Pavement Type Selection Process

Maryland State Highway Administration

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Prepared by the Maryland State Highway Administration in cooperation with the Federal Highway Administration Maryland Division, Maryland Asphalt Association and American Concrete Pavement Association

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FOREWORD

In 2003, MDSHA created a Pavement Type Selection Team (PTST) to develop and document a Pavement Type Selection Process (PTSP). In the fall of 2005, SHA published the Pavement Type Selection Report, which documented the process that was used to develop the PTSP. This 2005 report and an accompanying Appendix contained the PTSP. In 2007, a detailed Life Cycle Cost Analysis (LCCA) guide was developed.

In 2012, the PTST was reconvened with the goal of identifying, discussing, and perhaps making changes based on issues that had arisen in the time since the original PTSP was developed. Several items were discussed, and a handful of changes were approved. Those changes are discussed in the "Pavement Type Selection Team Report of Revisions Developed in 2012 – 2013" and will be highlighted in this document.

The PTST will be reconvened every three years, at which point SHA will solicit issues for discussion for possible updates to the PTSP. Unit cost updates will occur annually. All other input updates can occur every 5 years.

This document combines the processes laid out in the 2005 Report, 2005 Appendix, and 2007 LCCA guide, and is modified as per decisions made by the 2012 PTST.

The process and policies documented herein describe the steps to be taken by MDSHA to make pavement type selection decisions in the future, and include a step-by-step procedure for LCCA and policies for pavement type selection to be included in the MDSHA Pavement Design Guide. This step-by-step procedure and policies will provide MDSHA pavement engineers the guidelines to perform LCCA and follow through a pavement type selection process.

Refer to the 2005 Report and Appendix for further discussion and explanations as to how and why various aspects of the processes were chosen.

PAVEMENT TYPE SELECTION PROCESS

The pavement type selection process is not one simple procedure that is easily documented or implemented. There are many procedures and tasks involved when considering the numerous inputs and variables that have the potential to be subjective and debated.

The following items are documented:

- A graphical overview of the entire pavement type selection process.
- The criteria used to decide which projects enter into a PTSP. These criteria become critical when considering which projects the MDSHA Pavement and Geotechnical Division (PAGD) determines the pavement type and which projects follow a PTSP.
- The guidelines and procedures used to develop the pavement designs and strategies used in this process.
- The LCCA procedure and steps.
- The various components and factors that are considered consistently in the pavement type selection.
- The criteria used to identify projects that are more appropriate for innovative contracting.

Process Overview

The initial step in the pavement type selection process is to determine whether a project, or portion of a project, meets the requirements for the PTSP. If it does, then all viable pavement types and strategies are determined, and the pavement engineer then performs an LCCA for each option. If the LCCA results in a **LCCA cost less than a 20% difference in pavement type alternatives**, then the pavement type section process will continue. If the difference is greater, the pavement type alternative with the lowest LCCA cost will be selected.

If a project continues with the PTSP, a scoring matrix will be filled out. This matrix will include the LCCA results, as well as other non-cost factors such as construction, design and environment.

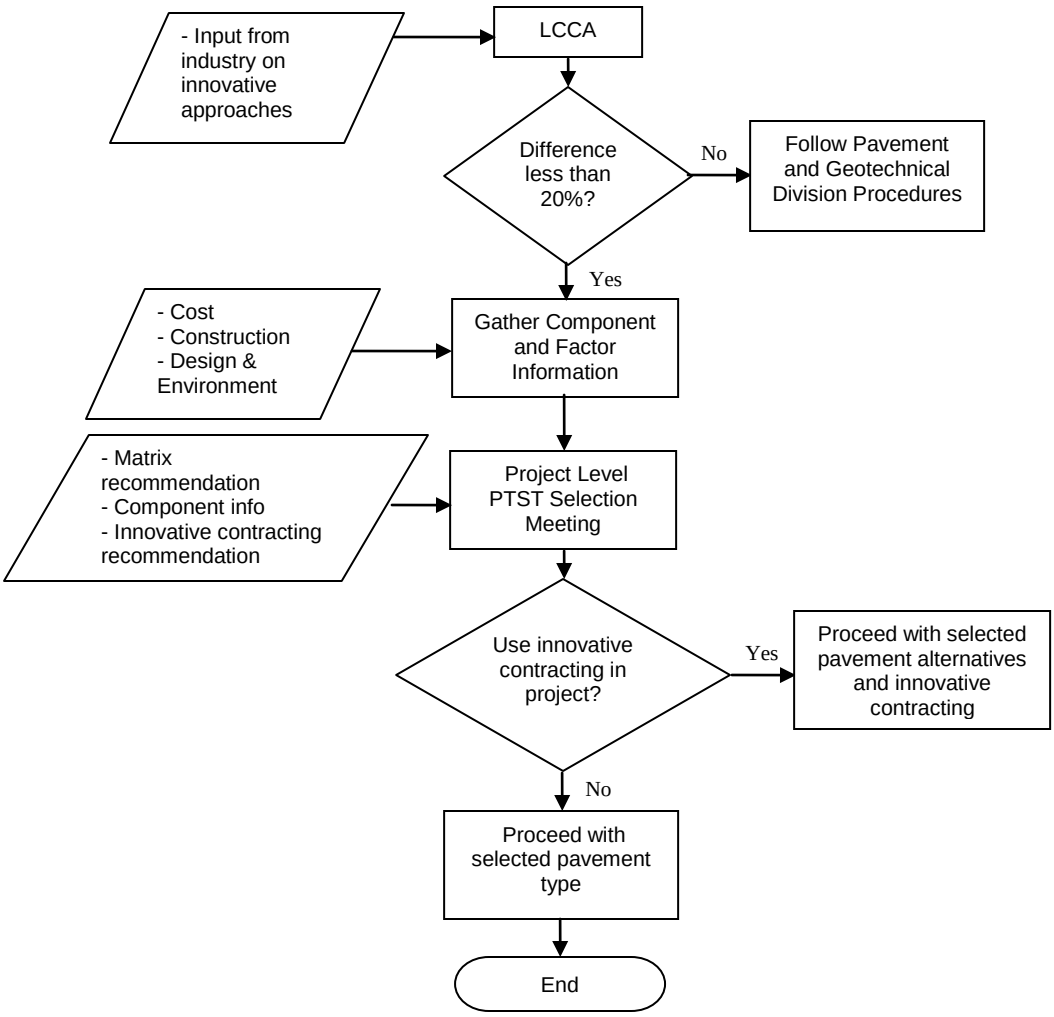
This score is used to develop a recommendation from PAGD. This recommendation will then be presented to a **project level pavement type selection team** (i.e. US 50 PTST) along with all the information about the project details, pavement type selection components and factors, and other information discussed above for review prior to a selection meeting.

At this selection meeting, six members of the MDSHA senior management and technical experts will discuss the information and come to consensus on a **final pavement type selection for the project.** PAGD will also provide a recommendation about the use of **innovative contracting** on the project.

If the difference in **rating scores** between pavement alternatives is **less than 20%** and other conditions do not prohibit the use, PAGD may recommend that innovative

contracting be utilized on the project. The project level pavement type selection team will make a final decision about the use of innovative contracting on the project.

Other projects could have a LCCA analysis completed or follow through a pavement type selection process if chosen by MDSHA senior management. All other projects would follow the guidelines established in the MDSHA Pavement Design Guide and the pavement type decision would be made by PAGD.



Selection Criteria

The first step in the pavement type selection process is to identify which projects will follow through this process. The following criteria shall be used to trigger a project to enter into a pavement type selection process:

- All projects requiring **Major Rehabilitation or Reconstruction "curb to curb",** which have a **pavement construction budget** greater than **$3 million.** Portions of a project involving widening shall not be included in the threshold.

- If a larger project is broken into smaller projects, the PTSP may be revisited if the smaller project still triggers the process.

It is estimated that approximately 6 to 10 projects per year will meet the criteria identified above based on historical trends and future workload predictions. The PTSP has several other decision factors within the process that may eliminate a project from further study during the steps in the process. Those decision factors are identified in the following sections of this report.

If a project does meet the criteria, the pavement designer should fill out the Pavement Type Selection Process checklist form throughout the process.

Pavement Design Alternatives

The first step in the PTSP is to identify viable pavement types and strategies. This will be done by PAGD. This should be done as early as possible in the design phase, as soon as the scope of work is detailed enough to go through the PTSP.

- For existing pavement, use the Guide to Pavement Preservation to identify which Major Rehabilitation or Reconstruction strategies are viable.
- For new pavement, both flexible and rigid alternative shall be considered.
- Different pavement types can be considered in a given project, i.e. a project can have some concrete pavement and some asphalt pavement sections.

Once each alternative is identified, a pavement design section should be developed for each, using the MDSHA Pavement Design Guide. All designs shall have an **initial design life of 25 years**.

If **curb and gutter** will be constructed in the project, then **1" of bound pavement shall be added** to the design section (i.e. if the 25 year design is for 10" of concrete over 6" of GAB, then the final design shall be 11" of concrete over 6" of GAB). The extra inch is needed in these cases to allow for more flexibility in future preservation activities, and to keep the future rehabilitation intervals consistent with the open-section intervals (since those can add pavement structure and thus longer intervals).

Material Industry Input

Once the design alternatives are developed, **Material industry representatives** will be contacted so that they may provide project-level input. They will be provided a description of the project scope and location and asked for their **input to be submitted**

in writing in 3 weeks. The information obtained from the material industries will be documented and considered by PAGD in the PTSP.

The input would be focused on providing any innovative technology and materials and "value engineering" types of information. The input could contain ideas the material industry representatives feel should be considered by MDSHA during the decision process.

LCCA PROCEDURE AND INPUTS

LCCA Description

Life cycle cost analysis (LCCA) is a cost comparison evaluation technique that is used in assisting in the investment decision process of roadway construction projects. LCCA assists an agency in determining the most cost-effective and beneficial alternative to constructing a project. LCCA requires an agency to have sound knowledge of the costs, operational functions and predictive models of future performance of its assets as well as a firm understanding of economic analysis techniques.

In terms of pavement construction, LCCA is used to identify the pavement type and/or repair strategy with the highest benefit/cost ratio over a predetermined analysis period into the future. Therefore, LCCA considers not only the initial cost of construction, but also future rehabilitation costs. User delay costs and impacts on the traveling public can be calculated based on future pavement rehabilitation strategies. User delay costs and agency costs are typically the two major calculation results from LCCA.

The computation step in the LCCA process will be completed using the software application developed by FHWA. The following are several types of costs that are calculated to determine the LCCA cost:

- **Agency costs**,
  - initial construction costs,
  - present worth future rehabilitation costs,
  - present worth salvage value / residual value, and
- **User delay costs** (present worth).

Agency costs are all the costs incurred by the agency responsible for the roadway facility. The agency cost most familiar is the initial construction cost to build the roadway improvement. **Future rehabilitation costs** are the costs incurred by the agency after the initial construction to maintain the roadway at an acceptable level of service for the traveling public. Future agency costs are then discounted back to present worth value for comparison and calculations with initial agency costs. **Maintenance activities are not included** in the LCCA for MDSHA projects.

Each pavement type has different initial service lives and different future rehabilitation strategies. This information is used with the material cost information to develop accurate estimates of future maintenance and rehabilitation strategies.

Another agency cost factor to consider is salvage value or **residual value**. This is the value of the roadway at the end of the analysis period for various pavement alternatives. The salvage value amount is then discounted back to present worth value for

comparison with initial agency costs. MDSHA defines salvage value/residual value as the remaining service life value of an alternative at the end of the service life.

User costs are the costs incurred by the traveling public through restricted and closed lanes in a work zone. These costs include vehicle operating costs, travel time costs, slow down costs, acceleration costs, and idling costs. The length and timing of lane closures coupled with traffic volume and type are used to calculate the user delay costs.

Costs that occur at the initial construction, at various future rehabilitation operations and user delay costs throughout the analysis period happen at different times and cannot be simply added together to calculate the total LCCA costs. All costs are converted to **present worth** dollar values so that costs that occur at different times in the future for different pavement alternatives can be compared equally.

There are two basic approaches to LCCA, deterministic and probabilistic. The deterministic LCCA approach calculates a single LCC value for a pavement type or rehabilitation alternative. The value is based on discrete input values for variable parameters like material unit cost, construction operation durations, user delay, and pavement rehabilitation duration. All of these values have the potential to be highly debated by both industries and thereby minimize the potential for developing consensus.

The probabilistic LCCA approach allows for a range of construction and material cost to be used in the analysis rather than a discrete cost value or duration. The calculations of this approach provide the pavement engineer the probability of user and agency costs occurring over the analysis period. Therefore, the final result is a probability value that construction costs will be less than a specific cost value rather than a single discrete value.

All agency and user delay costs are generated through numerous simulation runs by putting the probabilistic functions through their expected range of values. MDSHA has worked closely with FHWA to develop an LCCA approach that uses a probabilistic approach and incorporates detailed user delay costs.

LCCA Procedure and Criteria

Once all of the pavement alternatives have been identified, and material industry input is received, the next step is for PAGD to perform an LCCA. MDSHA will utilize a probabilistic approach to LCCA using guidelines and software developed by FHWA (RealCost).

The comparison of the various pavement type alternatives in the LCCA will include the initial agency construction costs and future agency rehabilitation costs. **User delay costs** will also be calculated, but they will only be considered in the scoring matrix **if they are higher than the total agency costs.**

The procedural steps for an LCCA are listed below:

1) Input pavement design alternatives with associated unit costs and production rates.
2) Run RealCost to determine costs and statistics for initial and future activities and sequencing

3) Run RealCost again to determine overall LCCA costs based on results of the initial Run.

4) Analyze the results. If the **LCCA costs** between different pavement type alternatives are **within 20% at the 80% probability** level, the pavement type selection process will continue. If the LCCA costs are greater than a 20% difference between pavement alternatives, the pavement type with the lowest LCCA cost will be selected as the pavement type and the process will end.

