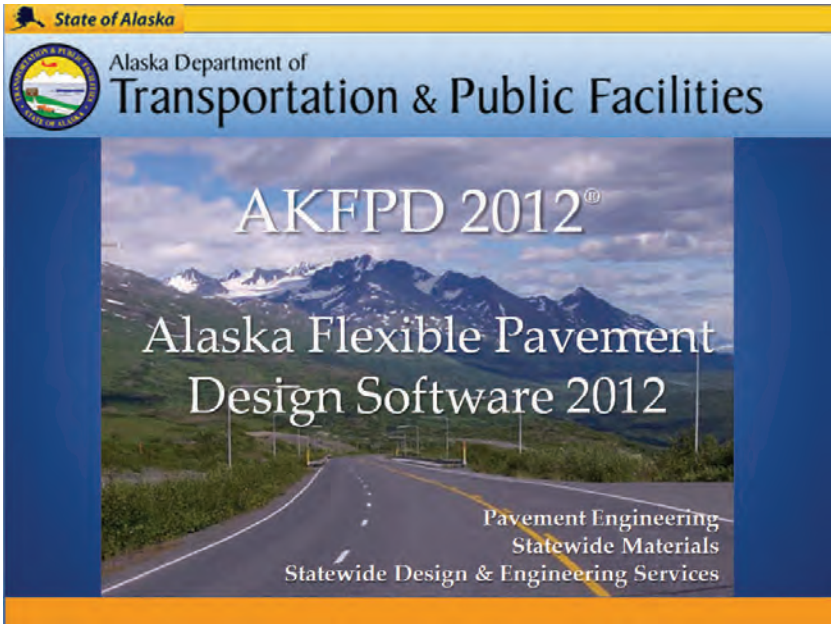
Alaska Department of Transportation & Public Facilities

Alaska University Transportation Center

Inclusion of LCCA in Alaska Flexible Pavement Design Software Manual



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Life cycle cost analysis is a key part for selecting materials and techniques that optimize the service life of a pavement in terms of cost and performance. While the Alaska Flexible Pavement Design software has been in use since 2004, there is no computerized analysis tool available to assist pavement engineers in developing this cost analysis for a given project. Including LCCA in the AKFPD software would be of immense benefit to pavement designers, allowing them to routinely improve infrastructure performance while making more cost-effective use of the design effort. This study seeks to update the current AKFPD program and create a single software package capable of executing the economic cost analysis and structural analysis functions. Upon completion, the project will provide the updated software, a modified AKFPD manual, and case studies with complete analysis processes to help the new user navigate the software. In the past year, the project team developed a new layout for the program. It also added new modules, including “equivalent single axle loads calculation” and “LCCA analysis,” and designed more user-friendly interfaces for two other modules, “Mechanistic Pavement Design” and “Excess Fines Design.”

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	$candela/m^2$	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	$candela/m^2$	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

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Addendum Part 1: Introduction and Installing the New Software

Introduction

The Alaska Flexible Pavement Design (AKFPD) 2012 software is designed to implement the design analysis methods of the Alaska Flexible Pavement Design Manual of the Alaska Department of Transportation and Public Facilities (AKDOT&PF). The AKFPD 2012 software is programmed with Microsoft Visual Studio 2008 in the Windows 7 environment. The compiled software is a 64-bit application that is not compatible with legacy software executables that are 8-bit or older.

In the current edition, pavement design modules of Mechanistic Design and Excess Fine Design are made inactive, because the mechanistic design method requires an old executable Elsym5 (i.e., the file is ***ElsymZ.exe***) to perform the calculation. However, Elsym5 is an 8-bit executable and cannot be run in the Windows 7 environment. Thus, since pavement design methods mechanistic design and excess fine are often used together, program features created for pavement design are all disabled in the current edition. It is expected that Elsym5 will be updated to 64 bit in a later date and pavement design features will be activated then.

The modules that are activated in the current edition are ESAL calculation and Life Cycle Cost Analysis (LCCA). The ESAL calculation component is essentially a graphical user interface that facilitates the data entry and ESAL calculation tasks that were previously performed by the engineers and analysts of AK DOT & PF using a Microsoft Excel spreadsheet. The LCCA component is a brand new software tool that is designed specifically for the new LCCA chapter (i.e., Chapter 9) of the Alaska Flexible Pavement Design Manual.

The AKFPD 2012 software adopts a workbook/worksheets approach similar to Microsoft Excel for project data and task management. That is, a workbook with multiple worksheets is first created and saved for a design/analysis project. Each worksheet of the workbook is then used to store the input and output data of a particular analysis (i.e., ESAL calculation and LCCA) pertaining to the project. For each analysis method, the AKFPD 2012 software uses specially designed user interfaces for data entry and analysis execution. Once the desired analyses are completed with the software, all the completed analysis results together with the original inputs are written on the corresponding worksheets of the project workbook. The completed workbook can eventually be saved as an Excel file to facilitate reporting with Microsoft Word and Powerpoint.

Software Installation

Included with this Tutorial are the setup files for the Beta version of AKFPD 2012 software.

To install the software, simply run the setup.exe file by double clicking at the file in Windows Explorer. The Setup Wizard will appear to guide you through the setup process (Figure 1).

Figure 1 AKFPD 2012 Beta Software Setup Wizard

After clicking next, the second dialog box asks you to specify the directory where the software is to be installed (Figure 2).

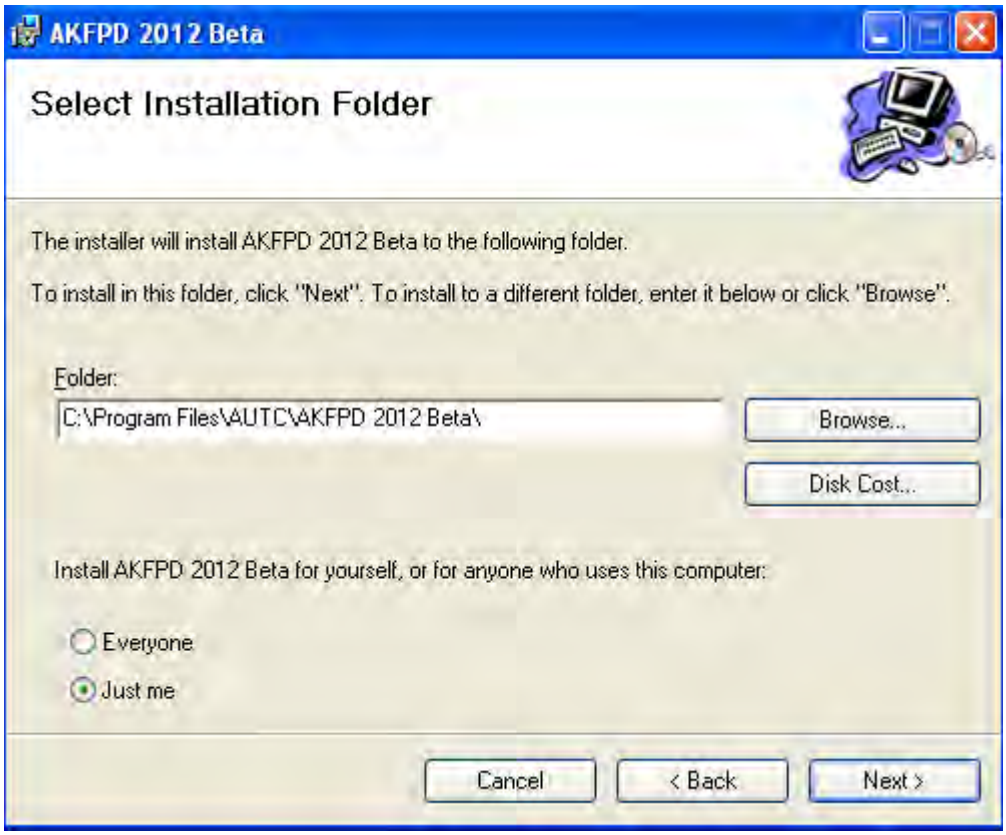


Figure 2 Select Installation Folder

After determining the directory to install the software, clicking Next will begin the installation process. When it is done, you will be notified that the installation is finished and a shortcut icon is placed on the computer desktop.

Before you can run the program, depending on the security setup of your computer and the directory you selected, if you install the software in the C:\Program Files(X86)\ directory you may need to make the data folder under the program directory available to all users:

- C:\Program Files(X86)\AUTC\AKFPD 2012\Data (Windows 7)
- C:\Program Files\AUTC\AKFPD 2012 \Data (Windows XP)

To do this, in Windows Explorer, find the two folders and use the right mouse button to access the Properties page of the folder (Figure 3).

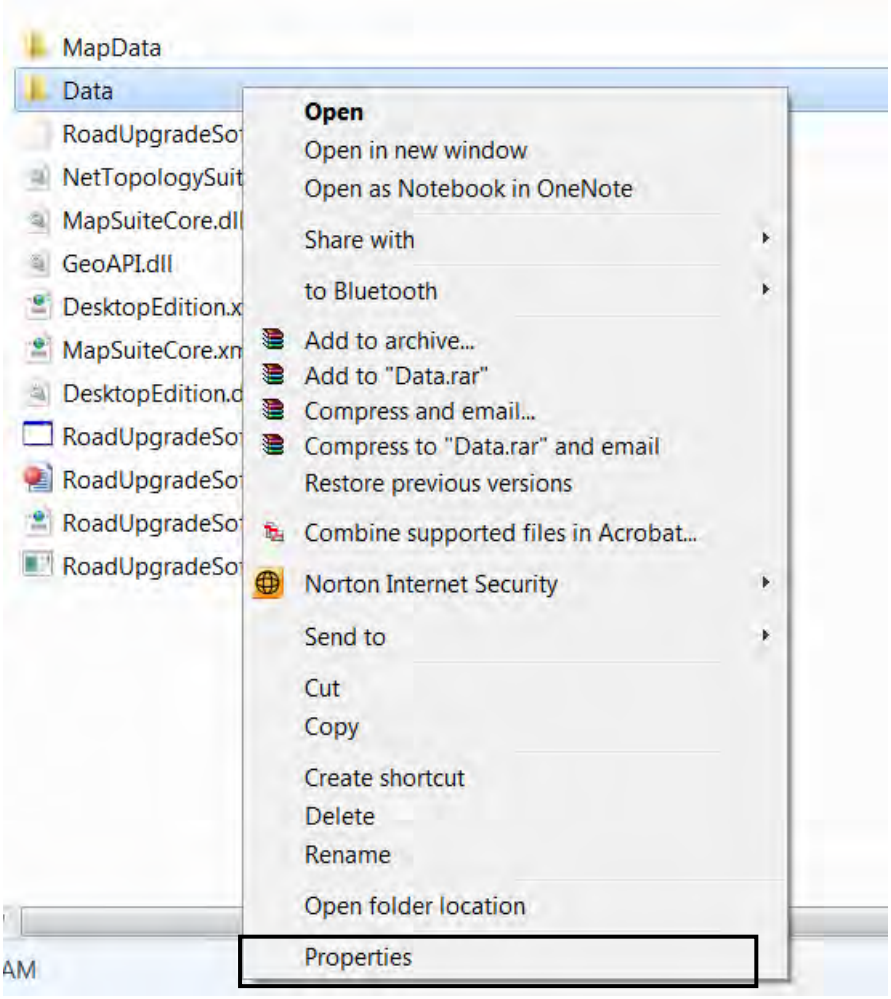


Figure 3 Accessing Data Folder Properties

When the Properties page of the Data folder appears, first uncheck the Read-only attributes (Figure 4), because the software will read and write to files in this folder.

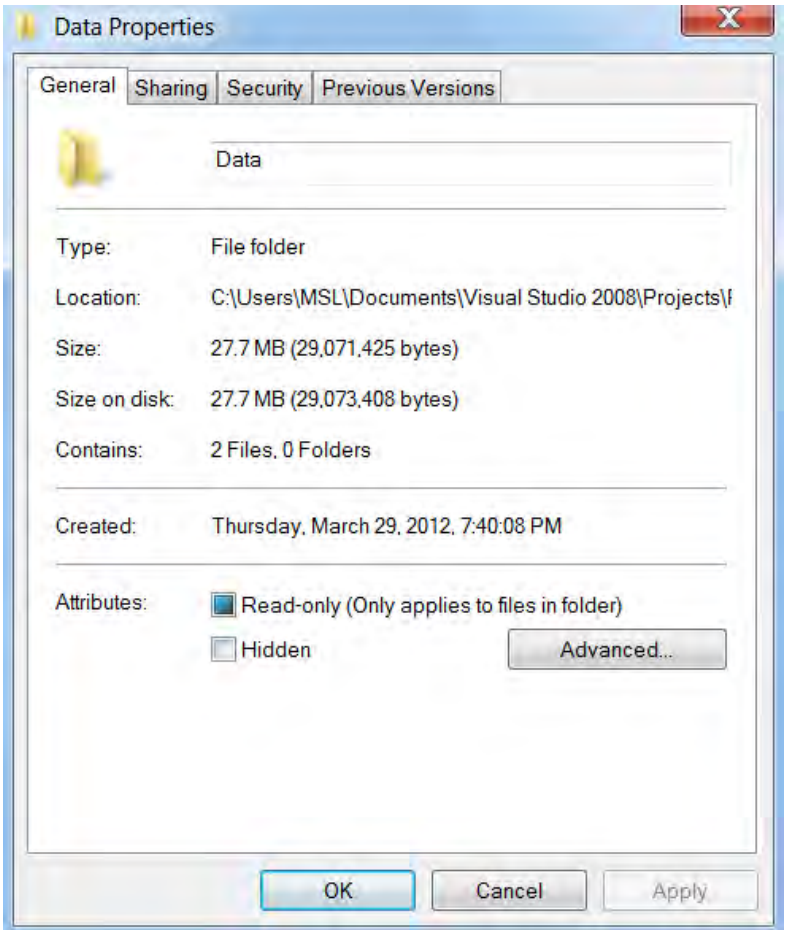


Figure 4 Uncheck Read-only Attribute of the Data Folder

Next, go to the Security tab of the properties page. Make sure the user of the software have full control of the folder (Figure 5). If not, use the Edit button to assign full control to the intended user.

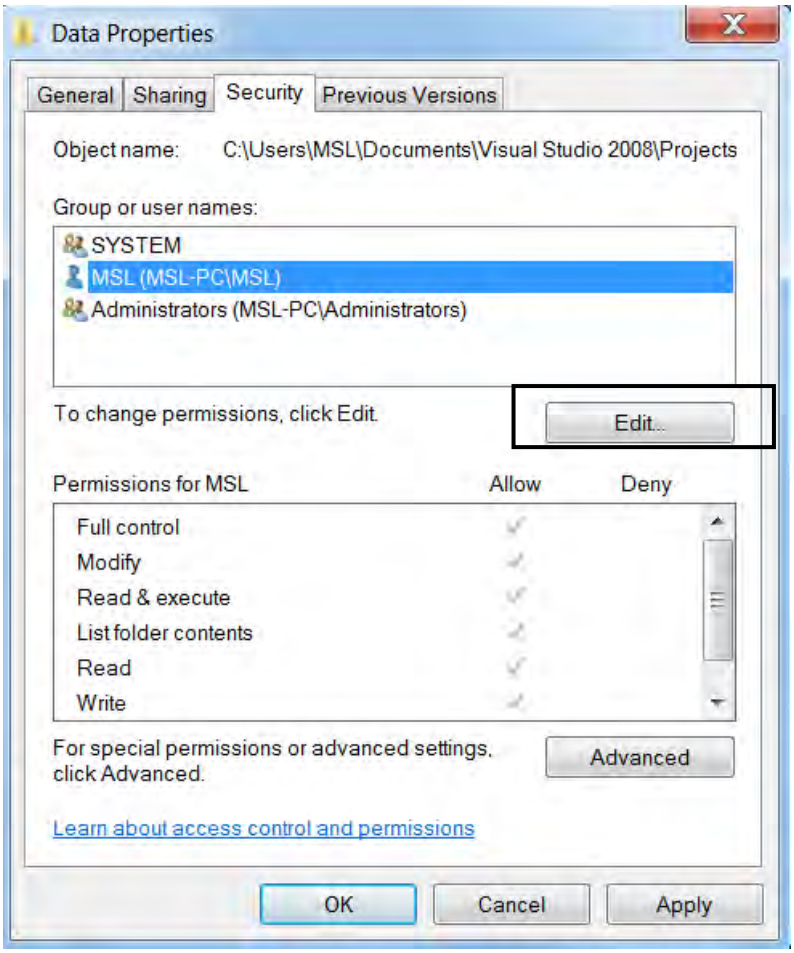


Figure 5 Edit Security Setting of the Data Folder

New Project

Upon launching the program, users are first greeted by the program title window that is to display the software version, authorship, and copyright ownership information (Figure 6). This window is also displayed after users go to Help/About AKFPD2012. This window will go away after a few seconds of lag time. After that the user will see the program main window of AKFPD 2012 (Figure 7).

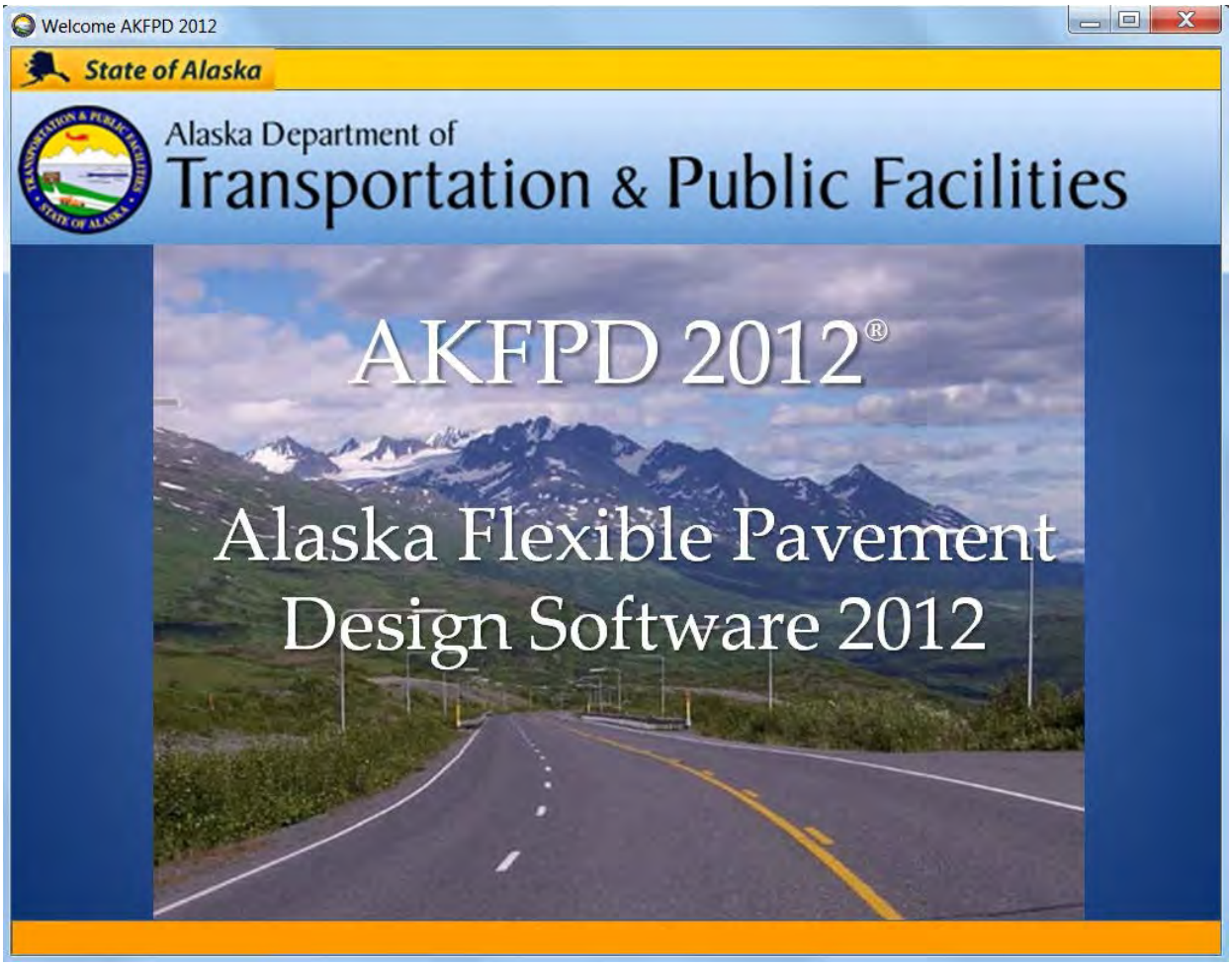


Figure 6 Program Title Window

To perform an analysis with AKFPD2012, a new project is first created by going to File/New (Figure 7).

