAdmixture/Additive View:	1: Properties 2:Impact Indicators 3:Metadata
<ul> <li>Aggregate</li> <li>Asphalt Binder</li> <li>Cementitous</li> <li>Electricity</li> <li>Element</li> <li>Other</li> <li>Other</li> <li>Steel, Co-Product, or Waste Material</li> <li>Steel, Reinforcing, Epoxy-coated</li> <li>Steel, Rod, Galvanized</li> <li>Steel, Stainless</li> <li>Dowel Bar</li> <li>Dowel Bar, 1.5" x 18"</li> <li>Dowel bar, 1.25" x 18"</li> <li>Tie-bar, threaded</li> </ul>	al Properties terial Type: Steel tem Name: Steel, Reinforcing asure Type: Mass Quantity: 1 short-ton Conversion: Factor Not Needed Agency ID: From EPD?: No Description: WorldSteel LCI
Copy     Add New     Edit       Paste     Delete	Editable?: No (Default Database Item)

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
  - 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 lifecycle 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).

Library				×	
Library       Close         Use the controls below to define library items that will be available for use when conducting an analysis session.       Close         Library Selection					
Library Collection: 'Materials' Accelarator, hardening Accelarator, set Air Entrainer Plasticizer Retarder Wotes Resefice Asset	Selection De View: <u>1</u> : P Life-Cycle Ir Library Iter Quantil	tails: 'Material' Item roperties 2:Impact Indicators 3:N wentory Life-Cycle Impact Assessmer n: Steel, reinforcing ty: 1 short-ton	1etadata		
Water Proofing Agent	Included?	Impact Indicator	Quantity	Units	
	Yes Yes Yes Yes Yes Yes Yes Yes Yes	Acidification Ecotoxicity Eutrophication Fossil Fuel Depletion Global Warming Human Health - Cancer Human Health - NonCancer Human Health - Particulates Ozone Depletion Smog Formation	5.2 3,677 0.6707 1,123 1,462 0.0003 0.0009 1.42 5.35E-05 72.5	kg SO2 eq CTUeco/kg kg N eq MJ surplus kg CO2 eq CTU/kg CTU/kg kg PM2.5 eq kg CFC-11 eq kg O3 eq	
Copy         Add New         Edit           Paste         Delete					

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

Library	×				
Library       Close         Use the controls below to define library items that will be available for use when conducting an analysis session.       Close         Library Selection					
Library Collection: 'Materials'	Selection Details: 'Material' Item View: 1: Properties 2:Impact Indicators 3:Metadata General Data Quality Assessment Metadata Person recording data: No Data Defined Source of data/model calculations: No Data Defined Data produced/published year: No Data Defined Data accessed/recorded date: No Data Defined				
Steel, rod, galvanized       Steel, stainless       Dowel Bar, epoxy-coated, 1.5" x 18"       V       Copy     Add New       Edit       Paste	Flow type/description/name: No Data Defined Location where data is produced: No Data Defined Other properties: No Data Defined				

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.

Library			×
Library Use the controls below to define library items that will be Library Selection Materials Equipment Waste Transport M	available for use when conducting an analysis s Ii <u>x</u> Designs <u>A</u> ctivities	ession.	Cl <u>o</u> se
Library Collection: 'Materials'	Selection Details: 'Material' Item		
Aggregate     Asphalt Binder     Cementitous     Electricity     Element     Fuel     Other     Steel     Steel, Reinforcing     Steel, Reinforcing, Epoxy-coated     Steel, Rod, Galvanized     Steel, Stainless     Dowel Bar     Dowel Bar, 1.5" x 18"     Dowel bar, 1.25" x 18"     Tie-bar, threaded	General Data Quality Assessment Data Quality Assessment Ratings The following are different recorded data q specific details about each rating, click the 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	uality ratings (1 = Be 'Rating Details" butto 1 (1 to 5 scale) 1 (1 to 5 scale) 1 (1 to 3 scale) 1 (1 to 3 scale) 1 (1 to 4 scale) 1 (1 to 4 scale) 1 (1 to 4 scale) 1 (1 to 5 scale)	est). For in. <u>R</u> ating Details
Paste Delete	Process Completeness	1 (1 to 5 scale)	
			I

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):

- 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<sup>3</sup> 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.

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

- 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.

Add New 'Material' Library Item X				
Add New 'Ma	aterial' Library Item		<u>C</u> ancel <u>S</u> ave	
Use the controls belo	w to define a new 'Material' library item.			
General <u>P</u> roperties		Item <u>D</u> etails		
Material Type:	Admixture/Additive	View: Impact Indicators Metadata		
Item Name:	New Material Item	Impact Indicators		
Measure Type:	Volume 💌	Life-Cycle Inventory Life-Cycle Impact A	ssessment	
Quantity:	1 Units: fluid ounces 💌	Impact Indicator	Quantity Units	
Mass Conversion:	1 lbs/fluid ounce	🗖 Renew. Energy (Non Raw Matl)	No Data MJ	
Agency ID:		🗖 Renew. Energy (Raw Matl)	No Data MJ	
From EPD?:	⊂ Yes ☉ No	🗖 Total Renew. Energy Use	No Data MJ	
Description:		🗖 Nonrenew. Energy (Non-Raw Matl)	No Data MJ	
		🗖 Nonrenew. Energy (Raw Matl)	No Data MJ	
		🗖 Total Nonrenew. Energy	No Data MJ	
		🗖 Recycled Matl, Use	No Data Short-tons	
		🗖 Disposed Non-Hazardous Waste	No Data Short-tons	
		🗖 Disposed Hazardous Waste	No Data Short-tons	
		Disposed Radio-Active Waste	No Data Short-tons	
		Net Use of Fresh Water	No Data Cubic meters	
]		🗖 SCM Usage	No Data Short-tons	
		Select <u>A</u> ll D <u>e</u> select All		

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.

- 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.
- 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
- 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:

Add New 'Material' I	library Item			×
Add New 'Ma	aterial' Library I	tem		<u>C</u> ancel <u>S</u> ave
Use the controls belo General <u>P</u> roperties Material Type:	w to define a new 'Materia Admixture/Additive	al' library item.	Item Details	
Macriai Type: Item Name: Measure Type: Quantity: Mass Conversion: Agency ID: From EPD?: Description:	New Material Item Volume  I Units: C Yes No	juarts	View:mpact indicators   Metadata Background Data General   Data Quality Assessment   Metadata Person recording data: Source of data/model calculations: Data produced/published year: Data accessed/recorded date: Flow type/description/name: Location where data is produced: Other properties:	

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

Add New 'Material' Library Item X				
Add New 'Ma	aterial' Library Item			<u>C</u> ancel <u>S</u> ave
Use the controls belo	w to define a new 'Material' library iter	n.		
General Properties			Item Details	
Material Type:	Admixture/Additive	•	View: Impact Indicators Metadata	
Item Name:	New Material Item		Background Data	
Measure Type:	Volume 💌		General Data Quality Assessment	
Quantity:	1 Units: fluid ounces	•	Data Quality Assessment Ratings	
Mass Conversion:	1 lbs/fluid ounce		Use these controls to rate the quality of this specific details about each rating, click the "	data (1 = Best). For Rating Details" button.
Agency ID: From EPD?: Description:	C Yes ⊙ No		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	N/A     Rating Details       N/A     Details       N/A     N/A       N/A     N/A

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.

Add New 'Material' Library Item				
Use the controls belo	w to define a new 'Material' library item.			
General Properties	,			
Material Type:	Admixture/Additive			
Item Name:	New Material Item			
Measure Type:	Volume 💌			
Quantity:	1 Units: cubic yards 💌			
Mass Conversion:	1 Ibs/cubic yard			
Agency ID:				
From EPD?:	• Yes O No			

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.

	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

- Select an existing item in the library.
- Click the "Copy" button and then then click the "Paste" button.

```
Keyboard Shortcuts
Copy: ALT + C
Paste: ALT + P
```

• 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).

Library	×
Library Library Use the controls below to define library items that will be available for use when co Library Selection Materials Equipment Waste Iransport Mix Designs Activities Library Collection: 'Materials' Cementitous Library Content Cementitous Library Cementitous Lib	Close
Copy     Add New     Edit       Paste     Delete	Yes (User-Defined Item)

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

### 4.1.5 Edit Existing Data

- 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.

#### 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 userdeveloped 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.

Keyboard Shortcuts

Delete: ALT + D

Edit: ALT + E

#### 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.
# 4.2 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."

Keyboard Shortcuts Within Equipment Library

Properties interface: ALT + 1

Impact Indicators: ALT + 2

Metadata interface: ALT + 3

- 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.

Library	×	
Library       Close         Use the controls below to define library items that will be available for use when conducting an analysis session.       Close         Library Selection		
Library Collection: 'Equipment'	lection Details: 'Equipment' Item	
□       Cement and Mortar Mixers       ✓         □       Cement/Mortar Mixer (3 to 6 hp, Diesel)       ✓         □       Cement/Mortar Mixer (6 to 11 hp, Gasolin)       Ge         □       Cement/Mortar Mixer (6 to 11 hp, Gasolin)       Ge         □       Cement/Mortar Mixer (16 to 11 hp, Diesel)       ✓         □       Cement/Mortar Mixer (11 to 16 hp, Gasolin)       Ge         □       Cement/Mortar Mixer (11 to 16 hp, Diesel)       Pi         □       Cement/Mortar Mixer (11 to 15 hp, Diesel)       Pi         □       Cement/Mortar Mixer (16 to 25 hp, Diesel)       Pi         □       Cement/Mortar Mixer (50 to 75 hp, Diesel)       Se         □       Cement/Mortar Mixer (100 to 175 hp, Diesel)       Se         □       Cement/Mortar Mixer (300 to 600 hp, Diese)       De         □       Cement/Mortar Mixer (600 to 750 hp, Diese)       De         □       Cranes       E       Crushing/Processing Equipment       FI         □       Excavators       ×       Lo	w:       1: Properties       2:Impact Indicators       3:Metadata         neral       Data Quality Assessment       Adetadata         erson recording data:       EPA         EPA       Device of data/model calculations:         Moves       Moves         ata produced/published year:       2018         ata accessed/recorded date:       2/20/2020         No type/description/name:       No Data Defined         No Data Defined       Deviced:	
Copy     Add New     Edit       Paste     Delete	US ther properties: No Data Defined	

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

Add New 'Equipment' Library Item X			
Add New 'Eq	uipment' Library Item		Cancel Save
Use the controls belo	w to define a new 'Equipment' library item.		
General Properties		Item Details	
Equipment Type:	Cement and Mortar Mixers	View: Impact Indicators Metadata	
Item Name:	New Equipment Item	Impact Indicators	
Measure Type:	Time 💌	Life-Cycle Inventory Life-Cycle Impact A	ssessment
Quantity:	1 Units: hours	Impact Indicator	Quantity Units
Fuel Type:	Diesel	Renew, Energy (Non Raw Matl)	No Data MJ
Horsepower Rng.:		Renew. Energy (Raw Matl)	No Data MJ
Agency ID:		🗖 Total Renew. Energy Use	No Data MJ
Description:		🗖 Nonrenew. Energy (Non-Raw Matl)	No Data MJ
		🗖 Nonrenew. Energy (Raw Matl)	No Data MJ
		🗖 Total Nonrenew. Energy	No Data MJ
		🗖 Recycled Matl. Use	No Data Short-tons
		🗖 Disposed Non-Hazardous Waste	No Data Short-tons
		Disposed Hazardous Waste	No Data Short-tons
		Disposed Radio-Active Waste	No Data Short-tons
		Net Use of Fresh Water	No Data Cubic meters
		🗖 SCM Usage	No Data Short-tons
		Select <u>All</u> Deselect All	

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.	Keyboard Shortcuts in the Impact Indicator Interface
• Input Agency ID for the equipment (if	Impact Indicators: ALT + I
available).	Life-Cycle Inventory tab: ALT + V
• Provide a brief description of the item	Life-Cycle Impact Assessment tab: ALT + Y
being input.	Select All: ALT +A
	Deselect All: ALT + E

Then 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 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).