Required Tools to Complete an Analysis

Under the current MDSHA method, the following two tools are required to complete an LCCA:

- The latest version of RealCost, the Microsoft Excel-based software tool developed by FHWA: http://www.fhwa.dot.gov/infrastructure/asstmgmt/lccasoft.cfm

- The supplemental Microsoft Excel workbook (LCCA-Details.xls) and RealCost files that were prepared by the MDSHA to facilitate the process of inputting data. These can be found on the MDSHA server at the following location: *N:\OMT\Pavement\PAVEDSGN\Technical\LCCA\LCCA_InputsForRealCost*

Brief introductions to each of these tools are provided below.

RealCost Excel-Based Software

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

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

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

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

The default RealCost user interface is not designed to calculate agency costs or service lives for individual construction or rehabilitation activities. That is, in the interface, these values must be input directly by the analyst and should reflect the construction and rehabilitation practices of the agency. However, since the MDSHA process is interested in generating these numbers based on estimated quantities and user-defined unit costs, MDSHA has incorporated this capability into the LCCA process (see the explanation of the MDSHA-developed Excel workbook tool described in the next section).

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

MDSHA LCCA Excel Workbook

In the RealCost software, the interface ultimately requires that only one cost distribution (or one discrete value) be defined for each included construction activity (note: a construction activity is defined as either the initial construction or a rehabilitation activity). Similarly, when considering user costs, the interface requires that one work zone duration distribution (or one discrete value) be defined for each construction activity.

Within the current MDSHA LCCA approach, these required distributions are simulated based on 1) the chosen construction line items included in each construction event (e.g., different material layers, included rehabilitation techniques, etc.), 2) the computed quantities and unit costs associated with each included construction line item, and 3) the expected daily production rate associated with each included construction line item. To make the computation more realistic, the construction line item unit costs and daily production rates are defined in terms of probabilistic distributions rather than single values.

In a typical MDSHA LCCA, the definition of unit cost and work zone distributions for many different line items per construction event, for up to seven different construction events per design alternative, repeated for two design alternatives, results in a large number of probabilistic distributions that need to be simulated in the RealCost software. Initially, the MDSHA LCCA developers attempted to outline these detailed cost and work zone duration computations within the RealCost software.

However, when the large number of cost and work zone duration distributions were included alongside the other probability functions used in the analysis, the software did not function properly. It was believed that the large number of included probability

functions exceeded an internal RealCost limit on the number of allowable probabilistic functions. To work around this apparent internal limit, the MDSHA developed a process in which the LCCA could be conducted in two steps rather than all at once. To facilitate this two-step analysis, the MDSHA developed its Microsoft Excel Workbook (LCCA-Details.xls).

In the first step of the analysis, the user enters inputs in the LCCA-Details.xls workbook to define all of the construction line items associated with each construction activity, and the quantities, unit cost distributions, and work zone duration distributions associated with those line items. This initial information defined in the LCCA-Details.xls workbook is then used in the first simulation run of RealCost to simulate the required distributions of total agency cost and work zone duration associated with each individual construction activity.

In preparation for the second (or final) simulation run in RealCost, the simulated cost and work zone duration information from the first simulation run are used to define those required inputs for each of the included construction events. The final run of the software produces LCCA results that can be analyzed and used to select the most cost-effective design alternative. The detailed step-by-step procedures for completing this two-part simulation process is described in the next section titled *Conducting an LCCA Using the MDSHA Procedure*.

Finally, in order to be more comfortable using the LCCA-Details.xls workbook, it is important to understand the purpose of and contents of the six worksheets included in the workbook. Brief summaries of the contents of each worksheet are as follows:

- *Alternate1*: This sheet houses all of the inputs used to define the initial construction and rehabilitation activity characteristics for the first design alternative. This sheet is the primary data entry interface for Alternative 1. Included on this worksheet are inputs that define the quantities, unit cost distributions, and work zone duration distributions associated with each construction line item included in the initial construction and rehabilitation activities.
- *Alternate2*: The *Alternate2* sheet is used to collect the same inputs for design Alternate 2 as outlined above for Alternate 1.
- *SimulationOutput-1stRun*: After completing the first simulation run of the RealCost software, the RealCost simulation results are manually copied by the user and pasted into this worksheet.
- *1stRunOutput*: This sheet contains a summary of the first run simulation results that are stored in the *SimulationOutput-1stRun* worksheet of the workbook. Specifically, this worksheet is used to compute the distribution characteristics associated with the simulated construction activity–specific agency costs and work zone durations.
- *SimulationOutput-FinalRun*: After completing the second (final) run of the RealCost software, the RealCost simulation results are manually copied by the user and pasted into this worksheet.

- *FinalResults*: This sheet contains a summary of the simulation results of the *SimulationOutput-FinalRun* worksheet into a MDSHA designed output format. All of the final LCCA results for both alternatives are summarized here. The information summarized on this sheet is the primary output of the LCCA.

MDSHA RealCost Default Input Files

To facilitate the two-part simulation process, the MDSHA has prepared five different MDSHA-defined RealCost input files that store many of the default values required for the simulations. Brief descriptions of the contents of each file are described below. Detailed instructions on when and how to use each input file is contained in the *Conducting an LCCA Using the MDSHA Procedure* section.

- *FirstRun.LCC*: This file contains project-level default simulation setting inputs that are used to populate the RealCost software during the first simulation run. Other variables included in this project-level input file are set to dummy variables so that only the agency cost and work zone duration probabilistic functions are simulated during the first simulation run. Note that the project-level default simulation setting inputs are summarized in table A-2 of Appendix A.

- *FirstRunRehabAlt.LCA*: This file contains alternative-level default dummy values that are used to define both design alternatives during the first simulation run. The purpose of the population of RealCost with dummy values is so that only the agency cost and work zone duration probabilistic functions are simulated during the first simulation run.

- *FinalRunDefault.LCC*: This file contains some project-level default values that are used to populate the RealCost software during the final simulation run. While most of the actual project-specific values need to be entered manually by the user in the RealCost interface prior to the final simulation, this file defines the input form (i.e., whether or not it is a simulated variable, and if so, the type of distribution that is applicable).

- *FinalRunDefault-HMA.LCA*: This file contains many of the default values associated with the typical HMA pavement design in MDSHA. While most of the alternative-specific values need to be entered manually by the user in the RealCost interface prior to the final simulation, this file automatically populates the software with information associated with the initial construction and rehabilitation activities. For example, the typical construction activity names, associated service lives, and work zone hours are populated.

- *FinalRunDefault-JPCP – with C&G.LCA, FinalRunDefault-JPCP – No C&G.LCA, FinalRunDefault-CRCP – with C&G.LCA, FinalRunDefault-CRCP – No C&G.LCA*: These file contain many of the default values associated with the typical JPCP or CRCP pavement design for the scenarios where curb and gutter will or will not be constructed in MDSHA. While most of the alternative-specific values need to be entered manually by the user in the RealCost interface prior to

the final simulation, these files automatically populates the software with information associated with the initial construction and rehabilitation activities.

CONDUCTING AN LCCA USING THE MDSHA PROCEDURE

The purpose of this section is to guide a user through all of the steps of the MDSHA procedure in order to successfully complete an LCCA for a given project. Before getting started, make sure that you:

1) Have successfully installed the RealCost software on your computer,
2) Have ready access to the MDSHA LCCA workbook (LCCA-Details.xls), and
3) Have ready access to the five different MDSHA prepared RealCost input files:
   1. *FirstRun.LCC,*
   2. *FirstRunRehabAlt.LCA,*
   3. *FinalRunDefault.LCC,*
   4. *FinalRunDefault-HMA.LCA,*
   5a. FinalRunDefault-JPCP – with C&G.LCA,
   5b. FinalRunDefault-JPCP – No C&G.LCA,
   5c. FinalRunDefault-CRCP – with C&G.LCA, and
   5d. FinalRunDefault-CRCP – No C&G.LCA.

The remainder of this section describes the detailed procedures associated with conducting preliminary activities, populating the MDSHA LCCA workbook, using the MDSHA LCCA workbook in conjunction with the RealCost software to obtain LCCA results, and printing and analyzing the results.

1. Conduct Preliminary Activities

When initiating an LCCA using the MDSHA approach, the first step is to set up your electronic project folder and gather all of the files that you will need to complete the analysis. This requires the following two steps to get started:

1.1. Create a project folder on your computer using Windows Explorer. This folder will be used to house all of the project-related files.

1.2. Copy the necessary files into your project folder. To finish the project set up activities, copy the LCCA-Details.xls workbook and the MDSHA prepared RealCost input files (i.e., *FirstRun.LCC, FirstRunRehabAlt.LCA, FinalRunDefault.LCC, FinalRunDefault-HMA.LCA,* and *FinalRunDefault-PCC.LCA*) into the project folder.

2. Define the LCCA Inputs Associated with the Design Alternatives

The second step in the LCCA process is to define all of the inputs required for the design alternatives being compared. Start by opening the MDSHA LCCA-Details.xls workbook. Rename to the file to something project-specific, such as I-95 LCCA-Details. All of the alternative-specific inputs required in the LCCA approach are entered for the alternatives in the *HMA, JPCP* and *CRCP* worksheets in this workbook. The inputs included on these sheets can be divided into categories of general inputs, inputs required to compute quantities, and default MDSHA unit cost and construction duration inputs.

Each of these different input type categories is discussed separately below. The following discussion is the same for the *HMA, JPCP* and *CRCP* worksheets. Within this LCCA-Details.xls workbook, all cells shaded gray in the *HMA, JPCP* and *CRCP* worksheets are project-specific inputs that should be defined or verified for each given project. The values shaded in orange represent default values that are reviewed by MDSHA annually. Cells shaded in light blue are cells that include a LCCA probabilistic equation that will be simulated by RealCost during the first simulation.

General Inputs

The upper left portion of the *HMA, JPCP* and *CRCP* worksheets is used to store some of the general information associated with each alternative. This information should be readily available as a result of the pavement design process. Specific inputs include:

- Project Description: Enter the project name, location, and date.
- Alternative name: Enter the name of the current alternative is stored in cell A2.
- Total number of lanes: Enter the total number of lanes for the project in cell D1. This value is used in the calculation of the "Max ADT" traffic value shown in cell H2. The computed "Max ADT" value is a required input in the RealCost traffic inputs.
- Job length (in miles): Enter the total length of the project being analyzed in cell D2. This value is used in the calculation of the total project area for the mainline and shoulders, shown in cells C5 and D5, respectively.
- Total number of longitudinal joints: Enter the total number of longitudinal joints associated with mainline and shoulder calculations in cells C3 and D3, respectively. These values are used to determine the total quantities associated with longitudinal joint-related construction activities (e.g., patching longitudinal joints).
- Total widths for the mainline and shoulder: In cell C4, enter the total width of the mainline section being considered. Similarly, in cell D4, enter the total width of the shoulder section being considered. These values are used to determine the areas associated with each included construction line item.
- Construction line item names: In column A of each worksheet, the individual construction line items associated with the initial construction and rehabilitation activities are defined. For the most part, all construction activities contain default construction line items that should not be changed by the user. These line items represent the typical construction activities that are commonly practiced and accepted by the MDSHA (see Future Rehabilitation Activities). Those item names that can be changed are those cells that are highlighted in gray. When changing those item names in gray, make sure that the unit costs and work zone duration number (stored in the columns further to the right in the spreadsheet) are truly representative of the chosen construction line item.

Inputs Required to Compute Quantities

A number of different inputs on these alternative sheets are required to determine the construction quantities associated with the various construction line items. Each of these is described in more detail below:

- Percentage of mainline: For the HMA pavement design (i.e., the *HMA* worksheet), the construction activity-related inputs in column C are user inputted values that define the percentage of the total mainline area for which the current construction line item will be applied. This entered percentage is used to determine the quantity associated with a given construction line item. For example, if your total mainline area was 10,000 square feet and you entered "50" percent for the "HMA Base" construction line item, your calculations would compute an HMA Base-related cost for the mainline on 10,000 * 0.5 = 5,000 square feet of area.

  For the PCC pavement design (i.e., the *JPCP or CRCP* worksheet), while the majority of construction line items also expect a percent of area entry, the following construction items have noteworthy exceptions to this rule:

  - "PCC Patching": For the "PCC Patching" construction line item, the column C input represents the percentage of total transverse joints included in the project length that are to receive a PCC patch. Each PCC patch is assumed to be the full width of the pavement and be 6-ft in length (i.e., 3-ft on either side of the repaired transverse joint).

- Percentage of shoulder: The same types of calculations and exceptions that are described above for the mainline, also apply for the shoulder calculations. These shoulder-related input percentages are entered in column D for the specific construction item inputs.

- Number of lifts: The construction line-item values entered in column E represent the number of times the current line item is applied. For example, if the line item is a material layer, the column E input represents the number of lifts (of the layer thickness stored in column F) that are applied. For grinding-related line items, the column E input represents the number of grinding passes required. One final exception is the column E input for the "Clean and Seal Joints, Transverse" line item on PCC pavements. For this input, the transverse joint spacing value (in feet) is entered in column E.

- Depth (or thickness): The last input needed for many of the quantity calculations is the thickness of each construction line item. These thickness values (entered in units of inches) are entered in column F for all material layer-related line items. This input provides the third dimension required to compute volume quantities for layer materials.

After the two alternative-related sheets are populated with user-defined inputs, quantities for each construction line item are computed and presented in column G. The units associated with the computed quantities are presented in column B.

MDSHA Default Input Values Associated with Each Construction Line Item

As stated previously, the cells shaded in orange in the *HMA, JPCP* and *CRCP* worksheets are MDSHA default values that do not need to be changed by the user on a project-by-project basis. These values will be reviewed by PAGD annually and updated in a new version of the LCCA-Details.xls workbook. For clarification, the MDSHA default inputs include the both construction line item unit costs and typical daily production values. Each of these is discussed in more detail below.

MDSHA Default Construction Line Item Unit Costs

In the MDSHA LCCA process, regularly tabulated bid results that are stored in the pavement management system are used to define material and construction item-related unit costs. When the population of data for a cost item is not large enough to be statistically significant, MDSHA uses available unit price data from surrounding states and input from the materials industries.

To make these values even more accurate within the LCCA process, different cost values are included for small, medium, and large quantities. The unit cost of any construction line item typically decreases as the quantity size increases. In order to use these values in the probabilistic LCCA approach, unit costs are not expressed in terms of just one value, but in terms of statistics that can be used within a truncated normal distribution (see figure 1 for the physical meaning of a truncated normal distribution).

