Athena Pavement LCA

User Manual and Transparency Document

Pavement LCA v3.1 – Web Application www.PavementLCA.com

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This document can be found on the Athena software web site calculatelca.com. It will be periodically updated as required.

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Disclaimer
The Athena Institute provides no warranty for the software and does not assume any liability for the accuracy, completeness or usefulness of the software.

About the Athena Institute
The Athena Sustainable Materials Institute is a non-profit consultancy and think tank in life cycle assessment (LCA) for the built environment. The North American pioneer and only specialist in construction-sector LCA, the Athena Institute works with sustainability leaders in product manufacturing, building and roadway design, construction, policy, and green rating programs to enable smaller footprints in the production and consumption of materials, buildings and infrastructure. Athena's common-good work includes development and maintenance of a large life cycle inventory database on construction materials and processes, and free LCA software tools for architects and engineers.

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1.0 - Overview

This document explains the inner workings of the Pavement LCA web app including the underlying databases and methodology, and provides detailed instruction on how to use the software. **Find this document and tutorial videos at http://www.calculatelca.com/.**

1.1 – What the software is all about

Pavement LCA is a web application that provides environmental life cycle assessment (LCA) and Life Cycle Cost Analysis (LCCA) results for Canadian regional materials manufacturing, roadway construction and maintenance life cycle stages. It allows users to enter custom roadway designs, or draw on a library of over 48 existing Canadian roadway designs. It can be run on any modern standards-compliant web browser. If your project in the US, then you need our PC desktop version of this tool, which supports both Canadian and US regional data.

Pavement LCA is a simplified LCA tool

Life cycle assessment (LCA) is the science behind Pavement LCA, and is typically practiced by experts. Pavement LCA is an LCA-based software package that makes life cycle assessment data easily accessible to transportation engineers. Pavement LCA is built using the same methodology as the Athena Institute's well-established Impact Estimator for Buildings software. It provides a life cycle inventory profile for a given area of paved roadway. The inventory is not quite cradle-to-grave; roadways tend to last "forever", so while the software supports complete roadway reconstruction, there is no end-of-life per se.

The inventory results comprise the flows from and to nature: energy and raw material flows plus emissions to air, water and land. The software reports life cycle impact assessment results and enables easy comparison of different design options. The purpose of the software is to enable pavement designers to bring environmental effects into their decision processes.

The optional Use phase allows for the modelling of excess fuel use due to Pavement Vehicle Interaction (PVI) and operational energy use by fuel type (e.g. lighting, maintenance vehicles, etc.). The tool was intended for freeways and major arterials but can be applied to any paved surface.

Pavement LCA reports results for the following environmental impact measures consistent with the US EPA TRACI methodology[1]: global warming potential, acidification potential, human health particulate, ozone depletion potential, smog potential, and eutrophication potential. Pavement LCA additionally reports various resource uses such as primary energy and water, and emissions to air, water, and land.

Pavement LCA also supports life cycle cost analysis

Pavement LCA allows users to incorporate a life cycle cost analysis in their roadway models. Costs for initial construction, each maintenance or rehabilitation step, individual materials and fuel costs

[1] *Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts* (TRACI) is a life cycle impact assessment methodology developed by the US EPA and the most commonly used method in North America.

can be entered manually, or cost items can be saved in a library to help calculate those totals and can be used in subsequent projects. Interest and discount rates can be customized by users, and net present value (NPV) results can be produced and compared across multiple projects.

Pavement LCA delivers actionable results

Users can view data and results in various ways. The reporting functions make it easy to find environmental hot spots and to compare multiple design options simultaneously. When using the software, users may have two or more roadway designs already in mind or they may start with a baseline design and then look at various ways of improving that design's environmental performance.

All this for free?

The Athena Institute has a mandate to bring LCA to the construction sector for a verifiably reduced footprint of the built environment. We believe the best way to do this is by making Pavement LCA as accessible as possible. To us, this means keeping it free.

How do we do it? Through the generous support of our funding network: our partners, supporters and members. In particular, we acknowledge the contributions of the Cement Association of Canada, Morrison Hershfield, Environment Canada, and MIT, our collaborative partners in developing Pavement LCA.

It's expensive for us to perform on-going development and maintenance of the software and its underlying databases, and release periodic updates. . We never have quite enough funds to move as quickly as we'd like to tackle the wish list – please consider joining our family of supporters (http://www.athenasmi.org/membership/overview/).

1.2 - LCA Methodology

The software's underlying LCA method aligns with North American standard practice and is consistent with global best practices. We regularly revisit and update our methodology as required to maintain compliance with ISO, EN and North American standards.

1.2.1 - Impact assessment

Pavement LCA creates an almost- cradle-to-grave life cycle inventory (LCI) profile for a roadway over a user-selected analysis period. The inventory results comprise a long list of highly differentiated flows from and to nature in the form of energy and raw material flows as well as emissions to air, water and land. The software supports the following midpoint life cycle impact assessment (LCIA) measures based on the US EPA Tool for Reduction and Assessment of Chemical and Other Environmental Impacts[2] (TRACI) and in accordance with ISO 21930/31:

- Global Warming Potential – kg CO_2 equivalent mass
- Acidification (Air) Potential – kg SO_2 equivalent mass
- Human Health Particulate – kg PM 2.5 equivalent mass
- Eutrophication (air & water) Potential – kg N equivalent mass
- Smog (air) Potential – kg O_3 equivalent mass
- Ozone Depletion (air) Potential – kg CFC 11 equivalent
- Total Primary Energy Consumption – MJ
- Non-Renewable Energy Consumption - MJ
- Fossil Fuel Consumption - MJ

1.2.2 - Underlying LCI data

The heart of Pavement LCA is the Athena life cycle inventory database, which contains the most detailed, highest quality and regionalized construction data available in North America. We spend a lot of time and resources updating and expanding our databases on materials, systems and processes.

The Athena LCI database is comprised of ISO 14040/14044-compliant unit process LCI data (e.g. concrete manufacturing LCI results per m^3 concrete) related to basic materials, building products and components, fuel use, and transportation. The database is regionally sensitive, taking into consideration manufacturing technology, transportation and electricity grid differences as well as recycled content differences for products produced in various regions. Athena databases are typically built from the ground up using actual industry average, facility level or engineered process models. New regions are added to the software as our resources allow. All data is generally less than 10 years old.

The Athena Institute has developed data not only for construction materials and products but also for energy use, transportation, and construction equipment.

[2] TRACI v2.1; 2012.

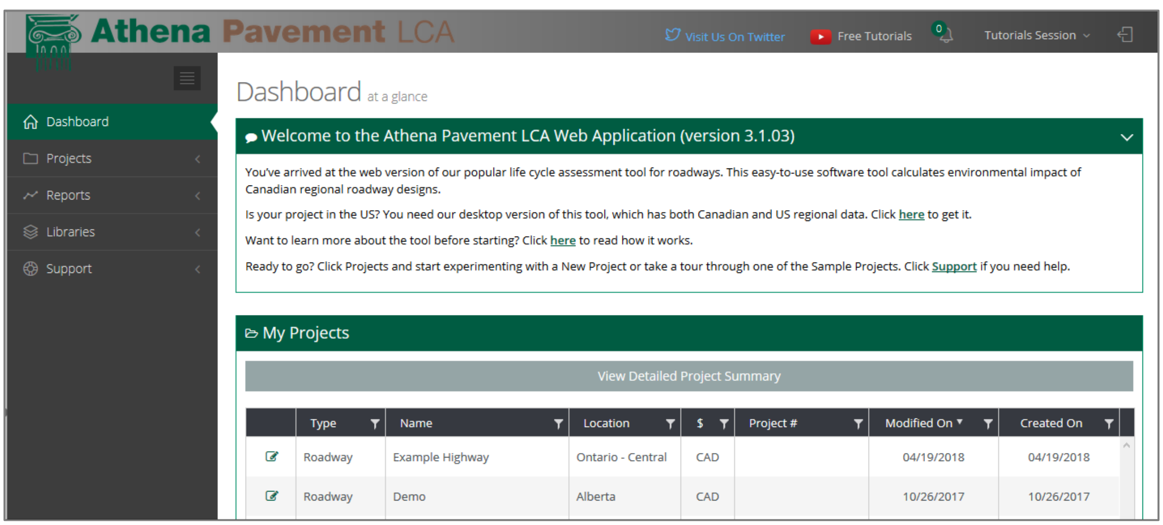
Assumptions and uncertainties are inherent to any LCA calculation. In our opinion, some of the uncertainties have balancing effects on the results, so that the end result is within an acceptable margin of error. In our opinion, LCA results with Pavement LCA should be viewed with a 15% margin of error perspective. In other words, we consider a comparative impact measure difference of 15% or less between two design scenarios as being equal or insignificant.

2.0 - How the software works

Users quickly describe roadway parameters through a few easy input screens, and can then view results in a variety of ways. In the background lie several large databases on materials, energy and transportation, sourced from the Institute's proprietary database or from commercial databases (e.g., ecoinvent), which we typically adjust for the appropriate system boundary. Material data represent national or industry averages for the extraction, processing and manufacturing of each material. Regional energy grids and transportation modes and distances are applied to the average data to arrive at regional data profiles.

2.1 - Getting Started

Go to www.pavementlca.com and you will be asked to register an account or sign in to an existing account. Your name, email address and a password is required. Once signed in, the application will open in the Dashboard.



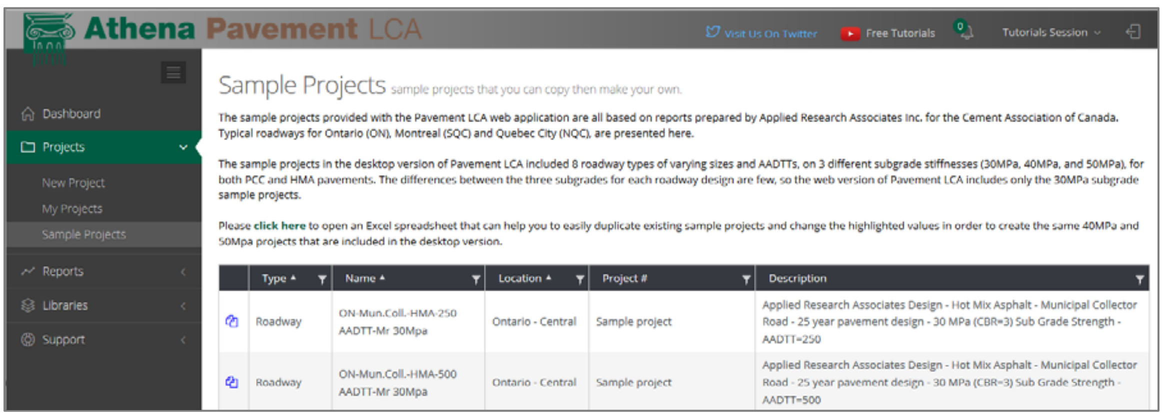
If you have existing projects, they will be shown in the dashboard, if it's your first time, the My Projects table will be empty. The navigation pane on the left shows five menus with drop down arrows to show each menu's options.

In the top frame click on your user name to se your account details or to log out. There are also links to our Twitter feed, tutorial videos and the notification centre (bell icon) that will indicate if any new messages have arrived. This is where we will notify of any updates or news regarding the tool.

2.2 - Projects

2.2.1 - My Projects and Sample Projects

Clicking on the Projects down arrow, three options will appear, New Project, My Projects and Sample Projects. If you're just starting, your My Projects page will be blank; if you have existing projects, they will appear in a table similar to the Sample Projects table below. The My Projects table will have a green edit icon and a red delete icon in the left hand column and two date columns; otherwise, it is the same table.



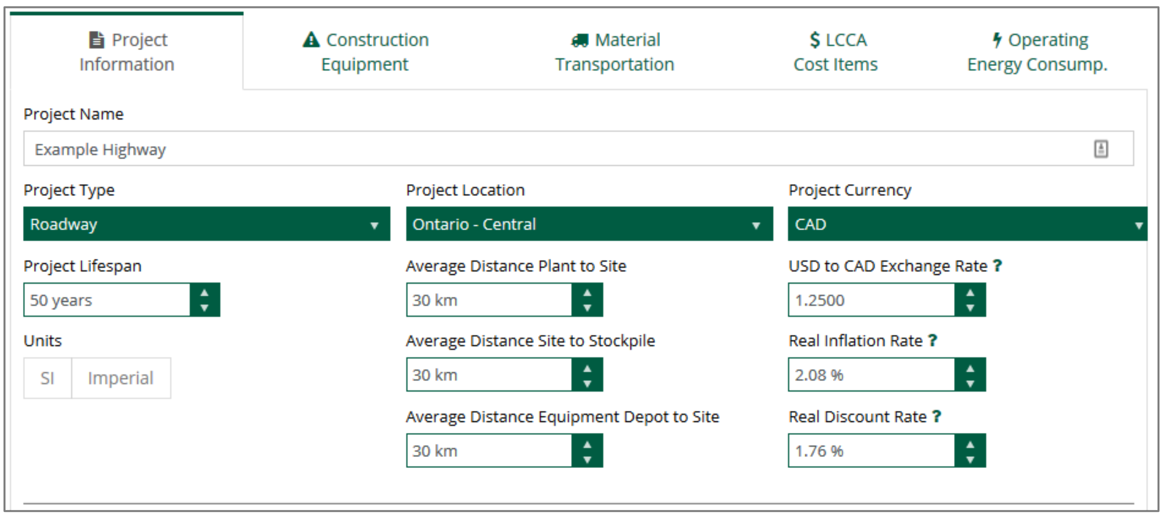
The sample projects are provided as examples of eight different roadway types of varying sizes and AADTTs (average annual daily truck traffic), based on Ontario (ON), Montreal (SQC) and Quebec City (NQC) designs, and can be used as starting points for your own designs if you wish.   You cannot edit a sample project, you must first copy it to your My Projects page and then you can rename edit the copy in any way you like. From the Sample Projects table, choose the project that you want to copy, then click the blue copy icon in the left column. Click on My Projects in the navigation pane, and that project will have been added to your My Projects table with a Copy 1 label added to the project name, and you can now edit this project as you wish.

2.2.2 - New Projects

Click on New Project to create a new project and the project information page will open.

2.2.2.1 - Project Information

In the starting screen, a few general data inputs are required. Project location is needed to calculate some material manufacturing transportation distances, to determine which electricity grids to draw from and which Athena materials regional manufacturing databases to use.



The Project Lifespan default value is 50 years but can be changed to any value between 30 and 100 years and dictates rehabilitation events such as scheduled resurfacing.

Three project distances are defined to calculate transportation effects during construction and maintenance operations. Average Distance Plant to Site is the distance from the asphalt or concrete mixing plants to the job site. Average Distance Site to Stockpile is the distance to calculate the transportation effects for disposing or stockpiling any removed (reclaimed) materials. Average Distance Equipment Depot to Site will be used to calculate the transportation effects of transporting equipment to the project site. Equipment is either "floated" or driven from the equipment depot to the job site.

Exchange rate, real inflation rate and real discount rate used in the life cycle cost analysis reports can be entered here (they can also be changed when generating results). The USD to CAD exchange rate is the amount of CAD$ it takes to buy a US$ (typically greater than 1.00).

CLICK “**SAVE PROJECT**” AT THE TOP LEFT OF THE PAGE TO CREATE A NEW PROJECT.

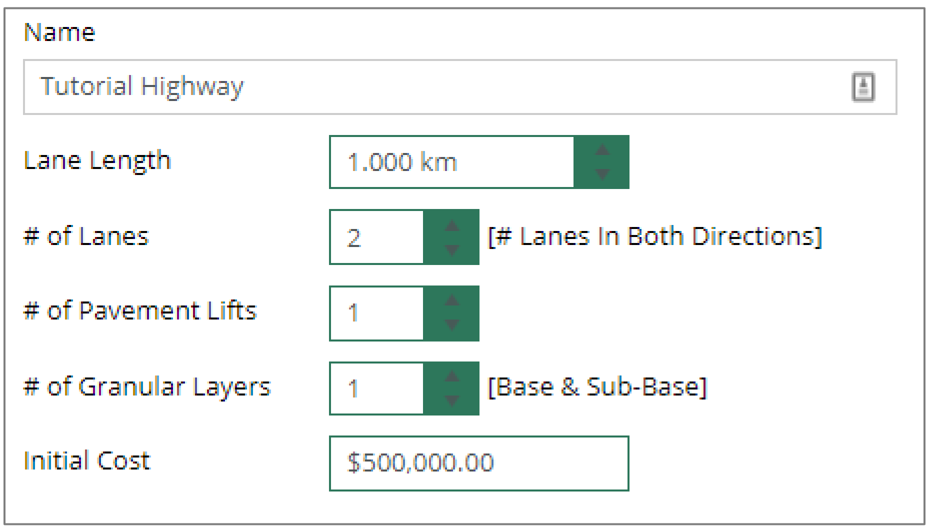
2.2.2.2 - Project Roadways

On the Project Roadways page click “**Add Roadway**” to create a new roadway (or click the green edit icon in the left column to open an existing roadway).