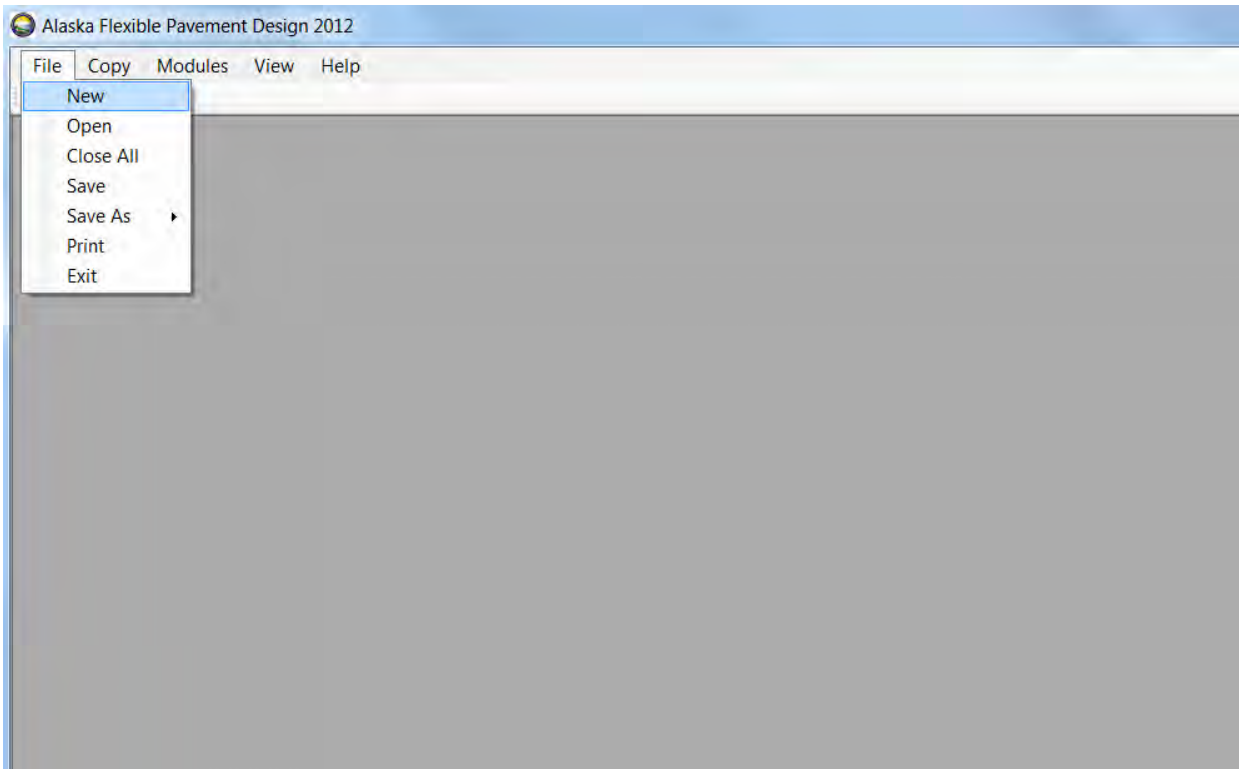


Figure 7 Creating a New Project in AKFPD2012

On the ensuring dialog box Project Info (Figure 8), enter information that identifies the project. The Mechanistic Design options let users specify the design of a New pavement structure or an Overlay Design. After specifying project information, clicking at the **Save** button will open the typical Windows Save As dialog box (Figure 9).

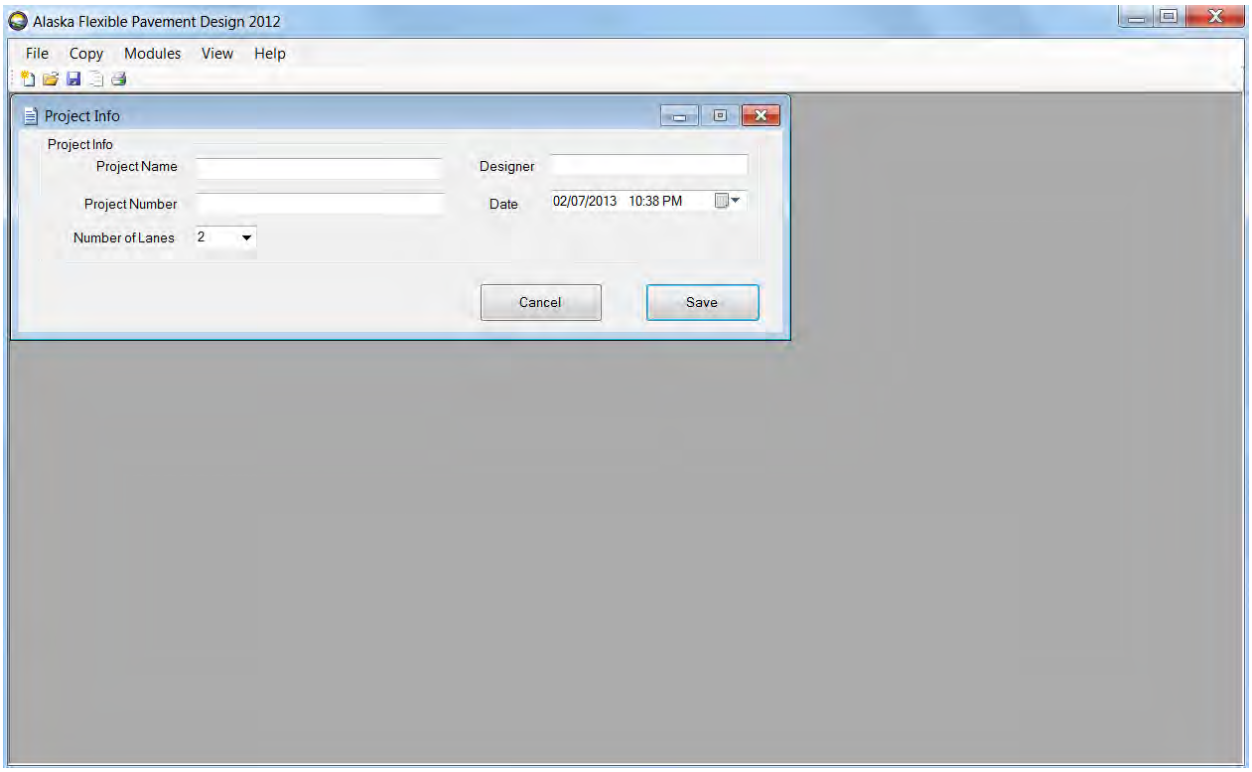


Figure 8 Project Info Dialog Box

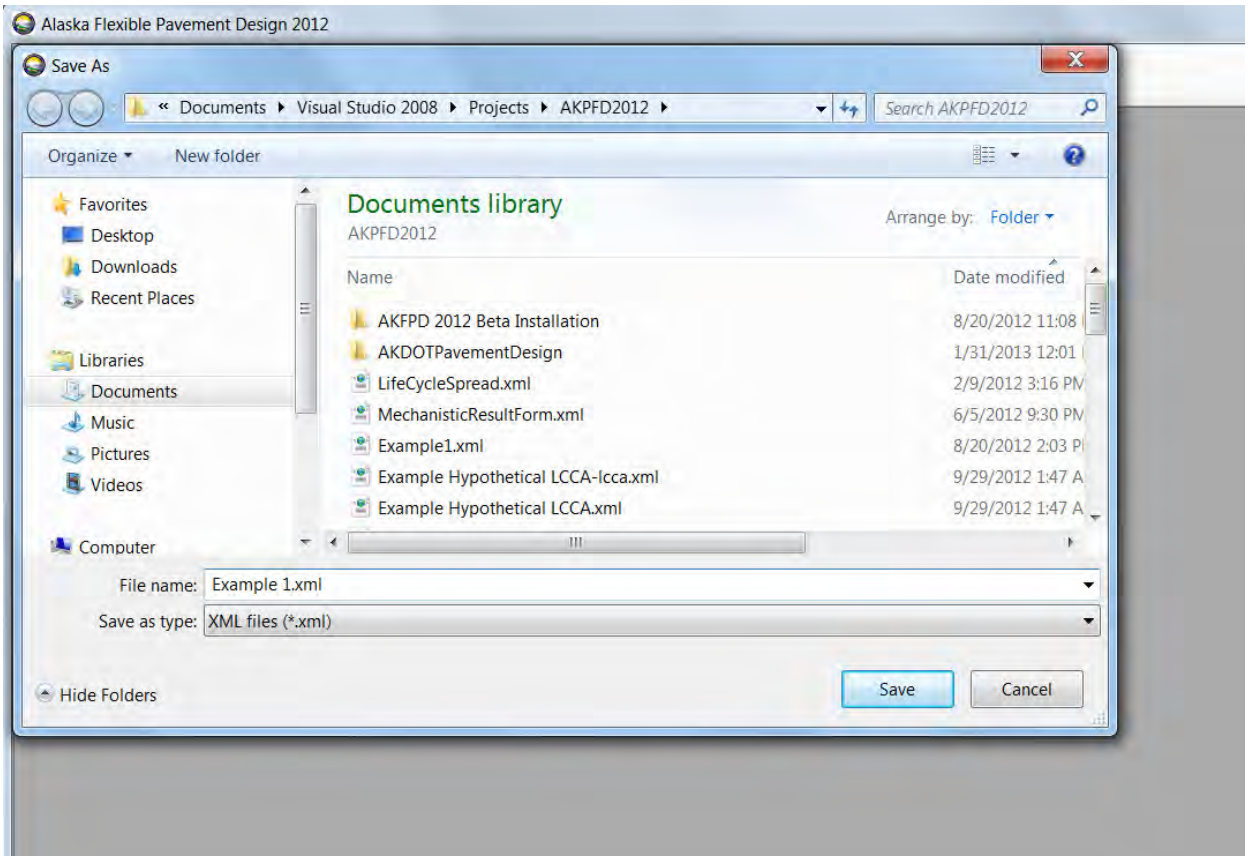


Figure 9 Save As Dialog Box

On the Save As dialog box, enter a file name (e.g., ***Example 1.xml***) in the desired directory for the new project and click at the **Save** button. The project workbook (Figure 10) will appear after the file is successfully created. The *.xml file is the data format adopted for the AKFPD2012 software. Although the XML file format is common to many software, the files saved by AKFPD2012 are effectively processed and displayed by only the AKFPD2012 software.

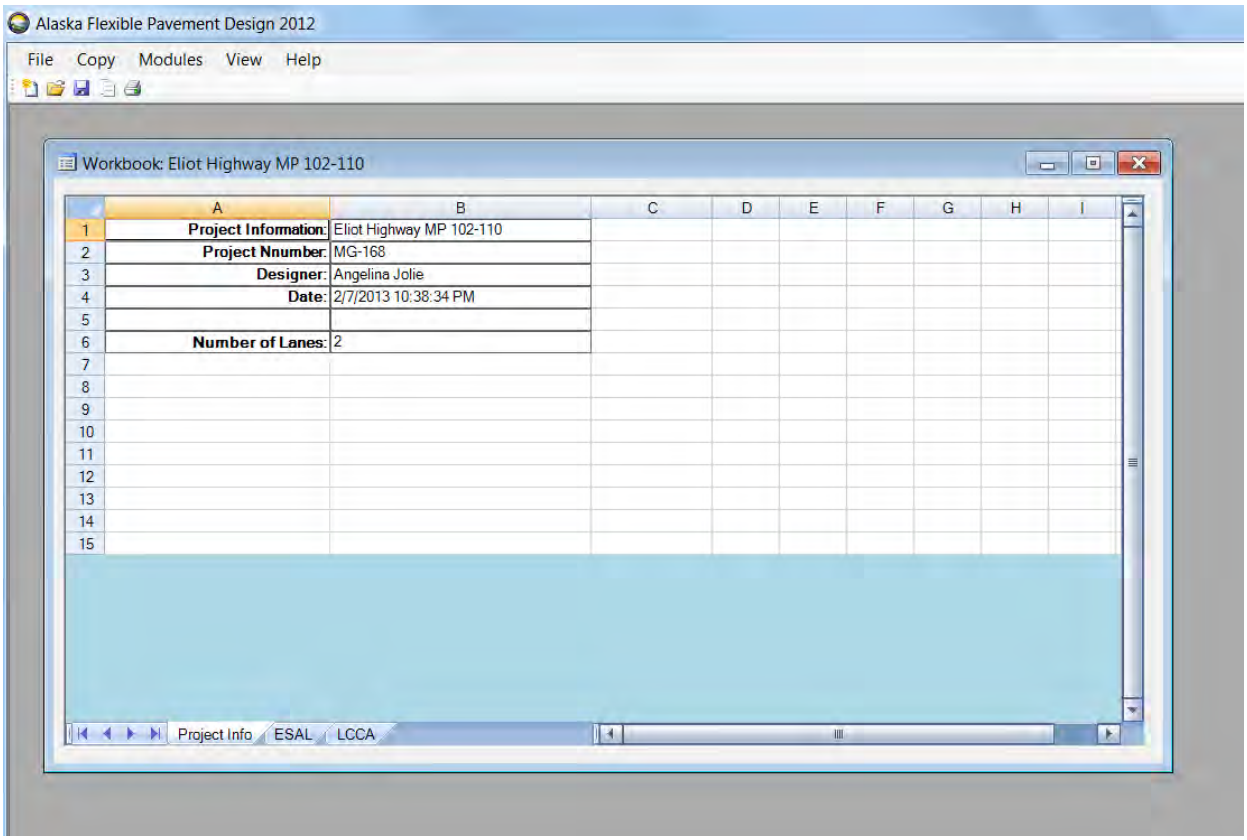


Figure 10 Project Workbook

Figure 10 shows that a project workbook contains three worksheets: Project Info, ESAL, and LCCA. Project Info contains basic project information that was previously entered in the Project Info dialog box. Except for the Project Info sheet, each worksheet is designed to store the input and output variables of a particular pavement design analysis.

Addendum Part 2: Equivalent Single Axle Load (ESAL)—Calculations Using New Software

ESAL Calculation

To begin an ESAL calculation with the software, when the project workbook is opened, go to Modules/ESAL Calculation (Figure 11). This will bring up the ESAL Calculation data entry window (Figure 12).

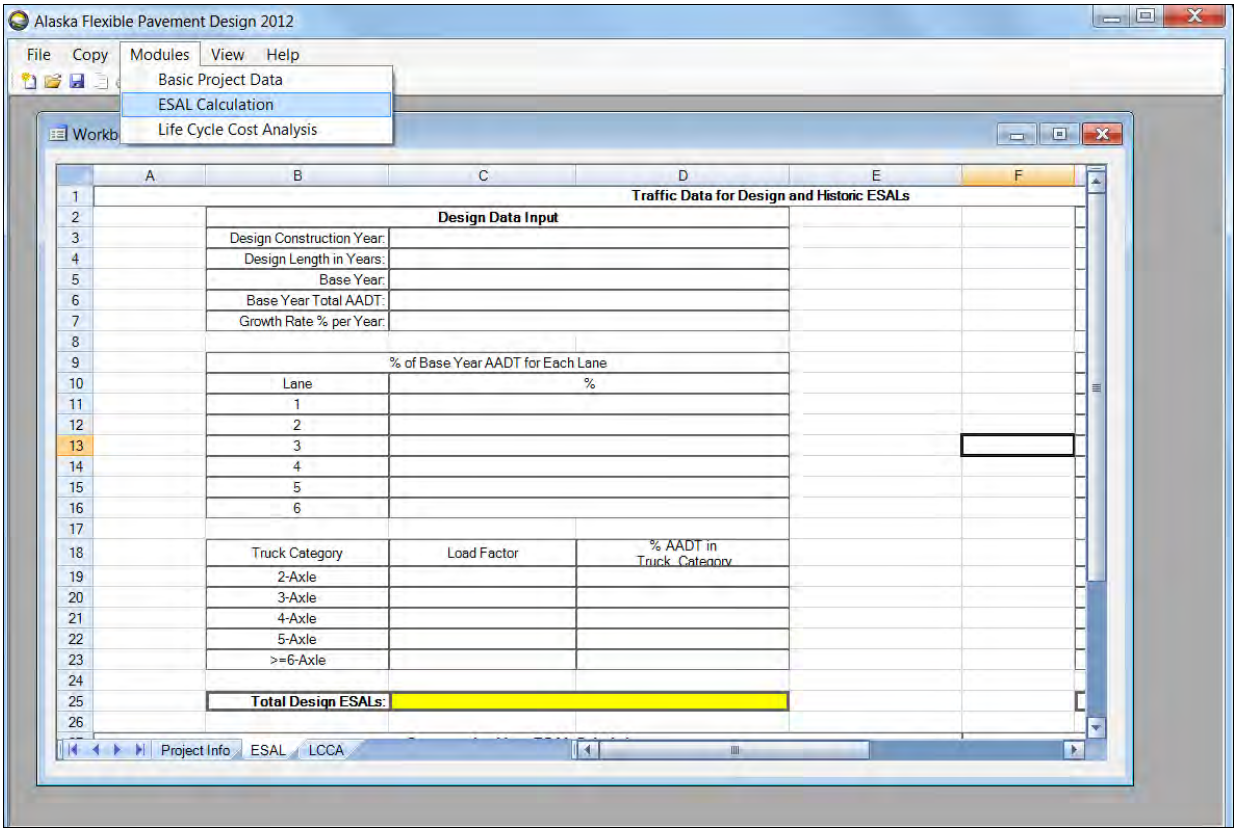


Figure 11 Modules/ESAL Calculation

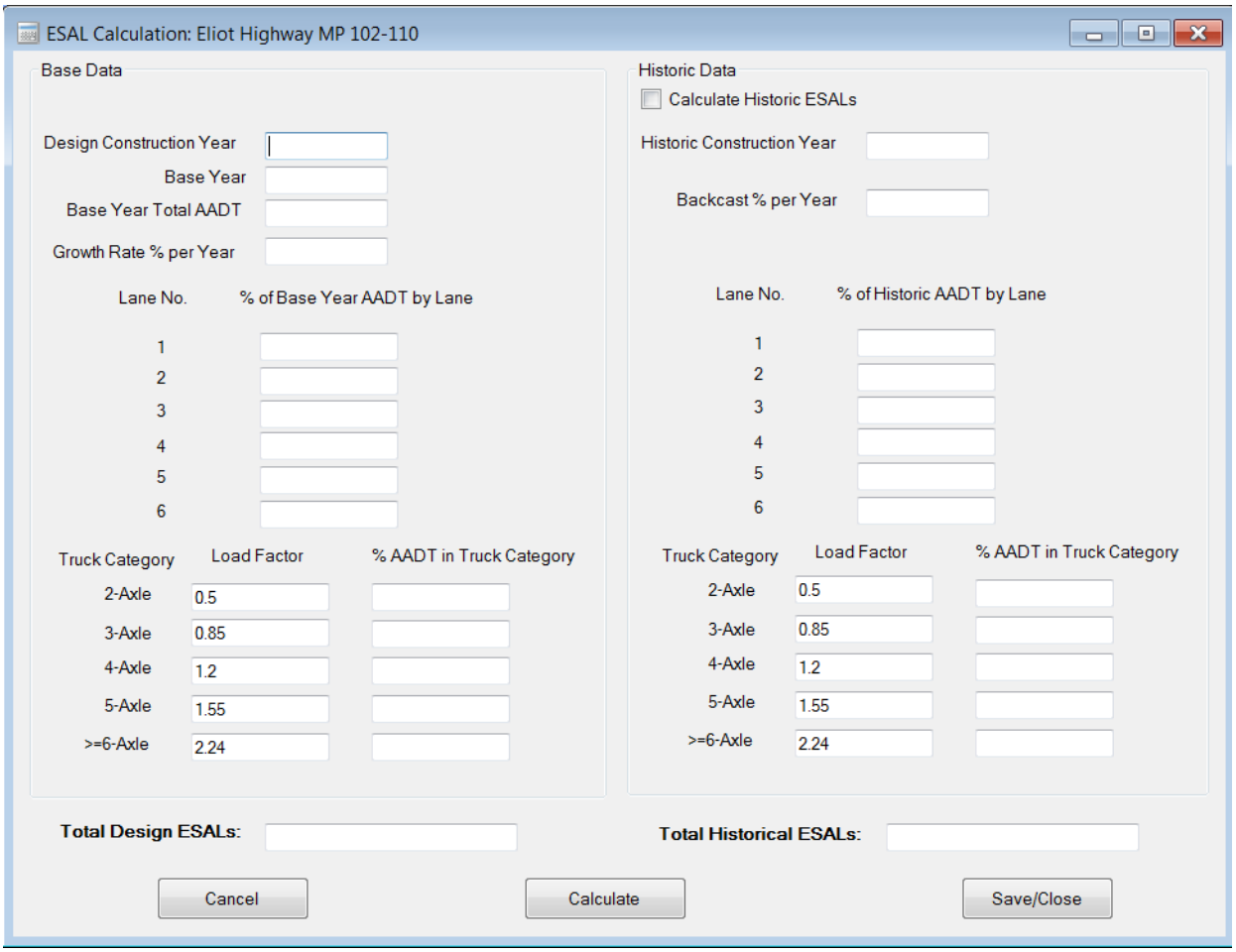


Figure 12 ESAL Calculation Data Entry Window

The left hand side of the ESAL data window is for the design ESAL calculation. The right hand side is for historic ESAL calculation that is used for overlay pavement design. The total Design ESALs and the Total Historic ESALs text boxes are to be filled with the final results of the calculation. Historic ESAL calculation will not be carried out unless the Calculate Historic ESAL is checked. The Load Factor numbers are default values used by AK DOT & PF.