Keyboard Shortcuts in the Metadata Interface:

General Tab: ALT + N

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

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

Library	×
Library Use the controls below to define library items that will be avai Library Selection  Materials Equipment Waste Transport Mix D  Library Collection: 'Waste'  Library Collection: 'Waste'  Library Collection: 'Waste'  Landfill-Aggregate Landfill-Aggregate Landfill-Aggregate Landfill-Composite Landfill-Concrete Landfill-Galvanized Steel Landfill-Plastic Landfill-Stainless Steel Landfill-Steel Recycled Onsite Recycled Offsite Recycled Offsite	Close         lable for use when conducting an analysis session.         esigns Activities         Selection Details: 'Waste' Item         iew: 1: Properties 2:Impact Indicators 3:Metadata         General Properties         Treatment Type: Landfill         Material Type: Aggregate         Measure Type: Mass         Quantity: 1 short-ton         Mass Conversion: Factor Not Needed         Agency ID:         Description:         End-fo-life process from the EcoInvent library representing average European data for the processes that take place on-site, with, where relevant a time period of 100 years, for exmaple relevant for leaching from a landfill
Copy     Add New     Edit       Paste     Delete	Editable?: No (Default Database Item)

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

Add New 'Waste' Librar	ry Item			×
Add New 'Wa	aste' Library Item			Cancel Save
Use the controls below	w to define a new 'Waste' library item.			
General Properties			Item <u>D</u> etails	
Treatment Type:	Landfill	•	View: Impact Indicators Metadata	
Material Type:	New Waste Item		Impact Indicators	
Measure Type:	Mass		Life-Cycle Inventory Life-Cycle Impact A	ssessment
Quantity:	1 Units: short-tons	•	Impact Indicator	Quantity Units
Mass Conversion: F	actor Not Needed		Renew, Energy (Non Raw Matl)	No Data MJ
Agency ID:			Renew. Energy (Raw Matl)	No Data MJ
Description:		_	Total Renew. Energy Use	No Data MJ
		-	🗖 Nonrenew. Energy (Non-Raw Matl)	No Data MJ
			🗖 Nonrenew. Energy (Raw Matl)	No Data MJ
			🗖 Total Nonrenew. Energy	No Data MJ
			🗖 Recycled Matl. Use	No Data Short-tons
			🗖 Disposed Non-Hazardous Waste	No Data Short-tons
			🗖 Disposed Hazardous Waste	No Data Short-tons
			Disposed Radio-Active Waste	No Data Short-tons
1			Net Use of Fresh Water	No Data Cubic meters
			CM Usage	No Data Short-tons
			Select <u>A</u> ll Deselect All	

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).

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

• Provide a brief description of the item being input.

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).

Library	×
Library Library Use the controls below to define library items that will be Library Selection Materials Equipment Waste Transport M Library Collection: 'Transport' Water Barge, Average Fuel Mix Barge, Diesel Barge, Residual Fuel Oil Ocean Freighter, average fuel mix Ocean Freighter, Residual Fuel Oil Cocean Freighter, Residual Fuel Oil	Close         available for use when conducting an analysis session.         tig Designs       Activities         Selection Details: 'Transport' Item         View:       1: Properties         2:Impact Indicators       3:Metadata         General Properties         Transport Type:       Water         Item Name:       Barge, Average Fuel Mix         Quantity:       1 short-ton-mile         Fuel Type:       Average Fuel Mix         Agency ID:       Description:         USLCI data as published by the Federal LCA Commons in OpenLCA. Prepared by MTU and The Right Environment as part of the FHWA Technical Support for the Infrastructure Analysis and Construction Team Contract
Copy     Add New     Edit       Paste     Delete	DTFH6117D00005 - Task Order No. 008 Mapping of Unit/Product System Processes for Pavement Life Cycle Assessment and Demonstration Case Studies. Editable?: No (Default Database Item)

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.

Keyboard	Shortcuts	Within
Transport	Library	

Properties interface: ALT + 1

Impact Indicators: ALT + 2

Metadata interface: ALT + 3

- **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.

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:

- 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

Keyboard shortcut for Add New: ALT + N

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

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).

• Provide a brief description of the item being input.

Add New 'Transport' Library Item		×
Add New 'Transport' Library Item		<u>C</u> ancel <u>S</u> ave
Use the controls below to define a new 'Transport' library item.		
General Properties	Item <u>D</u> etails	
Transport Type: Road 🔻	View: Impact Indicators Metadata	
Item Name: New Transport Item	Impact Indicators	
Quantity: 1 short-ton-mile	Life-Cycle Inventory Life-Cycle Impact Assess	sment
Fuel Type: Diesel	Impact Indicator Qu	antity Units
Agency ID:	🗖 Renew, Energy (Non Raw Matl)	No Data MJ
Description:	Renew. Energy (Raw Matl)	No Data MJ
	Total Renew. Energy Use	No Data MJ
	Nonrenew. Energy (Non-Raw Matl)	No Data MJ
	🗖 Nonrenew. Energy (Raw Matl)	No Data MJ
	Total Nonrenew, Energy	No Data MJ
	🗖 Recycled Matl. Use	No Data Short-tons
	Disposed Non-Hazardous Waste	No Data Short-tons
	Disposed Hazardous Waste	No Data Short-tons
	Disposed Radio-Active Waste	No Data Short-tons
	Net Use of Fresh Water	No Data Cubic meters
	SCM Usage	No Data Short-tons
	Select <u>All</u> Deselect All	

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 preloaded 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.* 

Library		×
Library Use the controls below to define library items that will be a Library Selection <u>Materials Equipment Waste Transport Miz</u>	Vailable for use when conducting an analysis session.	æ
Library Collection: 'Mix Designs'	Selection Details: 'Mix Design' Item         View:       1: Properties         2:Impact Indicators       3:Metadata         General       Description         General Properties       Pavement/Type: Asphalt         Name:       Level 2, 1/2" dense Superpave HMA: mix temp =         Quantity:       1 short-ton         Source Method:       Direct from EPD	
General     Description       Agency ID:     Description:       Description:     NAPA Published EPD        >       Copy     Add New       Edit     Delete	Editable?: No (Default Database Item)	

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.

Library	×
Library Use the controls below to define library items that will be a Library Selection <u>Materials Equipment Waste Transport M</u>	Close         available for use when conducting an analysis session.         ix Designs
Library Collection: 'Mix Designs' - Asphalt - Level 2, 1/2" dense Superpave HMA: mix terr - 3/4" dense-graded Marshall HMA: mix temp - 3/4" dense-graded Superpave HMA: mix tem - HMA - HMA - Beta-HMA-1 - Beta-HMA-2 - PCC	Selection Details: 'Mix Design' Item View: <u>1</u> : Properties <u>2</u> :Impact Indicators <u>3</u> :Metadata <u>General Description</u> General Properties Pavement Type: Asphalt Name: Beta-HMA-1 Quantity: 1 short-ton Source Method: Built From Library Items Editable?: Yes (User-Defined Item)
<ul> <li>&lt; →</li> <li>Copy Add New Edit</li> <li>Paste Delete</li> </ul>	Mix Design Definition

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

Add New 'Mix Design' Library Item	×
Add New 'Mix Design' Library Item Use the controls below to define a new 'Mix Design' library item. 'Mix Design' Definition Name: New Mix Design Pavement Type: Asphalt Source Method: © Build from library items © From EPD Quantity: 1 short-ton 'Mix Design' Details New Mix Design (1 short-ton)	Item Details       Add Items from Library       Metadata         Selected Item Details <ul> <li>'Mix Design' Properties</li> <li>Measure Type:</li> <li>Mass</li> <li>Quantity:</li> <li>1</li> <li>Units:</li> <li>short-tons</li> <li>Mass Conversion:</li> <li>Factor Not Needed</li> <li>Agency ID:</li> <li>Description:</li> <li>Add Transport Leg</li> </ul>
Delete Move Up Move Down	

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

Keyboard Shortcut for "Add to Mix Design":

ALT + A

example shown in figure 4-24, "Fine Aggregate" from the Materials library has been added to the current mix design.