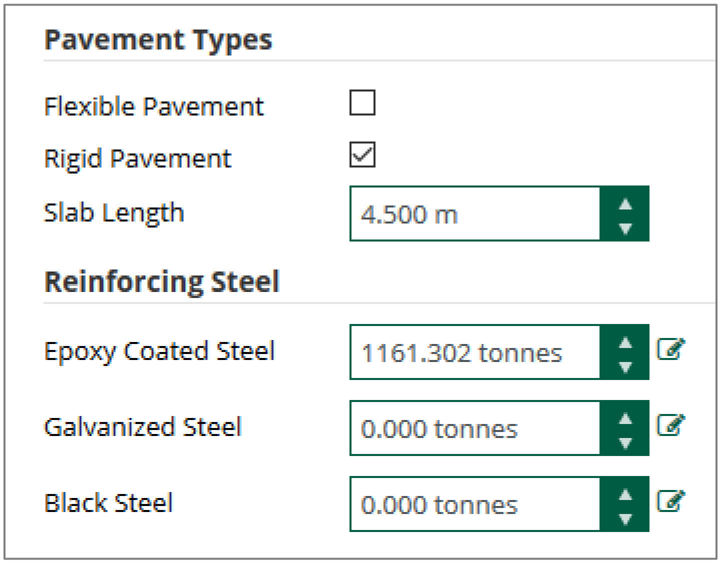
On the roadway information page, you can describe the roadway cross-section in the survey section. The purpose of this page is to determine the geometry of the roadway so that the software can calculate material volumes.

2.2.2.2.1 - Roadway Information

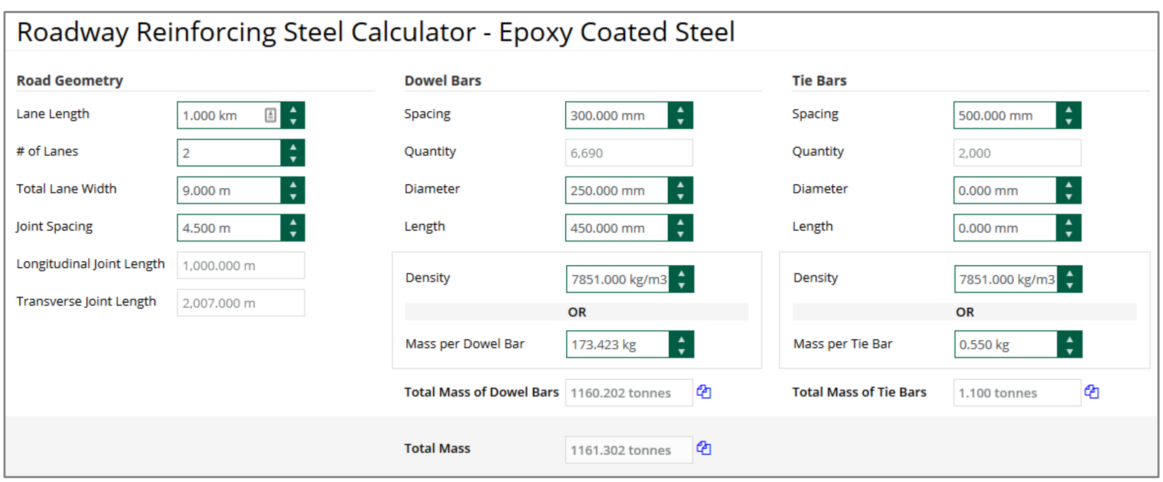
Give the roadway a meaningful name, then enter the length, number of lanes, number of pavement lifts, number of granular layers and optionally, initial cost. The cost input options are covered in the 2.4 - Life Cycle Cost Analysis section below.



Select a pavement type: flexible (asphalt) or rigid (concrete) and reinforcing steel if appropriate. The slab length and reinforcing steel apply to rigid pavements only.



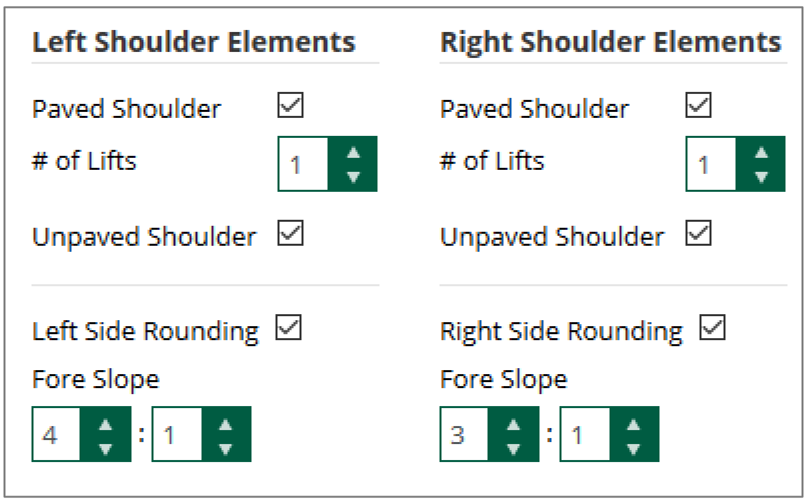
Longitudinal pavement joints are assumed along the entire length of the roadway between each lane, and transverse joints across the width of all lanes, every slab length for the length of the roadway. Dowel bars along the transverse joints and tie bars along the longitudinal joints add up to a total mass of reinforcing steel(s) that can be entered in the appropriate box(es). You can calculate these totals yourself and simply enter the values here, or you can click the green edit icon to the right of each steel box and a calculator page will open.



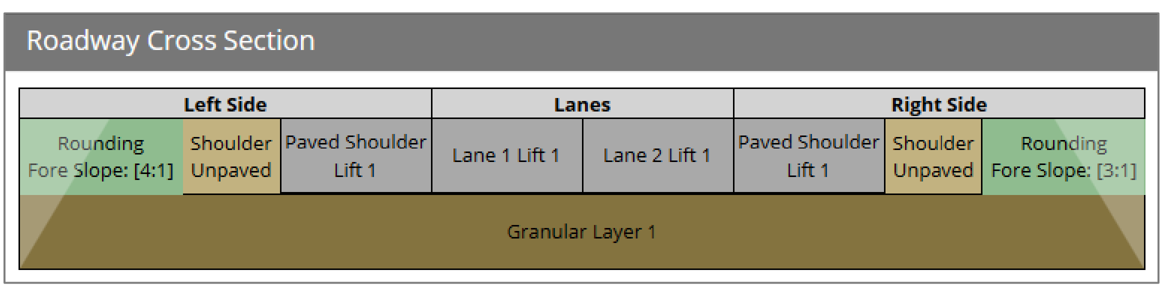
The road geometry from your roadway survey will be entered automatically, but you can edit those values if you wish. Editing these values here will not change the values in the roadway survey; they are used only on this page for steel calculation purposes. Enter the bar spacing, and the number of bars will be calculated. You can calculate the mass of each bar by entering the diameter, length and density of the bars, or you can enter the mass of each bar. There are instructions on how to copy the values into the roadway survey at the bottom of the page. Click the blue copy icon to the right of the mass you want to copy, then click Save; the page will close and the value will be entered in the corresponding steel mass box.

Note that if you have not yet defined your lane widths in the roadway design details section below, the steel calculator will open with a lane width of 0 and the transverse joint length will be 0. You can enter the width yourself, or just return to the steel calculator after you've entered your lane widths. Similarly, if your roadway has only one lane, the longitudinal joint length will be zero because joints are only assumed between two adjacent lanes.

Define right and left shoulders and rounding. You can include paved and unpaved shoulders and rounding. The roundings are defined by their slopes, entered here, and their thicknesses, which are defined in the roadway design details section below



Click "**Apply**" to commit your survey choices to the roadway. A schematic cross-section of the roadway will appear (not to scale) in the Roadway Cross Section area. It is simply an illustration of all the elements that you have selected in the survey section. It is also a good idea to click "**Save Roadway**" (or "**Update Roadway"** for previously saved roadways) at the top of the page to save any changes.

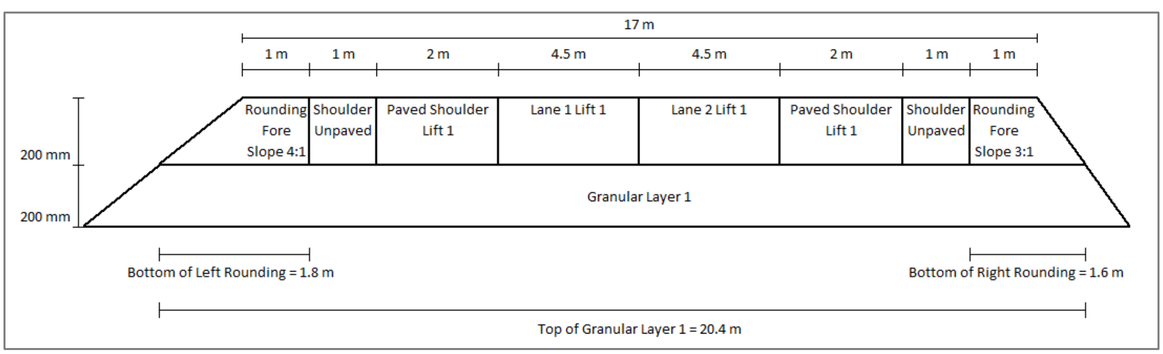


Use the Roadway Design Details section to define the materials, widths and thicknesses of each roadway element with the dropdown boxes and value boxes. The mass and volume of material as well as the cross-sectional area of each element is calculated.

Roadway Design Details

Element Name	Material	Width [m]	Thickness [mm]	Density [tonnes/m3]	Mass [tonnes]	Area [m2]	Volume [m3]
Lane 1 Lift 1	ON PCC	4.5000	200.0000	2.324	2091.6	0.9	900
Lane 2 Lift 1	ON PCC	4.5000	200.0000	2.324	2091.6000	0.9000	900.0000
Left Paved Shoulder Lift 1	ON HMA SuperPave 19	2.0000	200.0000	2.46	984.0000	0.4000	400.0000
Left Unpaved Shoulder	Granular A	1.0000	200.0000	2.4	816.0000	0.3400	340.0000
Left Side Rounding [4 : 1]	Granular A	1.0000	200.0000	2.4	672.0000	0.2800	280.0000
Right Paved Shoulder Lift 1	ON HMA SuperPave 19	2.0000	200.0000	2.46	984.0000	0.4000	400.0000
Right Unpaved Shoulder	Clear Stone 16	1.0000	200.0000	2.5958	882.5873	0.3400	340.0000
Right Side Rounding [3 : 1]	Clear Stone 16	1.0000	200.0000	2.5958	674.9197	0.2600	260.0000
Granular Layer 1	Granular B Type I	20.4000	200.0000	2	8440.0000	4.2200	4220.0000

For roundings and any granular layer below them, the shapes of those elements will be trapezoidal, and the cross-sectional area defined by the thicknesses and slope. The top width of these elements is what should be entered in the width column. In this example, the total width of the top of the roadway is 17 m, as defined for each individual element. Using the left side rounding as an example, with a slope of 4:1, the top width of the rounding is entered as 1.0 m, the thickness is 200 mm, which results in a bottom width of that element of 1.8 m. Similarly, the bottom of the right rounding is 1.6 m. This results in the top width of the granular layer is 17+1.8+1.6=20.4 m, and this is the value that is entered in the width column of Granular Layer 1. The areas and volumes of all elements are calculated automatically, including the fore slopes, but the bottom widths of the roundings are not, therefore you must calculate and enter the top width of any granular layers below yourself.

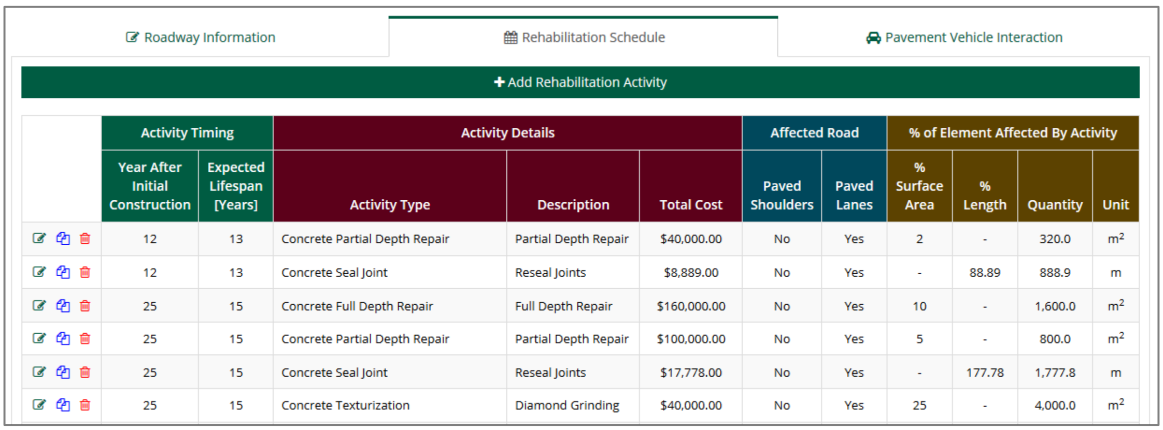


DON'T FORGET TO CLICK "**UPDATE ROADWAY**" AT THE TOP LEFT OF THE PAGE AFTER MAKING ANY CHANGES TO THE ROADWAY INFORMATION.

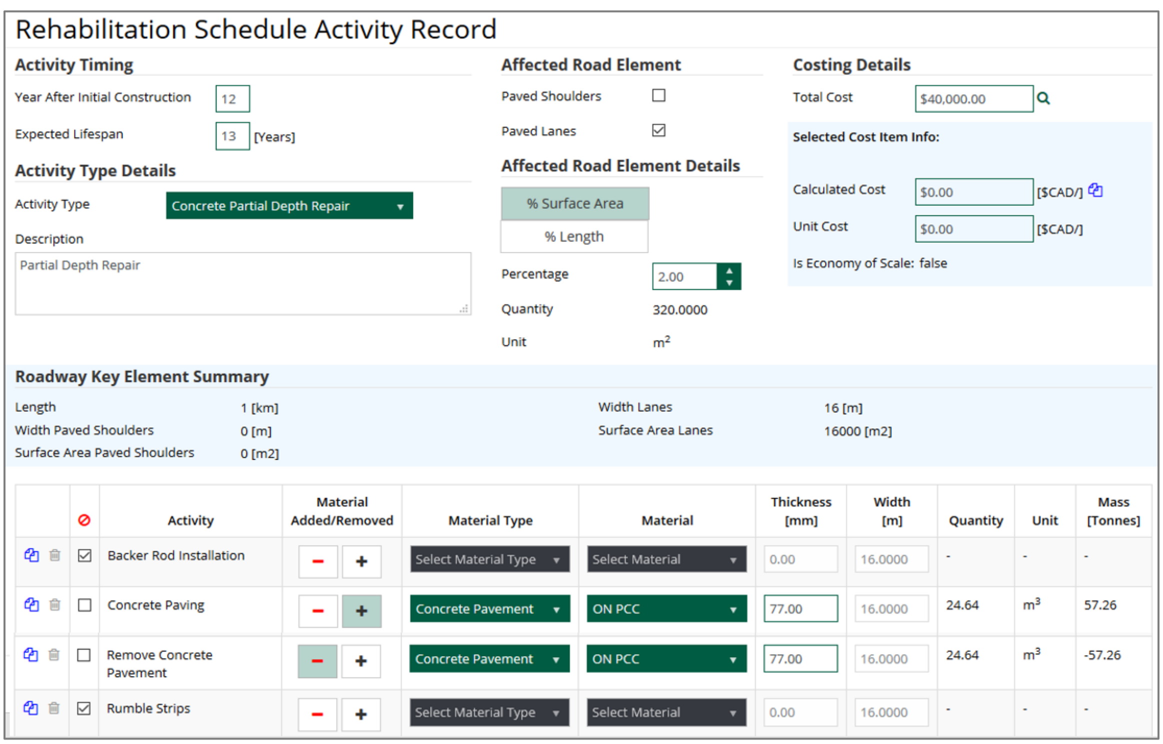
2.2.2.2.2 - Rehabilitation Schedule

Click the Rehabilitation Schedule tab to enter a rehabilitation/maintenance schedule. These pages address materials added and taken away over the service life of the roadway. The sample projects all include full rehabilitation schedules for both concrete and asphalt roads and are good examples of how several Activity Types are modelled in the projects.

The first page allows you to add rehabilitation steps and shows a summary of all existing rehabilitation steps, one per row, and by clicking "**Add Rehabilitation Activity**" (or the edit button in the leftmost column for existing records), the second page appears with the details of each rehabilitation step.



	Activity Timing		Activity Details			Affected Road		% of Element Affected By Activity			
	Year After Initial Construction	Expected Lifespan [Years]	Activity Type	Description	Total Cost	Paved Shoulders	Paved Lanes	% Surface Area	% Length	Quantity	Unit
	12	13	Concrete Partial Depth Repair	Partial Depth Repair	$40,000.00	No	Yes	2	-	320.0	m^2
	12	13	Concrete Seal Joint	Reseal Joints	$8,889.00	No	Yes	-	88.89	888.9	m
	25	15	Concrete Full Depth Repair	Full Depth Repair	$160,000.00	No	Yes	10	-	1,600.0	m^2
	25	15	Concrete Partial Depth Repair	Partial Depth Repair	$100,000.00	No	Yes	5	-	800.0	m^2
	25	15	Concrete Seal Joint	Reseal Joints	$17,778.00	No	Yes	-	177.78	1,777.8	m
	25	15	Concrete Texturization	Diamond Grinding	$40,000.00	No	Yes	25	-	4,000.0	m^2



The following is a description of each element of a rehabilitation activity record:

Activity Timing:
Enter the **Year After Initial Construction**, i.e. the year in the lifespan in which the activity occurs, and the **Expected Lifespan** of the activity. The lifespan of an activity is typically the number of years before the same activity occurs again. For material and construction effects, the only time when this affects the results is when an activity lifespan goes beyond the project lifespan. If you have a rehab activity at year 40 that would typically last for 15 years and your project lifespan is 50, only two thirds (10/15 years) of the effects are added to the results table. For LCCA calculations, the **Year After Initial Construction** is paramount to the NPV results.