Once the data entry is completed, clicking at the **Calculate** button will perform the calculation and fill the two ESAL text boxes with the corresponding results. The **Calculate** button keeps the ESAL Calculation window open and active (see Figure 13) such that users can examine the results, change input data and recalculate if necessary.

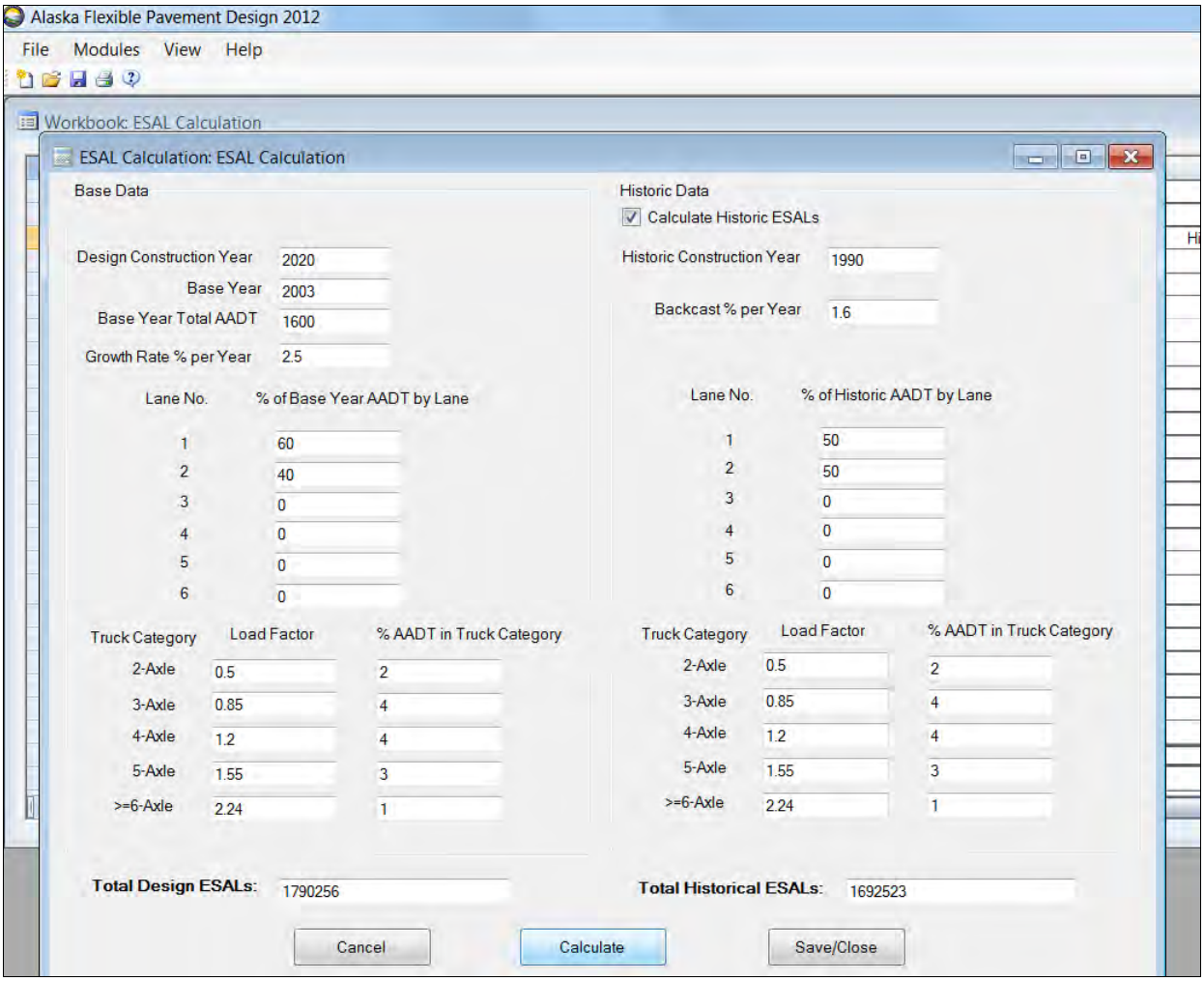


Figure 13 ESAL Calculation Data Entry Window with Results

Once users are satisfied with the results, clicking at the **Save/Close** button will close the ESAL calculation window and copy the calculation results to the ESAL worksheet of the project workbook. If not already turned to, clicking at the ESAL tab of the workbook will turn to the ESAL worksheet (Figure 14).

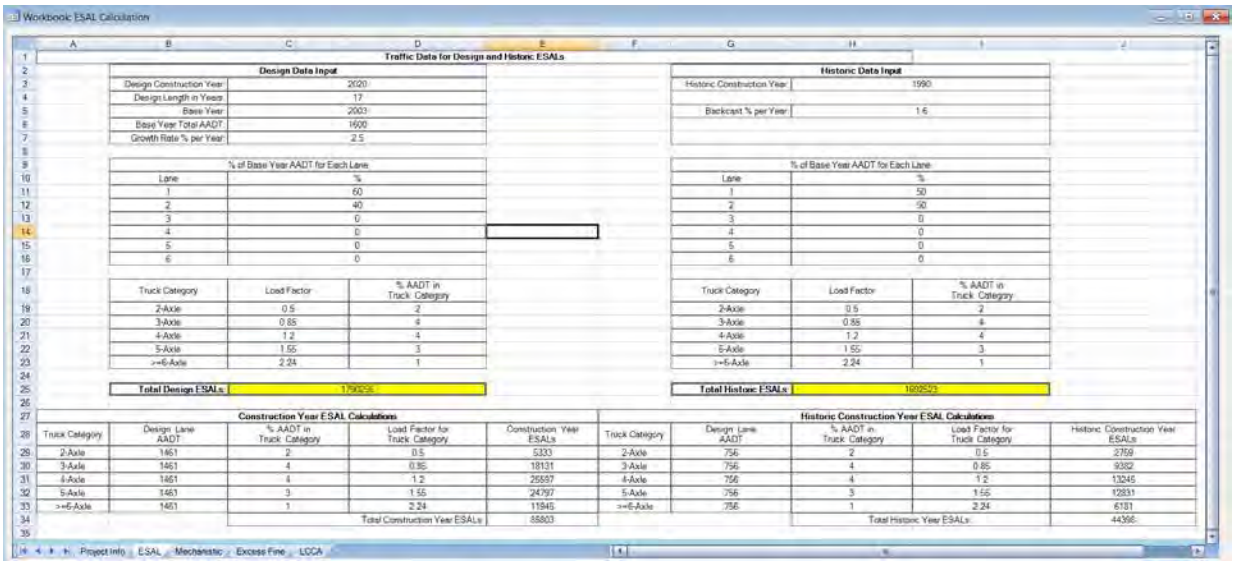
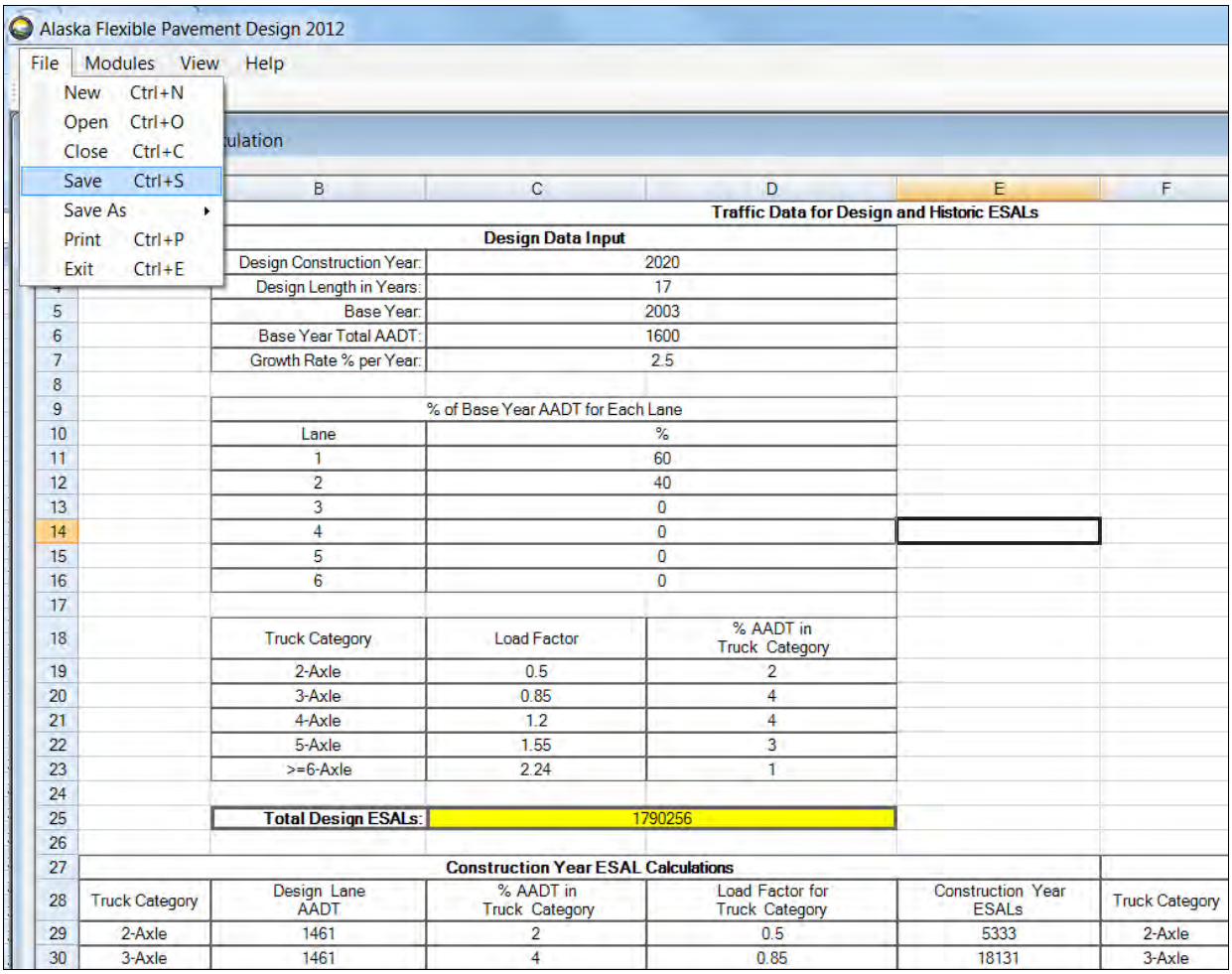


Figure 14 The ESAL Worksheet with Input Data and Calculation Results

To save the workbook at its current state, users can go to **File/Save** (Figure 15). This will save the workbook to the original file (e.g., ***Example 1.xml***).



	B	C	D	E	F
			Traffic Data for Design and Historic ESALs		
		Design Data Input			
		Design Construction Year:	2020		
		Design Length in Years:	17		
5		Base Year:	2003		
6		Base Year Total AADT:	1600		
7		Growth Rate % per Year:	2.5		
8					
9		% of Base Year AADT for Each Lane			
10		Lane	%		
11		1	60		
12		2	40		
13		3	0		
14		4	0		
15		5	0		
16		6	0		
17					
18		Truck Category	Load Factor	% AADT in Truck Category	
19		2-Axle	0.5	2	
20		3-Axle	0.85	4	
21		4-Axle	1.2	4	
22		5-Axle	1.55	3	
23		>=6-Axle	2.24	1	
24					
25		Total Design ESALs:	1790256		
26					
27	Construction Year ESAL Calculations				
28	Truck Category	Design Lane AADT	% AADT in Truck Category	Load Factor for Truck Category	Construction Year ESALs	Truck Category
29	2-Axle	1461	2	0.5	5333	2-Axle
30	3-Axle	1461	4	0.85	18131	3-Axle

Figure 15 Save the Project Workbook

Alternatively, the workbook can be saved as a different XML file (i.e., specific format for the AKPFD2012) or an Excel file (***.xls***) that can be further processed in Microsoft Excel. To do this, go to **File/Save As**. The options of XML and Excel will appear (Figure 16).

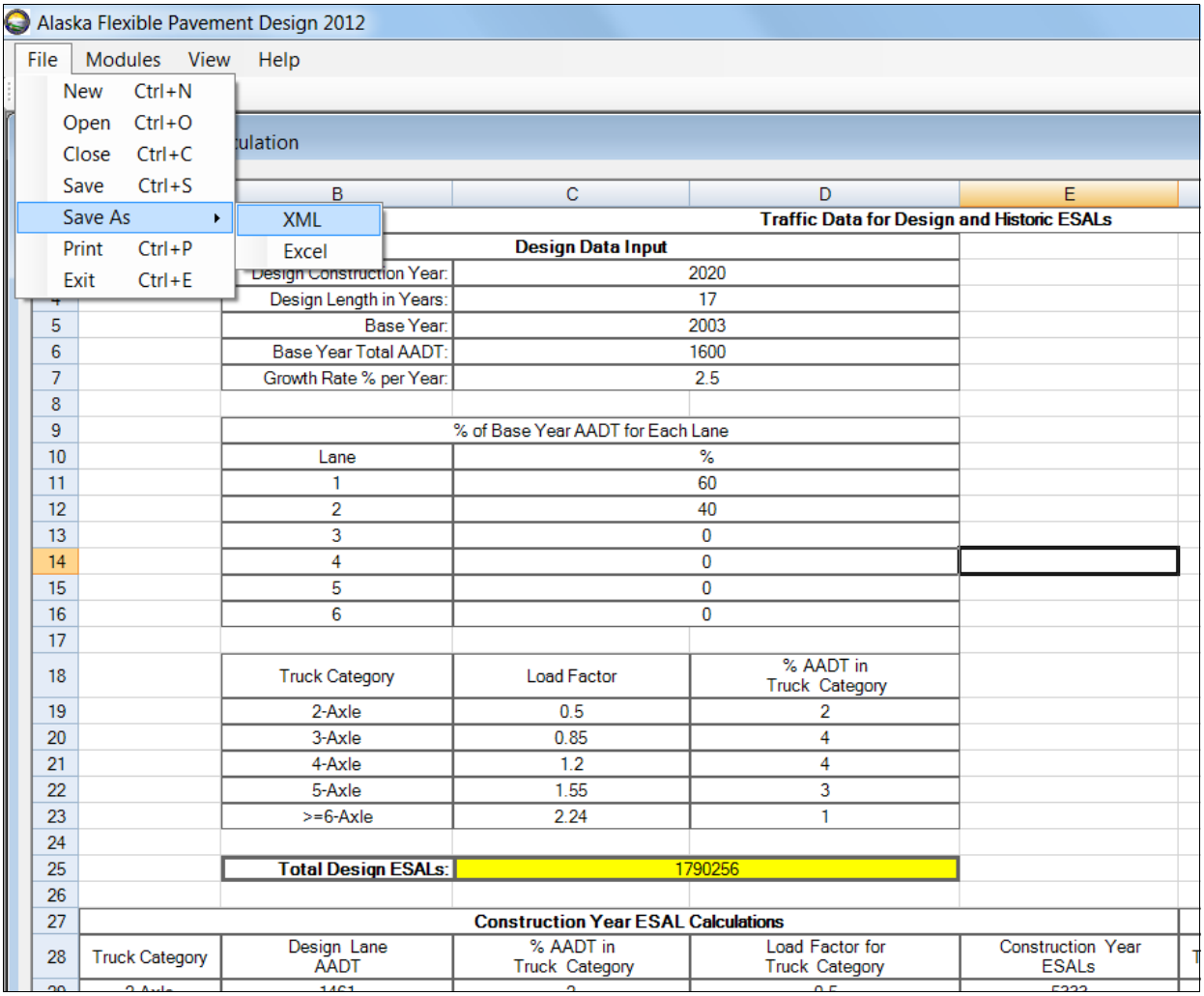


Figure 16 Save the Project Workbook As Different Files (XML or Excel)

Addendum Part 3: Life Cycle Cost Analysis (LCCA) Calculation—AKFPD Manual Chapter 9 & Calculations Using New Software

Life Cycle Cost Analysis

To demonstrate how to use AKFPD 2012 to run a life cycle cost analysis, a well established example is required. This part of the tutorial is taken from the section written for the new Life Cycle Cost Analysis chapter (Chapter 9) of the Alaska Flexible Pavement Design Manual. This section contains a well designed example with sufficient details to demonstrate a life cycle analysis scenario. Section 5.1 explains the details of the example and section 5.2 shows how to use AKFPD 2012 to carry out an LCCA for the example. For users who are not familiar with life cycle analysis methods, reviewing the entire chapter 9 of the Manual may be necessary.

3.1 Sample Hypothetical Analysis

Suppose it is proposed to repave an eight mile section of two lane rural highway. Two alternative design strategies have been developed. The subbase would be the same for either alternative and is thus ignored in the life cycle cost analysis. Alternative #1 includes a 3" asphalt concrete pavement and a 4" stabilized base course. In the future, annual preservation will be performed. Major rehabilitation will consist of a thick overlay, while a complete reconstruction will include a pavement structure exceeding the quality of the original (year 0) construction.

Alternative #2 consists of a 2" asphalt concrete pavement and an 8" base course. Future work includes routine annual preservation, minor rehabilitation with a thin overlay, and a major reconstruction with the same design as the original project.

The performance periods and activity timing for each of these alternatives are shown in Table 1:

Table 1 Performance Periods and Activity Timing for Sample Project

	Alternative #1	Alternative #2
Initial Structure	3” asphalt concrete + 4” stabilized base	2” asphalt concrete + 8” base
Initial Construction	Year 0	Year 0
Routine Preservation	Annually	Annually
Rehabilitation	Major rehabilitation @ years 15 & 25 (thick overlay)	Minor rehabilitation @ years 15, 20 & 25 (thin overlay)
Reconstruction	Complete rebuild at year 32, lasting 20 years	Major rebuild at year 30, lasting 15 years

Estimated costs are given in Table 2 shown below. Note that these are always stated as *real*, or *year zero*, costs. (It is not necessary to account for future inflation when listing future costs because of the *real* 4% discount rate that will be used in the analysis). User costs were obtained using Figure 9.1, Work Zone User Delay Cost Estimates, assuming daytime work for an eight mile, two lane rural highway and an assumed number of project days appropriate to the type of work. For example, for Alternative #1, if the initial construction requires 150 days, the AADT is 4500, and the value from the graph is 90, the calculated work zone user delay cost is $972,000.

Table 2 Estimated Costs for Sample Project

	Alternative #1	Alternative #2
Agency costs		
Initial construction		
Engineering & contract administration	$1,300,000	$900,000
Construction	$7,500,000	$5,500,000
Traffic control	$200,000	$170,000
Rehabilitation (overlays)		
Engineering & contract administration	$500,000	$350,000
Construction	$3,100,000	$1,900,000
Traffic control	$140,000	$80,000
Reconstruction		
Engineering & contract administration	$1,500,000	$1,100,000
Construction	$9,200,000	$6,400,000
Traffic control	$200,000	$170,000
User costs		
Initial construction	$972,000	$1,296,000
Rehabilitation	$432,000 (Year 15) $518,400 (Year 25)	$396,000 (Year 15) $435,600 (Year 20) $475,200 (Year 25)
Reconstruction	$1,404,000 (Year 32)	$1,814,400 (Year 30)

The costs of routine preservation are assumed to be equal for both alternatives and are therefore not included in the analysis. If this is not the case, it would be necessary to include such preservation costs

for the years when they are expected to occur. To find the salvage value for each alternative, using the pro-rated life method, we proceed as follows:

For Alternative #1, the $10,900,000 reconstruction cost at year 32 (shown in Table 3 and Figure 17) has a 20 year life. Thus, at year 35, its value will be $\left(\frac{17}{20}\right)\times(\$10{,}900{,}000)=\$9{,}265{,}000$.

For Alternative #2, the $7,670,000 reconstruction cost at year 30 (shown in Table 3 and Figure 18) has a 15 year life. Thus, at year 35, its value will be $\left(\frac{10}{15}\right)\times(\$7{,}670{,}000)=\$5{,}113{,}333\cong\ \$5{,}113{,}000$.