Add New 'Mix Design' Library Item		×
Add New 'Mix Design' Library Item	<u>C</u> ancel Sa	i <u>v</u> e
Use the controls below to define a new 'Mix Design' library item.		
Name: New Mix Design	Item Details Add Items from Library Metadata	
Pavement Type: Asphalt	Add Items From Library	
Source Method: • Build from library items • From EPD	Materials Equipment Waste	
Quantity: 1 short-ton	Material' Library Items	
<pre>'Mix Design' Details </pre>	<ul> <li>Admixture/Additive</li> <li>Accelarator, hardening</li> <li>Accelarator, set</li> <li>Air Entrainer</li> <li>Plasticizer</li> <li>Retarder</li> <li>Water Proofing Agent</li> <li>New Material Item</li> <li>Accelarator, hardening (Copy)</li> <li>Aggregate</li> <li>Base and Subbase material</li> <li>Chip Seal</li> <li>Concrete sand</li> <li>Crushed Stone (Coarse Aggregate)</li> <li>Crushed Stone, granite (Coarse Aggregate)</li> <li>Fine Aggregate</li> <li>Limestone quarrying operation</li> <li>New Material Item TEH</li> </ul>	*
Delete Move Up Move Down	<= <u>A</u> dd to 'Mix Design'	1

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.

li <u>x</u> Design' Defini Name: Ivement Type:	ow to define a new 'Mix Design' libra tion New Mix Design Asphalt C Build from library items	Item Details Impact Indicators Impact Indicators	<u>M</u> etadata Assessment	]
Quantity:	1 short-ton	Impact Indicator	Quantity	Units
Design' Deta	ils	Renew. Energy (Non Raw Matl)	No Data	MJ
New Mix Des	ign (1 short-ton)	🗖 Renew. Energy (Raw Matl)	No Data	MJ
		🗖 Total Renew. Energy Use	No Data	MJ
		□ Nonrenew. Energy (Non-Raw Matl)	No Data	MJ
		Nonrenew. Energy (Raw Matl)	No Data	MJ
		🗖 Total Nonrenew. Energy	No Data	MJ
		🗖 Recycled Matl. Use	No Data	Short-tons
		🗖 Disposed Non-Hazardous Waste	No Data	Short-tons
		🗖 Disposed Hazardous Waste	No Data	Short-tons
		🗖 Disposed Radio-Active Waste	No Data	Short-tons
		Net Use of Fresh Water	No Data	Cubic meters
		🗖 SCM Usage	No Data	Short-tons
		Net Use of Fresh Water SCM Usage Select All Deselect All	No Data No Data	Cubic mete Short-tons

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

Library	X
Library         Use the controls below to define library items that will be average of the control below to define library items that will be average of the control below to define library items that will be average of the control below to define library items that will be average of the control below to define library items that will be average of the control below to define library items that will be average of the control below to define library items that will be average of the control below to define library items that will be average of the control below to define library items that will be average of the control below to define library items that will be average of the control below to define library items that will be average of the control below to define library items that will be average of the control below to define library items that will be average of the control below to define library items that will be average of the control below to define library items that will be average of the control below to define library items that will be average of the control below to define library items that will be average of the control below to define library items that will be average of the control below to define library items that will be average of the control below to define library items that will be average of the control below to define library items that will be average of the control below to define library items that will be average of the control below to define library items that will be average of the control below to define library items that will be average of the control below to define library items that will be average of the control be average of the co	Close Close Close Close
Library Collection: 'Activities' - Pavement Layers - 4-inch HMA-1 (EXAMPLE) - 4-inch HMA-2 (EXAMPLE) - 8-inch PCC-1 (EXAMPLE) - 8-inch PCC-2 (EXAMPLE) - 6-inch Aggregate Base (EXAMPLE) - HMA Mill and Inlay - PCC Diamond Grinding - HMA End-of-Life - PCC End-of-Life - PCC End-of-Life - PCC End-of-Life - PCC End-of-Life - Edit Activity Type List	Select a node in the library tree within a defined 'Activity' to view associated details.

Figure 4-27. Activities library.

# 4.6.1 Categorizing Activities

The user can set up to 10 activity types.

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

С	ategory List Editor	r: 'Activity Type' List	×
C	Category L	ist Editor	Save
U a	se the controls b re included in the	elow to define the list of 'Activity' categories, a e interface.	and which ones
Γ	'Activity Type' L	ist	
	Is Included?	Category Name	Move <u>U</u> p
	Yes	Layers	
	Yes	Surface Treatments	Move Down
	Yes	Activity #3	
	Yes	HMA Mill and Inlay	
	Yes	PCC Diamond Grinding	
	Yes	HMA End-of-Life	
	Yes	PCC End-of-Life	
	Yes	Activity Category #8	
	Yes	Activity Category #9	
	Yes	Different Stuff	
L	Colocted Item [	Dotailo	
Selected Item Details			
Is Included?: 🔽			
	Category Nam	e: Layers	

Figure 4-28. Category list editor.

# 4.6.2 Viewing Existing Data

Select an Activity item in the tree interface.

Keyboard Shortcut in the
Category List Editor Window:

Save: ALT + S

Move Up: ALT + U

Activity Type List":

Move Down: ALT + D

Keyboard Shortcut for "Edit

ALT + Y

• 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).
  - 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.

Keyboard Shortcut for "Add New":

ALT + N

#### **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.

Add New 'Activity' Library Item	×
Add New 'Activity' Library Item Use the controls below to define a new 'Activity' library item.	<u>Cancel</u> Sa <u>v</u> e
'Activity' Definition Use the controls at the right to add 'Items' from the library to the current 'Activity'.	Item Details       Add Items from Library         Selected Item Details       Activity Details         Activity Type:       Pavement Layers         Name:       New Activity         Measure Type:       Volume         Quantity:       1         Units:       cubic yards

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).

Add New 'Activity' Library Item	×
Add New 'Activity' Library Item Use the controls below to define a new 'Activity' library item.	<u>C</u> ancel Sa <u>v</u> e
'Activity' Definition □-New Activity (1 cubic yard) □ Materials □ Limestone quarrying operation (1 short-ton)	Item Details       Add Items from Library         Selected Item Details       Material Details         Material Type: Aggregate       Name: Limestone quarrying operation         Quantity:       1 short-ton         From EPD?:       No         If Update quantity when parent object quantity changes         Add Transport Leg
Delete Move Up Move Down	

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

LCA PAVE (Version 1.01.03)				×
LCA 🍤 PAV	A tool for determining er	Life-Cyc	cle Assessment	Tool
Control Panel				
<u>C</u> onduct Analysis	Click the "Conduct Analysis" but specific analysis objective. Set design alternatives to analyze, a	ton and follow the ste up steps include defini and choosing desired	p-by-step procedures provided to setung the analysis session details, defininoutputs.	ip and analyze your ig up to five different
Library	To aid in the building of useful stored in the library for use in f library items.	project analyses, man uture project analyses	y of the needed project building block: Click the "Library" button below to v	s can be named and /iew, add, and edit
Additional Informat	tion			
The tabs below contain d	lisclaimer and general tool inform	ation, and a summary	of tool applications and limitations.	
Disclaimer General A	pplications and Limitations			
As used in this Tool, "d requirements. Instead, greater detail to shape	efinition" and "Design Alternative "definition" is commonly used or the analysis (e.g., when modelin	Definition" do not refe referenced in Life Cyo g design alternatives)	er to Federal regulatory definitions or le Assessment to instruct a user to de	egally binding scribe the term with
U.S. Departm	nent of Transportation	SUSTAINABLE		
Federal Hig	ghway Administration	PAVEMENTS		<u>E</u> xit Tool

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:

 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

Keyboard Shortcuts
Back: ALT + B
Next: ALT + X

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.

Analysis Session Details	(Step 1 of 3)	×
Analysis Sess	sion Details	<u>B</u> ack Ne <u>x</u> t
Use the controls below	v to define the details of the current analysis session.	
<u>A</u> nalysis Details		
Analysis Objectiv	e: Compare Treatment Cycles or Pavement Design Life-Cycle Options	
Descriptio	n: Compare Materials	re, or 2) pavement
	a chosen analysis period.	eries of activities over
<u>G</u> eneral Inputs		
Session Name:	Beta Test HMA Project	
Route:	Beta-99	
Location:	Phoenix, AZ	
Project Limits:	Elm St to Washington Ave	
Analyzed By:	John Doe	
Comments:	Comparison between two HMA design options that uses two different HMA mixtures.	
Desig <u>n</u> Alternative Number of Desig	s	

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: <b>ALT + 4</b>
Alternative 5: ALT + 5

Design Alternative Definition (Step 2 of 3)	×
<b>Design Alternative Definition</b> Use the controls below to define up to five different Design Alter	Back Next Next
Selected Alternative: Alternative <u>1</u> Alternative <u>2</u>	
Alternative Definition	Selection Details: 'Alternative' Name: myAlternatve 1 Description: 50 vrs (Analysis period for this alternative)
Move Up         Copy           Move Down         Delete	Add <u>N</u> ew 'Pavement' to Current 'Alternative'

Figure 5-3. Design alternative definition interface.

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

• Click the alternative node in the treeview (i.e., the top node in the tree).

Keyboard shortcuts for "Add New Pavement to Current Alternative": ALT + N

- 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<sup>2</sup> (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<sup>2</sup>.

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

Design Alternative Definition (Step 2 of 3)	X
Design Alternative Definition	Back Next
Ise the controls below to define up to five different Design Alt	rematives to compare in the analysis
Selected Alternative: Alternative <u>1</u> Alternative <u>2</u>	
Alternative Definition	Selection Details: 'Pavement'
E-myAlternatve 1	Type: Mainline
⊞New Pavement	Name: New Pavement
	Description: This is a new pavement.
	Num. Lanes: 1 💌
	Length: 5280 ft
	Width: 12 ft (total width of all lanes)
	Lane Miles: 1.00 lane-miles
	Area: 63,360 sf
	Include this pavement's lane-miles and area in the functional unit calculations for this alternative.
Move Up	
Move Down Delete	Add New 'Project' to Current 'Pavement'

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."

Design Alternative Definition (Step 2 of 3)		×
Design Alternative Definition		Back Next
Use the controls below to define up to five different Design Alter	ernatives to compare in the analysis.	
Selected Alternative: Alternative <u>1</u> Alternative <u>2</u>		
Alternative Definition	Selection Details: 'Project'	
□myAlternative1	Type: Initial Construction	•
New Pavement 0: Initial Construction 0: Init	Application Age: 0	
Move Up Copy		
Move Down Delete	Add New 'Activity' to 'Project' Library	om

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: <b>ALT + A</b>
Keyboard Shortcuts (Figure 5-6):
Edit Activity: ALT + E
Copy to Library: <b>ALT + L</b>

- 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.

Design Alternative Definition     Back     Negt       Use the controls below to define up to five different Design Alternatives to compare in the analysis.     Selected Alternative:     Alternative 1     Alternative 2       Alternative Definition     Alternative 1     Alternative 2       Image: Selection Details: Project     Type:     Initial Construction       Image: Selection Details: Project     Type:     Initial Construction       Image: Selection Details: Project     Image: Selection Details: Project     Application Age: Image: Selection	Design Alternative Definition (Step 2 of 3)		×			
Uses the controls below to define up to five different Design Alternatives to compare in the analysis.         Selected Alternative:       Alternative 1         Alternative Definition       Selection Details: Project'         Image: Initial Construction       Image: Image	Design Alternative Definition					
Use the controls below to define up to five different Design Alternatives to compare in the analysis. Selected Alternative: Alternative 1 Alternative 2  Alternative Definition  Alternative 1  - Mew Pavement  - G: Initial Construction  - G: Initial Construction - G: Initial Construction - G:	Design Alternative Definition	<u>Back</u> Ne <u>x</u> t				
Selected Alternative:       Alternative 1         Alternative Definition       Selection Details: Project'         Image: Ima	Use the controls below to define up to five different Design Alte	rnatives to compare in the analysis.				
Alternative Definition       Selection Details: Project'         Image: Selection Details: Project'       Type: Initial Construction         Image: Selection Agg: Selection Ag	Selected Alternative: Alternative <u>1</u> Alternative <u>2</u>					
Image: Second	Alternative Definition	Selection Details: Project				
Image: Section Age: Construction         Image: Constremon         Image:	⊡…myAlternatve 1	Type: Initial Construction	<b>•</b>			
Move Up         Copy           Move Down         Delete           Add New 'Activity' to 'Project'         Import 'Activity' from Library	New Pavement     O: Initial Construction     O: Initial Construction     O: Initial Construction     O: Initial Construction     O: Maintenance and Preservation     O: Maintenance and Preservation     O: Maintenance and Preservation     O: Inich Mill and Fill-HMA-1     O: Inich Mill and Fill And Fill-HMA-1     O: Inich Mill and Fill-HMA-1     O: Inich Mill	Application Age: 0				
Move Down Delete 'Project' Library	Move Up	Add Nour Activity to Toppent I anti-ity of				
	Move Down Delete	'Project'				

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.