Activity Type Details:
Choose an **Activity Type** from the dropdown box. Once an activity type is chosen, the activity table at the bottom of the table will populate with the activities that pertain to that activity type. You can enter a description here as well for further details of the activity record.

Affected Road Element:
Check Paved Lanes and/or Paved Shoulders. This will help determine the portion of the roadway upon which this activity will be performed.

Affected Road Element Details:
Choose "**% Surface Area**" or "**% Length**" and the percentage of the surface or length of the roadway upon which the activity will be performed. In this example, the activity is a partial depth repair on 2% of the surface of the roadway. The Roadway Key Element Summary is below, shaded in blue, and it summarizes the geometry of the roadway design, listing its length, widths of lanes and shoulders and area of lanes and shoulders. In this case, the surface area of lanes is 16,000 m^2, and we've opted to perform the repair on 2% of that, 320 m^2, which is calculated and listed as the **Quantity**. Quantity is the crucial value here; this is the value, along with the thickness specified in the table below, that will calculate the amount of material removed or added for this activity.

Use the Percentage box to manipulate the Quantity value to what you want for the activity. Let's say you want to rout and seal 1,400 m of expansion joints. The material and equipment calculations used in this activity are done on a per metre basis, as are typical specifications. To specify this, choose "**% Length**" and the **Unit** will change to "m". This road has a length of 1 km or 1000 m, so to achieve 1,400 m in the Quantity field, you can enter 140 in the Percentage box. Again, it's the Quantity value that is the important value, and you should use the Percentage box to get the correct quantity of m^2 or m for each activity.

Costing Details:
The costing details will be discussed in the Life Cycle Cost Analysis section below.

Roadway Key Element Summary:
This will summarize the geometry of your roadway as modelled on the Roadway Information page.

Activity table:
The diagram shows a truncated table for a concrete partial depth repair. This table will be populated with possible activity types according to the chosen Activity Type. Each activity can be skipped by checking the box in the second column from the left with the red circle in the heading (click the red circle to skip all the activities). In this example, Concrete Paving and Remove Concrete Pavement are both unchecked, meaning they are not skipped. The Material Type and Material for both are chosen as the same concrete that was used in the initial roadway. You are not constrained to this material, but you should choose the same material to remove, and you can choose a different material to replace it with. The thickness of the repair is specified, and since this step is done by the % Surface Area, it is based on a m^2 basis and the Width column is not editable. The quantity and mass of the material chosen is calculated and displayed. If you were modelling a rout and seal activity, by % Length and the unit was per m, then the Width column would be accessible and you will need to enter the thickness (depth) and width of the router.

In the Material Added/Removed column, the plus icon should be chosen if you are adding material (concrete paving) and the minus icon if material is removed. If you do not click the plus icon, the mass in the right most column will be 0 and the amount of material will not be added to the bill of materials nor will its effects be calculated. For the activity removing the concrete pavement, if the minus icon is not chosen, then the mass will also be 0. This is not a problem necessarily for the bill of materials, which will not be decreased regardless, and the equipment effects will be calculated no matter what, but if the mass is zero, then 0 mass will be transported away from the site. Click the minus icon; the mass will be calculated and displayed as a negative value, and the effects of the transport of that mass of material, by the Average Distance Site to Stockpile as defined in the Project Information section above. There may be cases where any material removed from the roadway is left on site, such as concrete texturizing. If the roadway is texturized, the “dust” may not be collected and trucked away; it just blows away or is just swept to the shoulder. In this case, the activity should be defined so the equipment effects are calculated, but the minus icon should not be selected, meaning the material will not be transported away. The plus icon must always be chosen whenever any material is added to the roadway.

DON’T FORGET TO CLICK “**SAVE CHANGES**” AT THE BOTTOM RIGHT OF THE PAGE AFTER MAKING ANY CHANGES TO THE ACTIVITY RECORD.

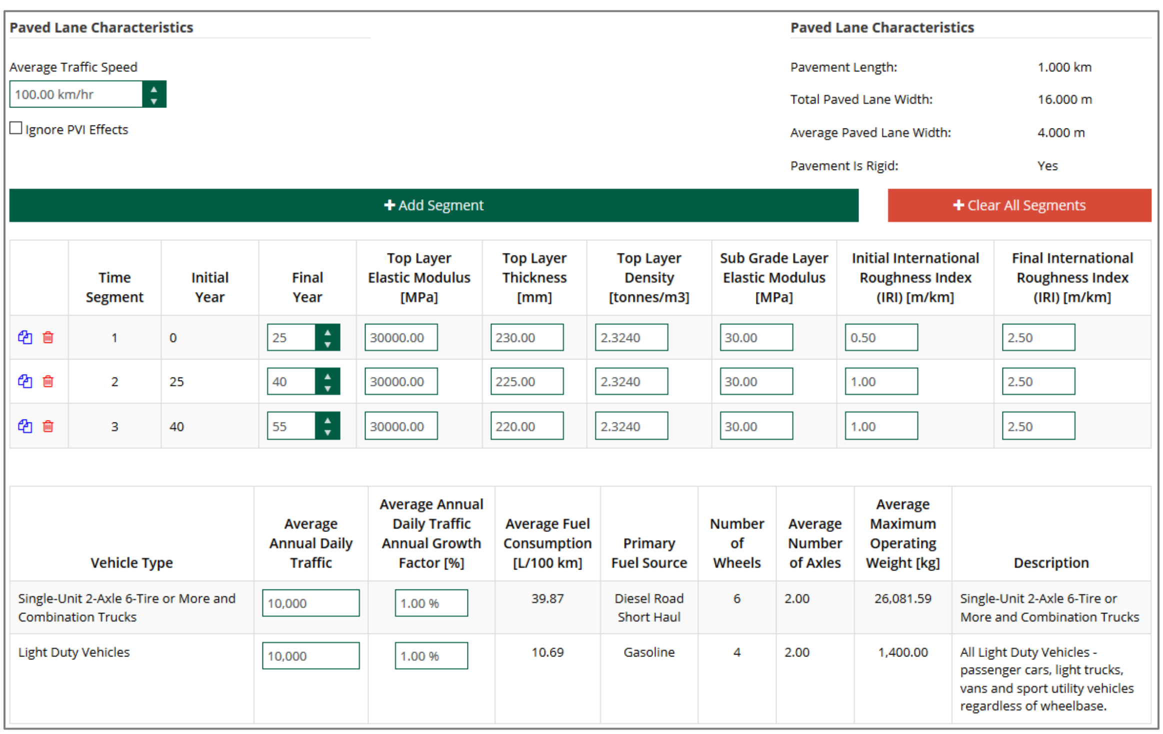
2.2.2.2.3 - Pavement Vehicle Interaction

The Pavement Vehicle Interaction (PVI) module is based on the latest research and model from the Concrete Sustainability Hub at the Massachusetts Institute of Technology (MIT): "PVI Mechanistic Model Gen II", by Dr. Arghavan Louhghalam, in collaboration with Mehdi Akbarian and Prof. Franz-Josef Ulm. December 2013 (http://cshub.mit.edu/pavements/pvi). A special note of appreciation to Dr. Mehdi Akbarian and Dr. Charles Thibodeau for their assistance with refining the PVI results.

The calculated PVI is a function of roadway deflection and surface roughness, both of which depend on the make-up of the top layer of pavement on a given roadway surface. The model demonstrates the possible increase in vehicle fuel consumption and related effects associated with the pavement performance over time. It does this by contrasting the pavement’s roughness and deflection over time relative to a theoretical rigid and smooth roadway, thereby focusing on the effect of the pavement's performance not the life cycle vehicle effects. GEN II improves on the PVI model by accounting for the impact of temperature and vehicle speed on fuel consumption. Using average fuel consumption for passenger vehicles and trucks (AADT(T)), it then models the influence of progressive increases in roughness and deflection of the roadway's top layer over time (between major rehabilitations) and interprets the calculated decline in performance as increased vehicle fuel use due to the pavement.

The upper table on the input form allows you to input multiple time segments throughout the lifespan of the roadway, so you can adjust the base PVI values when the surface is changed, for example after texturization or resurfacing

While PVI has been studied in a number of one-off pavement reports, to our knowledge it has never been incorporated into a commercial software tool. Unlike the LCI data for materials, plant operation and construction, which have been studied at length and for which there is considerable literature, PVI is relatively new and represents a forecast or future state scenario. A scenario carries with it a degree of uncertainty that needs to be duly considered. Obviously, uncertainty would best be handled using a statistical probability approach to the calculation model and the underlying data; this tool does not offer that. Hence, the Athena Institute advises those using the results from this PVI module to always acknowledge this uncertainty when discussing or presenting these results. Moreover, we recommend that when using this module, users complete a sensitivity analysis and err on the side of reporting conservative results in any public representation of these results.


Paved Lane Characteristics

Average Traffic Speed

100.00 km/hr

Ignore PVI Effects

Paved Lane Characteristics

Pavement Length:	1.000 km
Total Paved Lane Width:	16.000 m
Average Paved Lane Width:	4.000 m
Pavement Is Rigid:	Yes

+ Add Segment

+ Clear All Segments

Time Segment	Initial Year	Final Year	Top Layer Elastic Modulus [MPa]	Top Layer Thickness [mm]	Top Layer Density [tonnes/m3]	Sub Grade Layer Elastic Modulus [MPa]	Initial International Roughness Index (IRI) [m/km]	Final International Roughness Index (IRI) [m/km]
1	0	25	30000.00	230.00	2.3240	30.00	0.50	2.50
2	25	40	30000.00	225.00	2.3240	30.00	1.00	2.50
3	40	55	30000.00	220.00	2.3240	30.00	1.00	2.50

Vehicle Type	Average Annual Daily Traffic	Average Annual Daily Traffic Annual Growth Factor [%]	Average Fuel Consumption [L/100 km]	Primary Fuel Source	Number of Wheels	Average Number of Axles	Average Maximum Operating Weight [kg]	Description
Single-Unit 2-Axle 6-Tire or More and Combination Trucks	10,000	1.00 %	39.87	Diesel Road Short Haul	6	2.00	26,081.59	Single-Unit 2-Axle 6-Tire or More and Combination Trucks
Light Duty Vehicles	10,000	1.00 %	10.69	Gasoline	4	2.00	1,400.00	All Light Duty Vehicles - passenger cars, light trucks, vans and sport utility vehicles regardless of wheelbase.

The user must enter several parameters, for each time segment, in order to calculate the PVI effects:

Average Traffic Speed:
PVI calculations are based on the speed of traffic for a specific roadway; enter that speed here.

Ignore PVI Effects:
The PVI Effects are presented in dedicated columns in the Summary Measure results table, but if you do not want them to be included in the results, check this box.

Initial Year:
The initial year for each distinct time segment of the PVI calculation. After the first time segment, the initial year is automatically entered as the final year of the previous segment.

Final Year:
The final year for each distinct time segment of the PVI calculation. The final year of the final segment must be equal to or greater than 30 years (the default lifespan of the roadway). Time segment final year values should coincide with the years that M&R schedule major rehab or resurfacing events occur.

Top Layer Elastic Modulus (MPa):
The Elastic Modulus (E) or Young's Modulus of the pavement layer, for each time segment. The Elastic Modulus can vary greatly with temperature; an average value throughout the year is recommended. If you have multiple lifts of more than one type of pavement, you must calculate an average Elastic Modulus for the entire pavement layer. In other words, "top layer" here means the paved layer or layers above the granular base layers. This is simple in most concrete roadways, where there is only one layer, but asphalt roads usually have multiple lifts of asphalt, all of which make up the "top layer".

Asphalt Pavements typically have values between 5,000 and 10,000 MPa.
Concrete Pavements typically have values between 20,000 and 50,000 MPa.

Top Layer Thickness (mm):
The thickness of the top pavement layer, for each time segment. This is the entire depth of the pavement layer; if for example, you have three lifts of asphalt pavement of 50 mm each, you should enter 150 mm here. This value can increase or decrease due to M&R activities.

Top Layer Density (tonnes/m3):
The model is based on the deflection on a 1.0m beam (actually a 1.0 m x 1.0 m (1.0 m^2) beam) as thick as the user defines, and the mass of this beam, in kg, is needed as an input for the deflection calculation. This mass can be calculated by multiplying the thickness in mm by the density of the material in the top layer in tonnes/m^3. For example, a 200 mm layer of pavement, with a density of 2.345 tonnes/m^3 will have a Mass per Unit Length of 200 mm x 2.345 tonnes/m^3 = 469.0 kg (1.0 m x 1.0 m x 0.200 m x 2.345 tonnes/m^3 x 1000 kg/tonne). The user has already input the top layer

thickness, so all you need to do here is input the density of the top layer (in tonnes/m^3 or Tons/yd^3), and the mass of the 1.0 m beam will be calculated in the background. If you have multiple lifts of more than one type of pavement, you must calculate an average density for the entire pavement layer.

Sub Grade Layer Elastic Modulus (MPa):

The Elastic Modulus of the ground sub layer (below the granular layers). This is sometimes referred to as the California Bearing Ratio (CBR), but the input here is required in MPa or MBar.

Initial International Roughness Index (IRI) (m/km):

The IRI of the surface of the roadway, at the beginning of each time segment. Typical initial year values are between 0.5 and 1.0 [m/km] or equivalently 31.7 and 63.4 [in/mi] or equivalently 2.6 and 5.3 [ft/mi]. In practice, the difference in fuel consumption between an IRI of 0.5 and 1.0 [m/km] is negligible, so the model uses a reference IRI of 1.0 [m/km], and anything below that is assumed to be 1.0 [m/km].

Final International Roughness Index (IRI) (m/km):

The IRI of the surface of the roadway, at the end of each time segment. Although IRI can go beyond a value of 6.0 [m/km] or equivalently 380.2 [in/mi] or equivalently 31.7 [ft/mi] where the roadway is essentially unusable, values between 3.0 and 4.0 [m/km] or equivalently 190.1 and 253.4 [in/mi] or equivalently 15.8 and 21.1 [ft/mi] are typical for triggering a major rehabilitation activity.

Annual Average Daily Traffic - AADT:

Enter the AADT for both trucks and light duty vehicles.

Average Annual Average Daily Traffic Growth (%):

Enter the expected average annual increase in AADT for both trucks and light duty vehicles.

The following fields are constant inputs to the model and are not editable by the user; they are displayed for informational purposes only:

- Average Fuel Consumption (L/100 km)
- Primary Fuel Source
- Number of Wheels
- Average Number of Axles
- Average Maximum Operating Weight

Note:

The Average Fuel Consumption data was derived from the US Federal Highways Administration (FHWA) report found at the following URL:
http://www.fhwa.dot.gov/policyinformation/statistics/2010/vm1.cfm. The fuel consumption is calculated for each FHWA vehicle class based on total distance travelled and total fuel consumed for all vehicles in each class across all roads travelled on. These average data are then summarized on the basis of two vehicle types (Trucks and Passenger Vehicles). The resulting nominal fuel

consumption by vehicle type has not been correlated to vehicle speed, which varies by roadway type. In time, we hope to support all FHWA vehicle classes, if and when sufficient data is available.

Other Assumptions

For trucks (Single-Unit 2-Axle 6-Tire or More and Combination Trucks) we assume the truck has a single front axle that experiences a 0.036 MegaNewton force due to gravity and calculate the force per rear axle as (total force due to gravity – front axle force due to gravity)/number of rear axles.

For all supported vehicles, we use the higher heating value (HHV) in terms of MJ/litre.
As mentioned above, we are using a reference IRI of 1.0 [m/km].

DON'T FORGET TO CLICK "**UPDATE ROADWAY**" AT THE TOP LEFT OF THE PAGE AFTER MAKING ANY CHANGES TO THE PVI INFORMATION.

2.2.2.2 - Construction Equipment

An equipment table is filled in for large machinery like pavers and rollers. Identify pieces of equipment that will be used, their fuel consumption and their production rate. Default values are available, or users can provide custom values. "Typical" pieces of equipment are chosen for each Activity, and the user can skip any or all pieces of equipment for each Activity.

Project Information | Project Roadways | Basic Materials | Construction Equipment | Material Transportation | $ LCCA Cost Items | Operating Energy Consump.