From the above activity timing and cost estimates, we can develop the following cash flow table and the cash flow diagrams shown in Figure 17 and Figure 18:

Table 3 Cash Flow Table for Sample Project

Year	Alt #1 Agency Cost	Alt #1 User Cost	Alt #2 Agency Cost	Alt #2 User Cost
0	$9,000,000	$972,000	$7,570,000	$1,296,000
15	$3,740,000	$432,000	$2,330,000	$396,000
20			$2,330,000	$435,600
25	$3,740,000	$518,400	$2,330,000	$475,200
30			$7,670,000	$1,814,400
32	$10,900,000	$1,404,000		
35	-$9,265,000		-$5,113,000	

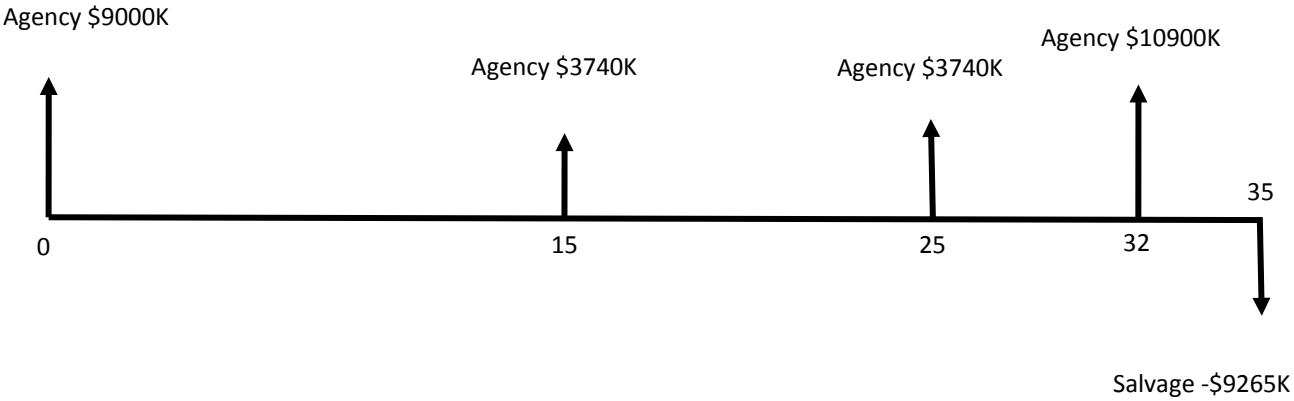


Figure 17 Cash Flow Diagram for Alternative #1

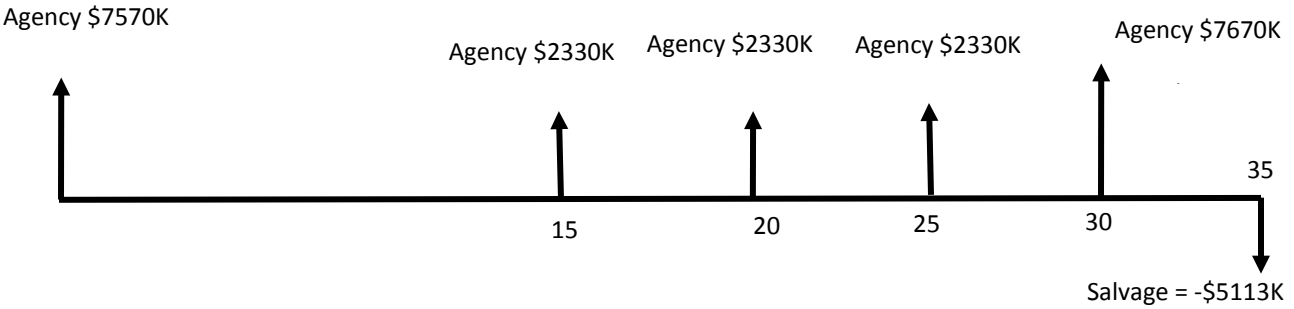


Figure 18 Cash Flow Diagram for Alternative #2

Computation of net present value for each alternative is based on the cash flow diagrams and a discount rate of 4%. We have separated the agency and user costs. The following spreadsheet shows the results of the analysis, which uses a simple $(1+i)^{-n}$ formula to calculate present value for each cash flow.

Table 4 Spreadsheet Output from Sample Hypothetical Analysis

Sample Hypothetical Life Cycle Cost Analysis — Discount rate = 4%

Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7	Column 8	Column 9
Year	Alt #1 Agency Cost	PV Alt #1 Agency Cost	Alt #1 User Cost	PV Alt #1 User Cost	Alt #2 Agency Cost	PV Alt #2 Agency Cost	Alt #2 User Cost	PV Alt #2 User Cost
0	$9,000,000	$9,000,000	$972,000	$972,000	$7,570,000	$7,570,000	$1,296,000	$1,296,000
15	$3,740,000	$2,076,689	$432,000	$239,874	$2,330,000	$1,293,766	$396,000	$219,885
20					$2,330,000	$1,063,382	$435,600	$198,802
25	$3,740,000	$1,402,937	$518,400	$194,461	$2,330,000	$874,022	$475,200	$178,256
30					$7,670,000	$2,364,804	$1,814,400	$559,413
32	$10,900,000	$3,107,132	$1,404,000	$400,221				
35	-$9,265,000	-$2,347,894			-$5,113,000	-$1,295,713		
Column Sums		$13,238,863		$1,806,556		$11,870,261		$2,452,356
Sum, NPV Agency & User Costs			$15,045,419				$14,322,617	

For this hypothetical example, Alternative #2 appears to be preferred. If only agency costs are considered (NPV of $13,238,863 v. $11,870,261), #2 is clearly the more economical with an NPV about $1.5 million less than that of #1. If user costs are included, the preference is still for #2, but by considerably less (an NPV difference of about $720,000). If user costs are considered very important, the agency might decide on Alternative #1.

A graphical presentation might be helpful as a visual means of seeing the results. Figure 19 summarizes the results of the basic analysis.

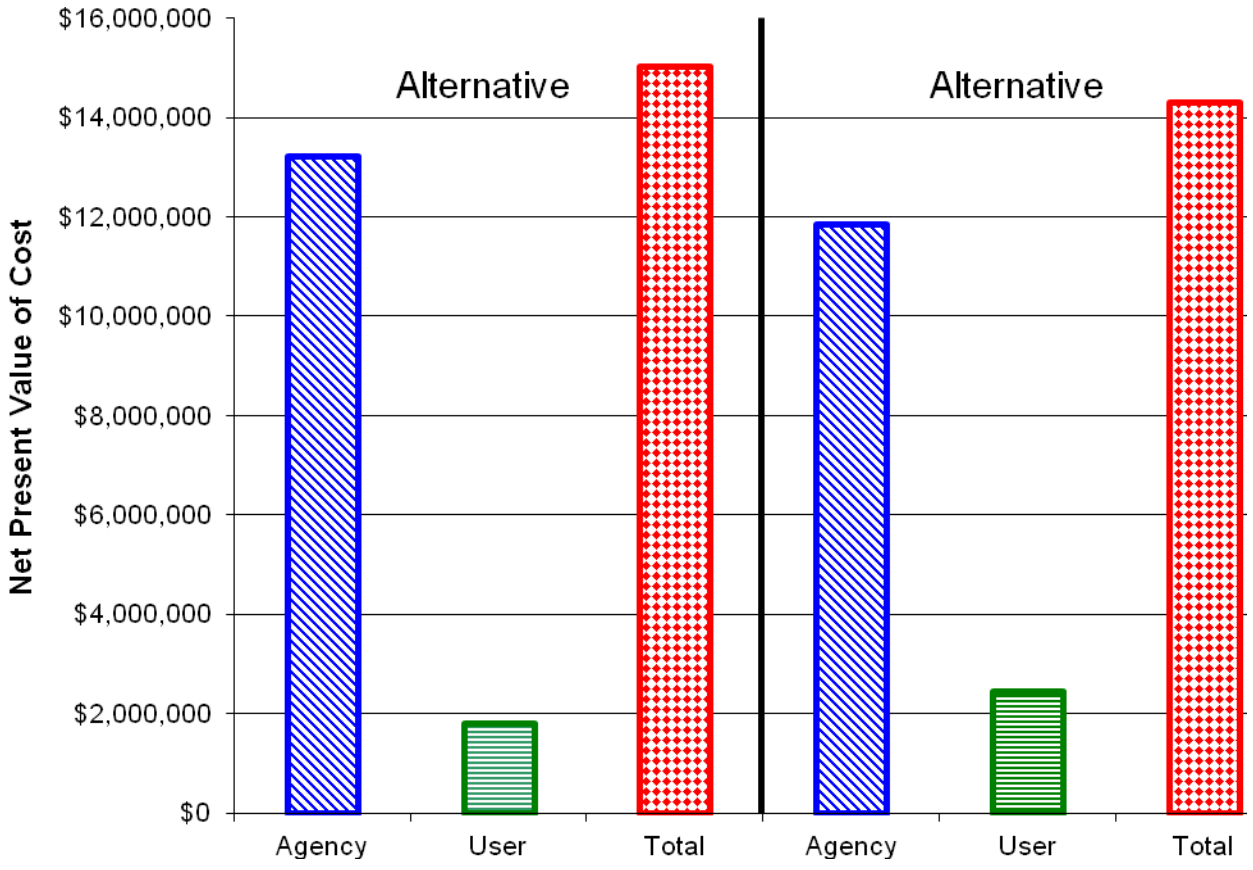


Figure 19 Graphical Comparison of NPV of Alternatives #1 and #2

3.2 Sample Hypothetical Analysis with AKFPD 2012

In this section, a demonstration of how to use the Life Cycle Cost Analysis (LCCA) component of the AKFPD2012 software to perform a LCCA analysis for the previous hypothetical example is provided. The LCCA component of the AKFPD2012 software is specifically designed to carry out analysis outlined in the new chapter 9 of the Alaska Flexible Pavement Design Manual. Thus the input and output variables of the LCCA component of the software are named and formulated to be consistent with the terminologies and methodologies set forth previously in this chapter.

Before the analysis can proceed with the software, additional variables are derived from those used for the hypothetical example. For example, the hypothetical example does not specify the pavement width, which is necessary if construction costs are to be estimated with unit costs ($/yd^2). It is thus assumed that the project is to be built with two 12-foot lanes, each with a 6-foot paved shoulder. The total treatment area for the 8-mile project is thus 168,960 yd^2. With the assumption of total treatment area, unit costs for the different construction and rehabilitation activities of the two alternatives are calculated based on the corresponding construction costs shown in Table 2. The calculated unit costs are shown in Table 5.

In addition, the previous example does not show the number of work days for the planned activities. It also does not specify the AADT growth rate that drives the user costs to increase for the same rehabilitation activities at different years (see Table 3). With the assumption of a 2% annual growth rate for AADT, the number of work days for the different construction and rehabilitation activities of the two alternatives are back-calculated from the user costs shown in Table 2. The number of work days are also shown in Table 5. The variables in highlighted rows are those that are back-calculated from the numbers in Table 1 and Table 3 with the assumption of 168,960 yd^2 total treatment area and 2% annual AADT growth rate.

Table 5 Input Variables for the AKFPD2012 LCCA Example

	Alternative 1	**Alternative 2**
Length (miles)	8	8
Pavement Width (12 foot lane and 6 foot paved shoulder)	36	36
Total Treatment Area (yd^2)	168,960	168,960
Agency Cost		
Initial Construction		
Initial Construction Unit Cost ($/$yd^2$)	$44.39	$32.55
Rehabilitation (Overlay)		
Rehabilitation Unit Cost ($/yd2)	$18.35	$11.25
Re-Construction		
Re-Construction Unit Cost ($/yd2)	$54.45	$37.88
User Cost		
Initial Construction		
Base AADT	4500	4500
Number of Work Days (rural daytime)	150	200
$/(1000 AADT-lane mile-day)	$90	$90
Calculated User Cost ($)	$972,000	$1,296,000
Rehabilitation 1		
Year	15	15
AADT Growth Rate (%/yr)	2%	2%
AADT (rounded)	6000	6000
Number of Work Days (rural daytime)	50	45

$/(1000 AADT-lane mile-day)	$90	$90
Calculated User Cost ($)	$432,000	$388,800
Rehabilitation 2		
Year	25	20
AADT Growth Rate (%/yr)	2%	2%
AADT (rounded)	7200	6500
Number of Work Days (rural daytime)	50	45
$/(1000 AADT-lane mile-day)	$90	$90
Calculated User Cost ($)	$518,400	$435,600
Rehabilitation 3		
Year		25
AADT Growth Rate (%/yr)		2%
AADT (rounded)		7,300
Number of Work Days (rural daytime)		45
$/(1000 AADT-lane mile-day)		$90
Calculated User Cost ($)		$475,200
Re-Construction		
Year	32	30
AADT Growth Rate (%/yr)	2%	2%
AADT (rounded)	8480	8150
Number of Work Days (rural daytime)	115	155
$/(1000 AADT-lane mile-day)	$90	$90
Calculated User Cost ($)	$1,404,000	$1,814,400

It is noted that the previous example in the new Chapter 9 of LCCA analysis uses a user-delay cost figure to estimate the work zone user delay cost for the hypothetical project. For the 8-mile project, the user

delay cost per (1000 AADT-Lane mile-day) is visually determined from the figure to be $90 dollars for the rural, day-time construction curve.

Instead of using visual approximation with the delay cost figure, the user cost calculation performed by the AKPFD2012 software uses regression equations to calculate work zone delay unit costs. Four sets of equations are used, each represents a curve in the Figure. In the four sets of equations shown below, the variable ***x*** is the project work zone length and ***y*** is the work zone delay user cost per (1,000 AADT – lane mile - day). With the equations, the user delay cost for the rural 8-miles project is approximately $81 dollars per (1,000 AADT – lane mile - day) by day-time construction.

When 0.25 =<x=<24,

Urban, Day $y = 0.0074x4 - 0.4817x3 + 11.208x2 - 115.79x + 627.85$ $R^2 = 0.9954$

Rural, day $y = 0.0047x4 - 0.307x3 + 7.2593x2 - 74.424x + 349.64$ $R^2 = 0.9983$

Urban night $y = 0.0026x4 - 0.1721x3 + 4.0692x2 - 41.903x + 219.3$ $R^2 = 0.997$

Rural, night $y = 0.0025x4 - 0.151x3 + 3.2753x2 - 31.462x + 141.16$ $R^2 = 0.9974$

When x =<0.25, y = y (0.25);
Urban, Day y = y(0.25)=600.0;

Rural, day y = y(0.25)=331.5

Urban night y = y(0.25)=209.1

Rural, night y = y(0.25)=133.5

When 24 =<x, y=y(24);

Urban, Day y = y(24)=100.8;

Rural, day y = y(24)=60.2

Urban night y = y(24)=45.0

Rural, night y = y(24)=14.7

To perform the analysis with AKFPD2012, a new project is first created by going to File/New (Figure 20).

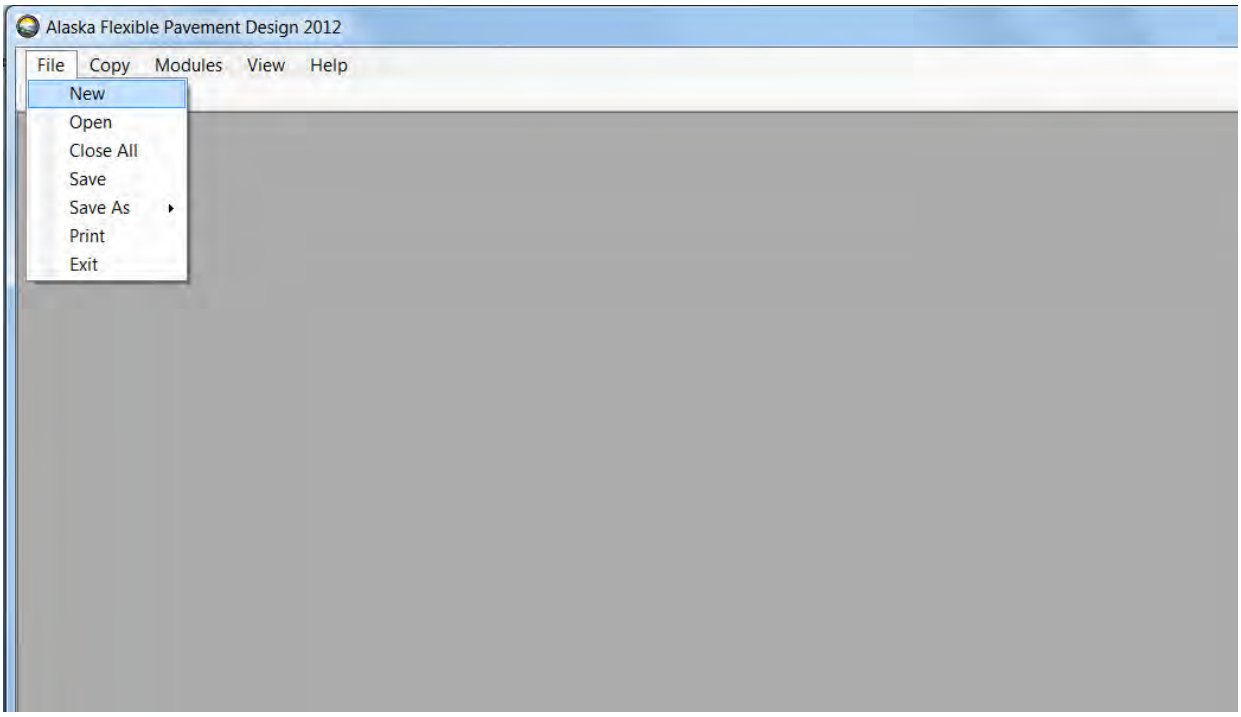


Figure 20 Creating a New Project in AKFPD2012

On the ensuring dialog box Project Info (Figure 21), enter information that can be used to identify the project. The Mechanistic Design function is not used for a LCCA, thus there is no need to specify the New or the Overlay Design option. After specifying project information, clicking at the **Save** button will open the typical Windows Save As dialog box (Figure 22).