### 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.

Keyboard Shortcuts (Figure 5-8):Results Setup: ALT + ROverall Summary: ALT + STree Comparison: ALT + TBy Category: ALT + CSelect All: ALT + ADeselect All: ALT + EView Detailed Output: ALT + V

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.

Back       Yiew Detailed Output         Setup:       Results Setup       Summary Results:       Overall Summary       Tree Comparison       By Category         Output Setup:       Use the controls below to choose a functional unit and select the impact indicators you want to include in your results. Note some functional unit choices are dependent on the user-defined analysis period, computed lane-miles, and computed total area for each alternative.       Use the controls below to choose a functional unit and select the impact indicators you want to include in your results. Note some functional unit choices are dependent on the user-defined analysis period, computed lane-miles, and computed total area for each alternative.         Functional Unit:       Per Lane-Mile Per Year         Per Year       Iffe-Cycle Inwart Assessment (LCIA) Results         Iffe-Cycle Invent       Per Year         Per Year       as raw materials         If Use of renew       Per Square Foot         Per Square Foot       as raw materials         If Use of nonrenewable primary energy used as raw materials       If clobal Warming         If Use of nonrenewable primary energy resources       If Human Health - Concer         If Numan Health       View Obspeed Radio-Active Waste       If Song Formation         If Disposed Radio-Active Waste       If Song Formation       Song Formation         If Net Use of Fresh Water       Supplementary Cementitious Material Usage       Song Formation<	Results (Step 3 of 3)	×
Output Setup       Summary Results       Overlangummary Results       Use the controls below to choose a functional unit and select the impact indicators you want to include in your results. Note some functional unit choices are dependent on the user-defined analysis period, computed lane-miles, and computed total area for each alternative.         Eunctional Unit:       Per Lane-Mile Per Year       Iffe-Cycle Invent       Iffe-Cycle Impact Assessment (LCIA) Results         Iffe-Cycle Invent       Per Lane-Mile Per Year       Iffe-Cycle Impact Assessment (LCIA) Results       Iffe-Cycle Impact Assessment (LCIA) Results         Iffe-Cycle Invent       Per Lane-Mile Per Year       Iffe-Cycle Impact Assessment (LCIA) Results       Iffe-Cycle Impact Assessment (LCIA) Results         Iffe-Cycle Invent       Per Square Foot       as raw materials       Iffe-Cycle Impact Assessment (LCIA) Results         Iffe-Cycle Invent       Per Square Foot Per Year       as raw materials       Iffe-Cycle Impact Assessment (LCIA) Results         Iffe-Cycle Invent       Per Square Foot Per Year       as raw materials       Iffe-Cycle Impact Assessment (LCIA) Results         Iffe Use of nonrenewable primary energy resources       Iffe Europhication       Iffe Europhication       Iffe Europhication         Iffe Use of nonrenewable primary energy resources       Iffe Recycled Material Usage       Iffe Human Health - Cancer       Iffe Human Health Effects -         Iffe Disposed Radio-Active Waste       Iffe Disposed Radio-Active	Results Use the controls on this page to select impact indicators of interest and view re Setup: Results Setup Summary Results: Overall Summary Tree	elated outputs.  By Category  Detailed Output
Select <u>A</u> ll Deselect All	Setup:       Results Setup       Summary Results:       Overall Summary       Tree         Output Setup       Use the controls below to choose a functional unit and select the impact indic unit choices are dependent on the user-defined analysis period, computed lar       Functional Unit:       Per Lane-Mile Per Year       Image: Computed lar         Functional Unit:       Per Lane-Mile Per Year       Image: Computed lar       Image: Computed lar         Life-Cycle Invent       Total (Entire Project)       Per Year       Image: Computed lar         Image: Use of renewa       Per Lane-Mile Per Year       Image: Computed lar         Image: Use of renewa       Per Square Foot       Per Square Foot Per Year       Image: Computed lar         Image: Use of nonrenewable primary resources       Image: Compute Pointary resources       Image: Compute Pointary Resources       Image: Compute Pointary Resources         Image: Use of nonrenewable primary energy used as raw materials       Image: Compute Pointary Resources       Image: Compute Pointary Resources       Image: Compute Pointary Resources         Image: Disposed Non-Hazardous Waste       Image: Disposed Radio-Active Waste       Image: Disposed Radio-Active Waste       Image: Disposed Radio-Active Waste       Image: Compute Pointary Computitious Material Usage       Image: Compute Pointary Computitious Material Usage       Image: Compute Pointary Computitious Material Usage       Image: Compute Pointary Compute Pointary Pointary Pointary Pointary	a Comparison       By Category         ators you want to include in your results. Note some functional ne-miles, and computed total area for each alternative.         Life-Cycle Impact Assessment (LCIA) Results         Image: Acidification         Ecotoxicity         Ecotoxicity         Fossil Fuel Depletion         Image: Alternative Human Health - Cancer         Image: Human Health Effects -         Image: Ozone Depletion         Image: Smog Formation
	Select <u>A</u> ll <u>De</u> select All	

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.

Results (Step 3 of 3)					
Results       Use the controls on this page to select impage       Setup:     Results Setup     Summary F	act indicators of Results: Over	interest and view all <u>S</u> ummary	w related outputs. Tree Comparison	By <u>C</u> ategory	<u>B</u> ack <u>V</u> iew Detailed Output
Output Results: Overall Summary					
Functional Unit: Total (Entire Project)					View Excel Table
Impact Indicator	Alternative 1	Alternative 2	Units		
Renew. Energy (Non Raw Matl)	422,612	1,157,563	L		
Renew. Energy (Raw Matl)	42,624	113,728	۲. CM		
Total Renew. Energy Use	432,659	1,238,715	L CM		
Nonrenew. Energy (Non-Raw Matl)	6,929,543	15,721,562	ĽΜ		
Nonrenew. Energy (Raw Matl)	4,280,400	4,123,800	MJ		
Total Nonrenew. Energy	10,930,825	19,587,124	ĽΜ		
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		
Acidification	2 059	4 4 9 0	Short-tons		
Ecotoxicity	2,038	4,480	Kg SOZ eq		
Eutrophication	312	237,772	ka N ea		
Eassil Fuel Depletion	837,169	1,238,962	M1 surplus		
Global Warming	495,136	1.065.372	ka CO2 ea		
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 In-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 lanemiles, and total area for each design alternative modeled by the user.

Results (Step 3 of 3)
Results Use the controls on this page to select impact indicators of interest and view related outputs.           Back         View           Detailed         Output
Setup:         Results Setup         Summary Results:         Overall Summary         Tree Comparison         By Category
Output Results: Tree Comparison
Use the controls below to view side-by-side environmental impact summaries for two different design alternatives.
Functional Unit: Total (Entire Project)       Impact Indicator:       Renew. Energy (Non Raw Matl) (MJ)       Impact Indicator:
Results Tree #1 Results Tree #2 Results Tree #
Selection <u>1</u> : 1: myAlternative 1
<ul> <li>Introduction (422,612 MJ)</li> <li>Intial Construction (41,449 MJ)</li> <li>G-inch Aggregate Base (14,037 MJ)</li> <li>H-10: Maintenance and Preservation (189,630 MJ)</li> <li>I-10: Maintenance and Preservation (189,630 MJ)</li> <li>I-10: Maintenance and Preservation (189,630 MJ)</li> <li>I-10: Mill and Fill-HMA-1 (189,630 MJ)</li> <li>I-10: Mill and Fill-HMA-1 (189,630 MJ)</li> <li>I-10: Mill and Fill-HMA-1 (189,630 MJ)</li> <li>I-10: Molifier and Preservation (190,291 MJ)</li> <li>I-10: Mill and Fill-HMA-1 (189,630 MJ)</li> <li>I-10: Molifier and Preservation (190,291 MJ)</li> <li>I-10: Mill and Fill-HMA-1 (189,630 MJ)</li> <li>I-10: Demolish 4-inch HMA-Landfill (1,903 MJ)</li> <li>I-25: Removal (732,888 MJ)</li> </ul>
Analysis Period: 50 yrs         Total Area: 63,360 sf         Analysis Period: 50 yrs         Total Area: 63,360 sf
Total Lane-Miles: 1.00 ln-mi Total Lane-Miles: 1.00 ln-mi

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."

Results (Step 3 of 3)					×
Results         Use the controls on this page to select imp         Setup:       Results Setup         Output Results:       By Category Summary         Functional Unit:       Total (Entire Project)         Impact Indicator:       Renew. Energy (Not         Category:       Life-Cycle Stage         Life-Cycle Stage       Facility Type         Initial Constructic       Activity Type         Maintenance and       Application Age         Removal       Femoval	act indicators of Results: Overa n Raw Matl) (MJ native 1 41,449 379,260 0 0 1,903	interest and view all <u>Summary</u> ) Alternative 2 44,094 380,582 0 0 732,888	w related outputs. [ree Comparison Units MJ MJ MJ MJ MJ MJ MJ	By <u>C</u> ategory	Back       View         Detailed       Output
Analysis Period: Total Lane-Miles: Total Area:	50 γrs 1.00 ln-mi 63,360 sf	50 yrs 1.00 ln-mi 63,360 sf			

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						
•					<u>R</u> etu	rn to
Overall and alternative-specific output	associated with you	ur current analysis session is provided	in the visible worksheet tab	os below. To		sion
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 betwee	en output tabs.		-	Export O	utput to
					New Wo	orkbook
Click the 'Return to Session' button to re	eturn to your currer	nt analysis session.				
Summary of Output Worksheets	5					
Tab Name	Tab Description					
Session Summary	Summary of gene	ral analysis session attributes.				
Alternative Comparison Summary	Comparison of inc	luded impact indicators for all include	d Design Alternatives.			
Alternative 1 Definition	General description	on of the Alternative 1 object and all o	f its components.			
Alternative 1 Definition 508	508-compliant ver	sion of the table shown on tab 'Altern	ative 1 Definition'.			
Alternative 1 Details	1 Details Summary of the environmental impacts for each component in Alternative 1, for each included					
	impact indicator.					
Alternative 1 Details 508	508-compliant ver	sion of the table shown on tab 'Altern	ative 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	atg 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	Definition 508 508-compliant version of the table shown on tab 'Alternative 2 Definition'.					
Alternative 2 Details	Summary of the e	nvironmental impacts for each compo	nent in Alternative 2, for ea	ch included		
	impact indicator.					
Alternative 2 Details 508	ive 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 imp	oact indicator.				
Alternative 2 Pct of Catg Data	Summary of the b	y category environmental impact perc	entages for each componen	t in		
	Alternative 2, for	each included impact indicator.				
Alternative 2 Summary Charts	Series of by categ	ory environmental impact charts for A	Iternative 2.			
Output Control Panel	Session Summary	Alternative Comparison Summary	Alternative 1 Definition	Alternative -	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.