Load Values From Database | Load User Defined Values | (values are from the user library) | * Indicates User Defined Equipment

					Fuel Consumption			Production Rates		Load Factor	hr/day	min/hr	Secondary Fuel Consumption		
		Activity	Equipment	Qty	Fuel	Value	Unit	Value	Unit	Value	Value	Value	Fuel	Value	Unit
☐		Asphalt Patch	Asphalt Paver *	1	Diesel	0.1239	l/tonne	607.5000	tonne/day	0.62	8	60			
☑		Asphalt Patch	Asphalt Remixer	1	Diesel	3.6409	l/tonne	8.3025	tonne/hr	0.62	8	60	LPG	26.8091	l/tonne
☑		Asphalt Patch	Black Topper	1	Diesel	0.0009	l/m2	10,000.0000	m2/hr	0.62	8	60	LPG	0.0042	l/m2
☑		Asphalt Patch	Cold In-Place Recycler	1	Diesel	0.0438	l/tonne	1,713.0000	tonne/hr	0.62	8	60			
☑		Asphalt Patch	Compactor	1	Diesel	0.0237	l/tonne	2,726.0000	tonne/day	0.56	8	60			
☑		Asphalt Patch	Heating Machine	1	Diesel	1.1307	l/tonne	8.3025	tonne/hr	0.62	8	60	LPG	41.6726	l/tonne

Default equipment fuel usage rates are included in the database, but can vary greatly due to many factors such a weather, soil conditions and equipment size or type. Therefore, the equipment table can be edited by users to suit their unique situation. There is an equipment library that users can customize and save for use in other projects. When a new project is started, the project construction equipment table will be populated from the equipment library. If you have customized the library, those values will appear in the project equipment table; in other words, the project will "**Load User Defined Values**". An asterisk next to an equipment name indicates that the fuel consumption value is user-defined and has been altered from the database default. In the figure above, the Asphalt Paver in the first row's fuel consumption rate has been altered; the default rate is 0.620 litres per tonne and the user defined rate is 0.1239 litres per tonne.

If the database values are required for this project, you can click on "**Load Values From Database**" and all the values in the table will revert to the database values, for this project only (any edits that you may have made to the library will remain in the library).

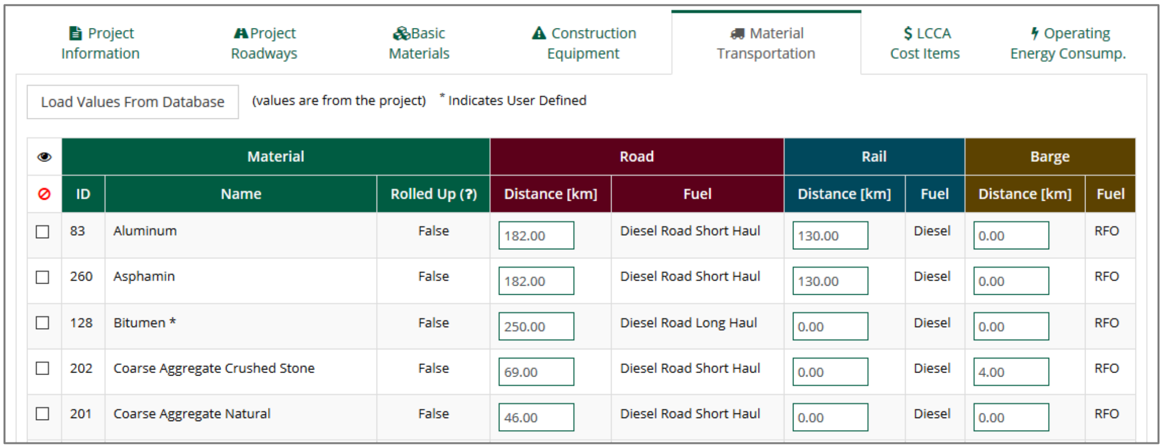
If you want to edit the fuel consumption rate for a piece of equipment, for this project, click on the green edit icon in the second column from the left, and you can change and save any or all the values pertaining to that equipment. Beware, using this example, that if you change the fuel consumption rate of the Asphalt Paver in the Asphalt Patch Activity, that same piece of equipment will NOT be changed in the other activities below. Scroll down to the Asphalt Paving HMA, Asphalt Paving WMA, Cold In-Place Recycling, Hot In-Place Recycling, Primer Coat Application, and Tack Coat Application activities all have Asphalt Paver available for use, but they will not reflect the changes just made to the first Asphalt Paver. You can change each one manually, or skip the ones you do not want to use, or, the recommended way to change them is to change the Asphalt Paver in the equipment library, then return to the construction equipment table in your project and click "**Load User Defined Values**" which will update all of the Asphalt Pavers (and every other piece of equipment too) with the values from the library.

Please refer to the Equipment Library section below for details on editing individual fuel consumption rates.

DON'T FORGET TO CLICK "**SAVE PROJECT**" AT THE TOP LEFT OF THE PAGE AFTER MAKING ANY CHANGES TO THE EQUIPMENT TABLE.

2.2.2.3 - Material Transportation

If desired, users can customize the data for transporting raw materials to manufacturing facilities (for example, moving limestone from the quarry to the cement plant). Pavement LCA uses default data from the Athena materials databases, and most users will never need to modify this; however, this table is available to do so. The default data from Athena is regionalized – average national data for materials is adjusted for energy grids and typical transportation distances by region.



Material			Road		Rail		Barge	
ID	Name	Rolled Up (?)	Distance [km]	Fuel	Distance [km]	Fuel	Distance [km]	Fuel
83	Aluminum	False	182.00	Diesel Road Short Haul	130.00	Diesel	0.00	RFO
260	Asphamin	False	182.00	Diesel Road Short Haul	130.00	Diesel	0.00	RFO
128	Bitumen *	False	250.00	Diesel Road Long Haul	0.00	Diesel	0.00	RFO
202	Coarse Aggregate Crushed Stone	False	69.00	Diesel Road Short Haul	0.00	Diesel	4.00	RFO
201	Coarse Aggregate Natural	False	46.00	Diesel Road Short Haul	0.00	Diesel	0.00	RFO

You can scroll down to the material of your choice and change the distances by road, rail and barge that that material travels from its source. If you change any of the default distances, an asterisk will appear next to that material (see Bitumen above) to indicate that it the distances are user-defined and not the database values. If you want to revert to the database values, click “**Load Values From Database**” at the top of the table.

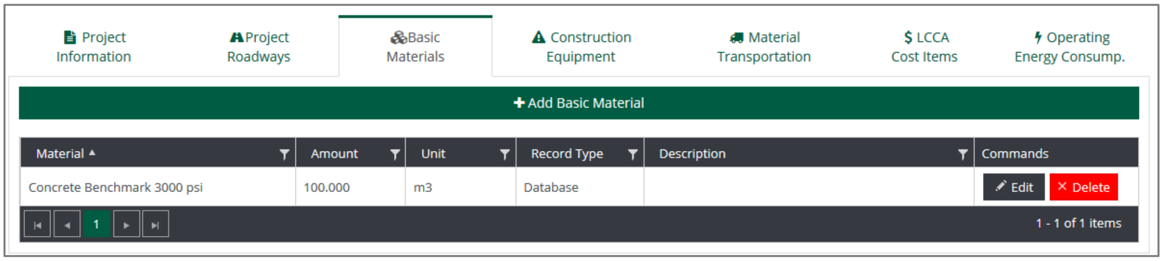
Note that these distances apply to the transportation of raw materials, from their extraction to their use point, these are not the distances that finished products like concrete or HMA travel. For instance, this table will describe the distance for bitumen to travel to the asphalt mixing plant, and aggregate distances will reflect the distances from the quarry to the site or to the mixing plant. The distance that the finished HMA travels to the site is defined in the Project Information section as Average Distance from Plant to Site.
It is likely that the distance from the quarry to the HMA plant is different than from the quarry to the job site, but you can only enter one distance per transportation mode. In that case an average distance can be used, or you can choose one or the other.

Most of the material data sets include transportation distances and modes as a separate portion, and that allows the user to customize the data here. But some material data sets have the transportation component included in the overall LCA profile and we cannot separate the process and transportation portions from each other, we call this “rolled up” data. That means that the user cannot customize these distances, and those materials are greyed out in the table and cannot be selected.

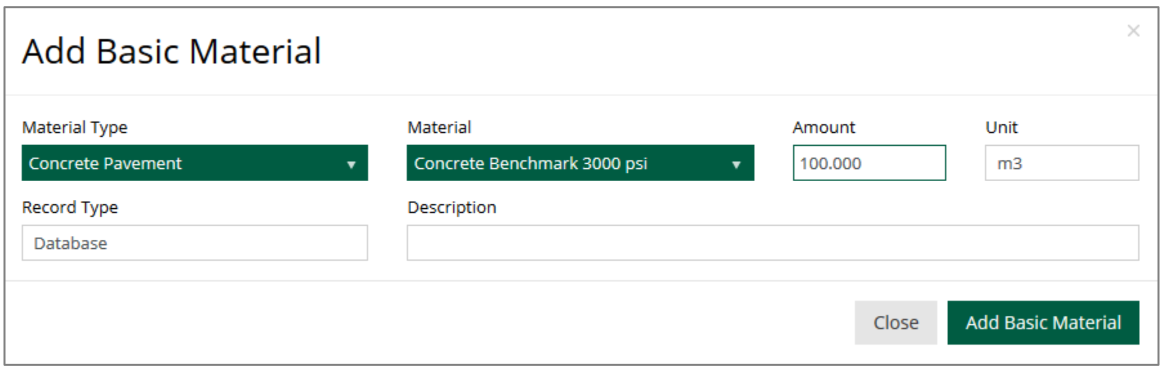
DON’T FORGET TO CLICK “**SAVE PROJECT**” AT THE TOP LEFT OF THE PAGE AFTER MAKING ANY CHANGES TO THE MATERIAL TRANSPORTATION TABLE.

2.2.2.4 - Extra Basic Materials

You can add extra basic materials to your project without modelling them in the roadway or rehabilitation activities.



Click "Add Basic Material" and the page will appear.

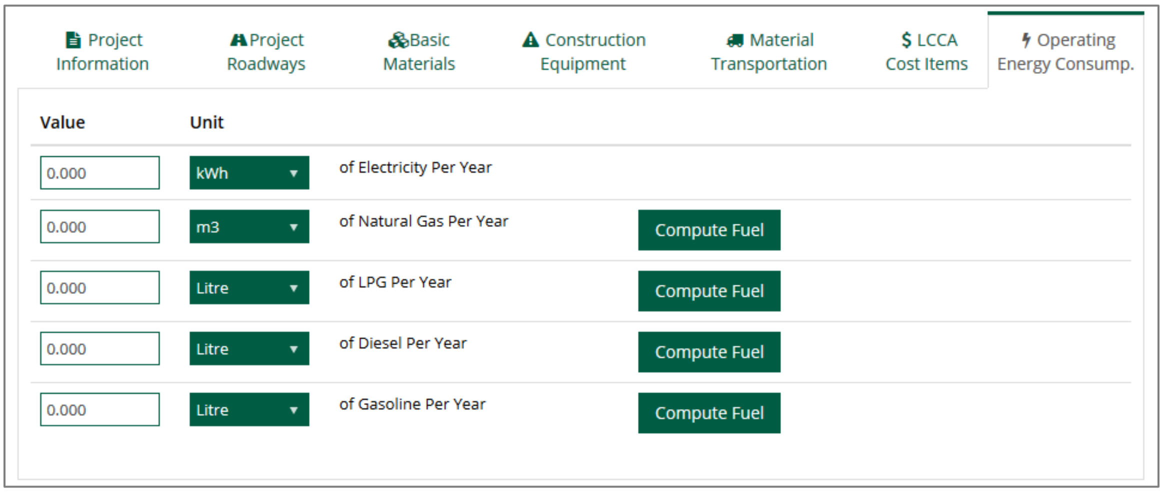


Choose a Material Type and a Material from the dropdown boxes. Then enter the amount that you wish to add to your project. The base unit is automatic and cannot be edited. A description is optional. You can enter a negative value if you wish to reduce a material amount.

Extra Basic Materials (EBMs) are treated only at year 0, or the initial construction phase of the roadway. You cannot add EBMs to rehabilitation steps in future years. This means that the effects of any EBMs will be seen in the Manufacturing phase to account for the manufacturing effects of the materials, and in the Construction Transportation phase to account for the transportation of those materials to the job site. EBMs will be included in the bill of materials, but there will be no Construction Equipment effects. Equipment effects are calculated according to Activity Types which have specific pieces of equipment associated with them, but EBMs are just materials, and you cannot specify what you are doing with those materials, hence there is no equipment associated with them.

2.2.2.5 - Operating Energy

Operating energy can be included in the LCA if the user inputs an estimate for annual operating energy consumption by fuel type (calculated using an energy simulation tool).



The software will calculate total energy, including pre-combustion energy (the energy used to extract, refine and deliver energy) and the related emissions to air, water and land over the life cycle of the roadway. The software can subsequently compare and contrast the life cycle operating and embodied energy and other environmental effects of various design options, allowing the user to better understand trade-offs.

DON'T FORGET TO CLICK "**Save Project**" AT THE TOP LEFT OF THE PAGE AFTER MAKING ANY CHANGES TO THE OPERATING ENERGY TABLE.

2.3 - Libraries

Click the down arrow on Libraries in the navigation pane, and four choices will appear: Equipment, Product, Cost Item and Roadway Assembly. The Equipment library allows you to customize the fuel consumption rate for each piece of construction equipment. The Product library allows you to define your own custom products (mixes) for concrete, asphalt or granulars, which can then be used in your roadway designs. The Cost Item library allows you to assign and save costs for products and/or activities to be used in life cycle cost analyses. Instructions for the Cost Item library will be covered in the Life Cycle Cost section of this manual. The Roadway Assembly library is hoped to be a future feature that will allow users to share roadway designs between their accounts, but is not available yet.

2.3.1 - Equipment Library

The on-site construction effects are calculated from the total fuel use of all the pieces of equipment that are assigned to each construction activity, and each piece of equipment has its own fuel consumption rate as defined in this library. The database has default values for equipment, but fuel consumption rates can vary greatly due to soil and climate conditions and equipment types, for example, and this table allows you to customize your fuel use for each piece of equipment.

The Equipment library is specific to your user account, and any edits can be applied to any of your projects. Equipment in each project can be edited separately in each project, but those changes will not affect the library values. If you want to change equipment fuel usages in general, change them in the library, then apply them to each project going forward.

Click on Equipment in the Libraries section of the navigation pane and the following table listing all the available pieces of equipment and their fuel consumption rates will appear. The fuel consumption value is used to calculate fuel use, all the other factors can be manipulated to calculate the fuel consumption. Or, if you know it, you can enter your own fuel consumption rate directly.

Equipment Library

Units SI Imperial * Indicates User Defined Equipment

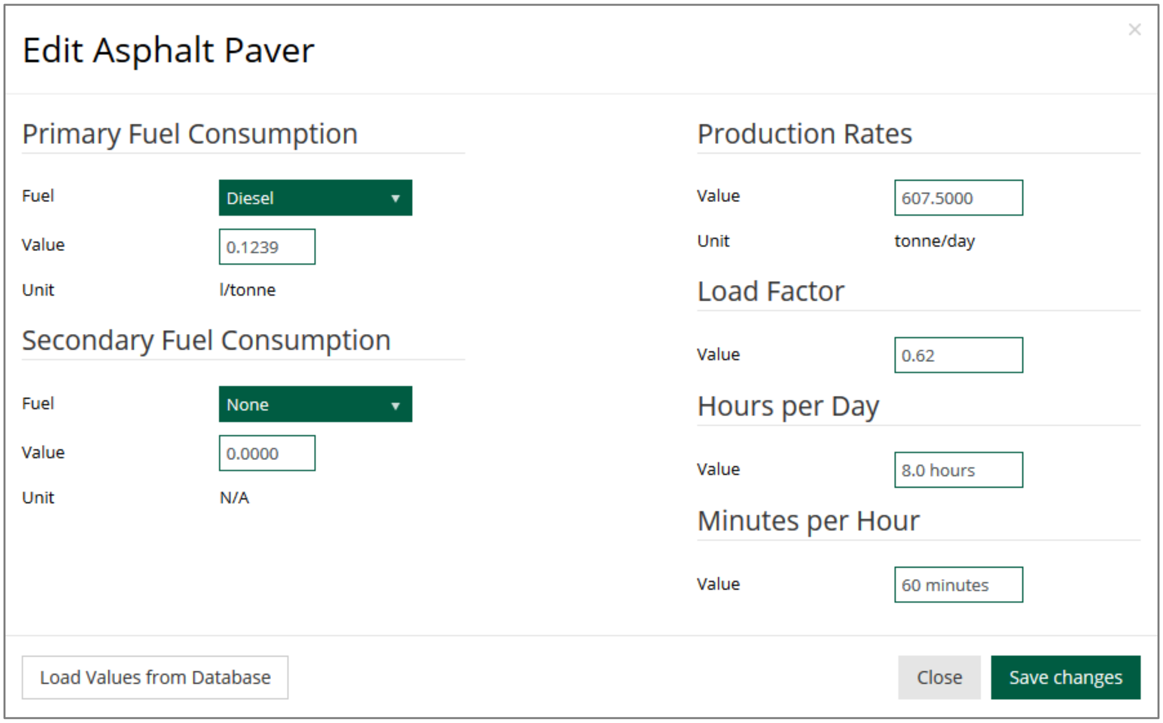
		Fuel Consumption			Production Rates		Load Factor	hr/day	min/hr	Secondary Fuel Consumption		
	Equipment	Fuel	Value	Unit	Value	Unit	Value	Value	Value	Fuel	Value	Unit
	Air Compressor	Diesel	0.0236	l/m	325.0000	m/hr	0.48	8	60			
	Asphalt Paver *	Diesel	0.1239	l/tonne	607.5000	tonne/day	0.62	8	60			
	Asphalt Remixer	Diesel	3.6409	l/tonne	8.3025	tonne/hr	0.62	8	60	LPG	26.8091	l/tonne
	Black Topper	Diesel	0.0009	l/m2	10,000.0000	m2/hr	0.62	8	60	LPG	0.0042	l/m2

Some equipment use supplementary fuels in their operation (e.g. propane heaters in a paving recycler); you can define this fuel consumption in the table.