Each unit cost truncated normal distribution is defined in terms of an *average*, *standard deviation*, a *minimum*, and a *maximum*. For reference, all of these unit cost-related values are stored in the Alternate1 and Alternate2 worksheets in columns N through AA. A summary of the current default unit cost values is located at Construction Item Unit Costs.

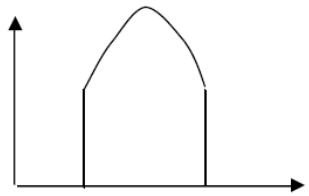


Figure 1. Example illustrating a *truncated normal* distribution.

MDSHA Default Typical Daily Production Values

Similar to the unit costs, there is daily production information associated with each construction line item. In order to use these values in the probabilistic LCCA approach, the range of typical production values are expressed in terms of statistics associated with a uniform distribution (see figure 2 for the physical meaning of a uniform distribution). Specifically, the uniform distribution requires the definition of a minimum and maximum value.

For reference, these minimum and maximum daily production values are stored in the *Alternate1* and *Alternate2* worksheets in columns AE and AF, respectively. Column AC contains a MDSHA default "Overlap" value that can be adjusted based on how construction items are viewed in terms of the critical path to complete the construction (note: the overlap value is typically set to "100%"). The total computed required construction days to complete a given construction line item are presented in column AB of the alternative-related worksheets. A summary of the current MDSHA default daily production values is presented in Construction Item Daily Production Rates.

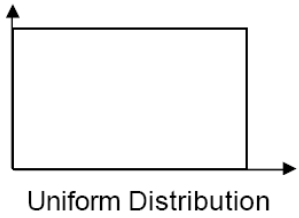


Figure 2. Example illustrating a *uniform* distribution.

3. Conduct the First RealCost Simulation Run

As discussed previously, for practical purposes, the LCCA procedures need to be completed in two different steps. Recall that the purpose of the first simulation run of RealCost is to compute values that can be used to define the probabilistic distributions associated with the construction activity agency costs and construction duration. The step-by-step procedures for completing this step are outlined in this section.

3.1. Save changes in the LCCA-Details.xls workbook: If you have not already done so, save the LCCA-Details.xls workbook with your user defined values populated in the *HMA, JPCP* and *CRCP* worksheets. It is advisable to copy the changes to avoid changing the original.

3.2. Open RealCost: Open the RealCost software on your computer. When the RealCost software is opened, enable macros. A "Switchboard" dialog box will then automatically open. Close the "Switchboard" dialog box by clicking on the close button (the red "X") in the upper right corner of the dialog box.

3.3. Rename and save the RealCost file into your project folder with a specific name for your project.

3.4. Copy the *HMA, JPCP* and/or *CRCP* worksheets from the LCCA-Details.xls workbook into the RealCost workbook: Note: if you have previously copied Alternate worksheets into the RealCost workbook, delete those worksheets before completing this step. If you are not familiar with copying worksheets between Excel workbooks, start by right clicking on the *HMA* worksheet tab at the bottom of the LCCA-Details.xls workbook. Select "Move or Copy" from the pop-up menu to open the "Move or Copy" dialog box. Within this dialog box, start by checking the "Create a copy" check box at the bottom of the dialog. Next, select the RealCost workbook name in the "To book" drop down list of files at the top of the dialog box, and then select a particular target location in

the RealCost workbook by selecting a worksheet name in the "Before sheet" list box in the middle of the dialog box. Repeat the same process to copy the *JPCP* worksheet.

3.5. Close the LCCA-Details.xls workbook.

3.6. Open the RealCost Switchboard: To re-open the RealCost Switchboard dialog box, select the "Add-Ins" tab at the top of the page, then select "RealCost" from the menu at the top left of the page, then select the "RealCost Switch Board" option.

3.7. Open the default project-level input file for the first run: To open the MDSHA prepared default project-level input file for the first run, click on the "Open Project-Level Inputs" button on the RealCost Switchboard. This action will open the "Open RealCost Project-Level Inputs" dialog box. Use the controls in this dialog box to browse to your project folder and select the default "FirstRun.LCC" input file. Click the "OPEN" button to close the dialog box and open the file.

3.8. Open the default alternative-level input file for *HMA, JPCP* and/or *CRCP*: To open the MDSHA prepared default alternative-level input file for HMA, JPCP and/or CRCP, click on the "Alternative" button on the RealCost Switchboard to open the "Alternative dialog box". Click the "Open" button in the lower left corner of this dialog box and use the provided controls to browse to your project folder and select the default *FirstRunRehabAlt.LCA* input file. Click the "Open" button on the "Open RealCost Alternative-Level Inputs" dialog box to open the file.

Next, click on the scroll bar at the top of the dialog box, so that the Alternative switches from Alternative 1 to Alternative 2. Click the "Open" button in the lower left corner of this dialog box and use the provided controls to browse to your project folder and select the same default *FirstRunRehabAlt.LCA* input file. Click the "Open" button on the "Open RealCost Alternative-Level Inputs" dialog box to open the file. To close the "Alternative" dialog box, click the "OK" button at the bottom of the window.

3.9. Run the first RealCost simulation: To initiate the first RealCost simulation run, click the "Simulation" button on the RealCost Switchboard. Clicking this button will open the "Simulation" dialog box. Note: this dialog box should be populated with the MDSHA default simulation inputs shown in Simulation Inputs. After verifying the simulation input values in this dialog box, click the "Simulate" button to begin the simulation. Note that the simulation will take several minutes to complete. Once the simulation begins, do not attempt to run anything else.

3.10. Close the "Simulation" dialog box: After the simulation finishes running, click the "Close" button at the bottom of the "Simulation" dialog box it to close it.

3.11. Close the RealCost Switchboard: To close this dialog box, click on the window's close button (the red "X") in the upper right corner of the RealCost Switchboard dialog box.

3.12. Print the *HMA, JPCP* and/or *CRCP* sheets from the RealCost workbook: After the simulation, the *HMA, JPCP* and/or *CRCP* sheets in the RealCost workbook (i.e., those that were originally copied from the LCCA-Details.xls workbook) will now be populated with simulated probabilistic variables. Print both of these sheets and place copies in the hard copy project file.

3.13. Open the LCCA-Details.xls workbook.

3.14. Copy the entire contents of the *Simulation Output* sheet in the RealCost workbook and paste the results into the *SimulationOutput-1stRun* sheet in the LCCA-Details.xls workbook: This step of the process is used to be able to view the simulated cost and construction duration results in a desired format outlined in the LCCA-Details.xls workbook. To copy the simulation results, start by navigating to the *Simulation Output* sheet in the RealCost workbook. To select all of the cells in the current worksheet, press the simultaneous combination of the "CTRL" button and the "A" button (i.e., CTRL+A) two times. Pressing the CTRL+A key combination twice ensures that all cells in the worksheet are highlighted. To copy the highlighted cells, press the CTRL+C key combination.

To paste the copied simulation results, start by navigating to the *SimulationOutput-1stRun* sheet in the LCCA-Details.xls workbook. Press the CTRL+A key combination twice to select all of the cells in that worksheet, and press the CTRL+V key combination to paste the copied data.

3.15. Save the LCCA-Details.xls workbook: To save this workbook, press the CTRL+S key combination with this workbook active. You may also save the workbook by clicking on the "File" menu and selecting the "Save" option.

3.16. Print the contents of the *1stRunOutput* worksheet in the LCCA-Details.xls workbook: The formatted simulated agency cost and construction duration results are summarized in the *1stRunOutput* worksheet in the LCCA-Details.xls workbook. Print the contents of this worksheet in preparation for completing the second RealCost simulation run. Then save and close the LCCA-Details workbook.

3.17. Close RealCost without saving changes: To close the RealCost workbook, return to the RealCost workbook and select "Close" from the "File" menu. Selecting this option will open a dialog box that asks if you want to save changes. Click on the "No" button to close the workbook without saving changes. Create a separate project folder to save the changed work.

4. Complete the Final RealCost Simulation Run

After completing the first simulation run to compute values that can be used to simulate agency costs and construction durations, the second (or final) simulation run can be

completed to produce the final LCCA results. The step-by-step procedures for completing this final simulation run are outlined in this section.

4.1. Re-open RealCost: Re-open the RealCost Microsoft Excel workbook on your computer.

4.2. Open the default project-level input file for the final run: To open the MDSHA prepared default project-level input file for the final run, click on the "Open Project-Level Inputs" button on the RealCost Switchboard. This action will open the "Open RealCost Project-Level Inputs" dialog box. Use the controls in this dialog box to browse to your project folder and select the default *FinalRunDefault.LCC* input file. Click the "OK" button to close the dialog box and open the file.

4.3. Open the default alternative-level input file for Alternative 1 (typically the HMA alternative): Since Alternative 1 is typically the HMA design, the discussion here will assume that this is the case. To open the MDSHA prepared default alternative-level input file associated with an HMA pavement design, click on the "Alternative" button on the RealCost Switchboard to open the "Alternative 1 dialog box".

Click the "Open" button in the lower left corner of this dialog box and use the provided controls to browse to your project folder and select the default *FinalRunDefault-HMA.LCA* input file. Click the "Open" button on the "Open RealCost Alternative-Level Inputs" dialog box to open the file. To close the "Alternative 1" dialog box, click the "OK" button at the bottom of the window. Note: if another alternative other than an HMA pavement design is being defined, all of the inputs will need to be defined manually within RealCost.

4.4. Open the default alternative-level input file for Alternative 2 (typically the PCC alternative): Since Alternative 2 is typically the PCC design, the discussion here will assume that this is the case. To open the MDSHA prepared default alternative-level input file associated with a JPCP pavement design, click on the "Alternative" button on the RealCost Switchboard and switch the slide near the top of the screen to Alternative 2 to open the "Alternative 2 dialog box".

Click the "Open" button in the lower left corner of this dialog box and use the provided controls to browse to your project folder and select the default *FinalRunDefault-[****].LCA* input file. This file could be any of JPCP or CRCP, and with our without curb and gutter, according to your situation. Click the "Open" button on the "Open RealCost Alternative-Level Inputs" dialog box to open the file. To close the "Alternative 2" dialog box, click the "OK" button at the bottom of the window. Note: if another alternative other than a PCC pavement design is being defined, all of the inputs will need to be defined manually within RealCost.

4.5. Define the "Project Details" inputs in RealCost: To define the general project characteristics, click the "Project Details" button in the RealCost Switchboard to open the "Project Details" dialog box. An example of this dialog box and the

included inputs is shown in figure 3. To complete this step, all input fields showing a "0" value in figure 3 should be populated by the user with data available from the pavement design results.

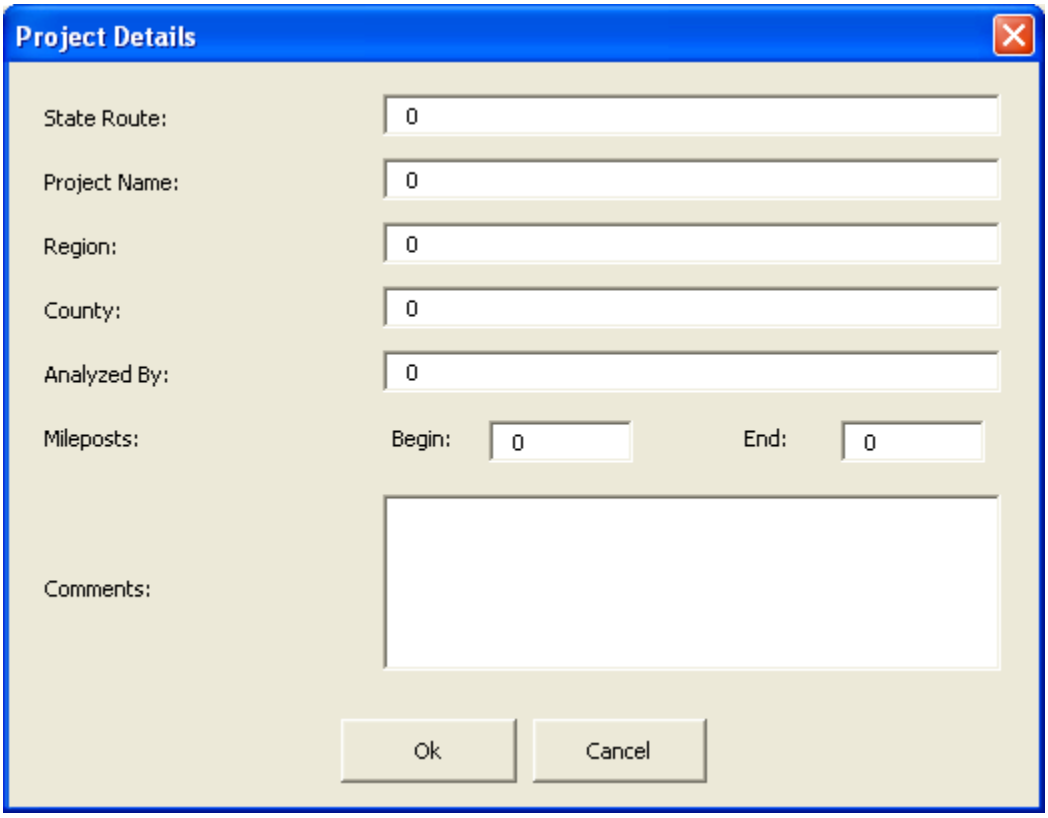


Figure 3. Example of the *Project Details* dialog box in RealCost.

4.6. Define the "Analysis Options" inputs in RealCost: The analysis options inputs in RealCost refer to the general analysis inputs that can be found in General Analysis Inputs. Click the "Analysis Options" button in the RealCost Switchboard to open the "Analysis Options" dialog box shown in figure 4. With the exception of the "Beginning of Analysis Period" input, the rest of the inputs in this dialog box should be automatically populated when the default project-level input file *FinalRunDefault.LCC* is opened under step 4.2. To complete this step, enter the chosen year for the "Beginning of Analysis Period" input. The number of alternatives can also be adjusted here.