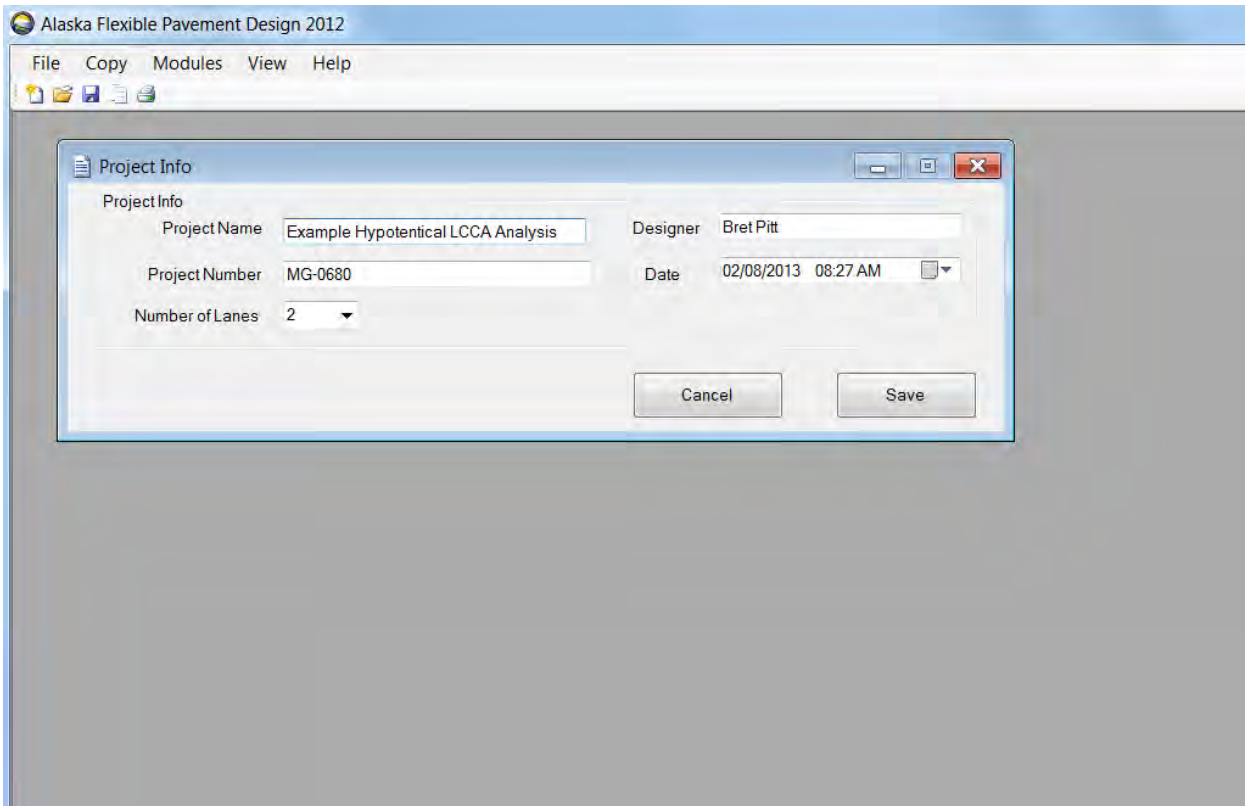


Figure 21 Project Info Dialog Box

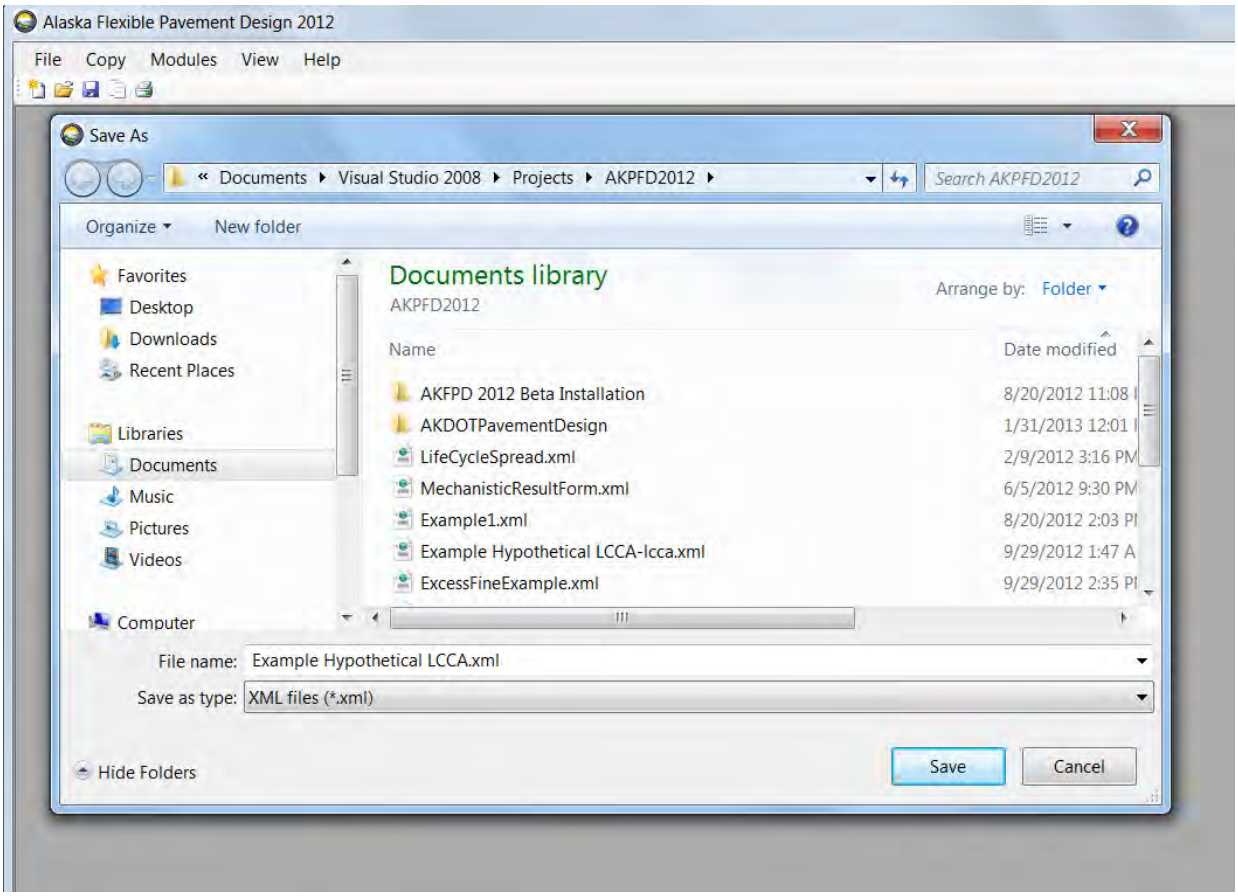


Figure 22 Save As Dialog Box

On the Save As dialog box, enter a file name (e.g., ***Example Hypothetical LCCA.xml***) in the desired directory for the new project and click at the **Save** button. The project workbook (Figure 23) will appear after the file is successfully created.

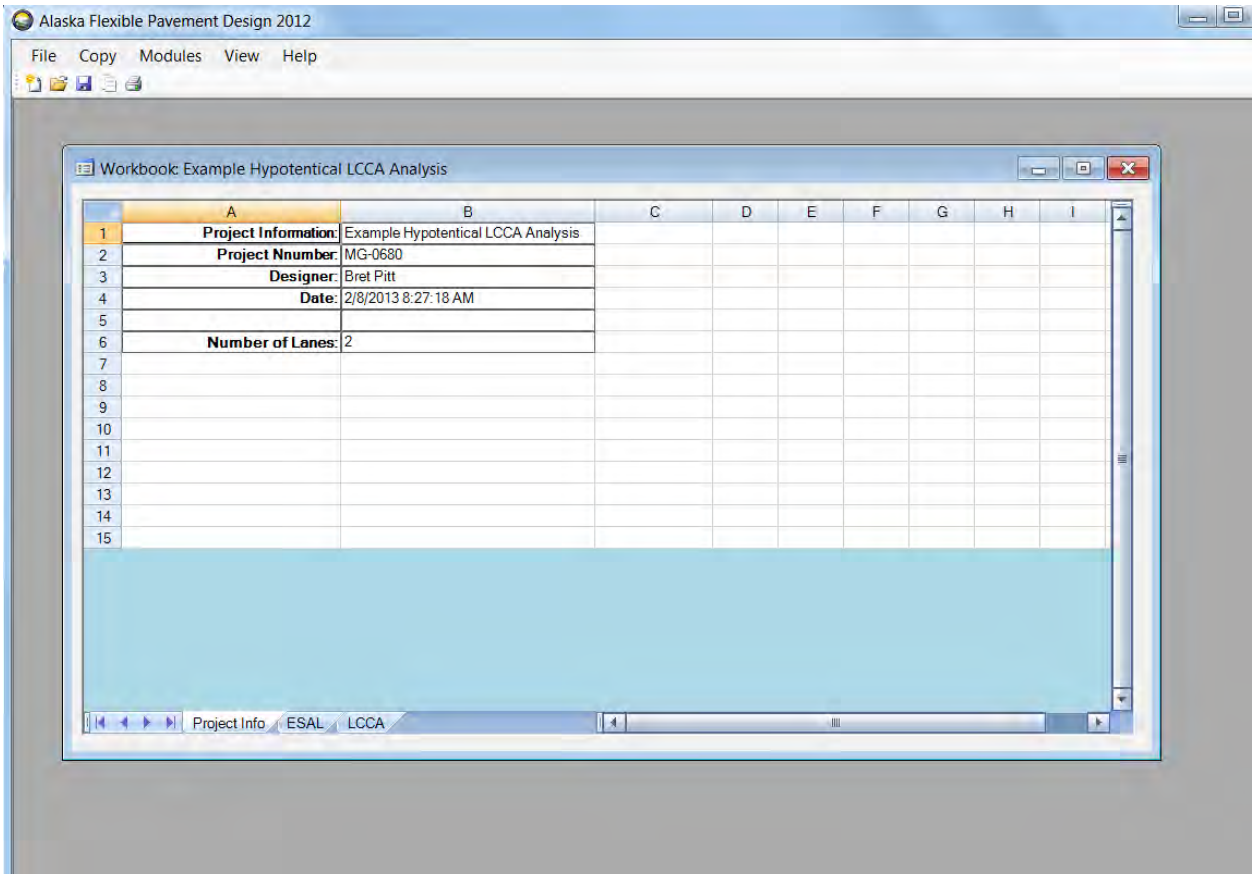


Figure 23 Project Workbook

Figure 23 shows that a project workbook contains three worksheets: Project Info, ESAL, and LCCA. Except for the Project Info sheet, each worksheet is designed to store the input and output variables of a particular pavement design analysis. Clicking at the LCCA tab will turn the workbook to the LCCA worksheet (Figure 24).

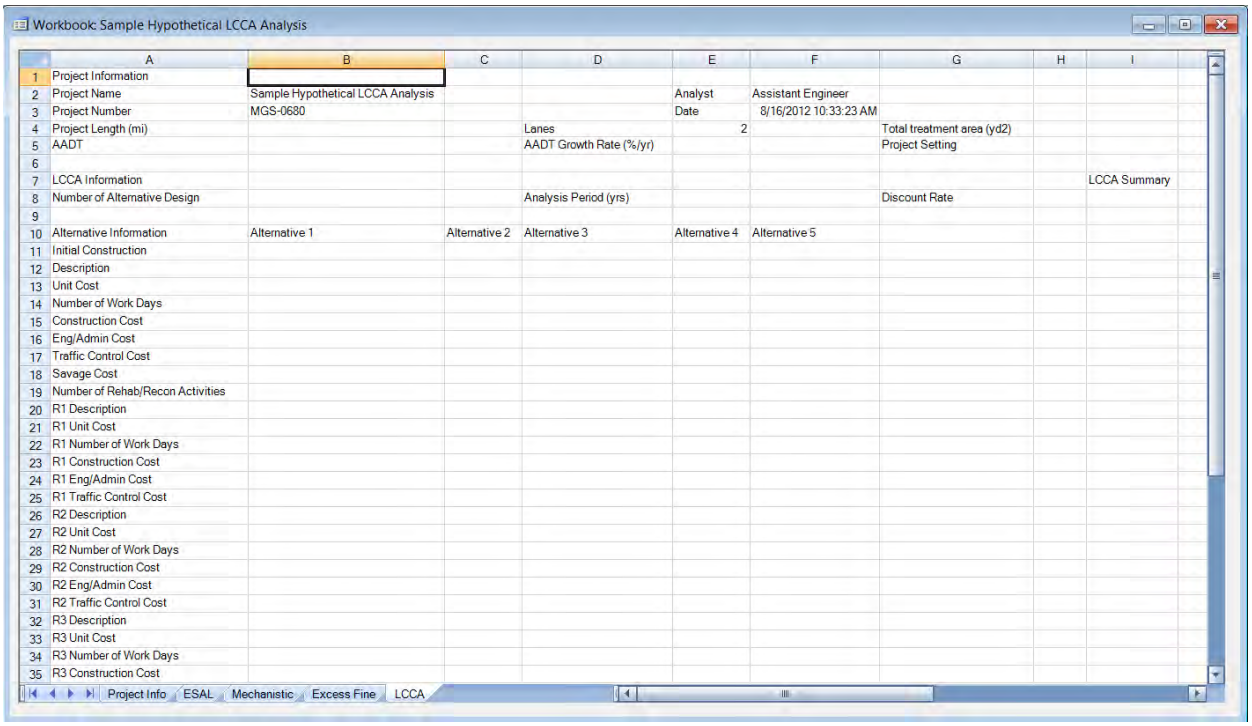


Figure 24 LCCA Worksheet

Figure 24 shows that the LCCA worksheets is formatted with cells that will be filled with LCCA variables. The columns B to F of the worksheet will be filled with input variables whose names are shown in the row headings (Column A). The cells of (Column I, Row 7) is labeled with LCCA Summary. Worksheet area beyond this cell will be filled with analysis output variables.

To perform a LCCA, go to Modules/Life Cycle Cost Analysis (Figure 25) to bring up the Life Cycle Cost Analysis Input Data window (Figure 26).

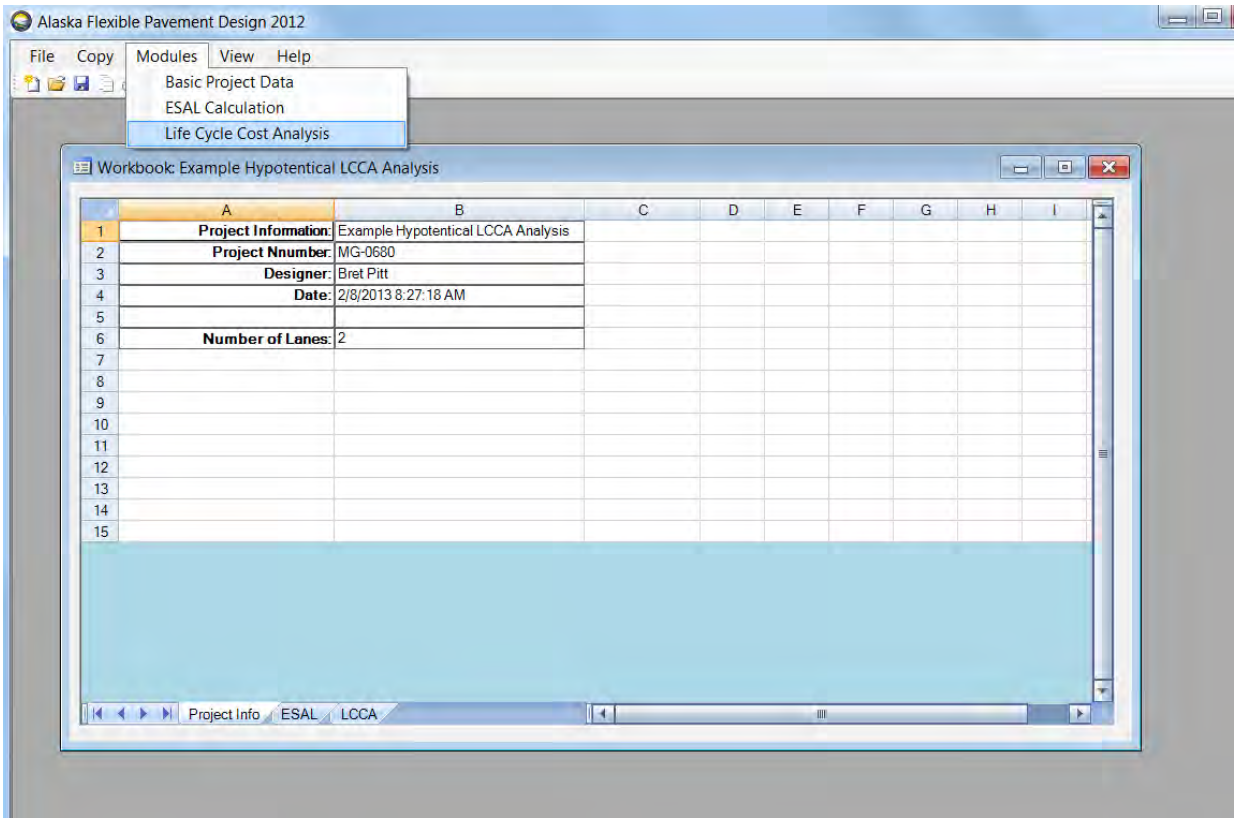


Figure 25 Modules/Life Cycle Cost Analysis

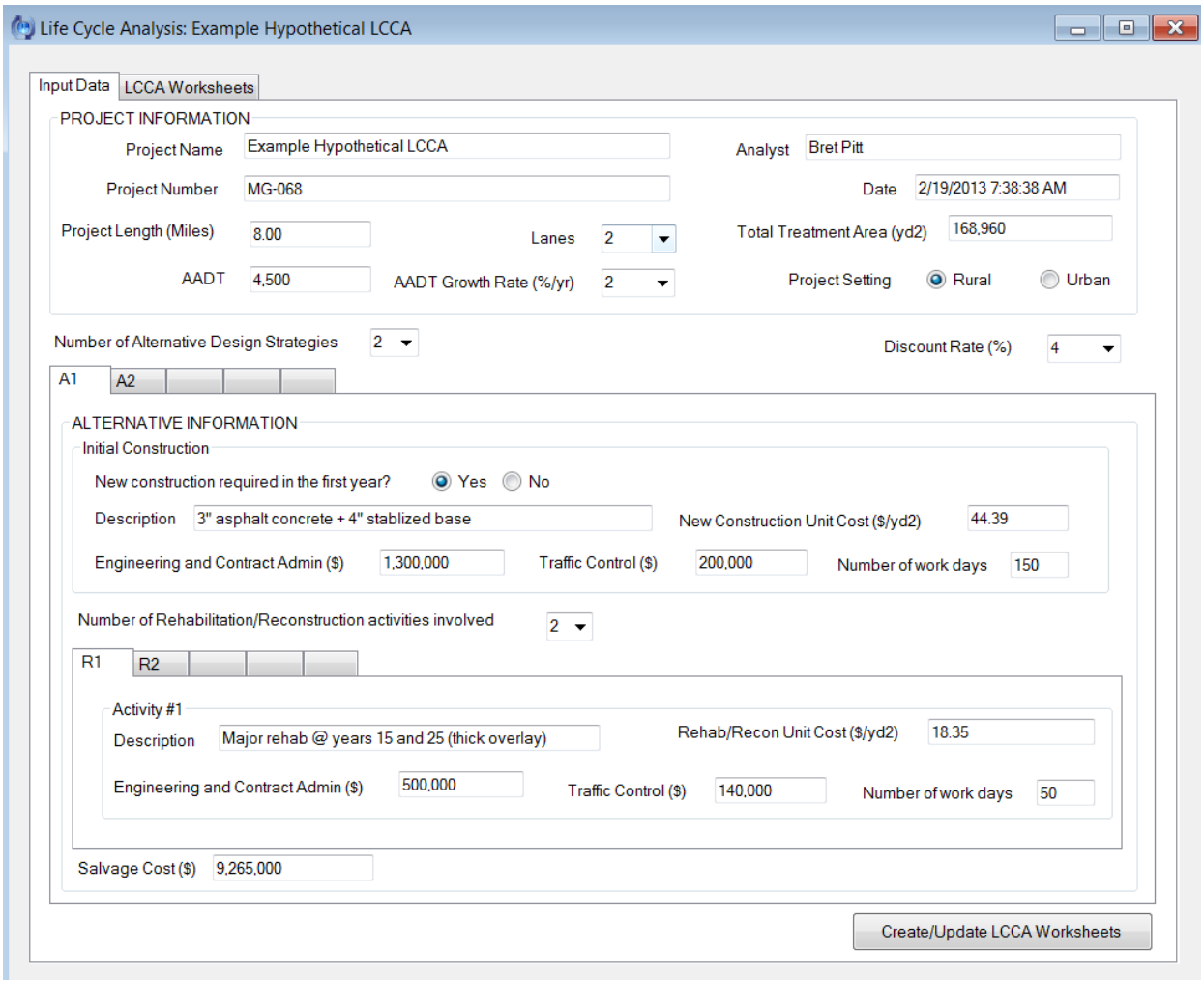


Figure 26 Life Cycle Cost Analysis Input Data Window (A1/R1 Tab)

In the LCCA data input window, enter variables according to those shown in Table 1, Table 2 and Table 5. The data input window can let user specify a LCCA project of up to 5 alternatives. The number of alternatives is specified by selecting a number from the Number of Alternative Design Strategies pull down list. In the hypothetical example, there are two alternatives. After selecting 2 for the hypothetical example, the labels A1 and A2 will appear atop of the corresponding data entry tab for Alternative 1 and Alternative 2.

For each alternative, 5 distinct rehabilitation or reconstruction activities can be specified in the software. In the hypothetical example, for alternative 1, there is the initial construction, an identical (i.e., in terms of cost) rehabilitation activity that is performed at years 15 and 25, and a re-construction activity that is scheduled for year 32. Thus, all of the planned activities for alternative 1 (A1) are specified on the LCCA data input window by checking **Yes** for the initial construction and selecting **2** for the Number of Rehabilitation/Re-Construction activities involved (R1 and R2 will automatically appear after the selection). Figure 26 shows the data for the R1 rehabilitation activity scheduled for years 15

and 25, while Figure 27 shows the data tab for the R2 re-construction at year 32. Before switching to the A2 data tab, remember to enter the estimated savage cost (i.e., in cash flow amount) for Alternative 1.

Note that during data entry, if you have to stop midway before completing, you can go to File/Save to save the data you have just entered. The entered data will be written and saved in the project workbook.