Once you have defined the fuel consumption table, it is saved as your custom equipment library, to be used in any project.

Once you have changed the fuel consumption rate of a piece of equipment, it becomes “user defined” and an asterisk will appear in the Name column. When starting any new project, that project will inherit all values from the equipment library, and any changes that you may have made there. If there is an asterisk in the library, there will also be an asterisk in the project construction equipment table.

To edit a piece of equipment, click on the green edit icon in the left hand column and the following page will open.



Edit any values you wish and then click "**Save Changes**" to save in the library.

The fuel consumption and production rate units are defined in the database and cannot be edited; you must convert any values that you may use yourself to the same units as in the table.

The following is a description of each field in the table and the edit dialogue boxes:

Primary Fuel Consumption:

Fuel consumption is the value used to calculate the construction energy for the project, for each piece of equipment; this is the one value in each row that will affect the final LCA results. The fuel consumption is calculated using the values from the columns to the right. Changing a value in any of those columns will change the Fuel Consumption rate. It is based on an average fuel usage per hp.hr (horsepower.hour) of the particular piece of equipment, and is the product of the production rate (typically in terms of a daily volume or mass of material worked e.g. tonnes per day), the load factor (e.g. how much of the maximum horsepower it uses on average), the hours per day and the number of minutes per hour that the equipment is in use. The user can override the defaults for any of these factors with custom values but cannot change the units of these values. If you know the fuel consumption rate of the equipment, you can input this value, in the default units, overriding any calculated or default value. The fuel type is chosen by the user.

Production Rates:

The default production rate for a particular piece of equipment is based on an average value across many pieces of equipment and operating conditions, which can vary greatly. It is typically expressed in material worked by mass or volume per hour or day (e.g. tonnes/hr or m^3/day). The user can override the default and input a custom value. The default unit cannot be changed. Changing this value will change the Fuel Consumption rate.

Load Factor:
Load factor is an average percentage of a piece of equipment's rated horsepower that the equipment usually operates at. Changing this value will change the Fuel Consumption rate.

Hours Per Day:
Hours per day is the average number of hours of operation during a typical day for this piece of equipment. This value is related to those pieces of equipment whose production rate is expressed in for example, tonnes per day. Changing this value will change the Fuel Consumption rate.

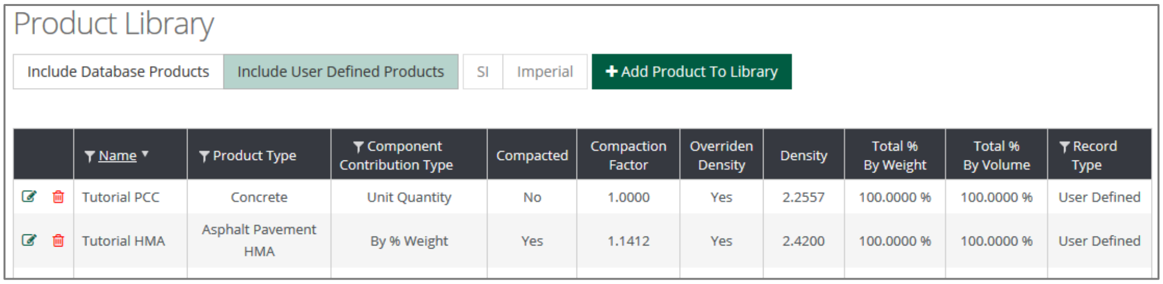
Minutes Per Hour:
This is the average portion of an hour that a piece of equipment is in use during an average hour. Changing this value will change the Fuel Consumption rate.

Secondary Fuel Consumption:
Some equipment uses supplementary fuel in its operation (e.g. propane for an asphalt recycler heater). The user can input a custom value for this fuel usage, in the default unit.

If you have edited any of the equipment and wish to revert to the database value(s), you must do so individually for each piece of equipment by clicking the edit button in the left column, then clicking “**Load Values from Database**” and then “**Save Changes**”. The value will change back to the database default and the user-defined asterisk will disappear from the library table. If you have existing projects that have used the equipment library before it was edited, they will not be automatically updated with any changes made to the library. If you want an existing project to reflect the changes made to the equipment library, open project’s Construction Transportation table and click “**Load User Defined Values**” to update the project’s equipment table with the new values in your library table. Beware, this will update all of the project equipment; if you have made custom changes specific to that project, this will overwrite those changes. If you don’t want this to happen, you must update any pieces of equipment manually in the project equipment table.

2.3.2 - Product Library

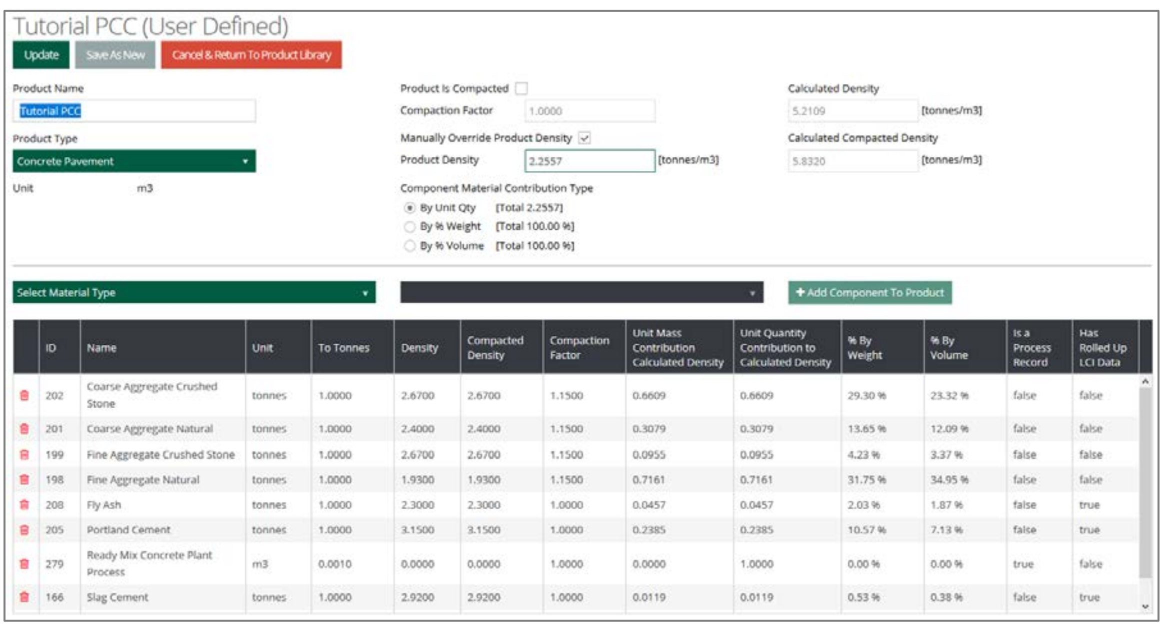
The Product Library provides you with the opportunity to add, update and manage a list of previously defined custom product "formulations" that can be re-used in any project. Click on Product in the Libraries section of the navigation pane and the following table listing your user defined products will appear. If you have not defined any custom products before the table will be empty. This figure shows two products that were previously saved in the library.



	Name	Product Type	Component Contribution Type	Compacted	Compaction Factor	Overriden Density	Density	Total % By Weight	Total % By Volume	Record Type
	Tutorial PCC	Concrete	Unit Quantity	No	1.0000	Yes	2.2557	100.0000 %	100.0000 %	User Defined
	Tutorial HMA	Asphalt Pavement HMA	By % Weight	Yes	1.1412	Yes	2.4200	100.0000 %	100.0000 %	User Defined

A custom product is composed of a set of materials that have LCI data in the database and where material contributions to the custom product are specified in either the "% by Weight" field, the "% by Volume" field, or the "Unit Quantity Contribution to Calculated Density" field. For example, a Portland cement concrete is a “product” that is made up of several “materials” like Portland cement, coarse aggregate, fine aggregate, fly ash and water.

To create a new custom product, click “**Add Product To Library**” and a blank version of the following figure will appear.



	ID	Name	Unit	To Tonnes	Density	Compacted Density	Compaction Factor	Unit Mass Contribution Calculated Density	Unit Quantity Contribution to Calculated Density	% By Weight	% By Volume	Is a Process Record	Has Rolled Up LCI Data
	202	Coarse Aggregate Crushed Stone	tonnes	1.0000	2.6700	2.6700	1.1500	0.6609	0.6609	29.30 %	23.32 %	false	false
	201	Coarse Aggregate Natural	tonnes	1.0000	2.4000	2.4000	1.1500	0.3079	0.3079	13.65 %	12.09 %	false	false
	199	Fine Aggregate Crushed Stone	tonnes	1.0000	2.6700	2.6700	1.1500	0.0955	0.0955	4.23 %	3.37 %	false	false
	198	Fine Aggregate Natural	tonnes	1.0000	1.9300	1.9300	1.1500	0.7161	0.7161	31.75 %	34.95 %	false	false
	208	Fly Ash	tonnes	1.0000	2.3000	2.3000	1.0000	0.0457	0.0457	2.03 %	1.87 %	false	true
	205	Portland Cement	tonnes	1.0000	3.1500	3.1500	1.0000	0.2385	0.2385	10.57 %	7.13 %	false	true
	279	Ready Mix Concrete Plant Process	m3	0.0010	0.0000	0.0000	1.0000	0.0000	1.0000	0.00 %	0.00 %	true	false
	166	Slag Cement	tonnes	1.0000	2.9200	2.9200	1.0000	0.0119	0.0119	0.53 %	0.38 %	false	true

1. Enter a meaningful name in the "Product Name" field.
2. Select the product type in the "Product Type" selection box.

3. Some products may be compacted, like aggregates and asphalt pavements. Others, such as concrete pavements, will not be compacted. Check the "Product is Compacted" button. The mass of products used in roadway elements will be calculated using their compacted densities and the volume of each element, while the equipment use may be calculated based on their uncompacted densities (e.g. aggregate is transported and moved uncompacted, but the final volume in a roadway is compacted).
4. If you want to manually set the final mix density, check the "Manually Override Calculated Density" checkbox and enter the product density in the box. To have the density automatically calculated according to your added components, uncheck the override box.
5. Select the "Component Material Contribution Type" from the following list:
    a. By Unit Quantity
    b. By % Weight
    c. By % Volume
6. Add the" Components" (materials) to the bottom table that compose the Product record.
    a. Select a Material Type from the left drop down box
    b. Select a Material from the right drop down box
    c. Click “Add Component To Product” and that material will appear in a new row in the table.
    d. Enter the contribution of that material in the appropriate column, either by Unit Quantity, % Weight or % Volume (according to what choice you made in the Component Material Contribution Type above).
    e. Repeat if necessary to add new components.
7. Click “**Save**” at the top left to save the new product in the library.

Notes:

1. If the "Component Material Contribution Type" is "By Percent Weight", then the Component Material "% By Weight" values must sum to 100%.
2. If the "Component Material Contribution Type" is "By Percent Volume", then the Component Material "% By Volume" values must sum to 100%.
3. For all Component Material "Process" records, e.g., "Ready Mix Concrete Plant Process", the Contribution Type can only be "By Unit Quantity". For instance, 1 unit of "Ready Mix Concrete Plant Process" is used to manufacture 1 unit of a Ready Mix Concrete Mix Design. Plant process records are added automatically when you create asphalt or concrete product types.

There are many products in the database: HMAs, WMAs, Portland cement concretes and granular mixes. These are not initially visible when you open the product library. If you want to see these products, click the “**Include Database Products**” at the top of the page and they will all appear in the table. Database products cannot be edited or deleted (the delete icon in the left column will be grey and will not work), but they can be copied. Click the green edit icon in the left column of whatever product you want to copy, and the product will open and will be listed as a Database Record. Change the name, then click “**Save As New**”, and a User Defined copy will be added to the library, and you can edit this copy as you wish and use it in your project.

2.4 - Life Cycle Cost Analysis

Life Cycle Cost Analysis (LCCA) is a new, optional feature in Pavement LCA as of v3.1 (May 2018). A deterministic economic assessment model is used to quantify agency costs associated with pavement production and their maintenance and rehabilitation (M&R), as well as user costs due to excess fuel consumption from pavement-vehicle interaction (PVI). This model was provided by Mehdi Akbarian from the Concrete Sustainability Hub at MIT.

2.4.1 - LCCA Overview

Cost data characterization is of significant importance to LCCAs. We focused on ensuring that Cost Item Data can be flexibly managed and is optimally reusable.

A **Cost Item Reference Library** has been created for Ontario and Quebec roadways using data from Applied Research Associates (ARA): “Methodology for the Development of Equivalent Pavement Structural Design Matrix for Municipal Roadways” (two reports, one for Ontario and another for Montreal and Quebec City). Additionally, starter collections are provided for Material Types for extra material costing, Activity Types as a quick pick for M&R activity costing, and Fuels used for Operating Energy Consumption and PVI. These library cost items can not be directly edited but can be copied to a User Cost Item Library or as Project Cost Items and the copies can be edited.

A **User Cost Item Library** can be created by each user. Cost Items can be copied from the Cost Item Reference Library, or manually created and uniquely specified. Users can fully edit these records.

Project Cost Items: Each project has a Cost Items tab where Cost Items can be manually created and uniquely specified, or copied from either the User or Reference Libraries. Only Cost Items that are present in the Project Cost Items tab can be inherited and applied to Initial Construction, M&R Activities, or automatically applied to costing for Extra Materials, Operating Energy Consumption, and Excess Fuel Consumption due to PVI.

Project LCCA Inputs: Project Currency, USD to CAD Exchange Rate, Real Inflation Rate, and Real Discount Rate inputs have been added to the Project Information tab. These values will be used by default when generating LCCA reports for the project. When generating LCCA comparison reports, values from the first project selected will be used.

USD to CAD Exchange Rate: Only USD and CAD currencies are supported. To find the most recent exchange rate, click the question mark to launch Bank of Canada Daily Exchange Rate webpage.

Real Inflation Rate: The real inflation rate corresponds to the latest annual inflation rate for the selected Project Location as determined by the World Bank. Click the question mark to launch the World Bank real inflation rate webpage. Download the Excel file to see the latest annual inflation rate.

2.4.2 - How to Use the LCCA Module

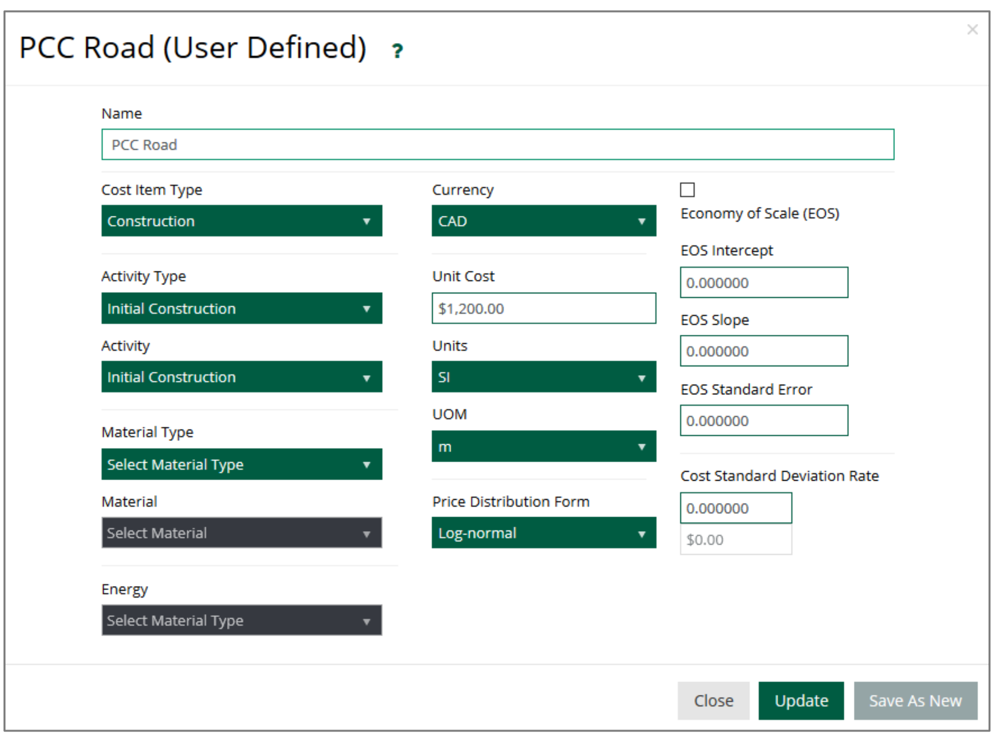
The easiest way to model your LCCA for the initial construction of a roadway and each maintenance and rehabilitation step, if you know the costs, is to enter them manually as you are modelling those elements. You can enter any value you want in the cost input boxes on each of those pages. If you want to calculate those costs using the Cost Item Library, you must first create those items, or you can use database items.

2.4.2.1 - Initial Construction:

If you want to calculate the cost of the initial construction, it is not possible to assign costs to individual materials and use your roadway design elements to arrive at a final cost. To use the cost item library to calculate the cost, the way to do it is to add up all the individual costs and divide by the length of the roadway to arrive at a $/m cost item to create in your library.