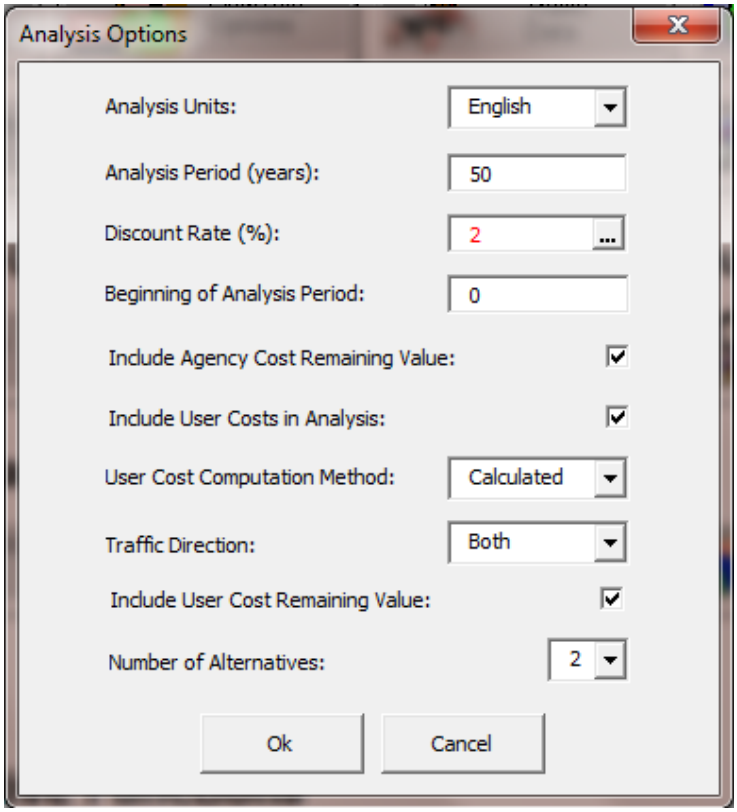


Figure 4. Example of the *Analysis Options* dialog box in RealCost.

4.7. Define the "Traffic Data" inputs in RealCost: The traffic data inputs in RealCost define all of the traffic analysis inputs used to estimate the future traffic to be applied to the project. Click the "Traffic Data" button in the RealCost Switchboard to open the "Traffic Data" dialog box shown in figure 5. On this dialog, only the "Queue Dissipation Capacity" and "Maximum Queue Length" inputs are automatically populated when the default project-level input file *FinalRunDefault.LCC* is opened under step 4.2. The remaining inputs must be manually entered by the user during this step of the analysis.

Note that whenever an input box followed by three dots is encountered, you should refer to Traffic Analysis Inputs for traffic data. Most of this project specific traffic information should be available in the pavement design documentation. Note that the "Maximum AADT" is the value computed in cell H2 on the *Alternate* worksheets in the LCCA-Details.xls workbook.

4.8. Verify the "Value of User Time" inputs in RealCost: The value of user time inputs in RealCost define the user delay costs (expressed in dollars per hour) associated with three different vehicle type classifications. Click the "Value of User Time" button in the RealCost Switchboard to open the "Value of User Time" dialog box shown in figure 6. All three inputs contained in this dialog box are automatically populated when the default project-level input file *FinalRunDefault.LCC* is opened under step 4.2. A summary of the MDSHA default values of user time-related inputs is presented in Value of Time Inputs.

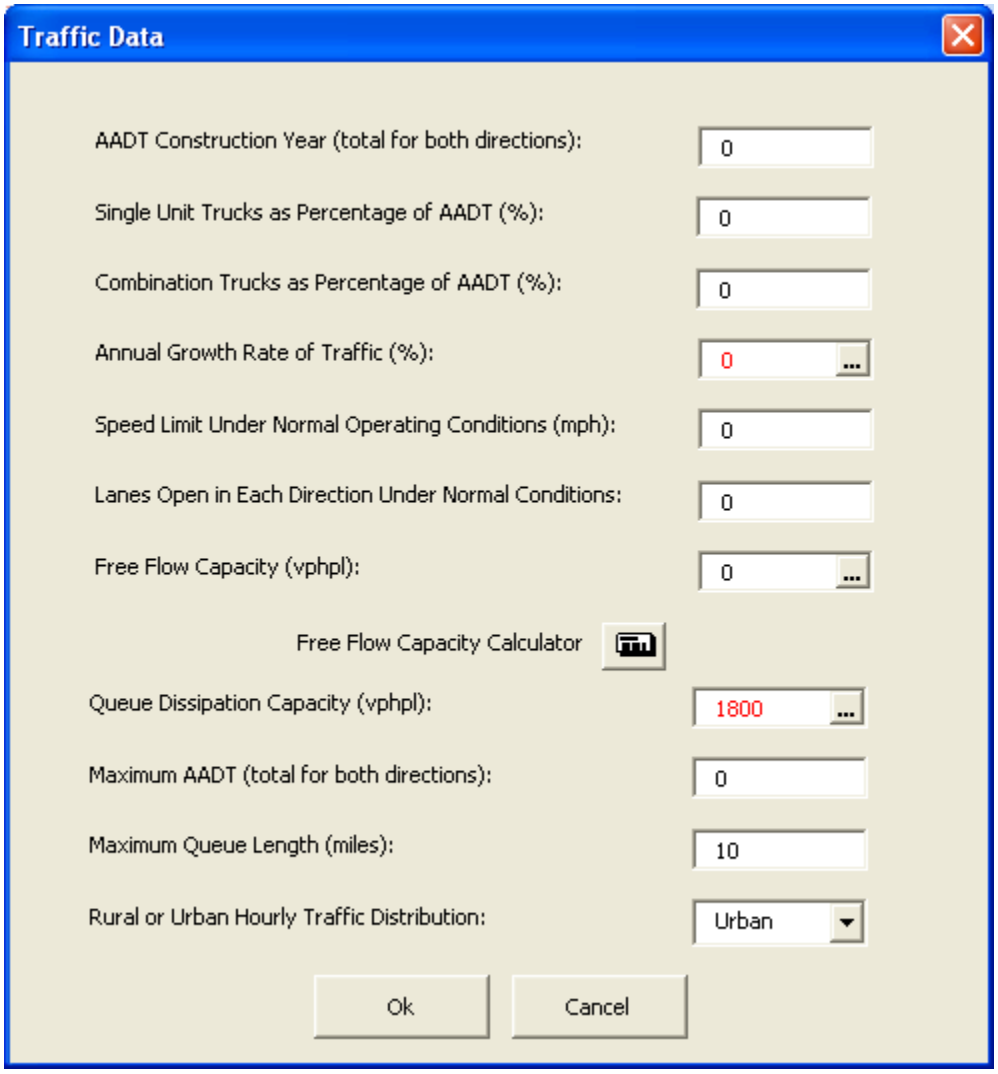


Figure 5. Example of the *Traffic Data* dialog box in RealCost.

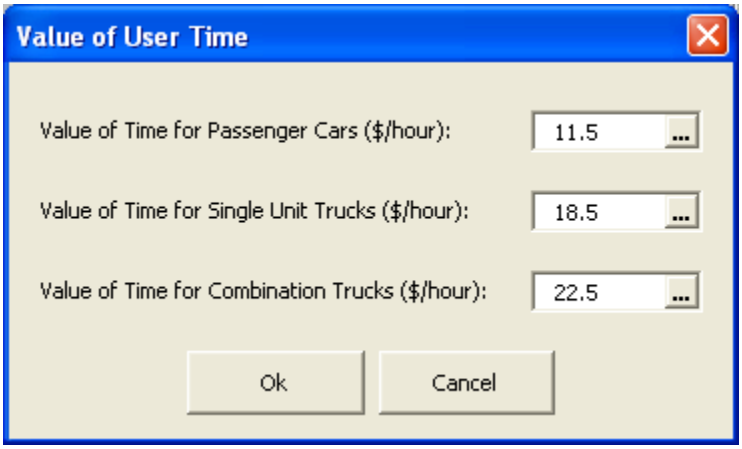
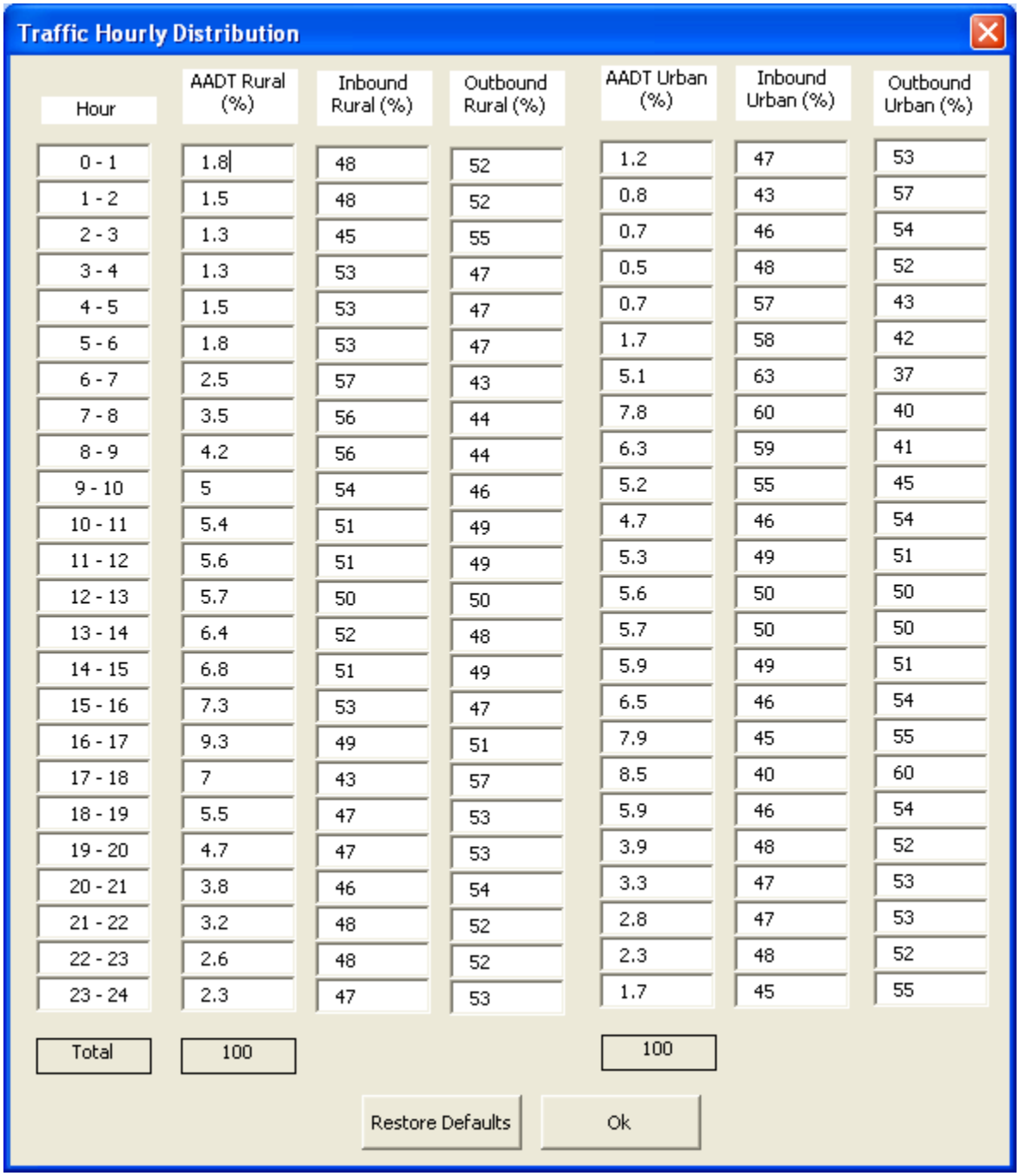


Figure 6. Example of the *Value of User Time* dialog box in RealCost.

4.9. Alter the "Traffic Hourly Distribution" inputs in RealCost (if necessary): For user cost calculations, it is important to know the hourly distribution of traffic over each 24 hour period. Currently, the default traffic hourly distribution included in RealCost is used for typical MDSHA projects. This default distribution is illustrated in figure 7. If project-specific hourly distribution data is available, it should be used. To view or alter the traffic hourly distribution, open the Traffic Hourly Distribution dialog box by clicking on the "Traffic Hourly Distribution" button in the RealCost Switchboard.



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

Figure 7. Example of the *Traffic Hourly Distribution* dialog box in RealCost.

4.10. Alter the "Added Time and Vehicle Stopping Costs" inputs in RealCost (if necessary): Also for user cost calculations, it is important to know the additional required time and costs associated with having to stop in a work zone. Currently, the RealCost default values (illustrated in figure 8) are used for typical MDSHA projects. If project-specific information is available, it can be entered in the "Added Time and Vehicle Stopping Costs" dialog box. To open this dialog box, click on the "Added Vehicle Cost and Time" button in the RealCost Switchboard.

It is in this dialogue box that Cost Escalation information is updated, as per the procedures outlined in Value of Time Inputs.