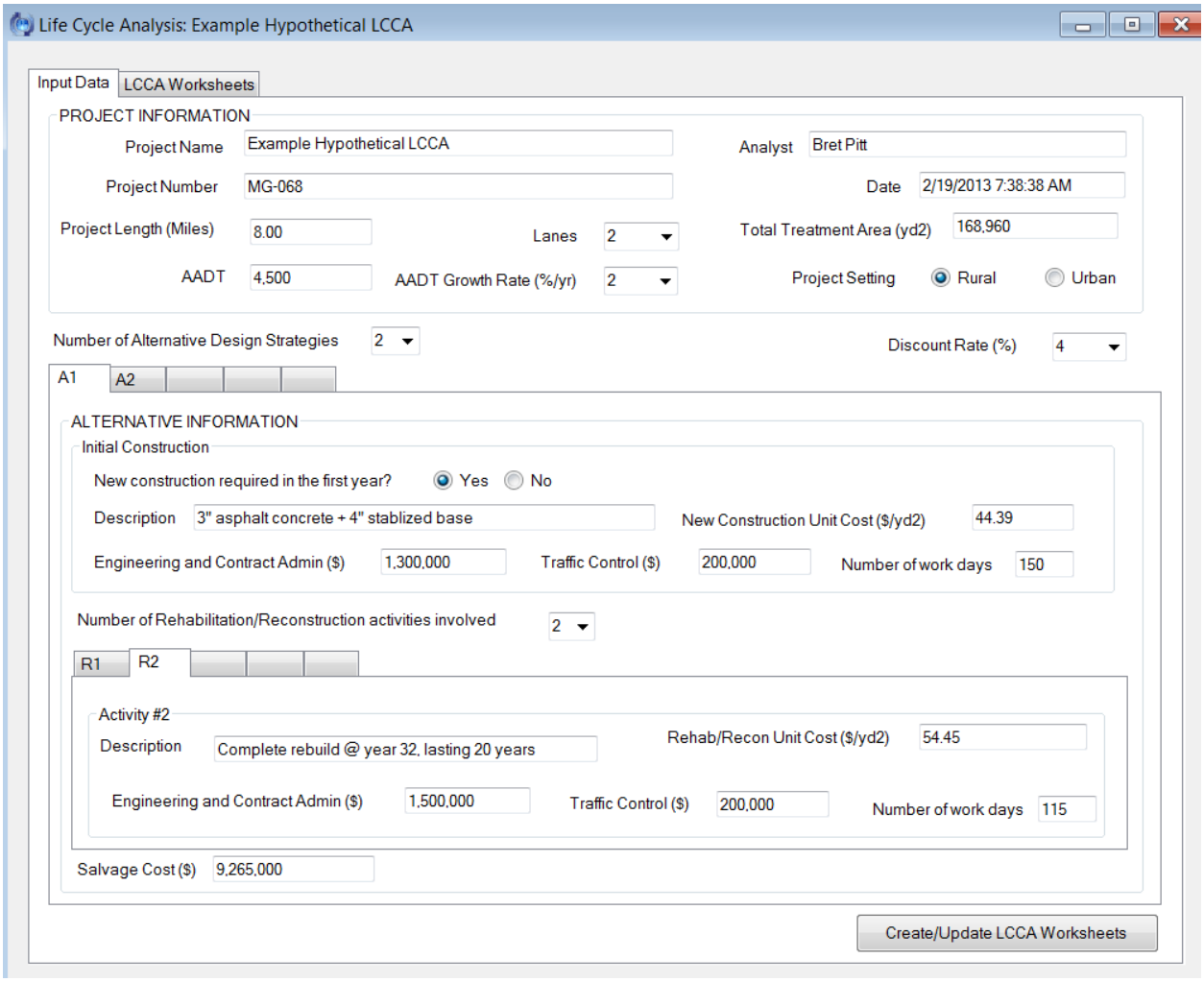


Figure 27 Life Cycle Cost Analysis Input Data Window (A1/R2 Tab)

Once data entry are completed for Alternative 1, clicking at the A2 tab to begin data entry for Alternative 2. Figure 28 and Figure 29 show the two Rehabilitation/Reconstruction data tabs for Alternative 2.

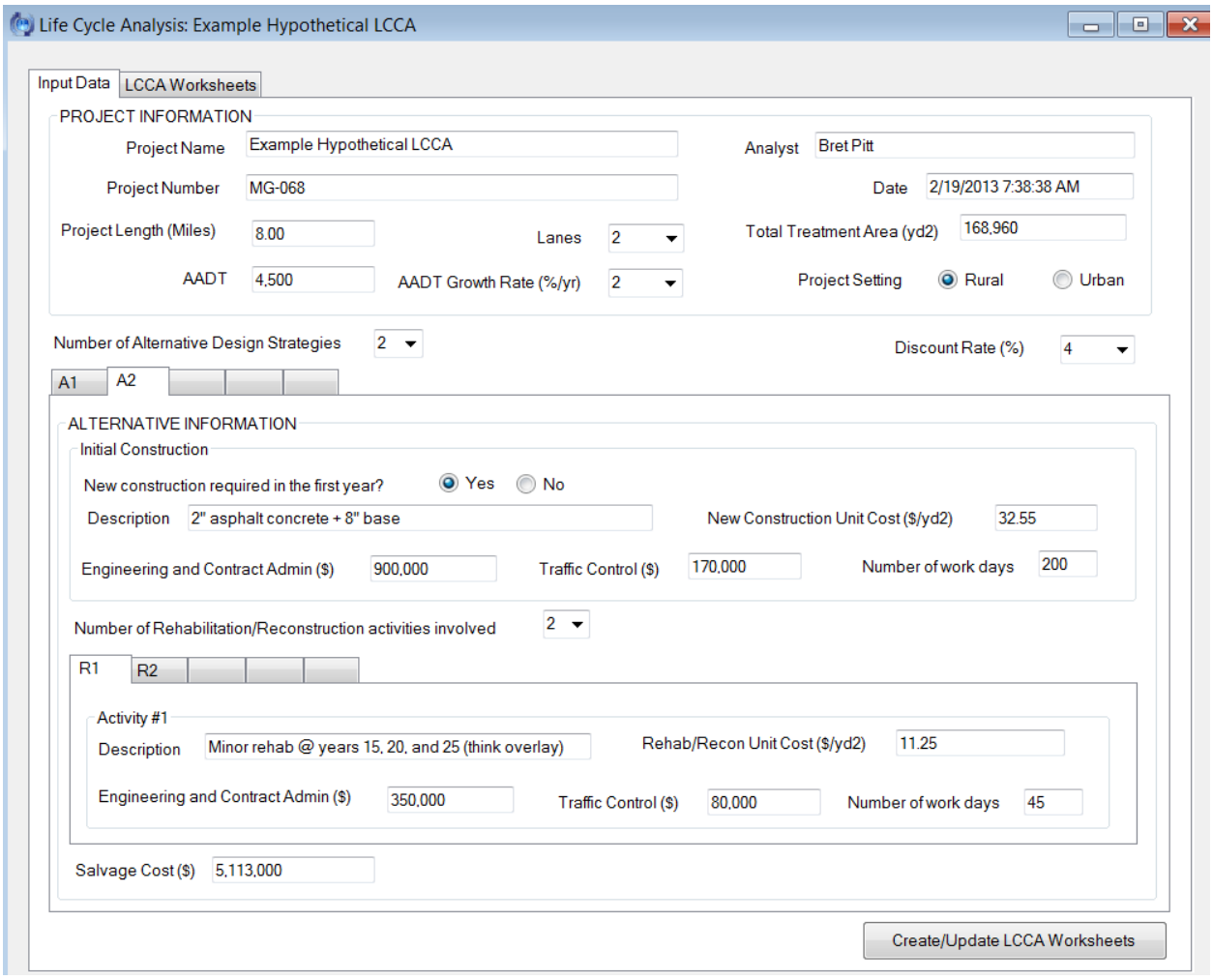


Figure 28 Life Cycle Cost Analysis Data Input Window (A2/R1 Tab)

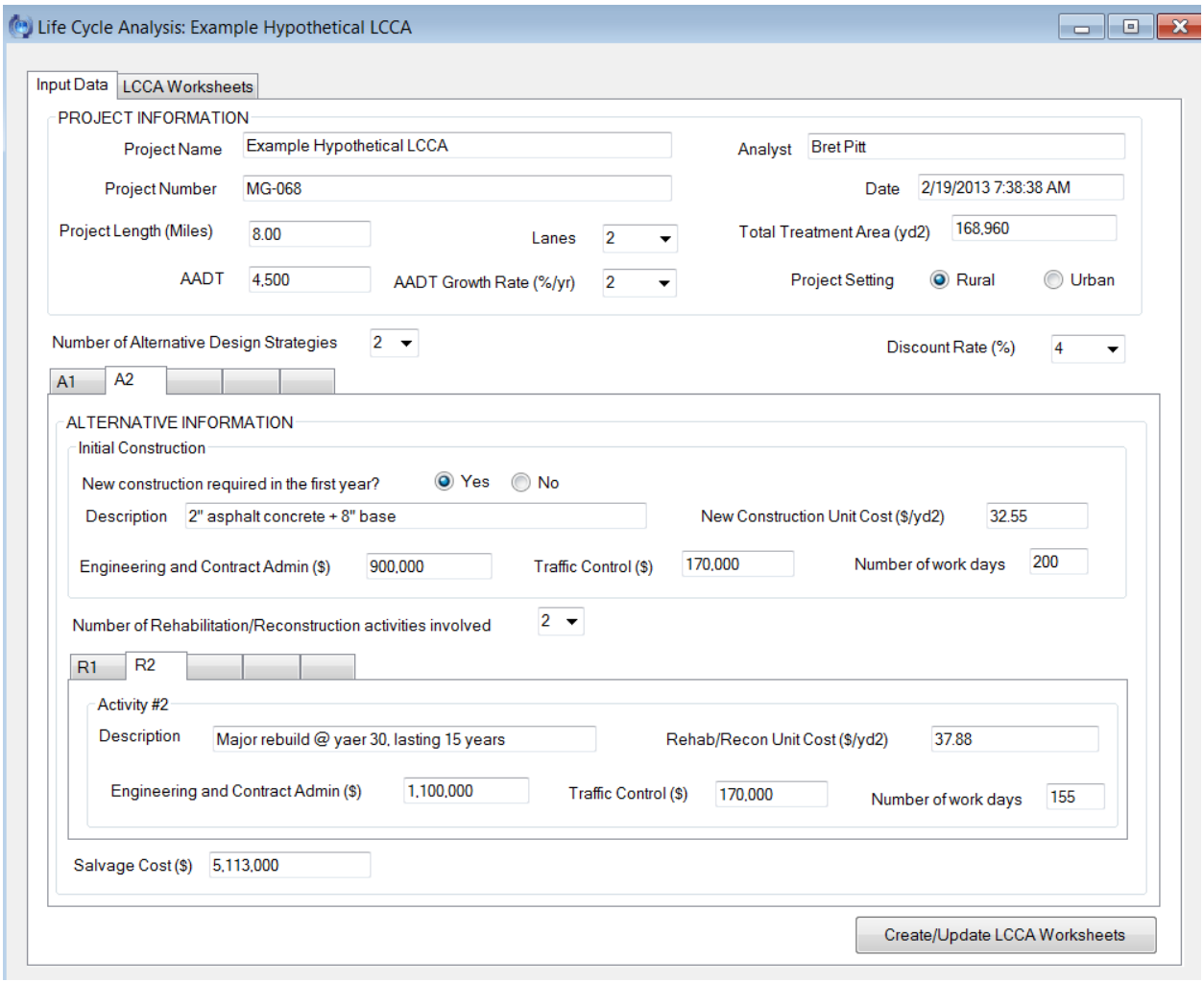


Figure 29 Life Cycle Cost Analysis Data Input Window (A2/R2 Tab)

After all the corresponding input data are entered, click at the **Create/Update LCCA Worksheets** button. The LCCA Worksheets are created on the tab that is stacked behind the Input Data tab. Clicking at the LCCA Worksheets tab on the top of the window (i.e., next to Input Data) will show the LCCA worksheets (Figure 30) that are used to specify the construction years and the construction time setting (i.e., day vs. night). The **Cancel** button shown in the bottom of the window (see Figure 30) is to close the LCCA window without keeping the data entered. Clicking the **Close** button will close the window while keeping the data and analysis results in the project workbook.

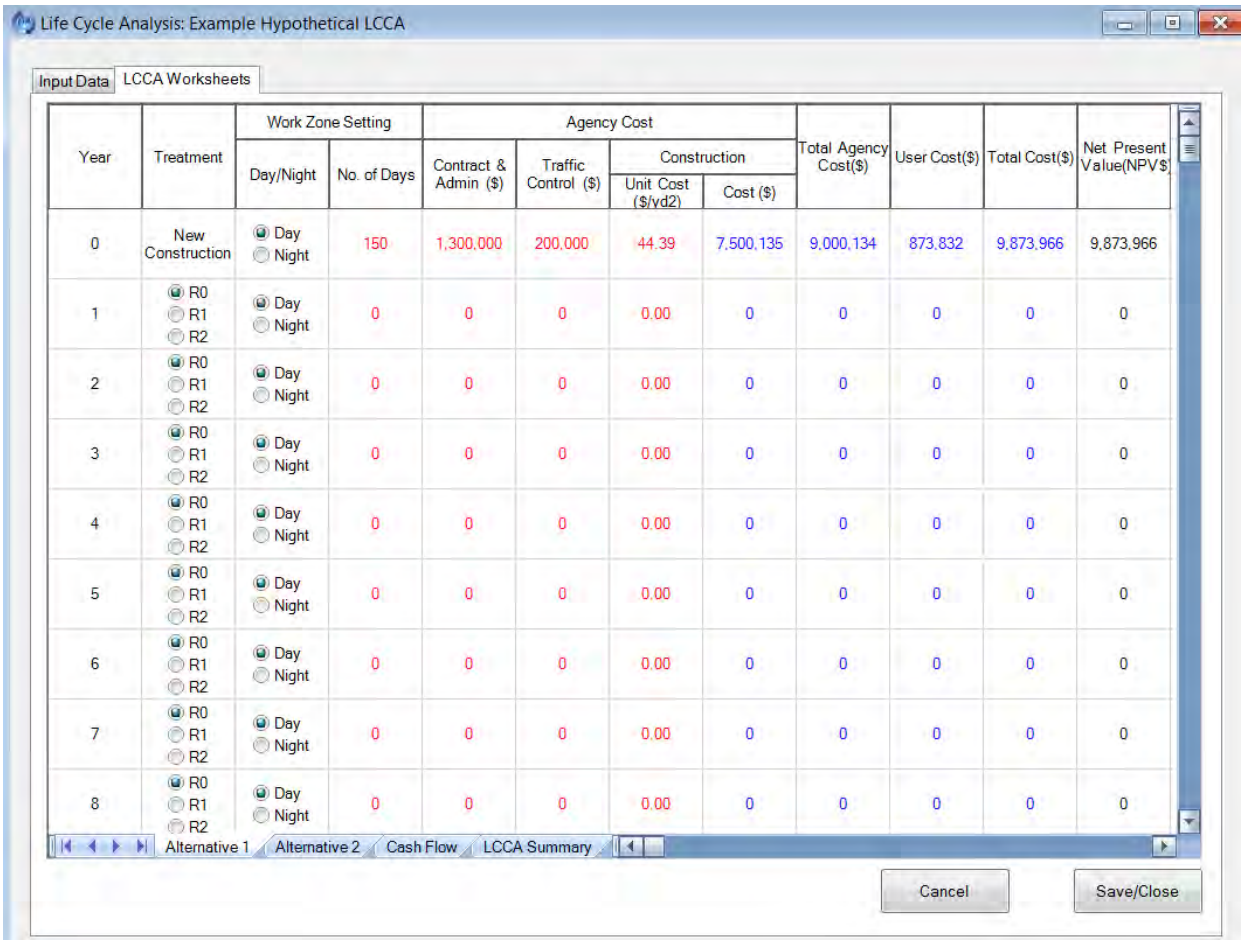
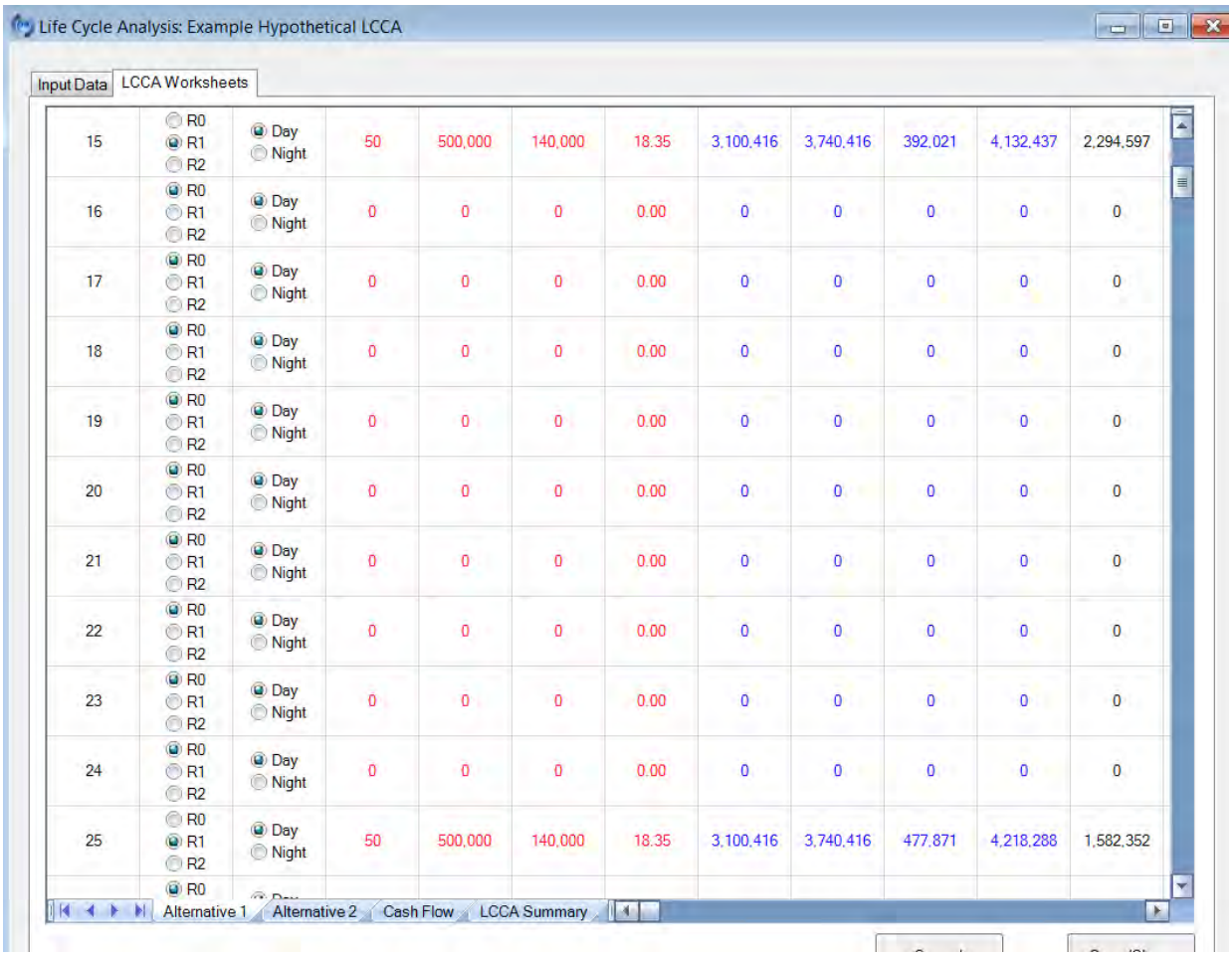


Figure 30 LCCA Worksheets (Alternative 1, Initial Construction)

For the hypothetical example, there are 4 LCCA worksheets: Alternative 1, Alternative 2, CFD (i.e., stands for Cash Flow Diagrams), and LCCA Summary. The Alternative sheets are for the specification of the years planned for all the rehabilitation/reconstruction activities. Figure 9.16 shows the data for the initial construction of Alternative 1. Numbers shown in red are input variables and those in blue are calculated by the software based on the input data and the analysis procedures presented earlier. To specify the construction year for a particular rehabilitation/reconstruction activity, simply click at the radio button corresponding to the scheduled activity at the planned year. Figure 31 and Figure 32 show the specification for Alternative 1.

Figure 31 shows that Rehabilitation activity R1 is to be performed at year 15 and 25. Both rehabilitation activities are planned to be day-time construction.



15	R0 R1 R2	Day Night	50	500,000	140,000	18.35	3,100,416	3,740,416	392,021	4,132,437	2,294,597
16	R0 R1 R2	Day Night	0	0	0	0.00	0	0	0	0	0
17	R0 R1 R2	Day Night	0	0	0	0.00	0	0	0	0	0
18	R0 R1 R2	Day Night	0	0	0	0.00	0	0	0	0	0
19	R0 R1 R2	Day Night	0	0	0	0.00	0	0	0	0	0
20	R0 R1 R2	Day Night	0	0	0	0.00	0	0	0	0	0
21	R0 R1 R2	Day Night	0	0	0	0.00	0	0	0	0	0
22	R0 R1 R2	Day Night	0	0	0	0.00	0	0	0	0	0
23	R0 R1 R2	Day Night	0	0	0	0.00	0	0	0	0	0
24	R0 R1 R2	Day Night	0	0	0	0.00	0	0	0	0	0
25	R0 R1 R2	Day Night	50	500,000	140,000	18.35	3,100,416	3,740,416	477,871	4,218,288	1,582,352

Figure 31 LCCA Worksheets (Alternative 1, Rehabilitation at Years 15 and 25)

It is important to note that, if any of the unit costs (i.e., red cells in Figure 31) of a rehabilitation activity at a particular year is going to be different from those of a previous year, these different unit costs can be specified on the Alternative worksheet directly. For example, if in Figure 9.17 the administration cost at year 25 is going to be $600,000 instead of $500,000, you can simply change the number 500000 in the circled cell to 600000 and observe the calculated numbers in the blue cells change accordingly. Manual changes to the worksheet should only be applied to red cells as the blue cells are calculation results based on the numbers in the red cells.