Using the tool to calculate a cost for you is a three-step process. First, you need to create the cost item in your library, and it can be used again and again in other projects. Second, you need to copy that cost item to your project's "**$ LCCA Cost Items**" table so you can use it in your current project. Lastly, you need to search for that cost item in the roadway or rehabilitation record pages to calculate the cost for you.

If you have a $/m cost for your roadway available, then you can create a cost item by clicking "**Cost Item**" under Libraries in the navigation pane, click "**Add Cost Item to Library**", and the following page will appear.



Not all of these inputs are mandatory. The Cost Item Mandatory inputs are:

1. **Name**: Provide a meaningful name for the cost item.
2. **Cost Item Type:** Site Prep, Construction, Maintenance, Operation, End of Life. At present, Site Prep and End of Life are not calculated. They are placeholders for possible future inclusion in the LCCA module. Note that the Energy drop-down list is only available when Operation is selected as the Cost Item Type.
3. **Activity Type**: all the M&R Activity Types plus Operation and Initial Construction. If Cost Item Type is Operation, the Activity Type must be Operation.
4. **Currency**: CAD, USD
5. **Unit Cost**: The default unit cost for the specified cost item. If EOS is enabled, the unit cost value will be calculated later.
6. **Units**: SI, Imperial
7. **Unit of Measure** (UOM)

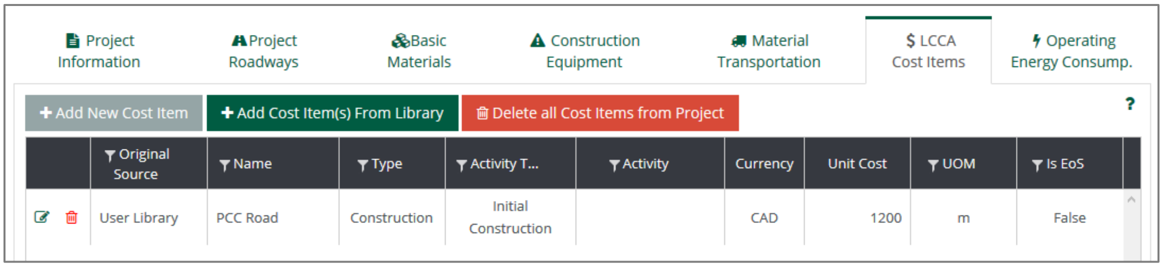
For this example we've chosen a name, Construction as the Cost Item Type, Initial Construction as the Activity Type, with a cost of $1,200 per m of roadway. Choosing Initial Construction as an activity type means that this cost item will be an available choice only from the Roadway Information page (where you model the initial construction of the roadway).

Click **Save** or **Update** to save the cost item or changes to your library.

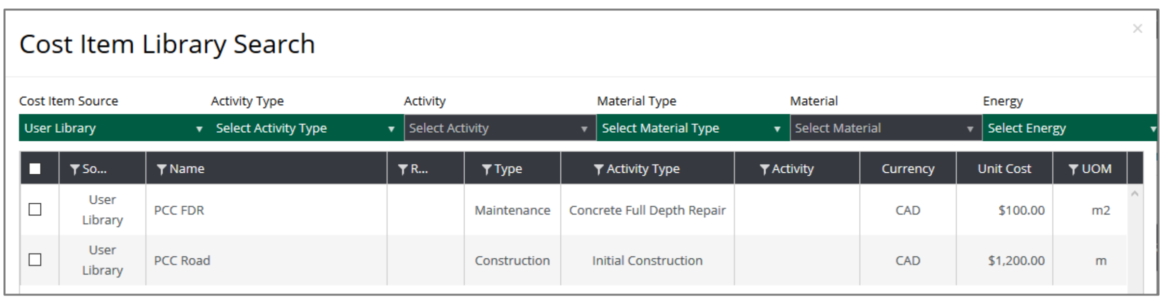
The rest of the items are optional inputs:

1. **Activity**: all the Construction and M&R Activities plus Operation and Initial Construction.
2. **Material Type**: all supported Material Type records. When a Material Type is selected, the Material drop down list is enabled and populated with a filtered list of material records that are linked to the selected Material Type. Selecting a Material Type record permits costing to be calculated for all linked materials that are used in Extra materials.
3. **Material**: all supported Material records that are linked to the selected Material Type. Selecting a material record permits material specific costing to be applied for calculating costs associated with Extra Materials and possible future ability to calculate the initial roadway construction based on the materials used in the Roadway Design plus site prep.
4. **Energy**: all supported Energy and Fuel records. The Energy drop down list is only available when Operation is selected as the Cost Item Type. Cost Item data entered here can be automatically used when calculating costs associated with Operating Energy Consumption and Excess Fuel Consumption due to PVI.
5. **Price Distribution Form**: The default is Log-normal and is included for possible future inclusion of probabilistic calculations.
6. **Economy of Scale (EOS)**: used for calculating a quantity dependent Unit Cost based on a straight-line relationship as defined by the following EOS inputs:
   a. EOS Intercept (the vertical axis value where the line crosses the vertical axis)
   b. EOS Slope (the slope of the straight line)
   a. EOS Standard Error (the standard error for the data. This is a placeholder for possible future inclusion of probabilistic calculations)
7. **Cost Standard Deviation Rate**: The default is 10% and is a placeholder for possible future inclusion of probabilistic calculations.

Now that you have saved an item in your library, the second step is to copy that item to your project. Open the "**$ LCCA Cost Items**" table in your project. It will be blank if you're working on a new project.



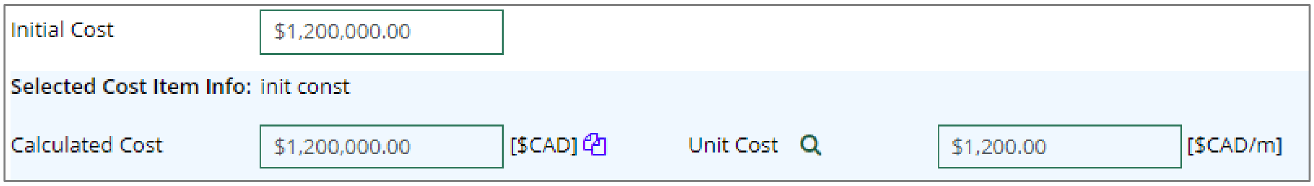
Click "**Add Cost Item(s) From Library**" and the Cost Item Library Search will appear, displaying all the cost items in the library. There are over 100 items in the library database, so you can filter the list by source, activity type, activity, material type, material or energy by clicking the down arrows in the appropriate filter box at the top of the table. The following example shows the table when the source is filtered to User Library items (those which you have created yourself).



We've created two library records for this example, PCC Road for the initial construction and PCC FDR as a full depth repair maintenance cost item. Check the Initial Construction item in the box at the left, then click "**Copy Selections**" at the bottom of the page to copy that item to the "**$ LCCA Cost Items**" table in your project.

You can also create a new cost item just for this project instead of copying one from your library. This item will only be available for use in this project and will not be saved in the library. Click on "**Add New Cost Item**" at the top of the table, and create the new item the same way as you would when creating a library item.

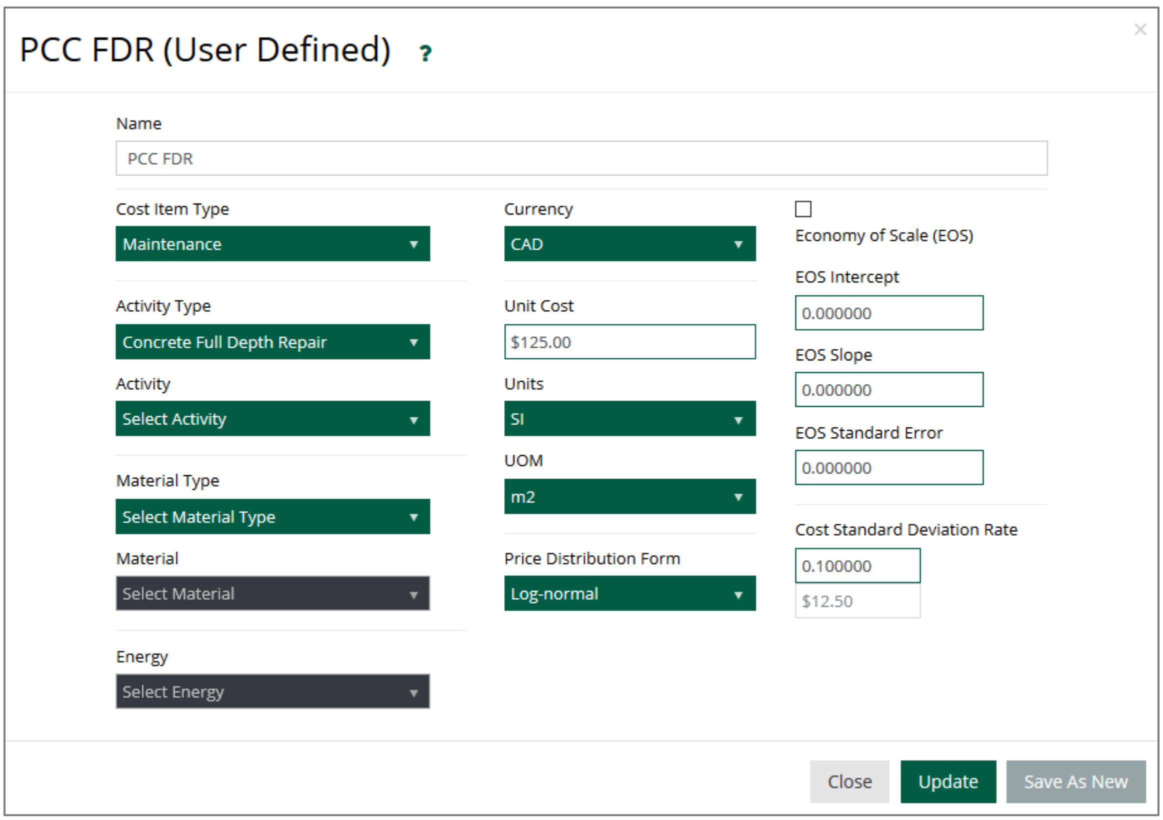
The third step is to use this cost time in the Roadway Information page. To the right of the Initial Cost box in the Survey section, click on the search icon (green magnifying glass) and a table listing all your project cost items will appear. Select the item you want, then click "**Copy Selection**". You will return to the Roadway Information page, the Unit Cost will show $1,200 and the Calculated Cost will display, $1,2000,000 in our example (a 1 km roadway, 1,000 m x $1,200/m). If you want to use this calculated cost, click the blue copy icon next to Calculated Cost, and the value will be copied to the Initial Cost box. Or, you can just copy and paste the value into the Initial Cost box.



DON'T FORGET TO CLICK "**Update Roadway**" AT THE TOP LEFT OF THE PAGE AFTER MAKING ANY CHANGES TO THE ROADWAY INFORMATION PAGE.

2.4.2.2 - Maintenance and Rehabilitation Records:

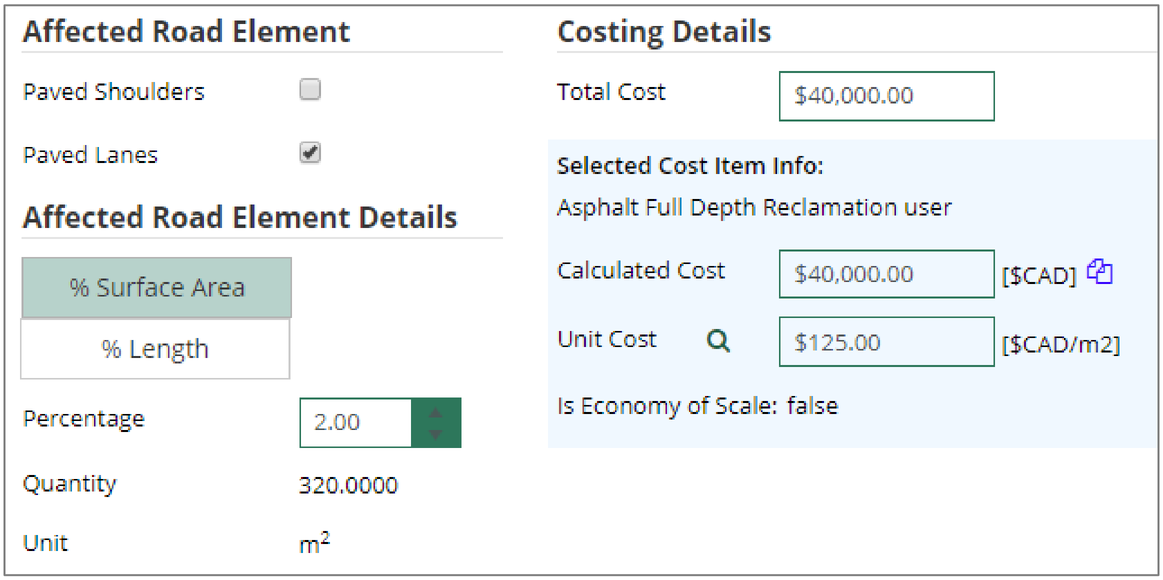
LCCA costs in maintenance and rehabilitation records work exactly the same way as those for Initial Construction: create a cost item in the library and copy it to the project, or create a new cost item in the project's "**$ LCCA Cost Items**" table, then copy it into the rehabilitation record. Our cost item example is below.



The Cost Item Type is Maintenance, and the Activity Type is Concrete Full Depth Repair, and the cost is $125.00 per m^2. The Activity, Material Type, Material and Energy choices are not necessary here because the price is based on the activity type as a whole, not on the individual steps or materials that are used. Similarly, to the initial construction costs, the tool does not calculate the cost of individual elements. The Material and Energy choices are only used when you want to calculate costs for Extra Basic Materials or Use Phase energy (operating energy and PVI fuel use).

It is important to know what the unit of measure is for the activity type that you are costing. The activity records for full and partial depth repairs, texturization, and resurfacing are all calculated on a per m^2 basis, while rout and seal and crack cleaning activities are on a per m basis. Correspondingly, you must cost those activities on a $\$/m^2$ or $/m basis.

Our example is a Concrete Full Depth Repair activity type, which is based per m^2.



On the Rehabilitation Schedule Activity Record page, click on the search icon next to the Total Cost box. The project cost items will appear, choose the one that applies to this Activity Type and click "**Copy Selection**". The Unit Cost (125.00 $\$/m^2$) and Calculated Cost (320 m^2 x 125 $\$/m^2$ = $40,000) boxes are populated. Click the blue copy icon to copy (or copy and paste) the Calculated Costto the Total Cost box.

You can also simply enter the Total Cost of the rehabilitation record directly if you know the cost, and bypass using the project cost items to calculate it.

Repeat these steps for each rehabilitation activity.

2.4.2.3 - Extra Basic Materials

You can assign cost items to EBMs. When defining the cost in the cost library or a project's cost table, you must choose a Material Type and a Material in the optional drop down boxes . Regardless of which Cost Item Type, Activity Type and Activity that you choose when defining the cost item, EBMs will be treated as Initial Construction materials in the results tables. The unit of measure will be chosen automatically according to the base unit of that material in the database.
Since EBMs are only treated as initial construction materials, the costs of EBMs will only appear in the Construction phase of the LCCA results (treated as year 0), and therefore the Net Present Value is always the same as the Total Agency Cost and no interest or discount rate calculations apply.

2.4.2.4 - Operating Energy and PVI

Operating Energy and PVI cost items are assigned the same way as initial construction, rehabilitation and operating energy cost items. They all fall under the Operation (i.e. Use Phase) Cost Item Type and Activity Type when defining the cost items and you must choose an Energy from the drop down box. Operating Energy and PVI results will be displayed in their own columns in the LCCA reports. When Choosing the Energy, a list of all the energy types in the database appears, and you can assign a cost to any of them you wish, however, not all those energy types are available for your use in the tool. For instance, there are four natural gasses in the Energy drop down box and if you add Natural Gas in Operating Energy, "Natural Gas (Industrial Boiler)" will be used in the calculations. If you add a cost item to one of the other three natural gasses, there will be no cost calculations in the LCCA reports because the Operating Energy uses the "Natural Gas (Industrial Boiler)" database profile. If you assign a cost item to "Natural Gas (Industrial Boiler)", you will get your LCCA results.
The same applies to PVI. PVI calculates a total of excess fuel use and the two profiles used in PVI results are "Diesel Road Short Haul" for trucks and "Gasoline" for light duty vehicles, so those are the two profiles that must have cost items if you want to calculate LCCA results. The following Energies are what should be assigned cost items if you want LCCA results for Operating Energy and PVI:

Operating Energy	Cost Item Energy
Electricity	Electricity
Natural Gas	Natural Gas (Industrial Boiler)
LPG	LPG (Industrial Boiler)
Diesel	Diesel (Industrial Boiler)
Gasoline	Gasoline

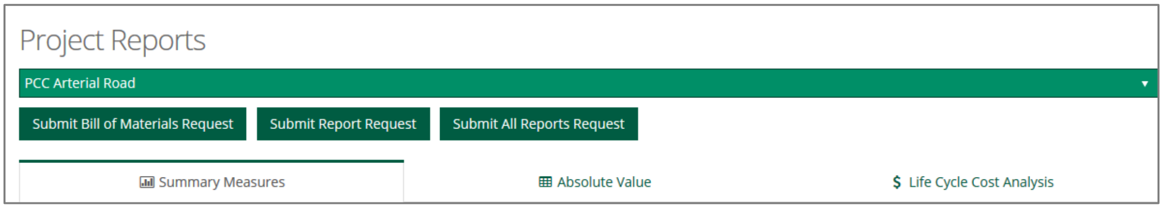
PVI	Cost Item Energy
Trucks	Diesel Road Short Haul
Light Duty Vehicles	Gasoline

2.5 - Results

The software reports footprint data for the following LCA environmental impact measures consistent with the US EPA TRACI methodology[1]: global warming potential, acidification potential, human health criteria, ozone depletion potential, smog potential, and eutrophication potential. Pavement LCA additionally reports total primary energy, non-renewable energy and fossil fuel consumption. Pavement LCA takes into account the environmental impacts of the following life cycle stages: material manufacturing, including resource extraction and recycled content and related transportation; on-site construction; and maintenance and rehabilitation effects; annual and total operating energy effects; and Pavement Vehicle Interaction effects. Demolition and disposal are not addressed, as highways typically have very long service lives. The software also presents a Bill of Materials report that sums up the totals of each material in the user's roadway design, and a Life Cycle Cost Analysis (LCCA) report.