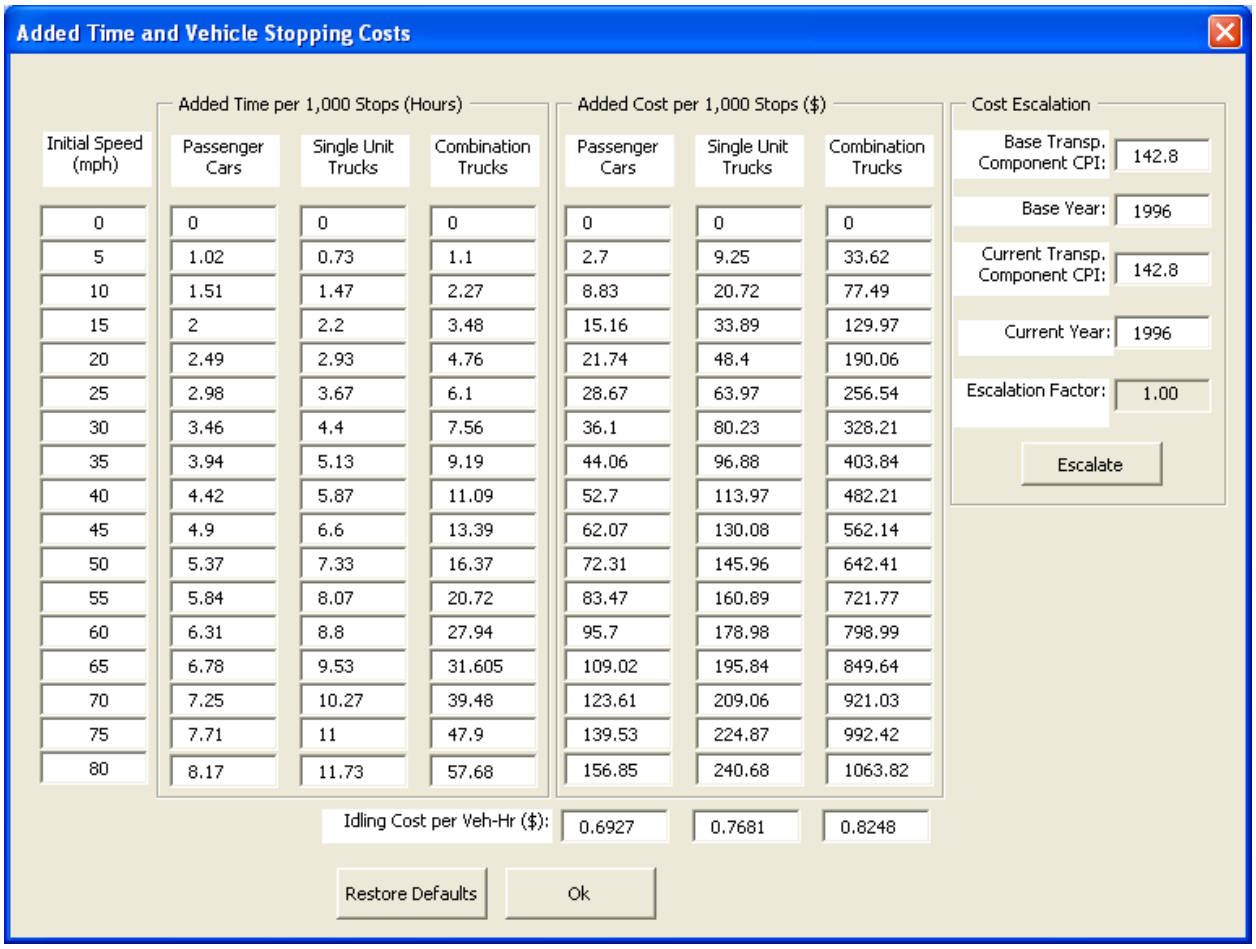


Figure 8. Example of the *Added Time and Vehicle Stopping Costs* dialog box in RealCost.

4.11. Define the alternative-related inputs associated with Alternative 1: To complete the LCCA setup, many different alternative-related inputs must be defined. To begin defining those inputs for the HMA alternative , click on the "Alternative" button in the RealCost switchboard to open the "Alternative 1" dialog box. An example of the "Alternative 1" dialog box is presented in Figure 9. In the "Alternative 1" dialog box, similar inputs need to be defined for all construction

activities (i.e., the initial construction and all six rehabilitations). To access the inputs associated with a specific construction activity, simply click on the desired tab at the top of the dialog box.

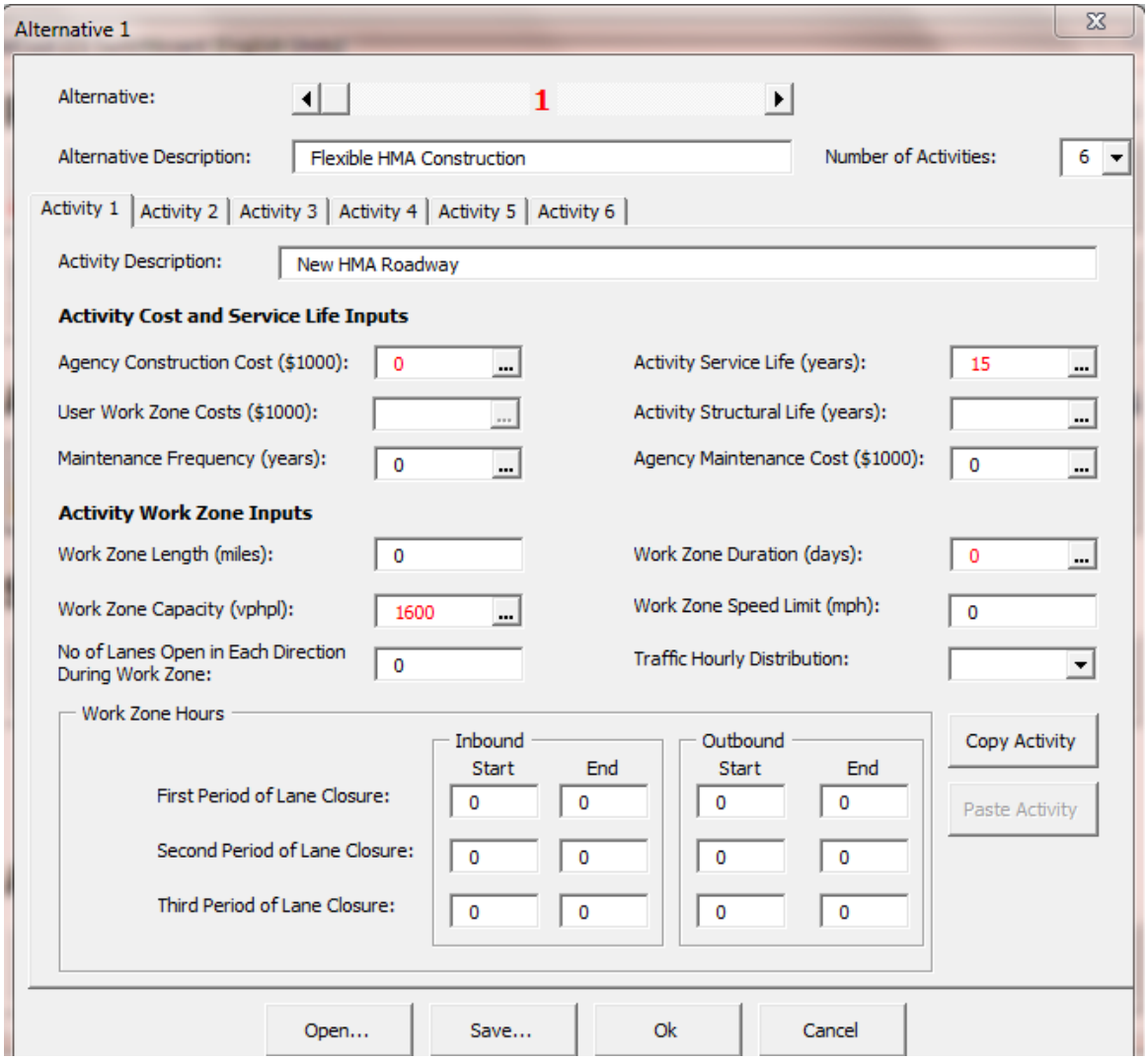


Figure 9. Example of the *Alternative 1* dialog box in RealCost.

Under each construction Activity tab, required inputs include an activity description, activity cost and service life inputs, and activity work zone-related inputs. A complete list of these inputs and the data sources for the information is summarized in table 1 below.

It is critical that each alternative have exactly 6 activities.

Table 1. Summary of alternative-related inputs and data sources.

Input Name	**Description and Source**
Activity Description	Use this input to provide a descriptive name of the current construction activity. Note that the "Activity Description" input fields are populated when loading the default *FinalRunDefault-HMA.LCA* or *FinalRunDefault-PCC.LCA* file. Manually alter these descriptions as necessary.

Activity Cost and Service Life Inputs	
Agency Construction Cost ($1000)	This is a probabilistic input that uses a **truncated normal** distribution type, and requires user-defined values for *average*, *standard deviation*, *minimum*, and *maximum*. These values are summarized in the *1stRunOutput* worksheet in the LCCA-Details.xls workbook, and were printed in step 3.16 of the analysis.
User Work Zone Costs ($1000)	Since the MDSHA method computes user costs as part of the LCCA process, this input is inactive in the dialog box.
Maintenance Frequency (years)	None. The current MDSHA default is to not include maintenance in the LCCA (see Future Maintenance Inputs). Therefore, this value is set equal to "0".
Activity Service Life (years)	This is a probabilistic input that uses a **truncated normal** distribution type, and requires user-defined values for *average*, *standard deviation*, *minimum*, and *maximum*. Note that these input fields are populated when loading the default *FinalRunDefault-HMA.LCA* or *FinalRunDefault-PCC.LCA* file. A complete summary of the MDSHA default values for this variable are presented in Service Life Statistics.
Activity Structural Life (years)	None. The current MDSHA default is to not include structural life in the LCCA. Therefore, this value is set equal to "0"
Agency Maintenance Cost ($1000)	None. The current MDSHA default is to not include maintenance in the LCCA. Therefore, this value is set equal to "0".

Activity Work Zone Inputs	
Work Zone Length (miles)	This input is defined as the distance from the beginning to the end of the reduced speed area. The value for this input is determined by the specific project characteristics.
Work Zone Capacity (vphpl)	This input is defined as the vehicular capacity of one lane of the work zone for 1 hour. This is a probabilistic input that uses a **truncated normal** distribution type, and requires user-defined values for *average*, *standard deviation*, *minimum*, and *maximum*. Note that these input fields are populated when loading the default *FinalRunDefault-HMA.LCA* or *FinalRunDefault-PCC.LCA* file. The MDSHA default values for this variable are summarized in Future Maintenance Inputs.
No. of Lanes Open in Each Direction During Work Zone	The value for this input is determined by the specific project characteristics.
Work Zone Duration (days)	This input is defined as the total number of days that the work zone will be affecting traffic. This is a probabilistic input that uses a **uniform** distribution type, and requires user-defined values for *minimum*, and *maximum*. These values are summarized in the *1stRunOutput* worksheet in the LCCA-Details.xls workbook, and were printed in step 3.16 of the analysis.
Work Zone Speed Limit (mph)	This input is the posted speed limit within the work zone. The value for this input is determined by the specific project characteristics.
Traffic Hourly Distribution	This input is for choosing the Hourly Distribution defined in the Traffic Hourly Distribution Tab. Choose among Week Day 1, Week End 1 or Week Day 2.
Work Zone Hours inputs	This series of inputs is used to define the hours each day of the work zone duration during which the work zone is in effect. These inputs are populated with MDSHA default values when loading the default *FinalRunDefault-HMA.LCA* or *FinalRunDefault-PCC.LCA* file. If it expected that the work zone hours for your project will be atypical, consult with District Traffic to determine the actual information.

4.12. Define the alternative-related inputs associated with Alternative 2: To define all of the inputs associated with Alternative 2, follow the same procedures outlined in step 4.11 for Alternative 1.

4.13. Save the project-level (.LCC) input file associated with your project: To save all of the newly defined project level-specific inputs, click on the "Save Project-Level Inputs" button in the RealCost Switchboard. Clicking this button will open the "Save RealCost Project-Level Inputs As" dialog box. Enter a descriptive name for your file and use the controls in this dialog box to browse to your project folder. Click the "Save" button to save your current file.

4.14. Save the alternative-level (.LCA) input files associated Alternative 1: To save all of the newly defined alternative level-specific inputs associated with Alternative 1, click on the "Alternative 1" button in the RealCost Switchboard to open the "Alternative 1" dialog box. Next, click the "Save" button at the bottom of the window to open the "Save RealCost Alternative-Level Inputs As" dialog box. Enter a descriptive name for your file and use the controls in this dialog box to browse to your project folder. Click the "Save" button to save your current file.

4.15. Save the alternative-level (.LCA) input files associated Alternative 2: To save all of the newly defined alternative level-specific inputs associated with Alternative 2, complete the same steps outlined in step 4.14, but for Alternative 2.

Note: Occasionally, RealCost will change a probabilistic value to deterministic, for no apparent reason. Before saving the LCA files, be sure that everything that is supposed to be probabilistic actually is probabilistic. Probabilistic values are shown in red.

4.16. Run the final RealCost simulation: Click the "Show Warnings" button to determine if there are any issues to resolve. Once there are no warnings, to initiate the final RealCost simulation, click the "Simulation" button on the RealCost Switchboard. Clicking this button will open the "Simulation" dialog box. Note: this dialog box should be populated with the MDSHA default simulation inputs shown in Simulation Inputs. After verifying the simulation input values in this dialog box, click the "Simulate" button to begin the simulation. Note that the simulation will take several minutes to complete.

4.17. Close the "Simulation" dialog box: After the simulation finishes running, click the "Close" button at the bottom of the "Simulation" dialog box it to close it.

4.18. Close the RealCost Switchboard: To close this dialog box, click on the window's close button (the red "X") in the upper right corner of the RealCost Switchboard dialog box.

4.19. Open the LCCA-Details.xls workbook.

4.20. Copy the entire contents of the *Simulation Output* sheet in the RealCost workbook and paste the results into the *SimulationOutput-FinalRun* sheet in the LCCA-Details.xls workbook: This step of the process is used to be able to view the simulated cost and construction duration results in a desired format outlined in the LCCA-Details.xls workbook. For more detailed instructions on how to copy and paste data, see the process previously described in step 3.14.

4.21. Copy the *Tornado Graphs* sheet in the RealCost workbook and paste the results into the LCCA-Details.xls workbook. To do this, right-click over the tab that says "Tornado Graphs", click on "Move or Copy", then in that dialogue box, click "Create a Copy" so that a check mark appears. In the "Move Selected Sheets To" area, change the file to the LCCA-Details.xls workbook and in the "Before Sheet" area, highlight "Final Results", and click OK.

4.22. Save the LCCA-Details.xls workbook: To save this workbook, press the CTRL+S key combination with this workbook active. You may also save the workbook by clicking on the "File" menu and selecting the "Save" option.

4.23. Print the contents of the *Tornado Graphs* and *FinalResults* worksheets in the LCCA-Details.xls workbook. Make sure the print format is sensible.