Figure 32 shows that the day-time reconstruction activity is scheduled at year 32. The row labeled for year 35 is where the savage cost is stored. The very last row of the worksheet for Alternative 1 shows the calculated total Net Present Values (NPV) for the Savage Cost, Total Agency Cost, Total User Cost, and the Total Cost. Note that the Total Agency Cost number does not include the savage cost. Thus, the NPV Total Cost is the sum of the NPV Savage Cost, NPV Total Agency Cost, and NPV Total User Cost.

25	R0 R1 R2	Day Night	50	500,000	140,000	18.35	3,100,416	3,740,416	477,871	4,218,288	1,582,352
26	R0 R1 R2	Day Night	0	0	0	0.00	0	0	0	0	0
27	R0 R1 R2	Day Night	0	0	0	0.00	0	0	0	0	0
28	R0 R1 R2	Day Night	0	0	0	0.00	0	0	0	0	0
29	R0 R1 R2	Day Night	0	0	0	0.00	0	0	0	0	0
30	R0 R1 R2	Day Night	0	0	0	0.00	0	0	0	0	0
31	R0 R1 R2	Day Night	0	0	0	0.00	0	0	0	0	0
32	R0 R1 R2	Day Night	115	1,500,000	200,000	54.45	9,199,872	10,899,870	1,262,525	12,162,400	3,466,992
33	R0 R1 R2	Day Night	0	0	0	0.00	0	0	0	0	0
34	R0 R1 R2	Day Night	0	0	0	0.00	0	0	0	0	0
35	Salvage Cost							-9,265,000		-9,265,000	-2,347,897
NPV Salvage Cost	-2,347,897		NPV Total Agency Cost	15,587,247		NPV Total User Cost	1,630,658		NPV Total Cost	14,870,011	

Figure 32 LCCA Worksheets (Alternative 1, Reconstruction at Year 32)

The series of Figure 33 to Figure 35 show the data specification for Alternative 2.

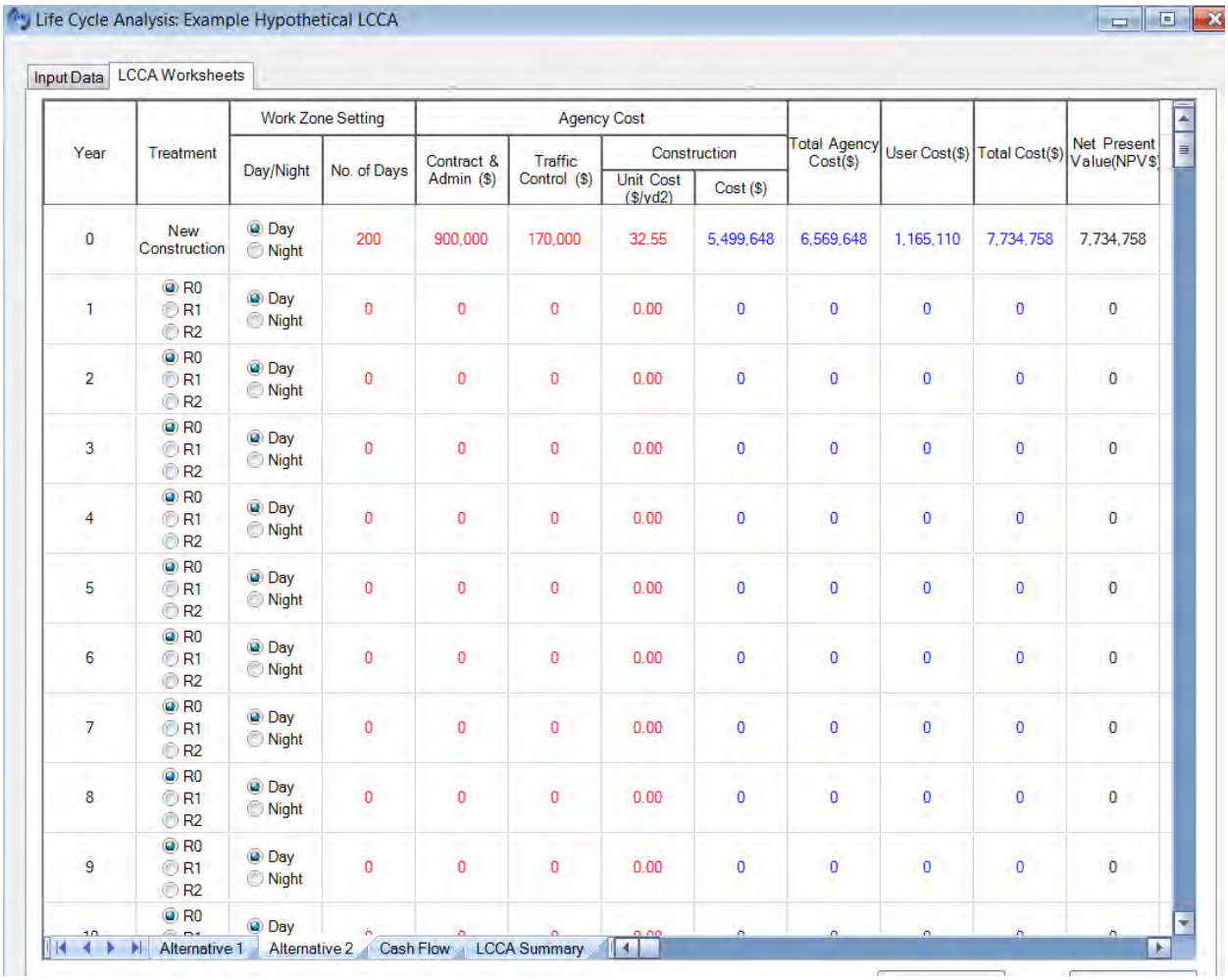
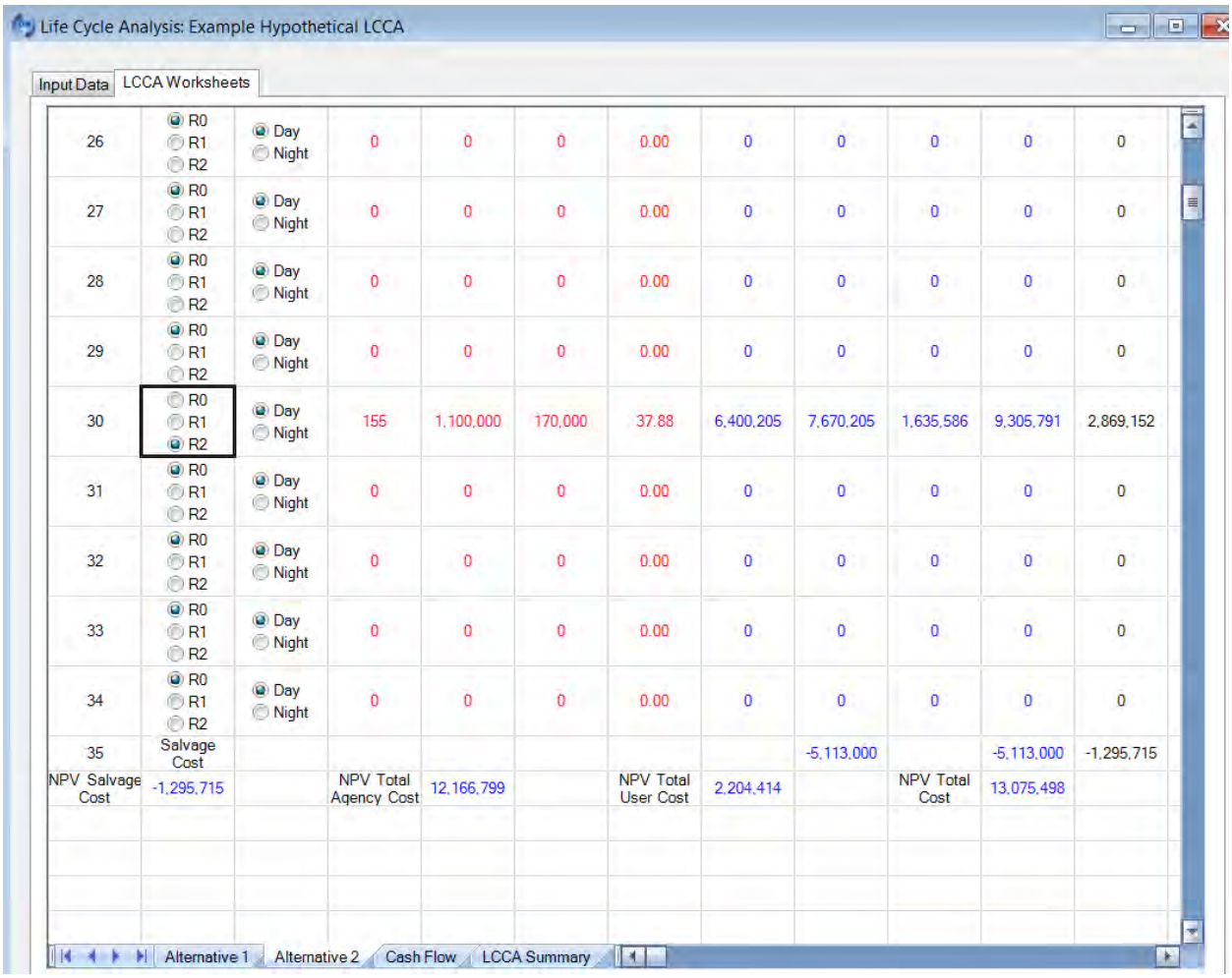


Figure 33 LCCA Worksheets (Alternative 2, Initial Construction)

14	R0 R1 R2	Day Night	0	0	0	0.00	0	0	0	0	0
15	R0 R1 R2	Day Night	45	350,000	80,000	11.25	1,900,800	2,330,800	352,819	2,683,619	1,490,119
16	R0 R1 R2	Day Night	0	0	0	0.00	0	0	0	0	0
17	R0 R1 R2	Day Night	0	0	0	0.00	0	0	0	0	0
18	R0 R1 R2	Day Night	0	0	0	0.00	0	0	0	0	0
19	R0 R1 R2	Day Night	0	0	0	0.00	0	0	0	0	0
20	R0 R1 R2	Day Night	45	350,000	80,000	11.25	1,900,800	2,330,800	389,541	2,720,341	1,241,529
21	R0 R1 R2	Day Night	0	0	0	0.00	0	0	0	0	0
22	R0 R1 R2	Day Night	0	0	0	0.00	0	0	0	0	0
23	R0 R1 R2	Day Night	0	0	0	0.00	0	0	0	0	0
24	R0 R1 R2	Day Night	0	0	0	0.00	0	0	0	0	0
25	R0 R1 R2	Day Night	45	350,000	80,000	11.25	1,900,800	2,330,800	430,084	2,760,884	1,035,655

Figure 34 LCCA Worksheets (Alternative 2, Rehabilitation at Years 15, 20 and 25)



26	R0 R1 R2	Day Night	0	0	0	0.00	0	0	0	0	0
27	R0 R1 R2	Day Night	0	0	0	0.00	0	0	0	0	0
28	R0 R1 R2	Day Night	0	0	0	0.00	0	0	0	0	0
29	R0 R1 R2	Day Night	0	0	0	0.00	0	0	0	0	0
30	R0 R1 R2	Day Night	155	1,100,000	170,000	37.88	6,400,205	7,670,205	1,635,586	9,305,791	2,869,152
31	R0 R1 R2	Day Night	0	0	0	0.00	0	0	0	0	0
32	R0 R1 R2	Day Night	0	0	0	0.00	0	0	0	0	0
33	R0 R1 R2	Day Night	0	0	0	0.00	0	0	0	0	0
34	R0 R1 R2	Day Night	0	0	0	0.00	0	0	0	0	0
35	Salvage Cost							-5,113,000		-5,113,000	-1,295,715
NPV Salvage Cost	-1,295,715		NPV Total Agency Cost	12,166,799		NPV Total User Cost	2,204,414		NPV Total Cost	13,075,498	

Figure 35 LCCA Worksheets (Alternative 2, Reconstruction at Year 30)

Once the construction year and construction time specification are completed in the Alternative worksheets, an LCCA calculation is immediately completed by the AKFPD2012 software. The Cash Flow worksheet shows plots of the Cash Flow Diagrams for the two alternatives. Clicking at the Cash Flow tab will turn the worksheet to the plots (Figure 36)

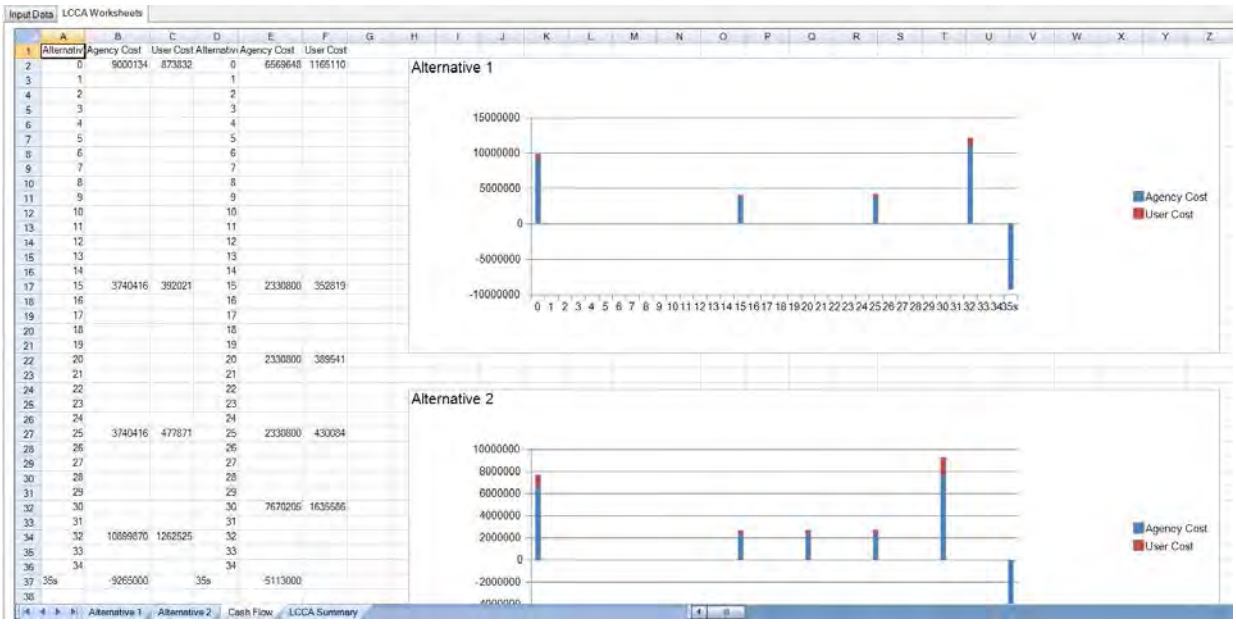


Figure 36 LCCA Worksheets (Cash Flow Diagram)

In Figure 36, the cash flow numbers for the two alternatives at the planned construction years are plotted in Columns A to F. The total cash flow for each year of an alternative is divided into agency cost and user cost to enable the plotting of a stacked bar series for each alternative. The two CFD charts in Figure 36 essentially combine the three manually charted figures shown in Figure 17 to Figure 19.

Once you are satisfied with the analysis results, you can generate summary information for the alternatives specified. The summary information is to be written to the **LCCA Summary** worksheet. When the LCCA Summary worksheet is created, it is a blank worksheet. Clicking at the **LCCA Summary** tab now will open the worksheet (Figure 37 and Figure 38). Figure 37 shows the left hand side of the worksheet. This portion of the worksheet is written with the input data of the analysis. Scrolling to the right of the worksheet will show the analysis summary. The summary table shown in Figure 38 is specifically formatted to present the same summary information of the previous Table 4.

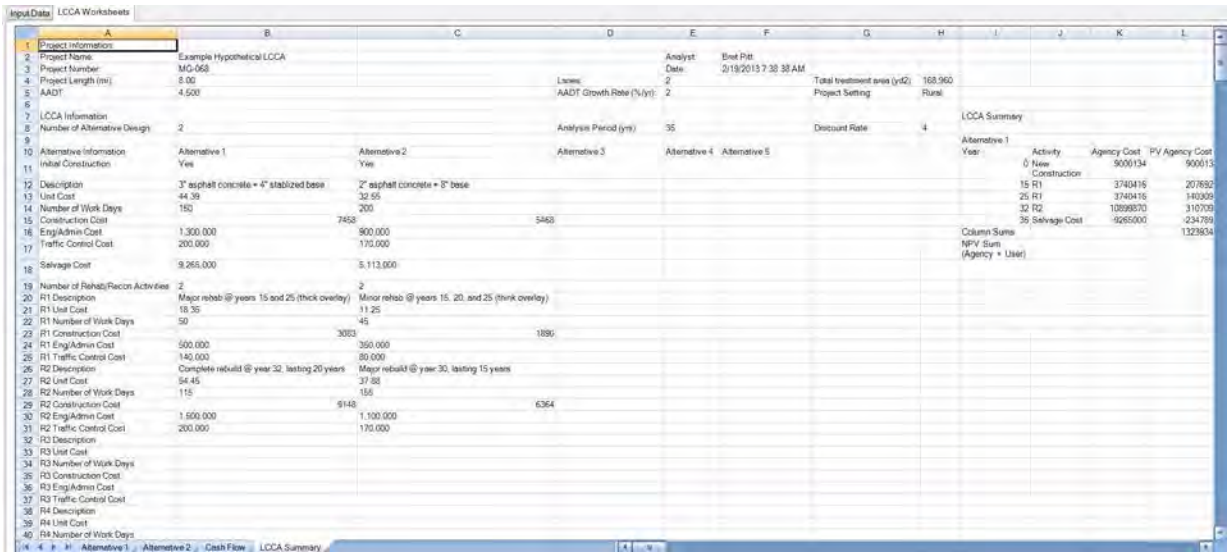


Figure 37 LCCA Summary Worksheet (the Input Data portion)

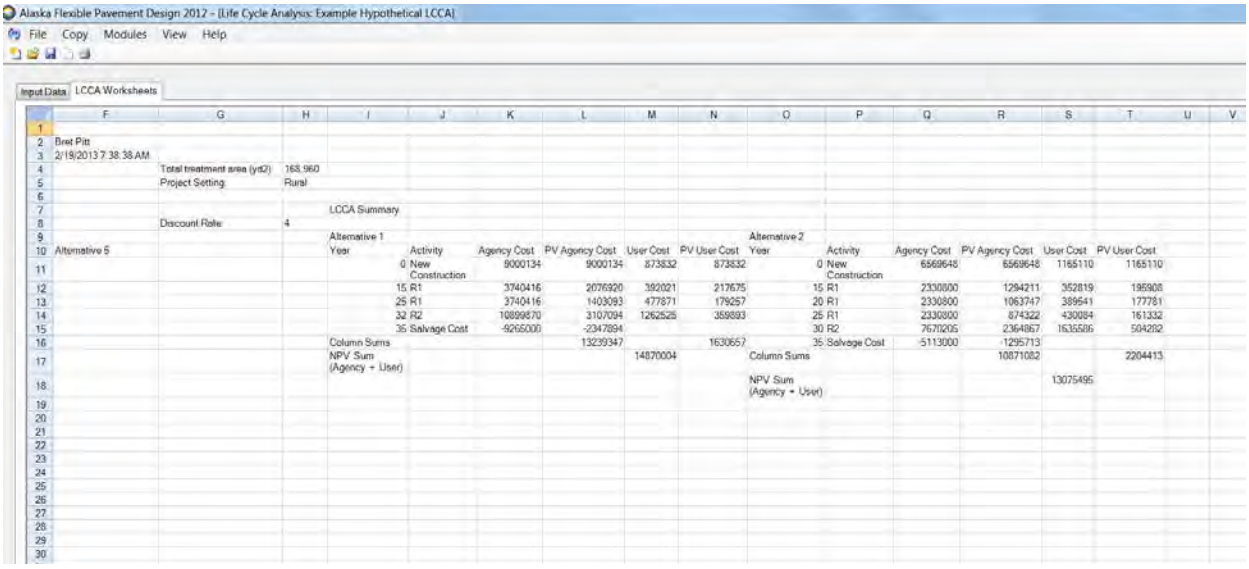


Figure 38 LCCA Summary Worksheet (the Output Data portion)

It is noted that the results shown in Figure 38 are mostly different from those in Table 4 at the User Cost and PV User Cost columns. The difference is due to two primary factors: the different work zone user delay cost unit value (i.e., the figure-determined value $90 used for Table 9.4 and the $81 calculated by the software) and the AADT projection at different years (i.e., arbitrarily rounded values for Table 9.4 and precise values calculated with 2% growth rate by the software).

If the analyst is satisfied with the analysis results and wants to save the LCCA worksheets as a Microsoft Excel spreadsheet file ***(*.xls***), this can be accomplished by going to File/Save As/Excel (Figure 39). Note

that to save the LCCA worksheets as an Excel file, the analyst needs to make sure that the LCCA worksheets of the Life Cycle Cost Analysis window is the current active window (i.e., the top window whose title bar is highlighted in a darker shade). To make sure that the LCCA worksheets is the active window, simply click at the title bar of the window Life Cycle Cost Analysis and observe that the clicked window is on top of other open windows and the title bar is in a darker shade than others.