	А	В		
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		
	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		
8		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		
	Comments	Comparison between two HMA design options that uses two different HMA		
16		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").

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$K14$ $\checkmark$ : $X \checkmark J_X$			
A	В	С	D
1 Alternative 1: Definition			
2		1	
3 Table 3. Alternative 1 Definition - 'myAlternatve 1'			
4		1	
5 Object Name	Object Type 🔽	Object ID 🔻	Parent Object 💌
18Crushed Stone (Coarse Aggregate)	Material	Material 3	Mix Design 1
19Fine Aggregate	Material	Material 4	Mix Design 1
20Asphalt, Al	Material	Material 5	Mix Design 1
21Transport: Asphalt, AI (To Production Site)	Transport	Transport 4	Material 5
22HMA plant operation, at plant	Equipment	Equipment 2	Mix Design 1
23Transport: Beta-HMA-1 (To Construction Site)	Transport	Transport 5	Mix Design 1
24Paver	Equipment	Equipment 3	Activity 2
25Transport: Paver (To Construction Site)	Transport	Transport 6	Equipment 3
26Pneumatic Roller	Equipment	Equipment 4	Activity 2
27Maintenance and Preservation (Year 10)	Project	Project 2	Pavement 1
281-inch Mill and Fill-HMA-1	Activity	Activity 3	Project 2
29Beta-HMA-1	Mix Design	Mix Design 1	Activity 3
30Crushed Stone (Coarse Aggregate)	Material	Material 7	Mix Design 1
31Fine Aggregate	Material	Material 8	Mix Design 1
32Asphalt, AI	Material	Material 9	Mix Design 1
33Transport: Asphalt, AI (To Production Site) Transport Transport 7 Materia			Material 9
34HMA plant operation, at plant	Equipment	Equipment 5	Mix Design 1
35Transport: Beta-HMA-1 (To Construction Site)	Transport	Transport 8	Mix Design 1
36Miller	Equipment	Equipment 6	Activity 3
37Transport: Miller (To Construction Site)	Transport	Transport 9	Equipment 6
38Paver	Equipment	Equipment 7	Activity 3
39Pneumatic Roller	Equipment	Equipment 8	Activity 3
40Waste: Asphalt	Waste	Waste 1	Activity 3
Transport: Recycled Onsite-Asphalt (To Production Site)	Transport	Transport 10	Waste 1
42Maintenance and Preservation (Year 18)	Project	Project 3	Pavement 1
431-inch Mill and Fill-HMA-1	Activity	Activity 4	Project 3
44Beta-HMA-1	Mix Design	Mix Design 1	Activity 4
45Crushed Stone (Coarse Aggregate)	Material	Material 11	Mix Design 1
46Fine Aggregate	Material	Material 12	Mix Design 1
47Asphalt, AI	Material	Material 13	Mix Design 1
48Transport: Asphalt, AI (To Production Site)	Transport	Transport 11	Material 13
49HMA plant operation. at plant	Equipment	Equipment 9	Mix Design 1
Output Control Panel Session Summary Alternative Compare	ison Summary	Alternative 1 Def	inition Alternat
	-		

Figure 5-15. Alternative definition worksheet.

#### LCA Pave—User Manual

#### Chapter 5

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A1	• : $\times \checkmark f_x$ Alternative 1: Details				
	А	В	C D	E	F
1	Alternative 1: Details				
2					
2	Table 4 Alternative 1 Details - 'mvAlternatve 1': Functional Un	nit = 'Per I ane-Mile I	Per Year'		
4					
-					
				Indicator 1: Use of	
				renewable energy	
				primary energy,	
				excluding renewable	
				primary resources	
				used as raw materials	Indicator 1:
5	Object Name	🔽 Object Type 🔽	Quantity 🔽 Units	🔄 (MJ per In-mi per y	Status 💌
6	myAlternatve 1	Alternative		8,452	Complete
7	New Pavement	Pavement	63,360 square fee	t 8,452	Complete
8	Initial Construction (Year 0)	Project		829	Complete
9	6-inch Aggregate Base	Activity	1,584 short-tons	281	Complete
10	Crushed Stone (Coarse Aggregate)	Material	950 short-tons	198	Complete
	Transport: Crushed Stone (Coarse Aggregate) (To Construction Site)	Transport	12,355 short-ton-	0.0968	Complete
11			miles		
12	Fine Aggregate	Material	634 short-tons	82.18	Complete
	Transport: Fine Aggregate (To Construction Site)	Transport	8,237 short-ton-	0.0645	Complete
13			miles		
14	Paver	Equipment	5 hours	0.7848	Complete
	Iransport: Paver (To Construction Site)	Transport	400 short-ton-	0.0031	Complete
15	4 :	A -41-114-1	miles	540	Consulat
10	Pota LIMA 1	Mix Design	1,531 Short-tons	548	Complete
10	Crushed Stope (Coarse Aggregate)	Matorial	756 short ton	330	Complete
10		Material	698 short tone	10/ 00	Complete
20		Material	153 120 pounds	20.45	Complete
20	Transport: Asphalt AI (To Production Site)	Transport	1.608 short-ton	0.0126	Complete
21		nansport	miles	0.0120	complete
22		Fauipment	1.531 short-tons	7.35	Complete
		Transport	7,656 short-ton-	0.06	Complete
23	,		miles		prese
24	Paver	Equipment	8 hours	5.9	Complete
	Transport: Paver (To Construction Site)	Transport	900 short-ton-	0.007	Complete
	Output Control Panel Session Summary Alternative Control Panel Session Summary Alternative Control Panel Session Summary Panel Session Session Summary Panel Session Sess	mparison Summary	Alternative 1 Definition	Alternative 1 Details	Alternative 1 B

Figure 5-1	6. Alternativ	ve details	worksheet.
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### 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).

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	А	В	С	D	E
1	Alternative 1:	By Category Data			
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3	Table 5. Alternativ	e 1 By Category Data - 'n	yAlternatve 1'; Fur	nctional Unit	= 'Per Lane-Mile Pe
4					
			Indicator 1: Use of		
			renewable energy		
			primary energy,		Indicator 2: Use of
			excluding renewable		renewable primary
			primary resources		energy resources used
			used as raw materials	Indicator 1:	as raw materials (MJ
5	Category	Metric	(MJ per In-mi per yr)	Status	per In-mi per yr)
6	Pavement Category	Mainline	8,452	Complete	852
7	Pavement Category	Shoulder	0	n/a	0
8	Pavement Category	Ramp	0	n/a	0
9	Pavement Category	Other	0	n/a	0
10	Pavement Category	TOTAL	8,452	Complete	852
	Life-Cycle Stage	Initial Construction	829	Complete	50.77
10	Life-Cycle Stage	Maintenance and	7,585	Complete	/60
12	Life Ovelo Stage	Preservation	0	n/2	0
14	Life-Cycle Stage	Reconstruction	0	n/a	0
15	Life-Cycle Stage	Removal	38.07	Complete	41.4
16	Life-Cycle Stage	ΤΟΤΑΙ	8 452	Complete	852
17	Activity Type	Lavers	829	Complete	50.77
18	Activity Type	Surface Treatments	0	n/a	0
19	Activity Type	Todd's Activity	0	n/a	0
20	Activity Type	HMA Mill and Inlay	7,585	Complete	760
21	Activity Type	PCC Diamond Grinding	0	n/a	0
22	Activity Type	HMA End-of-Life	38.07	Complete	41.4
23	Activity Type	PCC End-of-Life	0	n/a	0
24	Activity Type	Activity Category #8	0	n/a	0
25	Activity Type	Activity Category #9	0	n/a	0
26	Activity Type	Different Stuff	0	n/a	0
27	Activity Type	TOTAL	8,452	Complete	852
28	Process Type	Material	1,073	Complete	0
29	Process Type	Equipment	64.79	Complete	141
	<ul> <li>Alternat</li> </ul>	ive 1 Definition   Alternative	1 Details Alternativ	e 1 By Categor	Alternative 1

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

	AutoSave 💽 🕅 🖁	9· (°· ₹	Pavement LC4	A Tool v1.01.228c	xlsm +
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3	Table 6. Alternativ	e 1 Percent of Category I	Data - 'mvAlternatve	1': Functio	nal Unit = 'Per Lane
4				,	
			Indicator 1: Use of		
			renewable energy		
			primary energy,		Indicator 2: Use of
			excluding renewable	Indicator 1:	renewable primary
			primary resources	Percent of	energy resources used
			used as raw materials	Category	as raw materials (MJ
5	Category	Metric	(MJ per ln-mi per yr)	Total	per In-mi per yr)
6	Pavement Category	Mainline	8,452	100.0%	852
7	Pavement Category	Shoulder	0	0.0%	0
8	Pavement Category	Ramp	0	0.0%	0
9	Pavement Category	Other	0	0.0%	0
10	Pavement Category	TOTAL	8,452	100.0%	852
11	Life-Cycle Stage	Initial Construction	829	9.8%	50.77
	Life-Cycle Stage	Maintenance and	7,585	89.7%	760
12		Preservation			
13	Life-Cycle Stage	Rehabilitation	0	0.0%	0
14	Life-Cycle Stage	Reconstruction	0	0.0%	0
15	Life-Cycle Stage	Removal	38.07	0.5%	41.4
16	Lite-Cycle Stage	IUIAL	8,452	100.0%	852
1/	Activity Type	Layers	829	9.8%	50.77
18	Activity Type	Surrace Treatments	0	0.0%	0
20	Activity Type	HMA Mill and Inlay	7 505	0.0%	760
20	Activity Type	DCC Diamond Grinding	0	0.0%	/00
21	Activity Type	HMA End-of-Life	38.07	0.5%	41.4
23	Activity Type	PCC End-of-Life	0	0.0%	0
24	Activity Type	Activity Category #8	0	0.0%	0
25	Activity Type	Activity Category #9	0	0.0%	0
26	Activity Type	Different Stuff	0	0.0%	0
27	Activity Type	TOTAL	8,452	100.0%	852
28	Process Type	Material	1,073	12.7%	0
29	Process Type	Equipment	64.79	0.8%	141
	▲ ▶ Alternat	ive 1 Definition Alternative	1 Details Alternative	e 1 By Category	Data Alternative 1
	1				

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



■ Mainline 

Shoulder 
Ramp 
Other

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



% of Total Environmental Impact

Initial Construction	Maintenance and Preservation
Rehabilitation	Reconstruction
☑ Removal	

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



Layers
 Surface Treatments
 Activity #4
 HMA Mill and Inlay
 PCC Diamond Grinding
 HMA End-of-Life
 Activity Category #8
 Activity Category #9
 Different Stuff

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





■ Material □ Equipment ■ Waste S Transport

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



■Year 0 □Year 1 ■Year 10 ■Year 18 □Year 25

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.