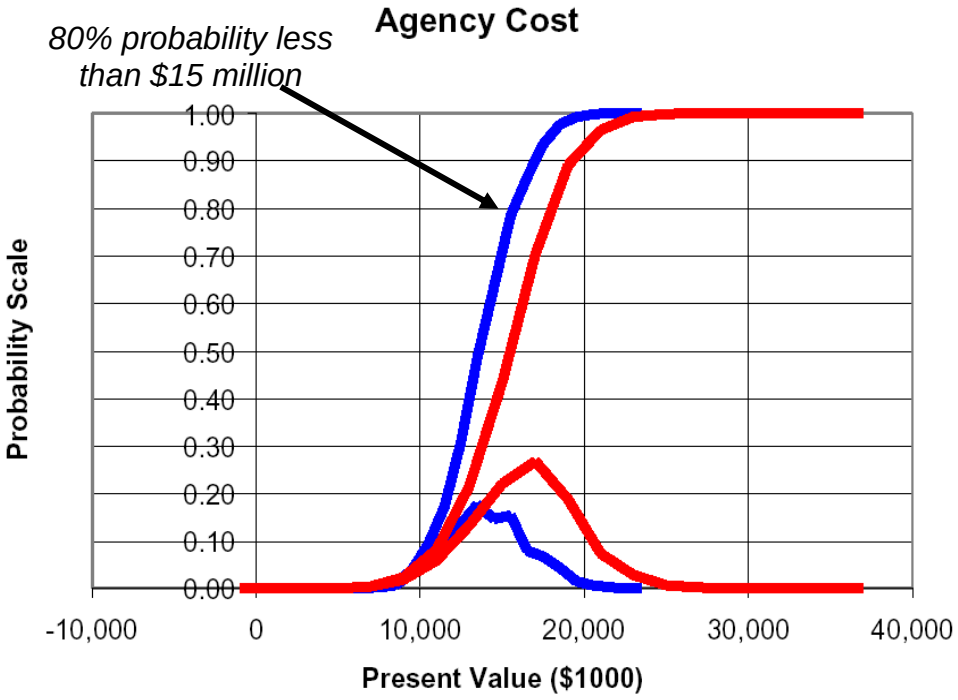
4.24. Close RealCost without saving changes: To close the RealCost workbook, return to the RealCost workbook and select "Close" from the "File" menu. Selecting this option will open a dialog box that asks if you want to save changes. Click on the "No" button to close the workbook without saving changes.

5. Analyze the Life Cycle Cost Results

LCCA Results Analysis

Once all calculations are completed through numerous simulation runs, the results need to be analyzed in order the develop conclusions and make decisions. The probabilistic approach does not provide one discrete dollar value, but rather a probability that the costs will be less than a certain dollar value. For instance, an example of a probabilistic result would be that there is an 80% probability that a pavement alternative is less than $10 million dollars.

The following graphs show a typical result from a probabilistic LCCA approach. On these graphs, two pavement alternatives are shown by the different colors. There are two plots for each pavement type. The lower plots show the probability density function. The more informative plots are the upper cumulative distribution function plots. These plots show the probability that a pavement alternative would equal a certain dollar value.



After the completion of the final RealCost simulation, the final LCCA results need to be analyzed in order the develop conclusions and make decisions. The probabilistic LCCA approach produces a probability distribution of the various costs for each given alternative.

These results, summarized in the *FinalResults* sheet of the LCCA-Details.xls workbook, are reported in terms of the cost *mean*, *standard deviation*, *20th percentile cost*, and *80th percentile cost*. The meaning of the percentile cost values can be realized by understanding that 20 percent of all simulated costs are less than the *20th percentile cost*, and 80 percent of all simulated costs are less than the *80th percentile cost*. These statistics are presented independently for a number of different cost types including: initial agency costs, future agency costs, total agency costs, user costs, and total LCC costs (i.e., total agency costs plus user costs). An example of the LCCA output summarized on the *FinalResults* sheet of the LCCA-Details.xls workbook is presented in figure 10.

Under the MDSHA LCCA process, it is the **Total Agency Costs (80th percentile)** values that are used to determine if further steps are necessary in the pavement type selection process. After calculating these total Agency LCC costs at the 80th percentile, the percentage difference between two costs is computed. This specific decision criterion for continuing with a pavement type selection process is the following:

- If the total LCCA costs between different pavement type alternatives are within 20% at the 80% probability level, the pavement type selection process will continue.

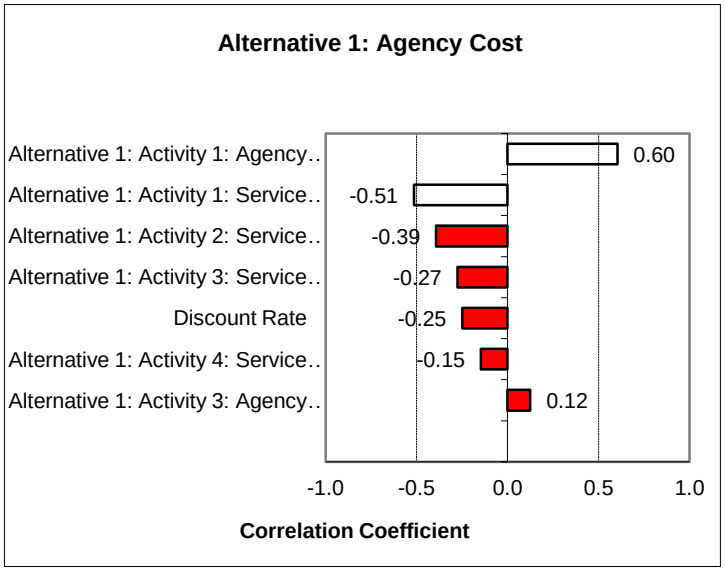
- If the LCCA costs are greater than a 20% difference at the 80% probability level between pavement alternatives, the pavement type with the lowest LCCA cost will be selected as the pavement type and the process will end.

This determination is included as part of the LCCA output summarized on the FinalResults sheet of the LCCA-Details.xls workbook.

If the results of this comparison find that the pavement type selection process needs to continue, additional construction, design, and environmental considerations will need to be taken into account to choose the best pavement type for the given project. More information on the additional pavement type selection components is contained in Pavement Type Selection Matrix.

Prior to the results being accepted as final, the tornado graphs should be analyzed to determine if any inputs need further investigation. The tornado graphs can be used to identify the inputs that have the most influence in the output: those inputs that are at the top of the tornado graph have the most influence, and thus should be scrutinized more closely to make sure they are as accurate as practical.

A sample tornado graph output from RealCost is as follows:



Alternative 1: Agency Cost

Input Variable	Corr. Coeff.
Alternative 1: Activity 1: Agency Cost	0.60
Alternative 1: Activity 1: Service Life	-0.51
Alternative 1: Activity 2: Service Life	-0.39
Alternative 1: Activity 3: Service Life	-0.27
Discount Rate	-0.25
Alternative 1: Activity 4: Service Life	-0.15
Alternative 1: Activity 3: Agency Cost	0.12

In this example, the new construction agency cost and the new construction service life has the most influence in the agency cost for activity 1. These inputs should be reviewed again and updated as appropriate.

Project Example

LCCA Results

	Alternate 1 HMA Construction	Alternate 2 JPCP Construction	Average Value	% Departure from Average
Initial Agency Costs (Mean)	$1,497,417	$1,599,476	$1,548,447	3.3%
Initial Agency Costs (Std. Dev.)	$100,150	$416,010	$258,080	
Initial Agency Costs (20th Percentile)	$1,413,190	$1,196,394	$1,304,792	
Initial Agency Costs (80th Percentile)	$1,581,548	$1,992,760	$1,787,154	11.5%
Initial Work Days (Mean)	13	39	26	50.5%
Initial Work Days (Std. Dev.)	1	2	2	
Initial Work Days (20th Percentile)	12	37	25	
Initial Work Days (80th Percentile)	14	41	28	49.1%
Future Agency Costs (Mean)	$640,680	$141,500	$391,090	63.8%
Future Agency Costs (Std. Dev.)	$63,868	$5,688	$34,778	
Future Agency Costs (20th Percentile)	$585,260	$137,384	$361,322	
Future Agency Costs (80th Percentile)	$695,544	$136,790	$416,167	67.1%
Total Agency Costs (Mean)	**$2,138,097**	**$1,740,976**	**$1,939,537**	**10.2%**
Total Agency Costs (Std. Dev.)	$164,017	$421,699	$292,858	
Total Agency Costs (20th Percentile)	$1,998,450	$1,333,778	$1,666,114	
Total Agency Costs (80th Percentile)	**$2,277,092**	**$2,129,550**	**$2,203,321**	**3.3%**
User Costs (Mean)	$4,124,958	$1,949,929	$3,037,444	35.8%
User Costs (Std. Dev.)	$1,517,093	$926,912	$1,222,003	
User Costs (20th Percentile)	$2,812,918	$1,161,400	$1,987,159	
User Costs (80th Percentile)	$5,315,566	$2,631,742	$3,973,654	33.8%
Total LCC Costs (Mean)	$6,263,055	$3,690,906	$4,976,980	25.8%
Total LCC Costs (Std. Dev.)	$1,681,110	$1,348,611	$1,514,861	
Total LCC Costs (20th Percentile)	$4,811,368	$2,495,178	$3,653,273	
Total LCC Costs (80th Percentile)	$7,592,658	$4,761,292	$6,176,975	22.9%

Are the two Total LCCA Costs within 20% at the 80th Percentile?	Number of Percentiles within 20%:	Are the two Total LCCA Costs within 20% at the Mean?
Yes	48	No

Figure 10. Example of LCCA results summarized in the *FinalResults* sheet of the LCCA-Details.xls workbook.

MDSHA LCCA Default Input Values

Many of the inputs required by the MDSHA LCCA procedure are inputs that do not have to be changed by the user on a project-by-project basis. This section summarizes those inputs for which the MDSHA has currently chosen to be default values in the procedure.

General Analysis Inputs

The general analysis inputs are options that the user needs to define before conducting the analysis, as shown in table A-1.

Table A-1. MDSHA default general analysis inputs.

Required Information	Design Input
Analysis Period (years):	50
Discount Rate (%):	Probabilistic Approach with a Truncated Normal Distribution
	Mean: 2% Standard Deviation: 0.25% Minimum: 1.5% Maximum: 2.5%
Include Agency Cost Residual Value:	Yes
Include User Costs in Analysis:	Yes
User Cost Computations Method:	Calculated
Traffic Direction:	Both – unless project specific information requires alternate information
Include User Cost Residual Values:	Yes

Simulation Inputs

The default simulation inputs used to define the Monte Carlo simulation parameters in RealCost are summarized in table A-2.

Table A-2. MDSHA default simulation inputs.

Required Information	Design Inputs
Sampling Scheme	
Reproducible Results:	Seed Value: 2000
Tail Analysis Percentiles	
Percentile 1:	10
Percentile 2:	20
Percentile 3:	80
Percentile 4:	90
Iterations	
Number of Iterations:	2000

Required Information	Design Inputs
Monitor Convergence:	Not selected
Monitoring Frequency (Number Iterations):	50
Convergence Tolerance (%):	2.5

Construction Item Unit Costs

The default construction item unit costs are based on the regularly tabulated bid results that are stored in the MDSHA pavement management system. When the population of data for a cost item is not large enough to be statistically significant, the MDSHA has used available unit price data from surrounding states and input from the materials industries.

Material cost information is updated each year. The latest information is found at Latest Material Unit Costs.pdf. This summarizes the costs that are currently used in the LCCA effort as a function of MDSHA-defined material quantity categories.

Construction Item Daily Production Rates

The default typical daily production rates associated with the various construction and rehabilitation activities are summarized in table A-4.

Table A-4. MDSHA default typical daily production rates.

Construction Operation	Rehabilitation or Under MOT Constraints	New Construction or Few MOT Constraints
HMA Placement	1,400 – 1,500 tons/day	1,500 – 2,500 tons/day
HMA Grinding	8,000 – 10,000 SY/day	
HMA Base Widening and HMA Wedge/Level	800 – 1,000 tons/day	
HMA Patching	200 - 250 tons/day	
PCC Placement*	3,000 – 4,000 SY/day	4,000 - 5,000 SY/day
PCC Patching	200 – 250 SY/day	
PCC Grinding	5,600 – 7,000 SY/day	
Clean and Seal Joints	5,000 – 6,000 LF/day	
Graded Aggregate Base Placement	3,000 – 4,000 SY/day	6,000 - 8000 SY/day
Excavation and Borrow Placement	1,600 - 2,400 CY/day	4,000 - 6,000 CY/day

* Add 28-days to final PCC construction duration to allow for cure time.

Traffic Analysis Inputs

Table A-5 shows the traffic analysis inputs applicable for the MDSHA procedure. Some of the input values not provided in the table can be found in the pavement design files.

Table A-5. MDSHA default traffic analysis inputs.

Click to return to Define Traffic Data

Required Information	Design Input
Annual Growth Rate of Traffic (%):	Probabilistic Approach with a Truncated Normal Distribution
	Mean: use project specific traffic growth Standard Deviation: 0.5% Minimum: Mean - 1% Maximum: Mean +1%
Calculation for Free Flow Capacity:	Upgrade (%): Assume the roadway is flat with no grade unless project specific information indicates otherwise
	Obstruction on Two Sides: None unless project specific information indicates otherwise (such as permanent concrete barrier)
	Distance to Obstruction: None unless project specific information indicates otherwise (such as width of shoulder between lane and permanent concrete barrier)
Queue Dissipation Capacity (vphpl):	Probabilistic Approach with a Truncated Normal Distribution
	Mean: 1800 Standard Deviation: 200 Minimum: 1400 Maximum: 2200
Calculation for Max AADT (Both Directions):	= (2600vphpl) (24 hrs) (no. lanes)
Maximum Queue Length (miles):	10
Work Zone Lane Capacity (vphpl):	Probabilistic Approach with a Truncated Normal Distribution
	Mean: 1600 Standard Deviation: 200 Minimum: 1000 Maximum: 2200

Value of Time Inputs

Table A-6 lists the default hourly values of user time inputs for LCCA and their applicable values for Maryland.

Table A-6. MDSHA default value of time inputs.