2.5.1 - Project Reports

You can produce a Bill of Materials, Summary Measure (LCA results), Absolute Value (LCI or life cycle inventory) and/or a Life Cycle Cost Analysis report for each single project. To create the reports, click on **Project Reports** after clicking the down arrow next to Reports in the navigation pane to the left and the Project Reports page will appear.

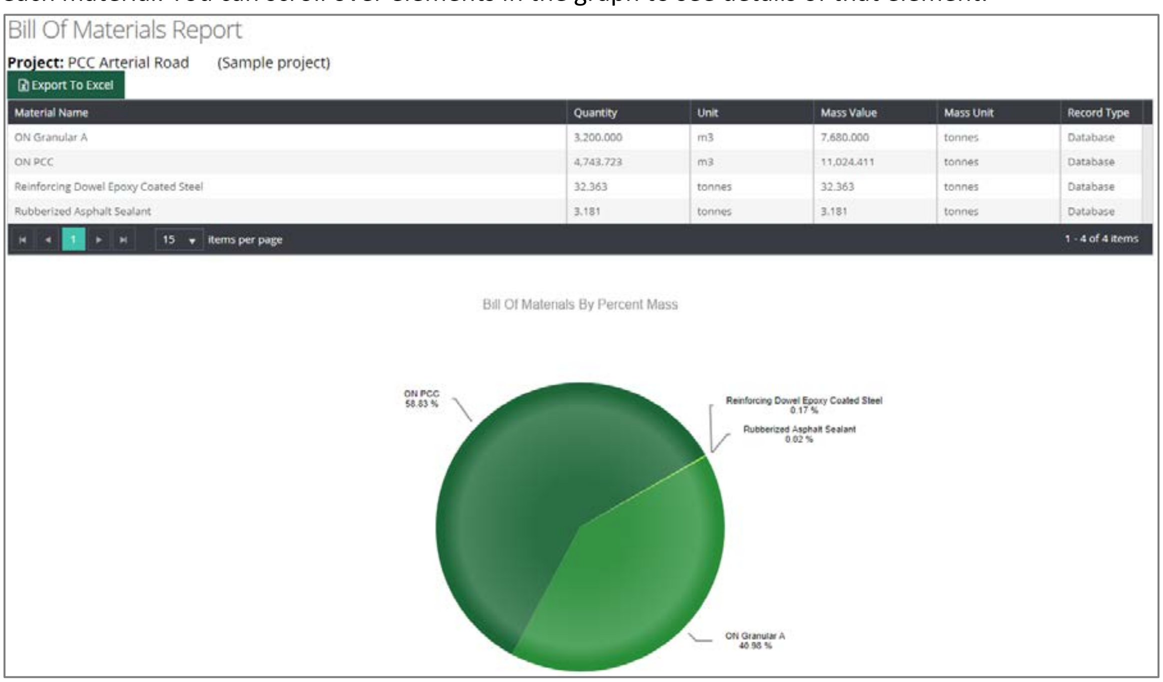


Select the project that you want from the drop down box at the top of the page. The "**Submit Report Request**" button will open a new tab in your browser and give you the single report of whichever of the three tabs you have chosen below: Summary Measures, Absolute Value or Life Cycle Cost Analysis. "**Submit All Reports Request**" will produce all the reports: BOM, Summary Measures, Absolute Value and LCCA.

All project reports can be exported to Excel by clicking the "**Export To Excel**" button at the top of the report.

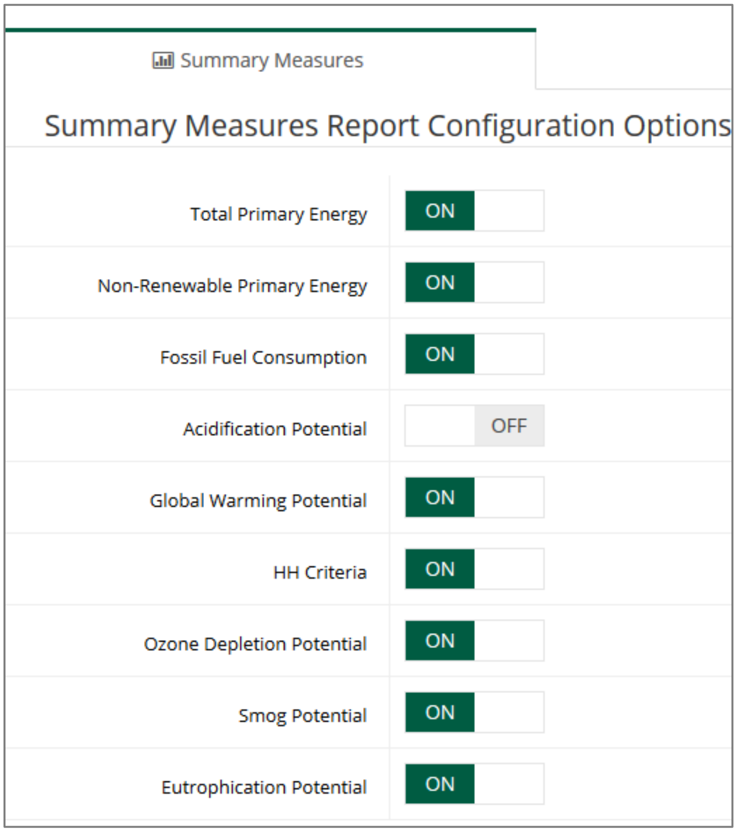
2.5.1.1 - Bill of Materials

The "**Submit Bill of Materials Request**" is self explanatory; click here if you want to produce a BOM report. The data is presented in tabular form as well as a pie chart of the percentages by mass of each material. You can scroll over elements in the graph to see details of that element.



2.5.1.2 - Summary Measures

Click on the Summary Measures tab, and you can choose which measures you want to appear in the report by clicking each measure on or off. They are all on by default.

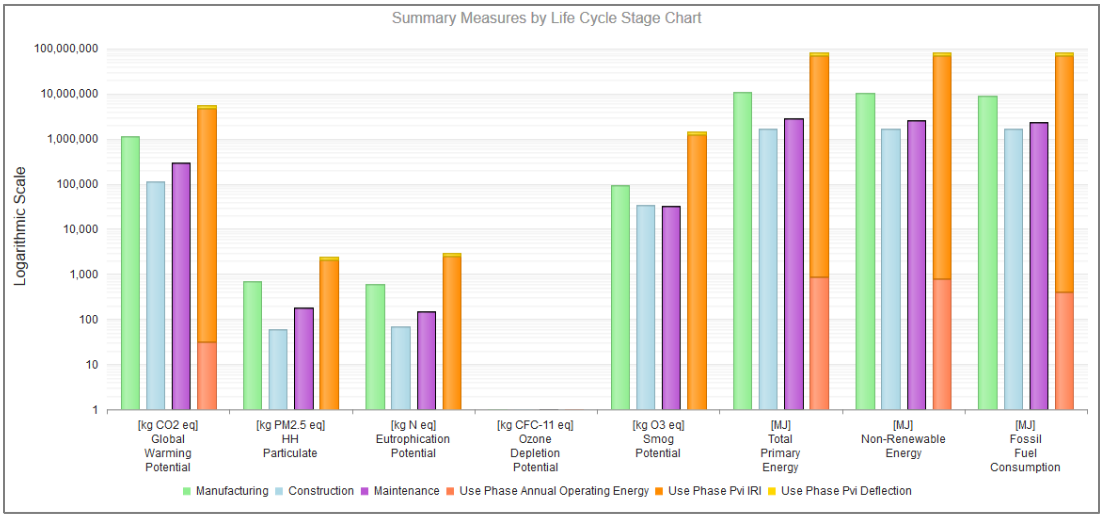


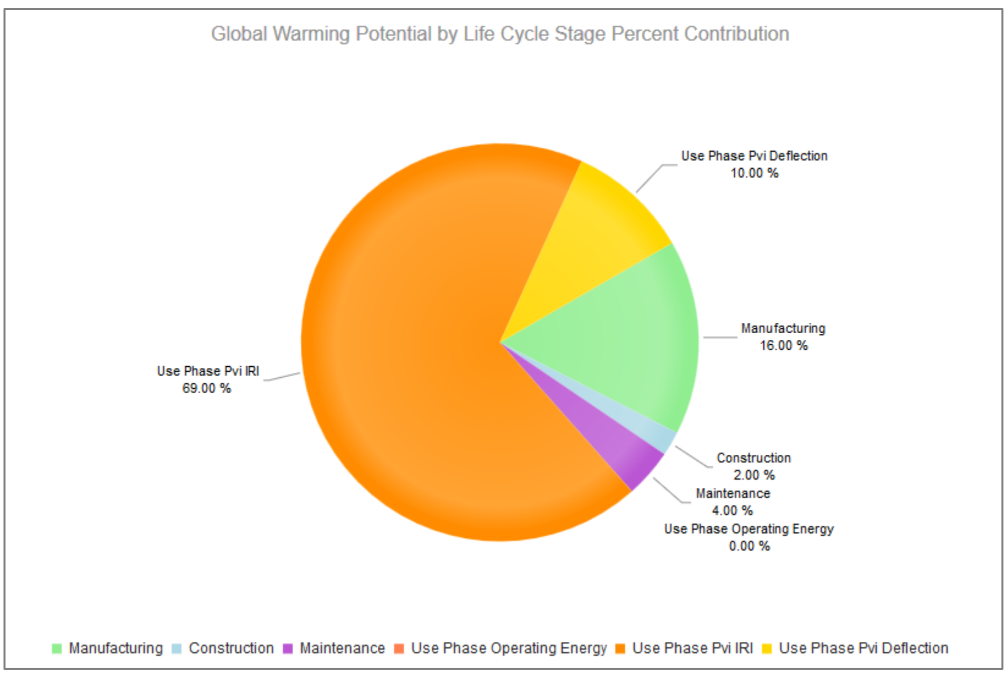
The table presents the LCA or environmental effects in life cycle stages, material manufacturing, (including resource extraction and recycled content and related transportation), on-site construction, maintenance and rehabilitation effects, annual and total operating energy effects and Pavement Vehicle Interaction effects.

Summary Measures

Summary Measure	Unit	Manufacturing			Construction			Maintenance & Rehabilita	
		Material	Transportat...	Total	Equipment	Transportat...	Total	Materials & Equipment	Transportat...
Global Warming Potential	kg CO2 eq	1.083e+6	5.762e+4	1.141e+6	7.259e+4	4.123e+4	1.138e+5	2.726e+5	1.828e+4
HH Particulate	kg PM2.5 eq	6.743e+2	3.061e+1	7.049e+2	3.867e+1	2.196e+1	6.062e+1	1.697e+2	9.726e+0
Eutrophication Potential	kg N eq	5.505e+2	3.508e+1	5.855e+2	4.338e+1	2.464e+1	6.802e+1	1.353e+2	1.098e+1
Ozone Depletion Potential	kg CFC-11 eq	1.526e-2	2.027e-6	1.526e-2	2.533e-6	1.439e-6	3.972e-6	3.535e-3	6.391e-7
Smog Potential	kg O3 eq	7.362e+4	1.785e+4	9.147e+4	2.203e+4	1.251e+4	3.453e+4	2.613e+4	5.579e+3
Total Primary Energy	MJ	1.030e+7	8.395e+5	1.114e+7	1.058e+6	6.011e+5	1.659e+6	2.550e+6	2.665e+5
Non-Renewable Energy	MJ	9.416e+6	8.391e+5	1.026e+7	1.058e+6	6.008e+5	1.659e+6	2.360e+6	2.663e+5
Fossil Fuel Consumption	MJ	8.046e+6	8.378e+5	8.883e+6	1.056e+6	5.999e+5	1.656e+6	2.119e+6	2.659e+5

The same results are also displayed in a bar chart showing all the chosen measures, by life cycle stage, and a pie chart showing the contribution of each life cycle stage of the global warming potential summary measure. You can scroll over elements in the graph to see details of that element.





When exported to Excel, the table is included with two versions of the bar chart, but the pie chart is not included. The Excel charts are editable and you can customize or create any chart you want from the tabular data.

Pavement LCA produces Life Cycle Impact Assessment (LCIA) results for these mid-point impact measures:

2.5.1.2.1 - Global Warming Potential (GWP)

Global warming potential is a reference measure. The methodology and science behind the GWP calculation can be considered one of the most accepted LCIA categories. GWP will be expressed on an equivalency basis relative to CO_2 – in kg or tonnes CO_2 equivalent.

Carbon dioxide is the common reference standard for global warming or greenhouse gas effects. All other greenhouse gases are referred to as having a "CO_2 equivalence effect" which is simply a multiple of the greenhouse potential (heat trapping capability) of carbon dioxide. This effect has a time horizon due to the atmospheric reactivity or stability of the various contributing gases over time.

As yet, no consensus has been reached among policy makers about the most appropriate time horizon for greenhouse gas calculations. The International Panel on Climate Change100-year time horizon figures have been used here as a basis for the equivalence index:
CO_2 Equivalent kg = CO_2 kg + (CH_4 kg x 25) + (N_2O kg x 298).

While greenhouse gas emissions are largely a function of energy combustion, some products also emit greenhouse gases during the processing of raw materials. Process emissions often go unaccounted for due to the complexity associated with modelling manufacturing process stages. One example where process CO_2 emissions are significant is in the production of cement (calcination of limestone). Because Pavement LCA uses data developed by a detailed life cycle modelling approach, all relevant process emissions of greenhouse gases are included in the resultant global warming potential index.

2.5.1.2.2 - Acidification Potential (AP)

Acidification is a more regional rather than global impact effecting human health when high concentrations of NO_x and SO_2 are attained. The acidification potential of an air or water emission is calculated on the basis of its SO_2 equivalence effect on a mass basis.

2.5.1.2.3 - Human Health (HH) Particulate

Particulate matter of various sizes (PM_{10} and $PM_{2.5}$) have a considerable impact on human health. The EPA has identified "particulates" (from diesel fuel combustion) as the number one cause of human health deterioration due to its impact on the human respiratory system – asthma, bronchitis, acute pulmonary disease, etc. It should be mentioned that particulates are an important environmental output of plywood product production and need to be traced and addressed. The Institute used TRACI's "Human Health Particulates from Mobile Sources" characterization factor, on an equivalent $PM_{2.5}$ basis, in our final set of impact indicators.

2.5.1.2.4 - Aquatic Eutrophication Potential (EP)

Eutrophication is the fertilization of surface waters by nutrients that were previously scarce. When a previously scarce or limiting nutrient is added to a water body it leads to the proliferation of aquatic photosynthetic plant life. This may lead to a chain of further consequences ranging from foul odours to the death of fish. The calculated result is expressed on an equivalent mass of nitrogen (N) basis.

2.5.1.2.5 - Ozone Depletion Potential (ODP)

Stratospheric ozone depletion potential accounts for impacts related to the reduction of the protective ozone layer within the stratosphere caused by emissions of ozone depleting substances

(CFCs, HFCs, and halons). The ozone depletion potential of each of the contributing substances is characterized relative to CFC-11, with the final impact indicator indicating mass (e.g., kg) of equivalent CFC-11.

2.5.1.2.6 – Smog Potential or Photochemical Ozone Formation Potential (SP)

Under certain climatic conditions, air emissions from industry and transportation can be trapped at ground level where, in the presence of sunlight, they produce photochemical smog, a symptom of photochemical ozone creation potential (POCP). While ozone is not emitted directly, it is a product of interactions of volatile organic compounds (VOCs) and nitrogen oxides (NOx). The "smog" indicator is expressed on a mass of equivalent O_3 basis.

2.5.1.2.7 - Total Primary Energy Consumption (TPE)

Total Primary Energy Consumption is reported in mega-joules (MJ).Embodied primary energy includes all energy, direct and indirect, used to transform or transport raw materials into products and buildings, including inherent energy contained in raw or feedstock materials that are also used as common energy sources. (For example, natural gas used as a raw material in the production of various plastic (polymer) resins.) In addition, Pavement LCA captures the indirect energy use associated with processing, transporting, converting and delivering fuel and energy.