	А	В	С	D	
1	Detailed LCA Output			rn to	
2			Ses	sion	
	Overall and alternative-specific output associated with your current analysis session is provided in the visible worksheet tabs below. To			45	
	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.			output to	
3	Click the 'Return to Session' button to return to your current analysis session.			DIKDOOK	
4					



- 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).

LCA PAVE (Version 1.01.03)		×
LCA 🌖 PAV	IE Pavement Life-Cycle Assessment To A tool for determining environmental impacts of pavement systems.	ol
Control Panel		
<b><u>C</u>onduct Analysis</b>	Click the "Conduct Analysis" button and follow the step-by-step procedures provided to setup and specific analysis objective. Setup steps include defining the analysis session details, defining up t design alternatives to analyze, and choosing desired outputs.	analyze your o five different
Library	To aid in the building of useful project analyses, many of the needed project building blocks can be stored in the library for use in future project analyses. Click the "Library" button below to view, a library items.	e named and dd, and edit
Additional Informat	tion	
The tabs below contain d	lisclaimer and general tool information, and a summary of tool applications and limitations.	
Disclaimer General Ap	pplications and Limitations	
As used in this Tool, "definition" and "Design Alternative Definition" do not refer to Federal regulatory definitions or legally binding requirements. Instead, "definition" is commonly used or referenced in Life Cycle Assessment to instruct a user to describe the term with greater detail to shape the analysis (e.g., when modeling design alternatives).		
U.S. Departm Federal Hig	SUSTAINABLE phway Administration	<u>E</u> xit Tool

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.

Add New 'Mix Design' Library Item	×
Add New 'Mix Design' Library Item Sadd New 'Mix Design' Library Item. Use the controls below to define a new 'Mix Design' library item. 'Mig Design' Definition Name: New Mix Design Pavement Type: Asphalt Source Method: & Build from library items C From EPD Quantity: 1 short-ton 'Mix Design' Details New Mix Design (1 short-ton)	Cancel       Save         Item Details       Metadata         Selected Item Details       Metadata         'Mix Design' Properties       Quantity:         Quantity:       1         Units:       short-tons         Quantity:       1         Units:       short-tons         Mass Conversion:       Factor Not Needed         Agency ID:
Delete Move Up Move Down	

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.

-'Mix Design' Definition	
Name: Beta-HMA-1	Item Details Add Items from Library Metadata
Pavement Type: Asphalt	Selected Item Details
Source Method: Built From Library Items Quantity: 1 short-ton 'Mix Design' Details Beta-HMA-1 (1 short-ton) Materials Crushed Stone, granite (Coarse Aggregate for Asph Gransport: To Production Site (4.94 short-ton-r Fine Aggregate (for asphalt) (0.456 short-tons) Transport: To Production Site (4.56 short-ton-r Asphalt binder, no additives, consumption mix, at te Transport: To Production Site (1.05 short-ton-r Fine Equipment Production of Asphalt Mixture at Plant only (Alternat Transport	'Mix Design' Properties         Measure Type:       Mass         Quantity:       1         Units:       short-tons         Mass Conversion:       Factor Not Needed         Agency ID:
	Add Transport Leg

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.

Edit 'Mix Design' Library Item	<u>C</u> ancel Sa <u>v</u> e
Use the controls below to edit the current 'Mix $\ensuremath{Design'}$ library item.	
Use the controls below to edit the current 'Mix Design' library item. 'Mix Design' Definition Name: Beta-HMA-1 Pavement Type: Asphalt Guantity: 1 short-ton 'Mix Design' Details Guantity: 1 short-ton 'Mix Design' Details Beta-HMA-1 (1 short-ton) Materials Geta-HMA-1 (1 short-ton)	Item Details       Add Items from Library       Metadata         Add Items From Library       Materials       Equipment       Waste         'Equipment' Library Items       'Equipment' Library Items       Production of Asphalt Mixture at Plant only (Alternative 1)         Production of Asphalt Mixture at Plant only (Alternative 2)       Production of Asphalt Mixture at Plant only (Alternative 3)         Production of Asphalt Mixture at Plant only (Alternative 3)       Mixing Operations - Concrete
Delete Move Un Move Down	<= <u>A</u> dd to
	'Mix Design'

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.

Library X
Library       Close         Use the controls below to define library items that will be available for use when conducting an analysis session.       Library Selection         Materials       Equipment       Waste       Transport       Mix Designs       Activities         Library Collection: 'Mix Designs'       Selection Details: 'Mix Design' Item       Selection Details: 'Mix Design' Item       View: 1: Properties       2:Impact Indicators       3:Metadata         General       Description       General Properties       General Properties       General Properties
Pavement Type: Asphalt HMA Beta-HMA-1 Beta-HMA-2 Quantity: 1 short-ton Source Method: Built From Library Items Editable?: Yes (User-Defined Item) €
<ul> <li>Mix Design Definition</li> <li>Materials</li> <li>Crushed Stone, granite (Coarse Aggregate for Asphalt) (0.494</li> <li>Transport: To Production Site (4.94 short-ton-miles)</li> <li>Fine Aggregate (for asphalt) (0.456 short-tons)</li> <li>Transport: To Production Site (4.56 short-ton-miles)</li> <li>Asphalt binder, 8% ground rubber tire (GRT), consumption mi Transport: To Production Site (1.05 short-ton-miles)</li> <li>Add New Edit</li> </ul>
Paste Delete

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.

'Mix Design' Definition	Item Details Add Items from Library Metadata
Pavement Type: PCC   Source Method: <ul> <li>Build from library items</li> <li>From EPD</li> <li>Quantity:</li> <li>1 cubic yard</li> </ul> 'Mix Design' Details	Selected Item Details 'Mix Design' Properties Measure Type: Volume Quantity: 1 Units: cubic yards Mass Conversion: 4000 lbs/cubic yard Agency ID: PCC-001 Description: Add Transport Leg

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.

'Mix Design' Definition	
Name: Beta-PCC-1	Item Details Add Items from Library Metadata
Pavement Type:     PCC       Source Method: <ul> <li>Build from library items</li> <li>From EPD</li> <li>Quantity:</li> <li>1 cubic yard</li> </ul> 'Mix Design' Details <ul> <li></li></ul>	Selected Item Details         Material Details         Material Type: Other         Name: Water         Quantity:       0.11 short-tons         From EPD?:       No         ✓       Update quantity when mix design quantity changes         Add Transport Leg

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.

'Mix Design' Definition         Name:       Beta-PCC-1         Pavement Type:       PCC         Source Method: <ul> <li>Build from library items</li> <li>From EPD</li> <li>Quantity: 1 cubic yard</li> <li>'Mix Design' Details</li> <li>Beta-PCC-1 (1 cubic yard)</li> <li>Materials</li> <li>Generation</li> <li>Free Aggregate for Concrete;</li> <li>Transport: To Production Site (8.63 short-tons)</li> <li>Transport: To Production Site (6.95 short-tons)</li> <li>Transport: To Production Site (4.13 short-tons)</li> <li>Equipment</li> <li>Production of Concrete Mixture at Plant only (=</li> <li>Transport: To Construction Site (16 short-ton-rr</li> <li>To Construction Site (16 short-ton-rr</li> <li>T</li></ul>	Item Details       Add Items from Library       Metadata         Add Items From Library       Materials       Eguipment       Waste         'Equipment' Library Items       'Equipment' Library Items       ''equipment' Library Items         Image: Mixing Operations - Asphalt       Production of Asphalt Mixture at Plant only (Alternative 1)         Production of Asphalt Mixture at Plant only (Alternative 2)       Production of Asphalt Mixture at Plant only (Alternative 3)         Image: Precast concrete, Barrier Section, operation, plant       Precast concrete, culvert operation, plant         Precast concrete, Barrier Section operation, plant       Precast concrete, elbow, operation, plant         Precast concrete, End Section operation, plant       Precast concrete, I Beam operation, plant         Precast concrete, I Beam operation, plant       Precast concrete, pipe operation, plant         Precast concrete, plant PCA       Precast concrete, plant PCA         Precast concrete, Vall Panel, operation, plant       Precast concrete, Wall Panel, operation, plant         Precast concrete, Wall Panel, operation, plant       Precast concrete, Wall Panel, operation, plant         Precast concrete, Wall Panel, operation, plant       Precast concrete, Wall Panel, operation, plant         Production of Concrete Mixture at Plant only (19% Fly Asi       Production fo Concrete Mixture at Plant only (19% Fly Asi
Delete Move Up Move Down	<= <u>A</u> dd to 'Mix Design'

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.

Library	×
Library Use the controls below to define library items that will be Library Selection <u>Materials Equipment Waste Transport M</u>	Close
Library Collection: 'Mix Designs'	Selection Details: 'Mix Design' Item View: 1: Properties 2:Impact Indicators 3:Metadata General Description General Properties Pavement Type: PCC Name: Beta-PCC-2 Quantity: 1 cubic yard Source Method: Built From Library Items Editable?: Yes (User-Defined Item) Mix Design Definition Mix Design Definition Mix Design Definition C-Fine Aggregate (for concrete) (0.695 short-tons) Water (0.11 short-tons) C-Cement (Blended with SCMs) (0.295 short-ton-miles) C-Equipment
Copy     Add New     Edit       Paste     Delete	Production of Concrete Mixture at Plant only (= 20% Fly Ash a Transport Transport: To Construction Site (16 short-ton-miles)



# 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<sup>2</sup>).

### 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.

-'Activity' Definition	
	Item Details Add Items from Library
⊢…4-inch HMA-1 (63,360 square feet)	Selected Item Details
■Beta-HMA-1 (1,531 short-tons)	Material Details
	Material Type: Mix Design
Crushed Stone, granite (Coarse Aggregate f	Namo: Pata-HMA-1
Transport: To Production Site (7,564 st	Name. beta-mma-1
Fine Aggregate (for asphalt) (698 short-tons	Pavement Type: Asphalt
I ransport: To Production Site (6,982 st	Dev Method: Built From Library Items
Aspnait binder, no additives, consumption m	
Faviance framework	Quantity: 1531.2 short-ton
Equipment     Dreduction of Acabalt Mixture at Plant only (	
	Update quantity when activity quantity changes
Transport: To Construction Site /7 656 chor	
Transport. To construction site (7,050 shor	Add <u>T</u> ransport Leg
< >>	
Delete Move Up Move Down	

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.