Click to return to Value_of_user_time
Click to return to Added_Time_Costs

Required Information	Design Input
Value of User Time for Passenger Cars ($):	11.50
Value of User Time for Single Unit Trucks ($):	18.50
Value of User Time for Combination Trucks ($):	22.50
Current Transportation Component CPI:	Current Consumer Price Index for Transportation (See procedure below)
Current Year:	Year obtained from CPI (See procedure below)

Use the current consumer price index cost for Transportation. Go to the US Department of Labor's web site and follow the following steps:

- Go to http://www.dol.gov
- Search for Consumer Price Index
- Click on Consumer Price Index (CPI) - U.S. Bureau of Labor Statistics
- Click on CPI Tables, then click on the most recent table.
- Go to Table 1: Consumer Price Index for all Urban Consumers Adjusted U.S. City Average, by Expenditure Category and Commodity and Service Group
- Go to Transportation
    - Find the most recent Month, Year for the current CPI Transportation Value

Future Maintenance Inputs

Table A-7 lists the current MDSHA default values and explanations for the future maintenance-related LCCA inputs.

Table A-7. MDSHA default future maintenance inputs.

Required Information	Design Input
User Work Zone Costs ($1000):	Inactive – No information is needed
Maintenance Frequency (years):	None – Maintenance will not be included in our analysis

Required Information	Design Input
Agency Maintenance Cost ($1000):	None – Maintenance will not be included in our analysis
Work Zone Hours:	Consult with the District Traffic to determine this information
Work Zone Lane Capacity:	Probabilistic Approach with a Truncated Normal Distribution
	Mean: 1600 Standard Deviation: 200 Minimum: 1000 Maximum: 2200

Future Rehabilitation Activities

The details of the default MDSHA rehabilitation activities for different tables are presented in table A-8.

Table A-8. MDSHA default rehabilitation activities by pavement type.

Click to return to Construction_Line_Items

Cycle	Rehabilitation Strategy - Flexible
1st Rehab	- 2” Grinding on mainline and shoulders - 2” HMA OL on mainline and shoulders - 1% Full-Depth patching of mainline area
2nd Rehab	- 2” Grinding on mainline and shoulders - 2” HMA OL on mainline and shoulders - 3% Full-Depth patching of mainline area
3rd + Rehab	- 2” Grinding on mainline and shoulders - 3” HMA OL on mainline and shoulder - 5% Full-Depth patching of mainline area

Cycle	Proposed Rehab Strategy – JPCP, No Curb & Gutter	Proposed Rehab Strategy – JPCP, Curb & Gutter
1st Rehab	- 5% Patching of mainline joints Diamond Grinding on mainline	- 1% Patching of mainline joints - Diamond Grinding on mainline
2nd Rehab	- 5% Patching of mainline joints - Diamond Grinding on mainline	- 5% Patching of mainline joints - Diamond Grinding on mainline
3rd Rehab	- 5% Patching of mainline joints - 4” HMA OL on mainline & shoulders	- 5% Patching of mainline joints - 3” HMA OL on mainline & shoulders

Cycle	Proposed Rehab Strategy – JPCP, No Curb & Gutter	Proposed Rehab Strategy – JPCP, Curb & Gutter
4th + Rehab	- 2” Grinding on mainline & shoulders - 2” HMA OL on mainline & shoulders - 3% Full-Depth composite patching of mainline area	- 3” Grinding on mainline & shoulders - 3” HMA OL on mainline & shoulders - 3% Full-Depth composite patching of mainline area

Cycle	Proposed Rehab Strategy – CRCP, No Curb & Gutter	Proposed Rehab Strategy – CRCP, Curb & Gutter
1st Rehab	- 3% Patching of mainline area - Diamond Grinding on mainline	- 1% Patching of mainline area - Diamond Grinding on mainline
2nd Rehab	- 5% Patching of mainline area - Diamond Grinding on mainline	- 5% Patching of mainline area - Diamond Grinding on mainline
3rd Rehab	- 5% Patching of mainline area - 4” HMA OL on mainline & shoulders	- 5% Patching of mainline area - 3” HMA OL on mainline & shoulders
4th + Rehab	- 2” Grinding on mainline & shoulders - 2” HMA OL on mainline & shoulders - 3% Full-Depth composite patching of mainline area	- 3” Grinding on mainline & shoulders - 3” HMA OL on mainline & shoulders - 3% Full-Depth composite patching of mainline area

Service Life Statistics

Table A-9 presents the MDSHA-computed typical service life statistics for flexible pavements. Note that the presented statistics include the average, standard deviation, minimum, and maximum values, all presented in terms of years. Tables A-10 and A-11 present similar statistics for JPCP and CRCP.

Table A-9. MDSHA typical service life statistics (in years) for flexible pavements.

	Flexible Pavements			
Construction Activity	Avg.	Std. Dev.	Min.	Max.
Initial Construction	15	5.5	9.5	20.5
1st Rehabilitation	14	5	9	19
2nd Rehabilitation	12.5	4.5	8	17
3rd+ Rehabilitation	12.5	4.5	8	17

Table A-10. MDSHA typical service life statistics (in years) for JPCP.

Construction Activity	Jointed Plain Concrete Pavements			
	Avg.	Std. Dev.	Min.	Max.
Initial Construction	25	10	15	35
1st Rehabilitation	18	7	11	25
2nd Rehabilitation	14	6	8	20
3rd+ Rehabilitation	12	5	7	17

Table A-11. MDSHA typical service life statistics (in years) for CRCP.

Construction Activity	Continuous Reinforced Concrete Pavements			
	Avg.	Std. Dev.	Min.	Max.
Initial Construction	25	7	18	32
1st Rehabilitation	15	5	10	20
2nd Rehabilitation	15	3	12	18
3rd+ Rehabilitation	15	3	12	18

PAVEMENT TYPE SELECTION MATRIX

Component Matrix

If the LCCA results are within 20% of each other, then the PTSP process continues with a scoring matrix. The following three major components and respective factors make up the matrix:

- Cost
  - Present Worth Agency Costs - Initial and Future
  - Present Worth User Delay Costs

  *LCCA

- Construction
  - Duration of Construction
  - Maintenance of Traffic
  - Maintenance of Access

  *Utilities & Future Maintenance

  *Material Sources

  *Reliability of Construction

- Design & Environment
  - Traffic & Geometry
  - Adjacent Pavement & Structures
  - Environmental Impact

  *Community Concerns

  *Future Planning

* Factors to be considered, but not part of scoring factors or part of the matrix. The frequency or significance of the impact of these factors is not expected to be high.

A matrix and scoring criterion was developed for each factor to be used in the calculation for a score for each pavement type alternative. This rating will be used by PAGD to arrive at a recommendation for the pavement type to be provided to the project level PTST.

The alternative with the highest rating based on the component matrix will be the selected pavement type to be recommended to the project level PTST. This recommendation in addition to all supporting background information will be provided to the project level PTST for consideration in their final pavement type decision.

The components and factors are utilized in a component matrix scoring system. There are a total of three components which make up 8 factors. Each factor is scored on a scale of 0 to 10. A factor rating of 5 is considered the average or neutral score indicating no particular benefit or detriment for choosing that alternative.

A weighting factor is given to each factor to model its importance in regard to the impact on the pavement type selection. Factors are multiplied by their weight and added up to develop a rating for each component. Each component rating is then multiplied by its weight and added up to develop an overall rating for that pavement alternative.

The table below shows the pavement type selection components and factors and their respective weightings. The final weight column gives the net impact of each scoring factor on the overall rating.

The weighting factors used in the matrix to develop the recommendation from PAGD will remain consistent regardless of the project. Once the recommendation is developed and provided with all the component information, the project-level PTST has the responsibility to review the data and the authority to adjust priorities based on their own agency knowledge.

Matrix Scoring Criteria

Component	Factor	Factor Weight	Component Weight	Final Weight
Cost			45%	
	Agency Cost – present worth cost	65%		29%
	User Delay – present worth cost	35%		16%
	*Initial and Future Agency			
	*LCCA			
Construction			30%	
	Duration of Construction (Climate)	25%		8%
	Maintenance of Traffic	50%		15%
	Maintenance of Access	25%		8%
	* Utilities & Future Maintenance			
	*Material Sources			
	*Reliability of Construction			
Design & Environment			25%	
	Traffic & Geometry	55%		14%
	Adjacent Pavement & Structures	25%		6%
	Environmental Impact	20%		5%
	*Community Concerns			
	*Future Planning			

* non-scoring elements

Example

The following table shows how a sample project with three pavement type alternatives might be rated.

Matrix Scoring - Example

Component / Factor	Weight	Ratings		
		Alt #1	Alt #2	Alt #3
Overall Rating		**4.6**	**5.2**	**5.5**
Cost	45%	5.1	5.4	6.3
Agency Cost – PW costs	65%	4.0	5.0	8.0
User Delay – PW costs	35%	7.0	6.0	3.0
Construction	30%	4.0	4.8	4.8
Duration of Construction (Climate)	25%	4.0	6.0	5.0
Maintenance of Traffic	50%	4.0	4.0	5.0
Maintenance of Access	25%	4.0	5.0	4.0
Design & Environment	25%	4.5	5.6	5.1
Traffic & Geometry	55%	4.0	6.0	6.0
Adjacent Pavement & Structures	25%	5.0	5.0	3.0
Environmental Impact	20%	5.0	5.0	5.0

Cost

The cost component is comprised of the present worth value of initial and future agency costs and user delay costs. Initial agency costs are defined as the total initial construction cost to the agency to build a particular pavement type. Future agency rehabilitation costs are defined as the cost to the agency to complete future rehabilitation activities. User delay cost is defined as the cost to the traveling public from delays of traversing a construction zone with minimized traffic flow capacity throughout the analysis period which includes initial construction and future pavement rehabilitation activities.

When these costs are compared to one another, the 80% probability threshold will be utilized.

Rating Guidelines

A summary of the LCCA which includes the agency costs and user delay costs will be provided to the project-level PTST for review. Both the initial and future agency costs will also be provided to the project-level PTST for review. While the individual agency costs will not be scored or rated, the present worth value

for the agency costs will be evaluated and scored. A rating of 0 to 10 will be given to each alternative in each of the rating factors for the cost component. The rating shall be based on the following criteria:

Agency Costs and User Delay Costs – Both cost factors will already be calculated as a result of performing the LCCA. Using all the pavement type alternatives, an average present worth Agency cost will be calculated. The same calculation will be done for the present worth User Delay cost for all pavement type alternatives.

The individual Agency cost for each alternative will then be compared to the average Agency costs of all the alternatives. Each alternative will be given a rating based on the percent difference between its value and the average. For example, if an alternative has an Agency cost that is 8% greater than the average Agency costs of all alternatives, then that alternative would receive a score of four (4).

The same process will take place to score the User Delay cost factor score. Each alternative will be given the maximum rating available for which it qualifies based on its individual agency cost and user delay cost according to the table below.

Agency Costs and User Delay Costs (Dollars)	**Rating**
< Average – 25%	10
< Average – 20%	9
< Average – 15%	8
< Average – 10%	7
< Average – 5%	6
<= Average + 5%	5
<= Average + 10%	4
<= Average + 15%	3
<= Average + 20%	2
<= Average + 25%	1
> Average + 25%	0

Construction

The construction component includes several factors that are critically important to the pavement type decision that also have the possibility of being subjective.

Duration of Construction - Total paving time for initial construction will be evaluated to determine which alternatives may provide a benefit in terms of project completion date. The time calculation will be based on historical production rate data and recent MDSHA experience. The evaluation will also consider phased or early completion bonuses, site climate impacts, material

cooling/curing times, and paving equipment mobilization restrictions. Construction duration will be developed and reviewed with the Regional Construction Engineer (RCE).

Maintenance of Traffic (MOT) - The MOT factor considers issues related to maintaining the flow of thru traffic during construction. Fully evaluating this factor will require a detailed review of lane closures, work zone times, lane shifts, shoulder use, work zone width, MOT phases, detours, alternate route availability, and temporary concrete barrier use among other things. This information will be gathered from project MOT plans and evaluated with the RCE and District Construction. Sufficient documentation should be provided in this factor to explain the rating score for each alternate.

Maintenance of Access - The maintenance of access factor relates to maintaining point access (vehicular and pedestrian) along the project to businesses and residences. Issues to consider include: commercial or residential properties, temporary or long term closures, potential right-of-way (ROW) compensation, double access points, cross streets, elevation differences, pedestrian needs, on-street parking, temporary concrete barrier, delivery truck size and mail delivery. This information will be gathered from project MOT plans and evaluated with the RCE, District Construction, and District ROW as needed.

Note:*Non-scoring elements
*Utilities & Future Maintenance - Roadway maintenance and future utility repairs in the pavement will be reviewed for pavement type impacts. In addition, any initial construction issues regarding utilities will be listed in this element. Some issues are pavement type independent.

For example, most common pavement types (PCC and HMA) will both require additional handwork around utilities. Trade-offs may be apparent in other areas. PCC patching tends to be more time consuming and expensive, but also will be more durable particularly considering any settlement in the utility repair trench. This information will be gathered from project plans and discussed with Highway Design's Utilities section, District Utilities, and District Maintenance as needed.

*Material Sources - Local and regional availability for the materials required in each alternate will be evaluated. Any materials not generally available in the project area or whose importation may cause an unreasonable premium in an item's unit bid price will be listed for consideration by the project-level Pavement Type Selection Team (PTST.) This information will be compiled by OMT's statewide technical teams (or Material Divisions) for Concrete, Asphalt, and Soils & Aggregates.

*Reliability of Construction - Some alternates may have sequences of construction that could hamper consistent operations and the overall quality of the final pavement. These difficulties are expected to be more of a lay-down issue than a plant production issue. In addition, small quantities of one material

in a contract may suffer from reduced quality. The alternates will be reviewed to determine if any items or paving operations would be likely to suffer from a reduced level of overall product quality. This information will be gathered from OMT's statewide technical teams (or Material Divisions), the RCE, and District Construction.

Rating Guidelines

A rating of 0 to 10 will be given to each alternative in each of the three rating factors for the Construction component. The rating shall be based on the following criteria:

Duration of Construction - The total paving time required to complete the initial construction for each alternative will be based on output from the LCCA. All alternatives will be estimated on the same basis whether that would be work days or calendar days. In addition to current established procedures, site climate (for any season of work conflicts), bridges (for any paving equipment mobilization conflicts), and material cooling or curing time will be considered.