When the Save As excel dialog box appears, enter the desired file name and file directory then click at Save (Figure 40).

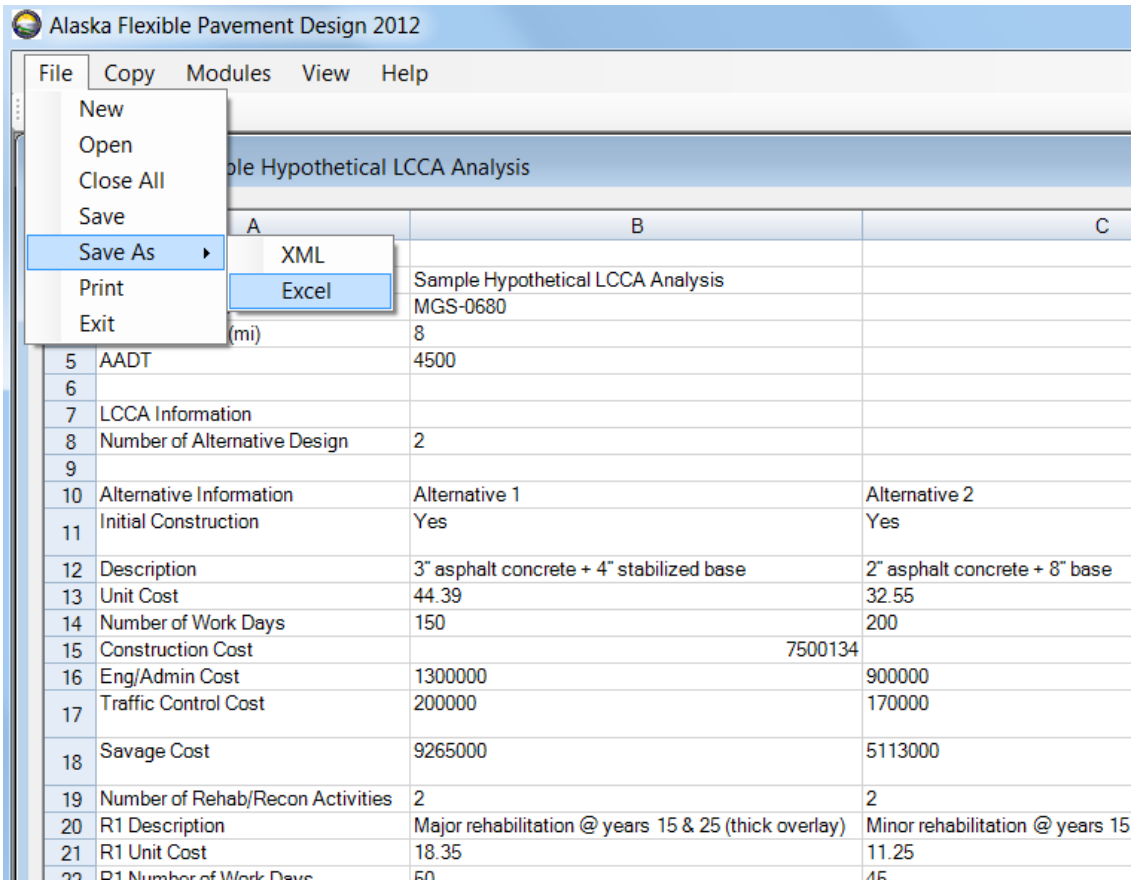


Figure 39 Save the LCCA Worksheets as an Excel File

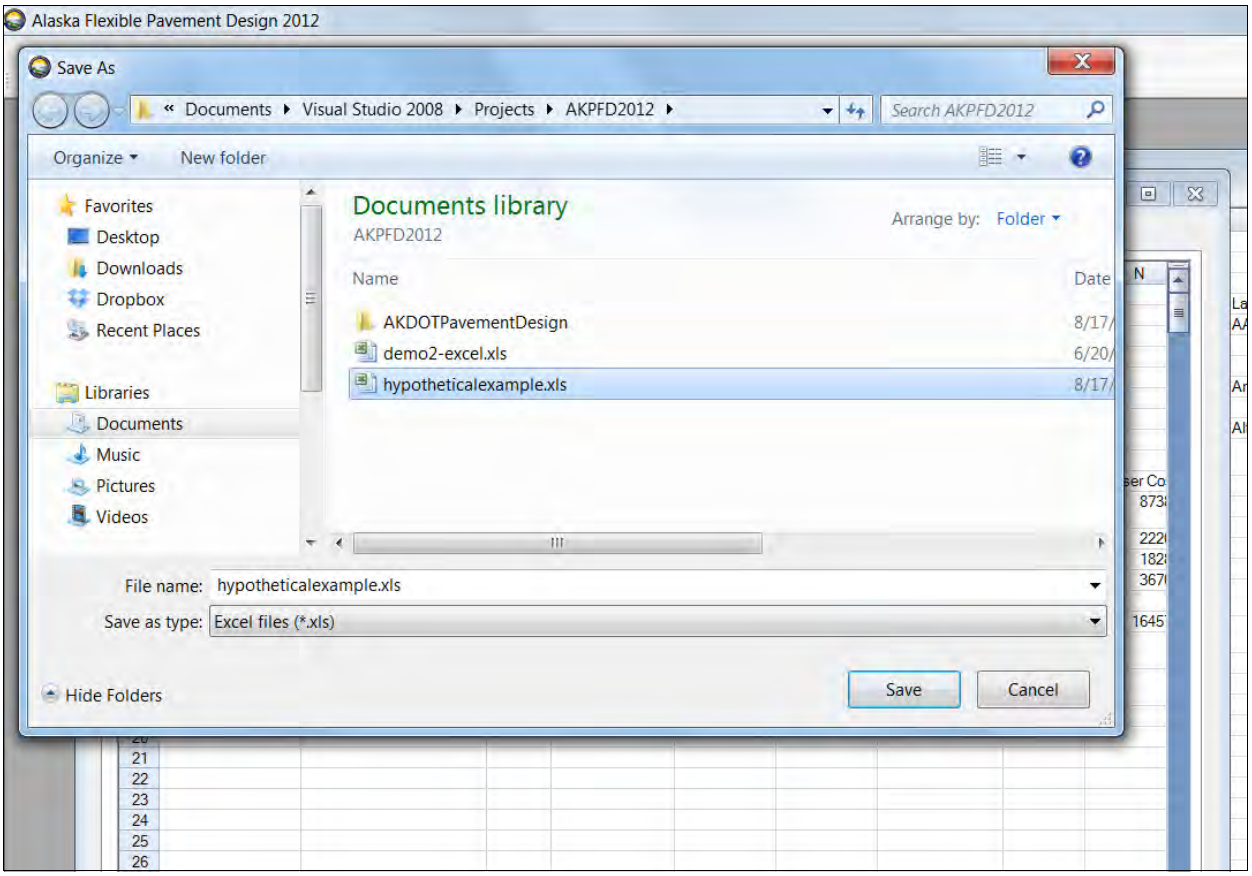


Figure 40 Save As an Excel File Dialog Box

Once the analysis data and results are examined, the entire analysis data set and results needs to be saved to the project workbook created in the beginning of the exercise. Clicking at the **Close** button on the lower right corner of the LCCA Worksheets Window. The LCCA window will then be closed and the LCCA data copied to the LCCA worksheet of the project workbook (Figure 41). In addition, after clicking the **Close** button of the LCCA Worksheets Window, a separate XML file is created to store the entire set of LCCA worksheets (i.e., Alternative 1, Alternative 2, CFD and LCCA Summary). This file is saved with the file name that begins with the original project file name and ends with "**-lcca**" to distinguish itself from the original project file.

Figure 42 shows a pair of such files displayed in a Windows Document Explorer. The ***Example Hypothetical LCCA.xml*** is the original project workbook (i.e., contains the Project Info, ESAL, Mechanistic, Excess Fine, and LCCA) and ***Example Hypothetical LCCA-lcca.xml*** is the LCCA worksheets (i.e., contains Alternative 1, Alternative 2, CFD and LCCA Summary).

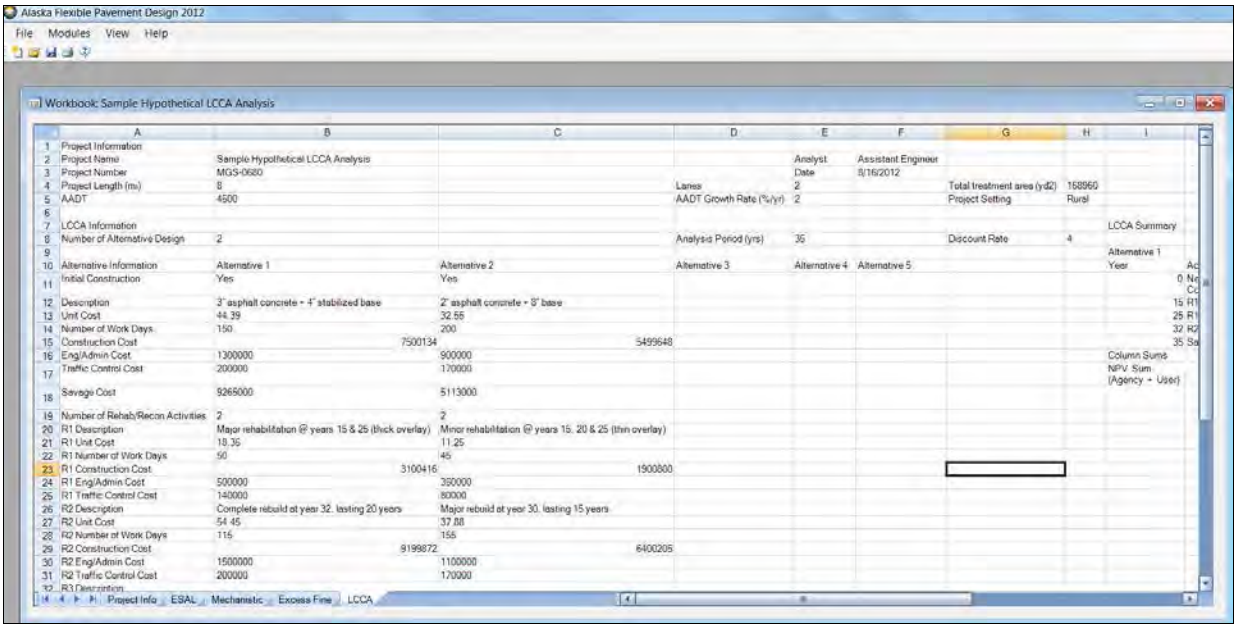


Figure 41 LCCA Summary Copied to the Project Workbook

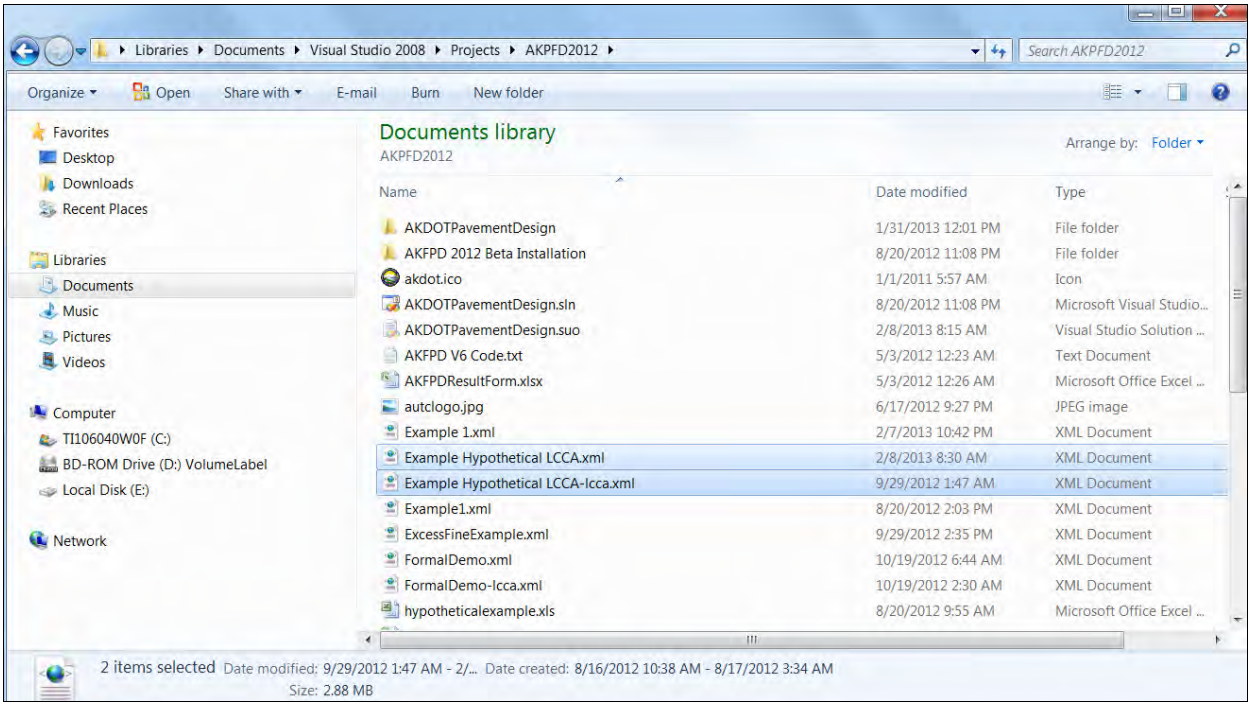


Figure 42 An AKFPD Project Files (Project Workbook and LCCA Worksheets)

To save the project workbook, simply go to File/Save (Figure 43). The workbook will be saved to the project file originally created (e.g., ***Example Hypothetical LCCA.xml***).

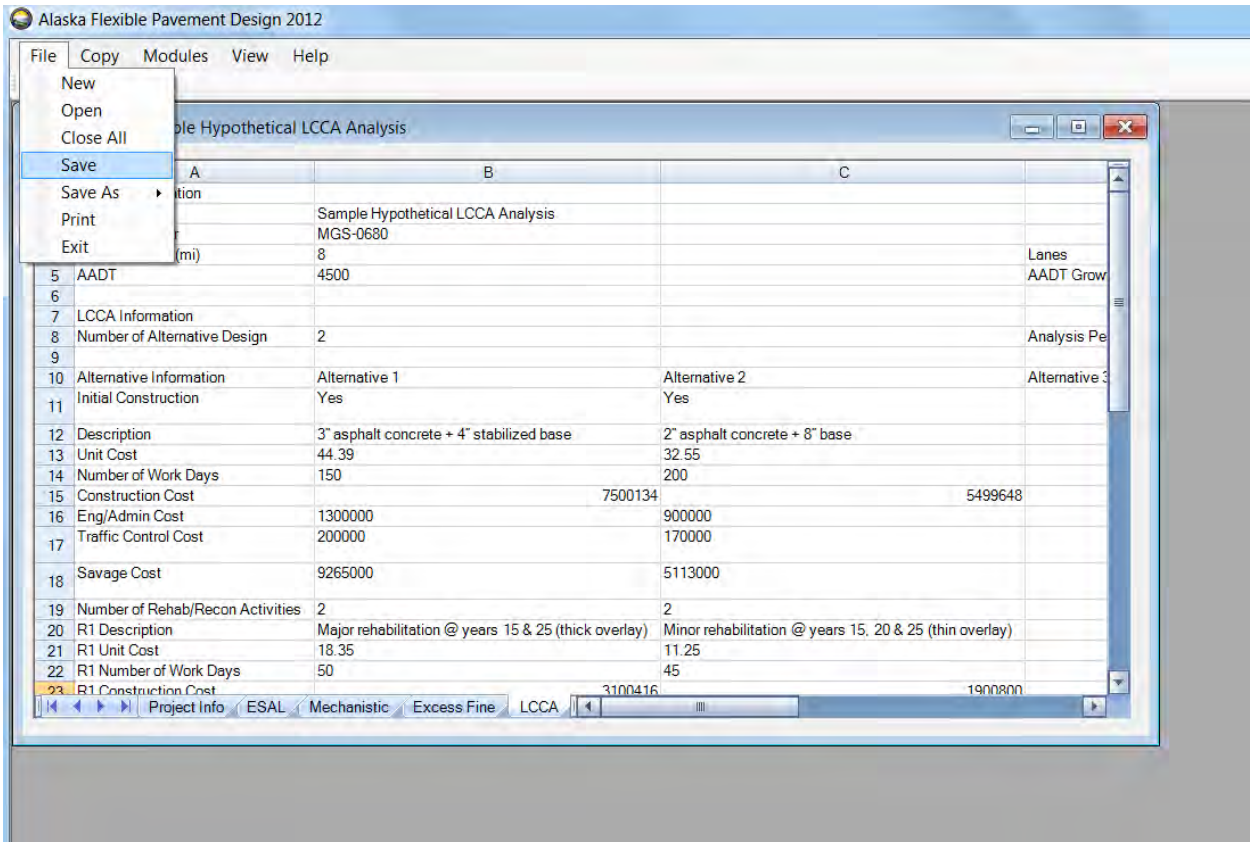


Figure 43 Save the Project Workbook to the Original Project File

Alternatively, the workbook can also be saved to another XML file of a different file name or save as an Excel workbook (
Figure 44).

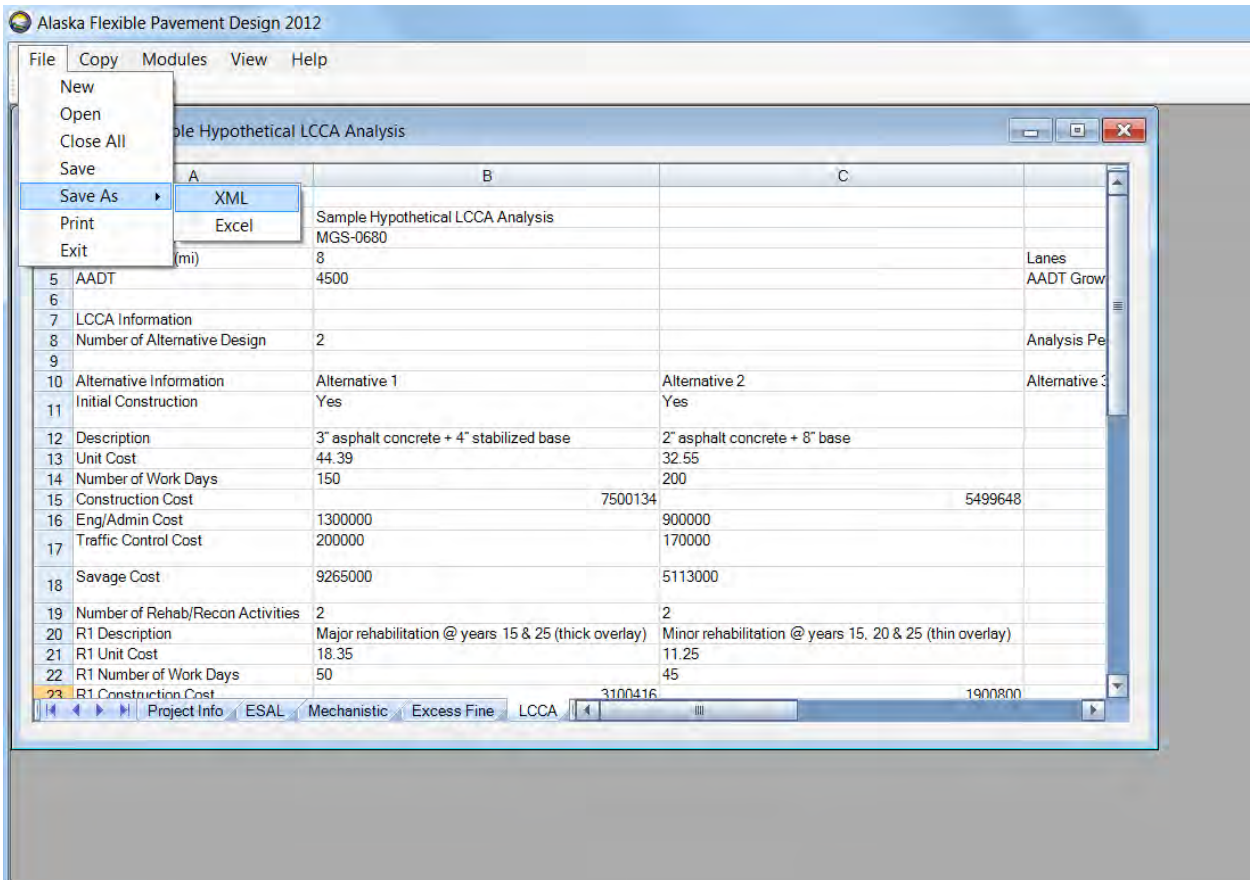


Figure 44 Save the Project Workbook as Different Files