'Activity' Definition         □-8-inch PCC-1 (63,360 square feet)         □-Materials         □-Materials         □-Materials         □-Transport: To Production Site (13,493 :         □-Transport: To Production Site (13,493 :         □-Transport: To Production Site (10,873 short-1)         □-Transport: To Production Site (10,873 :         □-Cement (Precalciner method) (461 short-tor         □-Transport: To Production Site (6,461 sl         □-Water (172 short-tons)         □-Equipment         □-Transport: To Construction Site (25,030 shc         □-Dowel bar, 1.5" x 18" (3,900 items)	Item Details       Add Items from Library         Selected Item Details       Transport Details         Transport Details       Item Being Transported         Item Type: Material       Name: Dowel bar, 1.5" x 18"         Quantity: 3,900 items       Mass Conv. Factor: 9 lbs/item         Quantity (tons): 17.55 short-tons       Transport Method         Transport Type:       Road         Transport Vehicle:       Combination Truck, Diesel
Image: Construction Site (527 short-ton-n       Image: Construction Site (527 short-ton-n <td< td=""><td>Usage Details Transport Leg: To Construction Site Trip Distance: 30 miles Total Transported Ton-Miles: 526.5 short-ton-miles</td></td<>	Usage Details Transport Leg: To Construction Site Trip Distance: 30 miles Total Transported Ton-Miles: 526.5 short-ton-miles

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.

-' <u>A</u> ctivity' Definition	Them Details Add Items from Library
Beinch PCC-1 (63,360 square feet) Image: Second	Selected Item Details Transport Details Item Being Transported Item Type: Equipment Name: Pavers, Nonroad Diesel Fuel, 300 < hp <= Quantity: 50 short-tons (default vehicle mass) Mass Conv. Factor: Factor Not Needed Quantity (tons): 50 short-tons Transport Method Transport Method Transport Type: Road Transport Vehicle: Combination Truck, Diesel Usage Details Transport Leg: To Construction Site Trip Distance: 10 miles Total Transported Ton-Miles: 500 short-ton-miles
Delete Move Up Move Down	



### 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.

' <u>A</u> ctivity' Definition —	Item Details Add Items from Library
- Materials	Add Items Erom Library
Crushed Stone (Coarse Aggregate for Concrete) (950 s	Materials Equipment Waste Mix Designs
me Aggregate (for concrete) (654 short-tons)	'Material' Library Items
	H Admixture/Additive
	Asphalt Binder
	Element
	I IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
	Recycled, Co-Product, or Waste Material
	⊞…Steel
Delete Move Up Move Down	<=Add to
	'Activity'

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.

'Activity' Definition         □-6-inch Aggregate Base (63,360 square feet)         □-Materials         □-Crushed Stone (Coarse Aggregate for Concrete) (950         □-Transport: To Production Site (9,504 short-ton-n         □-Fine Aggregate (for concrete) (634 short-tons)         □-Transport: To Production Site (8,237 short-ton-n         □-Equipment         □-Pavers, Nonroad Diesel Fuel, 75 < hp <= 100 (5 hour)         □-Transport: To Construction Site (400 short-ton-r)	Item Details       Add Items from Library         Selected Item Details       Transport Details         Item Being Transported       Item Type: Equipment         Name: Pavers, Nonroad Diesel Fuel, 75 < hp <= 100         Quantity: 50 short-tons (default vehicle mass)         Mass Conv. Factor: Factor Not Needed         Quantity (tons): 50 short-tons         Transport Method         Transport Type: Road         Transport Vehicle:         Combination Truck, Diesel
< > Delete Move Up Move Down	Usage Details Transport Leg: To Construction Site Trip Distance: 8 miles Total Transported Ton-Miles: 400 short-ton-miles



# 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.

'Activity' Definition □I-inch Mill and Fill-1 (383 short-tons) □Equipment □Willing Machine, Nonroad Diesel Fuel, 50 < hp <= 75 □Transport: To Construction Site (350 short-ton-n □Waste □Waste □Waste □Waste □	Item Details       Add Items from Library         Selected Item Details       Transport Details         Item Being Transported       Item Type: Waste         Name: Recycled Onsite-Asphalt       Quantity: 383 short-tons         Mass Conv. Factor: Factor Not Needed       Quantity (tons): 382.8 short-tons         Transport Method       Transport Type:         Road       •         Transport Vehicle:       Transfer Truck, Diesel         Usage Details       •         Transport Leg:       From Construction Site         Trin Distance:       10 miles
C     >       Delete     Move Up       Move Down	Trip Distance:       10       miles         Total Transported Ton-Miles:       3,828 short-ton-miles



#### 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.

Use the controls below to define a new 'Activity' library item.

Delete Move Up Move Down
--------------------------

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.

'Activity' Definition         □ - 0.25-inch Diamond Grinding (EXAMPLE) (63,360 square feet)         □ - Equipment         □ - equipment operation, > 75 hp and < 750 hp (6 hours         □ - Transport: To Construction Site (550 short-ton-n         □ - Waste         □ - Landfill-Concrete (95.7 short-tons)         □ - Transport: To Production Site (1,914 short-ton-n	Item Details       Add Items from Library         Selected Item Details       Transport Details         Item Being Transported       Item Type: Waste         Name: Landfill-Concrete       Quantity: 95.7 short-tons         Mass Conv. Factor: Factor Not Needed       Quantity (tons): 95.7 short-tons         Transport Method       Transport Type: Road         Transport Vehicle:       Transfer Truck, Diesel
<	Usage Details Transport Leg: To Production Site Trip Distance: 20 miles Total Transported Ton-Miles: 1,914 short-ton-miles

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.

<u>Activity' Definition</u> <u>Comparent Activity' Definition</u> <u>Comparent Activity' Definition</u> <u>Activity' Definition</u> <u>Comparent Activity' Definition</u> <u>Comparent Activit</u>	Item Details Add Items from Library	
Transport: To Construction Site (750 short-ton-r	Activity Type: HMA End-of-Life	<u>-</u> ]
⊡…Landfill-Asphalt (1,531 short-tons)	Name: Demolish 4-inch HMA-Landfill (EXAMPLE)	_
Transport: From Construction Site (30,624 short	Measure Type: Mass	r
	Quantity: 1,531 Units: short-tons	
<u>     Delete Move Up Move Down </u>		

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.

	Item Details Add Items from Library	
□Demolish 4-inch HMA-Recycle Onsite (EXAMPLE) (1,531 short-t	Selected Item Details	
equipment operation, > 750 hp and < 1200 hp (8 hou	Transport Details	
Transport: To Construction Site (750 short-ton-r	Ttem Being Transported	
Waste	Item Type: Waste	
Recycled Onsite-Asphalt (1,531 short-tons)		
Transport: From Construction Site (15,312 short	Name: Recycled Onsite-Asphalt	
	Quantity: 1,531 short-tons	
	Mass Conv. Factor: Factor Not Needed	
	Quantity (tons): 1,531.2 short-tons	
	Transport Method	
	Transport Type: Road	
	Transport Vehicle: Transfer Truck, Diesel	
	Usage Details	
	Transport Leg: From Construction Site	
	Trip Distance: 10 miles	
< >>	Total transported fon-whiles: 15,312 short-ton-miles	
Delete Move Up Move Down		

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



- 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.

<pre>'Activity' Definition Demolish 8-Inch PCC-Landfill (3,062 short-tons)     Equipment     Generation, &gt; 750 hp and &lt; 1200 hp (12 hc     Generation, &gt; 750 hp</pre>	Item Details       Add Items from Library         Selected Item Details       Activity Details         Activity Type:       PCC End-of-Life         Name:       Demolish 8-inch PCC-Landfill         Measure Type:       Mass         Quantity:       3,062         Units:       short-tons
Delete Move Up Move Down	

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.

<u>Activity'</u> Definition		
	Item Details Add Items from Library	
Equipment	Selected Item Details	
equipment operation, > 750 hp and < 1200 hp (12 hc	Transport Details	
Transport: To Construction Site (750 short-ton-r	Item Being Transported	
	Item Type: Waste	
Transport: To Production Site (1,540 short-ton-r	Name: Recycled Onsite-Concrete	
Encycled Onsite-Concrete (3,062 short-tons)	Quantity: 3,062 short-tons	
Transport. From Construction Site (50,024 short	Mass Conv. Factor: Factor Not Needed	
	Quantity (tons): 3,062.4 short-tons	
	Transport Method	
	Transport Type: Road	
	Transport Vehicle: Transfer Truck, Diesel	
	Usage Details	
	Transport Leg: From Construction Site	
	Trip Distance: 10 miles	
	Total Transported Ton-Miles: 30.624 short-ton-miles	
Delete Move Up Move Down		



#### 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:	Pavement Life-Cycle Activities:		
<ul> <li>Year 0: 4-inch HMA over 6-inch</li> </ul>	<ul> <li>Year 0: 4-inch HMA over 6-inch</li> </ul>		
aggregate base aggregate base			
<ul> <li>Year 10: 1-inch mill and fill</li> <li>Year 10: 1-inch mill and fill</li> </ul>			
<ul> <li>Year 18: 1-inch mill and fill</li> </ul>	<ul> <li>Year 18: 1-inch mill and fill</li> </ul>		
<ul> <li>Year 25: Demolish and Landfill</li> </ul>	<ul> <li>Year 25: Demolish and Recycle On-Site</li> </ul>		

#### 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.

Analysis Session Details	(Step 1 of 3)				×
Analysis Session Details Back Next					Ne <u>x</u> t
Use the controls below to define the details of the current analysis session.					
<u>A</u> nalysis Details					
Analysis Objectiv	e: Compare Treatment Cycles or Pavement De	esign Life-Cycle Options			
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.					
<u>G</u> eneral Inputs					
Session Name:	Beta Test HMA Project				
Route:	Beta-99				
Location:	Phoenix, AZ				
Project Limits:	Elm St to Washington Ave				
Analyzed By:	John Doe				
Comments: Comparison between two HMA design options that uses two different HMA mixtures.					
Design Alternatives       Number of Design Alternatives:     2					

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.

Selection Details: 'Alternative'			
Name:	HMA Design 1		
Description:	Design Using Beta-HMA-1, Landfilling at EOL		
Í	25 vrs (Analysis period for this alternative)		

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.