Once the construction duration time is estimated for all alternatives, the average paving construction time will then be calculated based on all alternatives. Each alternative will then be compared to the average of all alternatives and a score will be given based on the percent difference between the two values. Each alternative will be given the maximum rating for which it qualifies based on its percent difference from the average construction time for all alternatives according to the table below.

Construction Time (Days)	Rating
< Average - 25%	10
< Average - 20%	9
< Average - 15%	8
< Average - 10%	7
< Average - 5%	6
<= Average + 5%	5
<= Average + 10%	4
<= Average + 15%	3
<= Average + 20%	2
<= Average + 25%	1
> Average + 25%	0

In addition, if the project has any early completion bonuses (for phases or the overall project), any alternate that is estimated to meet those bonuses will be awarded one additional rating point. Even if all alternates would meet an early completion goal, all alternates will receive the extra rating point. The maximum score in this factor is limited to 10. The RCE shall also list any specific information with regard to construction duration for each alternate that should be

given special consideration or whose potential impact on the project may not be fully reflected in the numerical rating.

Maintenance of Traffic (MOT) - The base rating will be 5 for all alternatives. That rating will then be modified for each alternate according to the questions in the table below. When rating the MOT factor, both initial construction operations and future rehabilitation operations shall be considered and the appropriate rating adjustment applied for each.

Maintenance of Traffic Question	**Rating Adjustment**			
	# Yes	**# No**	**Initial Constr.**	**Future Rehabs**
If multiple or complicated MOT phases will be required during construction (consider lane shifts, lane splits, narrow lanes, temporary concrete barrier, extended lane closures, extended work zone times, road closures w/detours, etc.) will the pavement type alternate: - increase work zone durations - increase MOT costs, or - reduce work zone safety compared to other alternatives?	3	0	- 1.5	- 1.0
	2	1	- 1.0	- 0.5
	1	2	+ 1.0	+ 0.5
	0	3	+ 1.5	+ 1.0
	N/A - MOT not complicated		0	0

	Yes	**N/A**	**No**
If lane shifts or grade differences will require staged, multi-lift construction, is the pavement type under the alternate compatible with those operations?	+ 2	0	- 2
Will the alternate require shoulder reconstruction for temporary MOT use during construction?	- 0.5	0	+ 0.5

If a question does not apply or the information is unavailable, no rating adjustment will be applied for that question. Any specific information with regard to maintenance of traffic that should be given special consideration or whose potential impact on the project may not be fully reflected in the numerical rating shall be listed for each alternate. Supporting information for the first two questions in the rating table should be included to provide details of any MOT issues or complications and to explain the rating adjustment applied.

Maintenance of Access - The rating will be given for each alternate according to the number of impacts from the question below. When rating the maintenance of access factor, both initial construction operations and future rehabilitation operations shall be considered.

<table>
<tr><th>Maintenance of Access Question</th><th colspan="2">Rating Adjustment</th></tr>
<tr><td rowspan="13">Will the alternate have any of the following negative impacts (due to full depth construction, grade differences, temporary concrete barrier, etc.)?
- short term commercial entrance closures (when no secondary access exists)
- long term residential entrance closures
- long term commercial entrance closures (when no secondary access exists)
- cross street closures
- restricted pedestrian access (on one or both sides of the street)
- reduced on-street parking in an area of heavy street parking use (commercial or residential)
- restricted mail or commercial delivery vehicle access even if the entrance is open (based on type of delivery vehicle and any reduced turning radius, severe cross-slope roll over, or large drop-offs, etc.)</td><td colspan="2">Calculate the average number of impacts (rounded to a whole number) for all alternates and rate each alternate as follows:</td></tr>
<tr><td># of Impacts</td><td>Rating</td></tr>
<tr><td>Avg. - 5</td><td>10</td></tr>
<tr><td>Avg. - 4</td><td>9</td></tr>
<tr><td>Avg. - 3</td><td>8</td></tr>
<tr><td>Avg. - 2</td><td>7</td></tr>
<tr><td>Avg. - 1</td><td>6</td></tr>
<tr><td>Average</td><td>5</td></tr>
<tr><td>Avg. + 1</td><td>4</td></tr>
<tr><td>Avg. + 2</td><td>3</td></tr>
<tr><td>Avg. + 3</td><td>2</td></tr>
<tr><td>Avg. + 4</td><td>1</td></tr>
<tr><td>Avg. + 5</td><td>0</td></tr>
</table>

If a question does not apply or the information is unavailable, no rating adjustment will be applied for that question. Any specific information with regard to maintenance of access that should be given special consideration or whose potential impact on the project may not be fully reflected in the numerical rating shall be listed for each alternate.

Design & Environment

The Design & Environment component includes several factors that often have a significant impact on the performance of the roadway with regard to pavement type. Several of these factors also have the possibility of being subjective.

The three rating factors for the Design & Environment component are Traffic & Geometry, Adjacent Pavement & Structures, and Environmental Impact. The two non-scoring elements are Community Concerns and Future Planning. The following list highlights the issues to be considered for each factor and the source of the information.

Traffic & Geometry - The following issues will be considered in the traffic and geometric evaluations: truck traffic, tight radius ramps, intersections, and steep grades. Information such as nearby quarries, landfills, distribution centers, intersection density and location on the project are required to evaluate this factor. This information will be based on the project plans and a review of the

project location with input from Travel Forecasting and Highway Design as needed.

Adjacent Pavement & Structures - Any different pavement types to be involved in widening alongside existing pavement, the number and spacing of bridges, the number of intersection tie-ins, and curb and gutter will be reviewed to determine any benefits or impacts due to different pavement types or structures. This information will be gathered from construction history, borings/cores, and project plans.

Environmental Impact - Environmental impacts include cut and fill needs, wetland and forest disturbance, and highway noise on a project. Other potential impacts in environmentally sensitive areas may also be considered in this factor. This information will be collected from the projects plan, Highway Design, Environmental Programs, and Landscape Architecture.

Note:*Non-scoring elements
*Community Concerns - Any pertinent input from other agencies, municipalities, or community groups involved in the planning/design process will be compiled for consideration by the project-level PTST. Community concerns might relate to issues such as aesthetics, visibility, noise, heat and light reflection, traffic type, access to properties, and future utility maintenance. This information will be forwarded from Project Planning, Highway Design, the District, or any other MDSHA division holding public or interagency meetings regarding the project.

*Future Planning - Information regarding the future plans for the roadway corridor will be listed under this element for consideration by the project-level PTST. Plans for future widening, dualization, and intersections or interchanges should be included here. Future plans for major cross roads and/or other corridors in the region may also be included if they might have significant impacts on the project under review. The future planning information will be gathered through discussion with Project Planning.

Rating Guidelines

A rating of 0 to 10 will be given to each alternative in each of the three rating factors for the Design & Environment component. The rating shall be based on the following criteria:

Traffic & Geometry - The base rating will be 5 for all alternatives. That rating will then be modified for each alternate according to the questions in the following table.

Traffic & Geometry Question	**Rating Adjustment**					
	Yes		**No**	**N/A**		
If there will be a concentration of truck traffic on the project due to facilities such as quarries, landfills, distribution centers, etc. or a truck percentage ≥15%, could the alternate result in premature failure (ex. shoving or rutting) of the final pavement surface?	- 1		+ 1	0		
	High Truck Traffic			**No High Truck Traffic**		
If the project has intersections, considering the number and spacing of intersections on the project, will traffic be frequently stopping and standing such that premature failure (ex. shoving or rutting) of the final pavement surface could occur?	**Yes**	**N/A**	**No**	**Yes**	**N/A**	**No**
	-1	0	+1	-0.5	0	+0.5
If the project has any steep grades and/or truck pull lanes, could the pavement type alternate result in premature failure (ex. shoving or rutting) of the final pavement surface?	-1	0	+1	-0.5	0	+0.5
If the project has intersections, are there any intersections requiring traffic to stop on steep grades that could result in premature failure (ex. shoving) of the final pavement surface?	-1	0	+1	-0.5	0	+0.5
If there are roundabouts or tight radius ramps on the project, could the pavement type alternate result in premature failure (ex. slippage cracking) of the final pavement surface?	-1	0	+1	-0.5	0	+0.5

If a question does not apply or the information is unavailable, no rating adjustment will be applied for that question. Any specific information with regard to roadway geometry that should be given special consideration or whose potential impact on the project may not be fully reflected in the numerical rating shall be listed for each alternate.

Adjacent Pavement & Structures - The base rating will be 5 for all alternatives. That rating will then be modified for each alternate according to the questions in the table below.

Adjacent Pavement & Structures Question	**Rating Adjustment**		
	Yes	**N/A**	**No**
For widening areas in initial construction, will the new pavement be a different pavement type (flexible, rigid, or composite) than the existing pavement?	- 1	0	+ 1
For widening areas in initial construction, will the total pavement section depth (HMA, PCC, and GAB) of new pavement match existing adjacent total pavement section depth?	+ 1	0	- 1
If the project has intersections, will the alternate require tie-ins with an existing dissimilar pavement type?	- 1	0	+ 1
If the project has bridges with an average spacing between bridges less than 1 mile, will a pavement type transition at the approaches be required?	- 1	0	+ 1
If the roadway is closed section, will planned future rehabilitations for the alternative result in adverse impacts to curb reveal (less than 6" reveal at the end of the analysis period?)	- 1	0	+ 1

If a question does not apply or the information is unavailable, no rating adjustment will be applied for that question. Any specific information with regard to adjacent pavement type that should be given special consideration or whose potential impact on the project may not be fully reflected in the numerical rating shall be listed for each alternate.

Additional information may include issues such as the need to cut back the existing HMA surface when widening alongside composite pavement, the need to tie new PCC pavement to existing PCC pavement, and particularly short sections of pavement between bridges.

Environmental Impact - The base rating will be 5 for all alternatives. That rating will then be modified for each alternate according to the questions in the table below.

Environmental Impact Question	**Rating Adjustment**		
	Incr. (+)	**None (±)**	**Decr. (-)**
Considering the total pavement section depth for the alternate, how will the combined cut and fill quantity on the project change compared to other alternates?	- 2	0	+ 2
How will the wetland impacts for the project change if this alternate is selected compared to other alternates?	- 1	0	+ 1
How will the forest impacts for the project change if this alternate is selected compared to other alternates?	- 1	0	+ 1
How will the noise impacts for the project change if this alternate is selected compared to other alternates?	- 1	0	+ 1

In addition, any alternate that mitigates or minimizes environmental impacts of another type (such as heat and light reflection) in an environmentally sensitive area shall be given one additional rating point. The maximum score in this factor is limited to 10.

If a question does not apply or the information is unavailable, no rating adjustment will be applied for that question. Any specific information with regard to environmental impacts that should be given special consideration or whose potential impact on the project may not be fully reflected in the numerical rating shall be listed for each alternate.

Innovative Contracting Options

Innovative contracting is defined as non-traditional project delivery approaches. Examples of innovative contracting include advertising a project with alternate pavement type options or a pavement warranty. The project-level PTST will make the final decision on innovative contracting for any particular project. That decision would be based on the recommendations from PAGD and information gathered in the PTSP.

The criteria for alternate pavement type option projects shall be as follows: Projects presented to a project-level PTST with a **difference in component matrix scores less than 20%** between pavement type alternatives will be recommended by PAGD to utilize innovative contracting. The pavement type **adjustment factor** shall be designated as the difference in the present worth value of the **future agency costs** between the alternatives over a **50-yr analysis period**.

PROJECT-LEVEL PAVEMENT TYPE SELECTION TEAM

Once all the information for each factor and component is gathered, analyzed and recommendations are developed by PAGD, the findings will be presented to a project-level PTST (i.e. US 50 PTST). This team will be responsible for considering all the information identified in this document and to come to a consensus final decision about the pavement type for the project. The project level PTST shall consist of the following individuals:

- Deputy Administrator/Chief Engineer for Operations.
- Deputy Administrator/Chief Engineer for Planning, Engineering, Real Estate and Environment.
- District Engineer of MDSHA District that project resides.
- Director of Highway Development (OHD) for MDSHA.
- Director of Planning and Preliminary Engineering (OPPE) for MDSHA.
- Director of Materials & Technology (OMT) for MDSHA.
- Pavement and Geotechnical Division Chief of OMT for MDSHA.

FHWA is invited to witness the project-level PTST meeting and provide input, but will not be a contributing member in the final decisions made by the team. Industry representation shall not exist on the project-level PTST.

PAGD will provide a pavement type recommendation based on a scored rating of all factors and all supporting data will be provided to the project-level PTST. The project-level PTST will be provided time to review material prior to a meeting. At the project-level PTST meeting, each of the 7 members will come to consensus about the final pavement type selection.

The project-level PTST will also come to consensus about the use of innovative contracting on the project. Once a final consensus decision is made, the project development process will continue based on the pavement type selection of the project-level PTST.

For projects that do not follow the pavement type selection process or are removed from the process through the documented criterion, the pavement type selection will be made by PAGD.

PROJECT-LEVEL PAVEMENT TYPE SELECTION REPORT

Once a decision has been reached on the pavement type, the PAGD engineer will prepare a report documenting the pavement alternatives considered, the LCCA results, the PTSP-matrix results (if applicable) and the final decision. This report shall be submitted by the OMT Director to PTST representatives.

REFERENCES

Maryland State Highway Administration (MDSHA). 2007. "MDSHA LCCA Process Documentation for the Maryland State Highway Administration" Maryland State Highway Administration, Baltimore, MD.

Maryland State Highway Administration (MDSHA). 2005. "MDSHA Pavement Type Selection Team Final Report." Maryland State Highway Administration, Baltimore, MD.

Maryland State Highway Administration (MDSHA). 2005. "MDSHA Pavement Type Selection Team Final Report Appendix." Maryland State Highway Administration, Baltimore, MD.

Maryland State Highway Administration (MDSHA). 2013. "Pavement Type Selection Team Report of Revisions Developed in 2012 – 2013." Maryland State Highway Administration, Hanover, MD.