Selection Details: 'Pavement'		
Type:	Mainline	
Name:	New Pavement	
Description:	Design Alternative #1 using Beta-HMA-1 mix design.	
Num. Lanes:	1 –	
Length:	5280 ft	
Width:	12 ft (total width of all lanes)	
Lane Miles: 1.00 lane-miles		
Area: 63,360 sf		
$\overrightarrow{\mathbf{V}}$ Include this pavement's lane-miles and area in the functional unit calculations for this alternative.		
Add <u>N</u> ew 'Project' to Current 'Pavement'		

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.

Design Alternative Definition (Step 2 of 3)	×
Design Alternative Definition Use the controls below to define up to five different Design Altern	Back Next Next
Selected Alternative: Alternative <u>1</u> Alternative <u>2</u> Alternative Definition 	Selection Details: 'Alternative' Name: HMA Design 1 Description: Design using Beta-HMA-1, landfilling at EOL Analysis Period: 25 vrs (Analysis period for this alternative)
Move Down Delete	Add New 'Pavement' to Current 'Alternative'

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.

Design Alternative Definition (Step 2 of 3)	×
Design Alternative Definition Use the controls below to define up to five different Design Altern	Back Next Next
Alternative <u>1</u> Alternative <u>2</u> Alternative Definition Alternative Definition Alternative Definition Alternative Definition 	Selection Details: 'Alternative' Name: HMA Design 2 Description: Design using Beta-HMA-2, on-site recycling at EOL Analysis Period: 50 v yrs (Analysis period for this alternative)
Move Up     Copy       Move Down     Delete	Add <u>N</u> ew 'Pavement' to Current 'Alternative'

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	
<ul> <li>Pavement Life-Cycle Activities:         <ul> <li>Year 0: 8-inch PCC over 6-inch aggregate base</li> <li>Year 20: 0.25-inch Diamond Grinding</li> <li>Year 35: Demolish and Landfill</li> </ul> </li> </ul>	<ul> <li>Pavement Life-Cycle Activities:         <ul> <li>Year 0: 8-inch PCC over 6-inch aggregate base</li> <li>Year 20: 0.25-inch Diamond Grinding</li> <li>Year 35: Demolish and Landfill</li> </ul> </li> </ul>	

#### 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.

Analysis Session Detail	(Step 1 of 2)	
Analysis Session Detail		
Analysis Session Details Back Next		
Use the controls belo	w to define the details of the current analysis session.	
-Analysis Details-		
Analysis Objective: Compare Treatment Cycles or Pavement Design Life-Cycle Options		
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.		
<u>General Inputs</u>		
Session Name:	Beta Test PCC Project	
Route:	Beta-99	
Location:	Phoenix, AZ	
Project Limits:	Elm St to Washington Ave	
Analyzed By:	John Doe	
Comments:	Comparison between two concrete pavement design options that uses two different concrte mixtures.	
Desig <u>n</u> Alternative Number of Desig	es gn Alternatives: 2 💌	

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.

Selection Details: 'Alternative'		
	Name:	PCC Design 1
	Description:	Design Using Beta-PCC-1, landfilling at EOL
	Analysis Period:	35 vrs (Analysis period for this alternative)

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.

<u>Selection Detai</u>	ls: 'Pavement'	
Type:	Mainline 🔹	
Name:	New Pavement	
Description:	Design Using Beta-PCC-1, landfilling at EOL	
Num. Lanes:	1	
Length:	5280 ft	
Width:	12 ft (total width of all lanes)	
Lane Miles: 1.00 lane-miles		
Area: 63,360 sf		
Include this pavement's lane-miles and area in the functional unit calculations for this alternative.		
Add <u>N</u> ew 'Project' to Current 'Pavement'		

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.

Design Alternative Definition (Step 2 of 3)		×
Design Alternative Definition		Back Next
Use the controls below to define up to five different Design Altern	natives to compare in the analysis.	
Selected Alternative: Alternative <u>1</u> Alternative <u>2</u>		
Alternative Definition	Selection Details: 'Alternative'	
PCC Design 1	Name: PCC Design 1	
Initial Construction	Description:     Design using Beta-PCC-1, landfilling       Analysis Period:     35 r	g at EOL r this alternative)
Move Up     Copy       Move Down     Delete	Add <u>N</u> ew 'Pavement' to Current 'Alternative'	

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.

Design Alternative Definition (Step 2 of 3)	×
<b>Design Alternative Definition</b> Use the controls below to define up to five different Design Alternative 2	<u>B</u> ack Ne <u>x</u> t natives to compare in the analysis.
Alternative Definition  PCC Design 2  -New Pavement  -0: Initial Construction  - 6-inch Aggregate Base - 8-inch PCC Layer-PCC-2 - 20: Maintenance and Preservation - 0.25-inch Diamond Grinding - 35: Removal - Demolish 8-inch PCC-Recycled Onsite  Move Up Copy	Selection Details: 'Alternative' Name: PCC Design 2 Description: Design Using Beta-PCC-2, on-site recycling at EOL Analysis Period: 35 vrs (Analysis period for this alternative)
Move Down Delete	Add <u>N</u> ew 'Pavement' to Current 'Alternative'

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).

Results (Step 3 of 3)		
Results         Use the controls on this page to select impact indicators of interest and view results:         Setup:       Results Setup         Summary Results:       Overall Summary	elated outputs.           Back         View           Detailed         Output           e Comparison         By Category	
Output Setup Use the controls below to choose a functional unit and select the impact indicators you want to include in your results. Note some functional unit choices are dependent on the user-defined analysis period, computed lane-miles, and computed total area for each alternative. <u>Functional Unit:</u> Per Lane-Mile Per Year		
Life-Cycle Inventory (LCI) Results	Life-Cycle Impact Assessment (LCIA) Results	
$\overline{\mathbf{v}}$ Use of renewable energy primary energy, excluding renewable	✓ Acidification	
$\overline{{\bf arsigma}}$ Use of renewable primary energy resources used as raw materials	Ecotoxicity	
✓ Total use of renewable primary resources	Eutrophication	
$\overline{\checkmark}$ Use of nonrenewable primary energy, excluding nonrenewable	Fossil Fuel Depletion	
$\overline{\mathbf{V}}$ Use of nonrenewable primary energy used as raw materials	Global Warming	
Total use of nonrenewable primary energy resources	🔽 Human Health - Cancer	
Recycled Material Usage	🔽 Human Health - NonCancer	
☑ Disposed Non-Hazardous Waste	I Human Health Effects -	
☑ Disposed Hazardous Waste	✓ Ozone Depletion	
✓ Disposed Radio-Active Waste	Smog Formation	
☑ Net Use of Fresh Water		
✓ Supplementary Cementitious Material Usage		
Select <u>A</u> ll Deselect All		

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.



Alternative 1 Alternative 2



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.



■ Initial Construction □ Maintenance and Preservation ■ Rehabilitation ■ Reconstruction □ Removal







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.



■Year 1 ⊡Year 10 ■Year 18 ⊠Year 25

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

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# APPENDIX A. GLOSSARY

Table A-1. Tool	terminology.
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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	Atterial Something used in the pavement structure that does not have a pre-formed shape before arriviat the construction site.	
Mix Design	sign 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.	
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	t 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.

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?	<i>Is the material, its specification and manufacturing technology fit for purpose?</i>	
• 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?	

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

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

Impact Indicator	Units	Results
Global warming potential	kg CO <sub>2</sub> eq	6.06
Acidification potential	kg SO <sub>2</sub> eq	0.05
Eutrophication potential	kg N eq	0.01
Photochemical ozone creation potential	kg O₃ 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 <sup>3</sup>	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.

Add New 'Material' Librar	y Item					×	
Add New 'Mate	erial' Library Item				<u>C</u> ar	ncel <u>S</u> ave	
Use the controls below t	to define a new 'Material' library item.						
General Properties							
Material Type: A	\ggregate  ▼	Vi	ew: Impact Indicators	Metadata			
Item Name: P	leasanton 1/2" Crushed Aggregae	[     _ 1	impact Indicators				
Measure Type: M	Measure Type: Mass						
Quantity:	1.102 Units: short-tons		Impact Indica	tor	Quantity	Units	
Mass Conversion: Fac	tor Not Needed	III R	Acidification		0.05	kg SO2 eq	
Agency ID: E	XAMPLE EPD		Ecotoxicity	ĺ	No Data	CTUeco/kg	
From EPD?: O	Yes 🤄 No		Eutrophication	Γ	0.01	kg N eq	
Description:		E	Fossil Fuel Depletion	[	No Data	MJ surplus	
Vulcan Materials EPD Jan 13, 2016 https://www.vulcanmaterials.com/docs/default- source/default-document-library/pleasanton-epd_final		Global Warming		6.06	kg CO2 eq		
		Human Health - Cancer	ļ	No Data	CTU/kg		
		Human Health - NonCan	cer	No Data	CTU/kg		
			Human Health - Particula	ates	No Data	kg PM2.5 eq	
			Ozone Depletion	ŀ	000000159	kg CFC-11 eq	
			Smog Formation	L	0.73	kg O3 eq	
			Select <u>All</u> Deselect All	]			

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

Add New 'Material' Lib	orary Item						
Add New 'Ma	aterial' Library Item		<u>C</u> ar	ncel <u>S</u> ave			
Use the controls belo	w to define a new 'Material' library item.						
General Properties		Item Details					
Material Type:	Aggregate 💌	View: Impact Indicators Metadata					
Item Name:	Pleasanton 1/2" Crushed Aggregae	Impact Indicators					
Measure Type:	Mass 💌	Life-Cycle Inventory Life-Cycle Impact Assessment					
Quantity:	1.102 Units: short-tons	Impact Indicator	Ouantity	Units			
Mass Conversion:	Factor Not Needed	Renew, Energy (Non Raw Matl)	No Data	MJ			
Agency ID:	EXAMPLE EPD	🗖 Renew. Energy (Raw Matl)	No Data	MJ			
From EPD?:	⊂Yes ☉ No	✓ Total Renew. Energy Use	7.54	Ш			
Description:		🗖 Nonrenew. Energy (Non-Raw Matl)	No Data	CM			
Vulcan Materials EPD Jan 13, 2016 https://www.vulcanmaterials.com/docs/default- source/default-document-library/pleasanton-epd_final	Nonrenew. Energy (Raw Matl)	No Data	MJ				
	Total Nonrenew. Energy	90.7	CM				
	Recycled Matl. Use	No Data	Short-tons				
		Disposed Non-Hazardous Waste	0.000154	Short-tons			
		Disposed Hazardous Waste		Short-tons			
		Vet Use of Fresh Water	0 11	Cubic meters			
			No Data	Short-tons			
		Select <u>All</u> <u>Deselect All</u>	,				