2.5.1.2.8 - Non-renewable Energy Consumption (NRE)

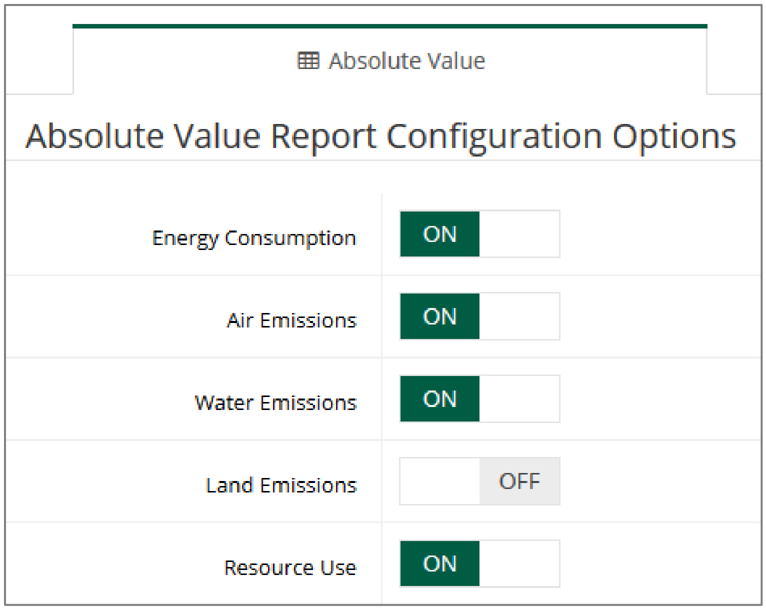
Non-renewable Energy Consumption is reported in mega-joules (MJ) and is a subset of Total Primary Energy Consumption, and includes all the fossil fuels and nuclear.

2.5.1.2.9 - Fossil Fuel Consumption (FF)

Fossil Fuel Consumption is reported in mega-joules (MJ) and is a subset of Total Primary Energy Consumption, namely all the fossil fuels. In other words, all the energy sources in the Energy Consumption Absolute Value table, except for hydro, non-hydro renewable, nuclear and wood.

2.5.1.3 - Absolute Value

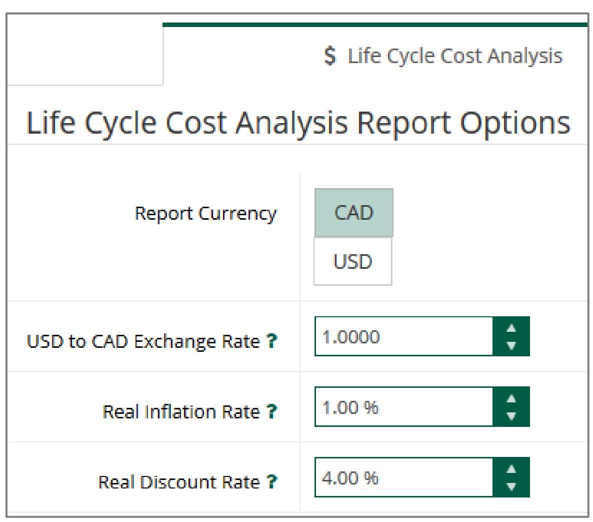
Click on the Absolute Value tab, and you can choose which absolute value or LCI tables you want to appear in the report by clicking each table on or off. They are all on by default.



Absolute Value tables for Energy Consumption, Air, Water and Land Emissions and Resource Use are available. Tabular results are presented by life cycle stage and bar graphs for Energy Consumption, Land Emissions and Resource Use. There are typically 100-200 Air and Water Emissions which renders those graphs unreadable, so they are not included. Absolute Value reports are also exportable to Excel.

2.5.1.4 - Life Cycle Cost Analysis (LCCA)

Click on the Life Cycle Cost Analysis tab, and you can choose which currency, exchange rate, inflation rate and discount rate that you wish to use in the report. All these will default to whatever values you specified in the Project Information page when you first created the project. You can change these values here and produce a report, as many times as you like, but that will not change the Project Information values that are saved with the project.



Two tables and three graphs are created when you submit the LCCA report request. The first is as summary table of actual costs for each year of agency costs (costs to construct, maintain and operate the roadway) and user costs (excess fuel use for vehicles due to PVI). This table will only show years in which costs are incurred; in our example, we are including operating energy PVI results, therefore there are costs every year. If we ignored the PVI effects and did not have any operating energy, the table would only be five rows long showing the initial construction costs at year O and the rehabilitation costs at years 12, 25 and 40, and the residual costs (the pro-rated costs of any rehabilitation step lifespans that extend past the lifespan of the roadway) at year 50.

There is a Site Preparation column, but that module is not yet available in the tool, so the values will all be 0; it is there as an expected future feature.

Life Cycle Cost Analysis Report - Annual Net Present Value Summary

Project: PCC Arterial Road (Sample project)

Currency: CAD **Calculated NPV:** $2,407,541 **Inflation Rate:** 1.00 % **Discount Rate:** 4.00 % **USD to CAD Exchange Rate:** 1.0000

Export To Excel

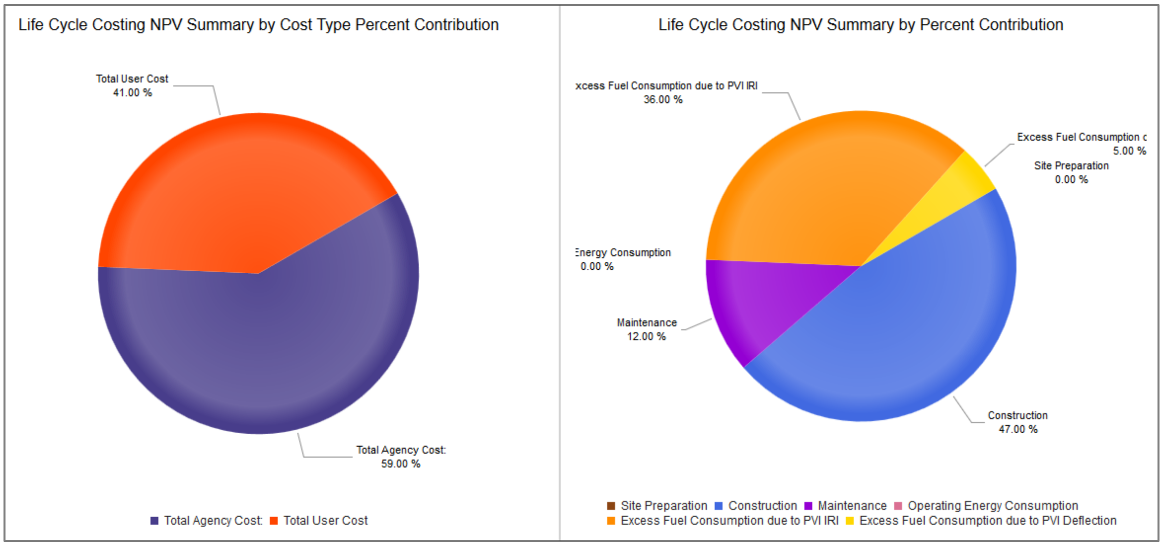
Year	Site Preparation	Construction	Maintenance	Operating Ener... Consumption	Total Agency C...	Excess Fuel Co... due to PVI IRI	Excess Fuel Co... due to PVI Defl...	Total User Cost	Total Cost
0	$0.00	$1,121,280.00	$0.00	$0.00	$1,121,280.00	$0.00	$0.00	$0.00	$1,121,280.00
1	$0.00	$0.00	$0.00	$97.12	$97.12	$26,973.56	$3,603.62	$30,577.18	$30,674.30
2	$0.00	$0.00	$0.00	$94.31	$94.31	$26,457.43	$3,534.67	$29,992.10	$30,086.41
3	$0.00	$0.00	$0.00	$91.59	$91.59	$25,951.18	$3,467.04	$29,418.21	$29,509.80
4	$0.00	$0.00	$0.00	$88.95	$88.95	$25,454.61	$3,400.70	$28,855.30	$28,944.26
5	$0.00	$0.00	$0.00	$86.39	$86.39	$24,967.55	$3,335.62	$28,303.17	$28,389.55
6	$0.00	$0.00	$0.00	$83.89	$83.89	$24,489.80	$3,271.80	$27,761.60	$27,845.49

The second table shows the annual net present value (NPV) details. Each individual cost is shown, the year that it occurs and the NPV or residual value.

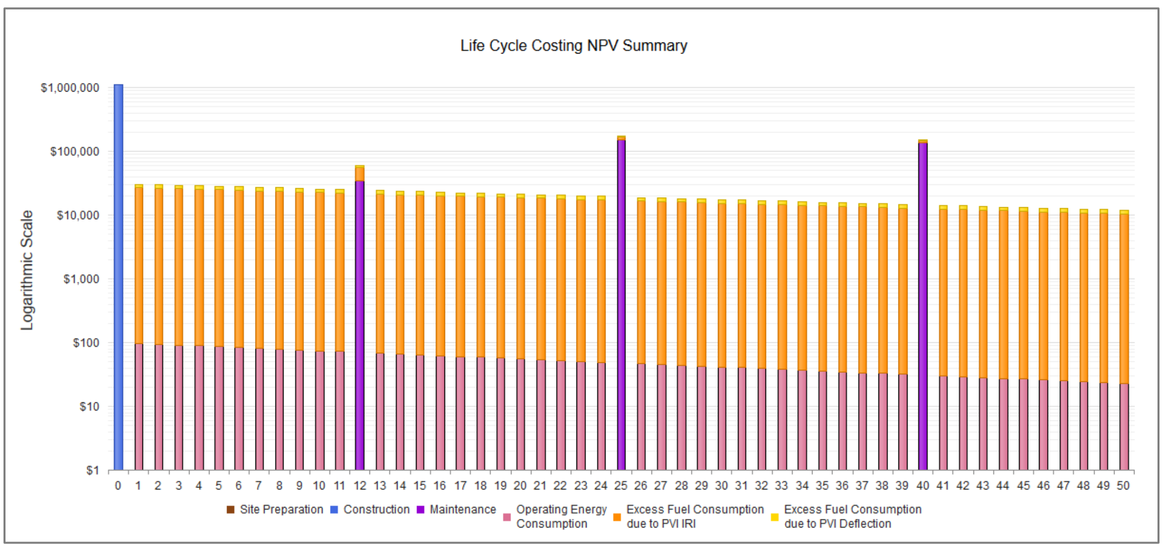
Life Cycle Cost Analysis Report - Annual Net Present Value Details

Year	Category	Sub Category	Specification Description	Cost	Net Present Value	Residual Value	Residual Net Present Value
0	Construction	Initial Construction	ON-Mun.Maj.Art.-PCC-10,000 AADTT-Mr 30Mpa	$1,121,280.00	$1,121,280.00	$0.00	$0.00
1	Operation	Operating Energy Consumption	Diesel (Industrial Boiler)	$101.00	$97.12	$0.00	$0.00
1	Operation	Diesel Road Short Haul	Diesel Road Short Haul	$18,894.31	$18,167.60	$0.00	$0.00
1	Operation	Gasoline	Gasoline	$9,158.19	$8,805.95	$0.00	$0.00
1	Operation	Diesel Road Short Haul	Diesel Road Short Haul	$3,735.84	$3,592.15	$0.00	$0.00
1	Operation	Gasoline	Gasoline	$11.93	$11.48	$0.00	$0.00
2	Operation	Operating Energy Consumption	Diesel (Industrial Boiler)	$102.01	$94.31	$0.00	$0.00
2	Operation	Diesel Road Short Haul	Diesel Road Short Haul	$19,274.08	$17,819.97	$0.00	$0.00
2	Operation	Gasoline	Gasoline	$9,342.27	$8,637.45	$0.00	$0.00
2	Operation	Diesel Road Short Haul	Diesel Road Short Haul	$3,810.93	$3,523.41	$0.00	$0.00

Two pie charts showing the total agency costs NPV vs. the total user costs NPV, and the percent NPV contribution of each life cycle phase. Residual values are not included in these charts. You can scroll over elements in the graph to see details of that element.



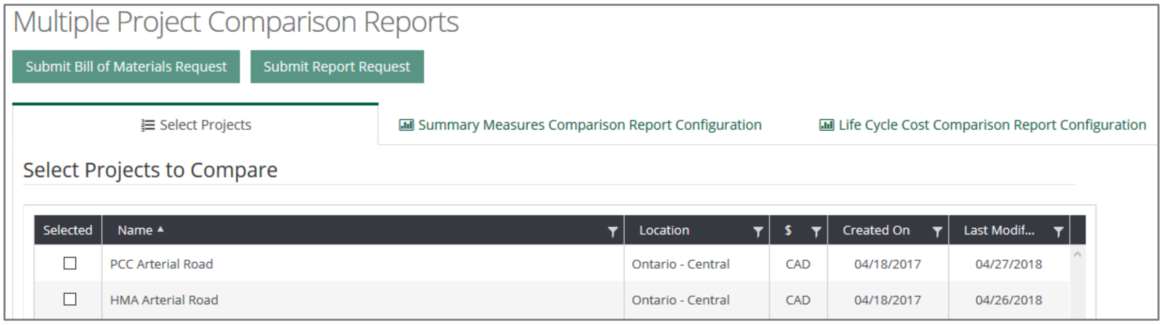
The third graph is a stacked bar chart summary of NPV for each year of the lifespan of the project. Residual values are not included in this chart. You can scroll over elements in the graph to see details of that element.



2.5.2 - Comparison Reports

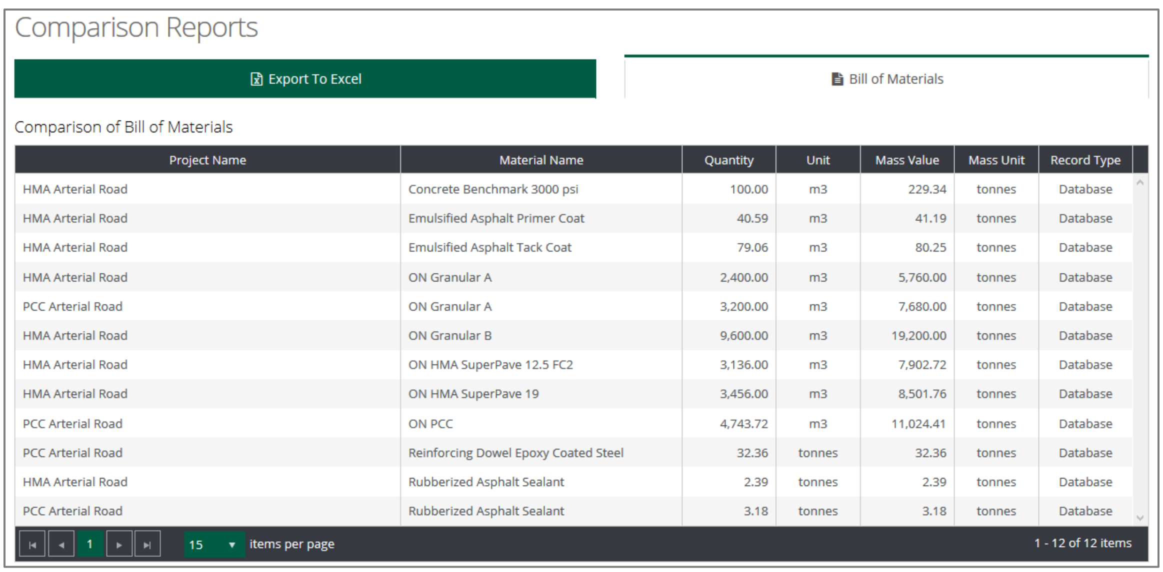
Comparison reports allow you to compare the bills of materials, summary measures and LCCA reports of multiple projects side by side. Click on **Comparison Reports** after clicking the down arrow next to Reports in the navigation pane to the left and the Multiple Project Comparison Reports page will appear, with all of your projects listed with check boxes to the left. Check the projects you want to compare, then submit a report request to create the report in a new tab in your browser.

All project comparison reports can be exported to Excel by clicking the "**Export To Excel**" button at the top of the report, except for the Life Cycle Cost Analysis charts.



2.5.2.1 - Bill of Materials

Click "**Submit Bill of Material Request**" and a BOM report (table only) sorted by material name and project name will be created. You can export the table to Excel.



Project Name	Material Name	Quantity	Unit	Mass Value	Mass Unit	Record Type
HMA Arterial Road	Concrete Benchmark 3000 psi	100.00	m3	229.34	tonnes	Database
HMA Arterial Road	Emulsified Asphalt Primer Coat	40.59	m3	41.19	tonnes	Database
HMA Arterial Road	Emulsified Asphalt Tack Coat	79.06	m3	80.25	tonnes	Database
HMA Arterial Road	ON Granular A	2,400.00	m3	5,760.00	tonnes	Database
PCC Arterial Road	ON Granular A	3,200.00	m3	7,680.00	tonnes	Database
HMA Arterial Road	ON Granular B	9,600.00	m3	19,200.00	tonnes	Database
HMA Arterial Road	ON HMA SuperPave 12.5 FC2	3,136.00	m3	7,902.72	tonnes	Database
HMA Arterial Road	ON HMA SuperPave 19	3,456.00	m3	8,501.76	tonnes	Database
PCC Arterial Road	ON PCC	4,743.72	m3	11,024.41	tonnes	Database
PCC Arterial Road	Reinforcing Dowel Epoxy Coated Steel	32.36	tonnes	32.36	tonnes	Database
HMA Arterial Road	Rubberized Asphalt Sealant	2.39	tonnes	2.39	tonnes	Database
PCC Arterial Road	Rubberized Asphalt Sealant	3.18	tonnes	3.18	tonnes	Database

2.5.2.2 - Summary Measures

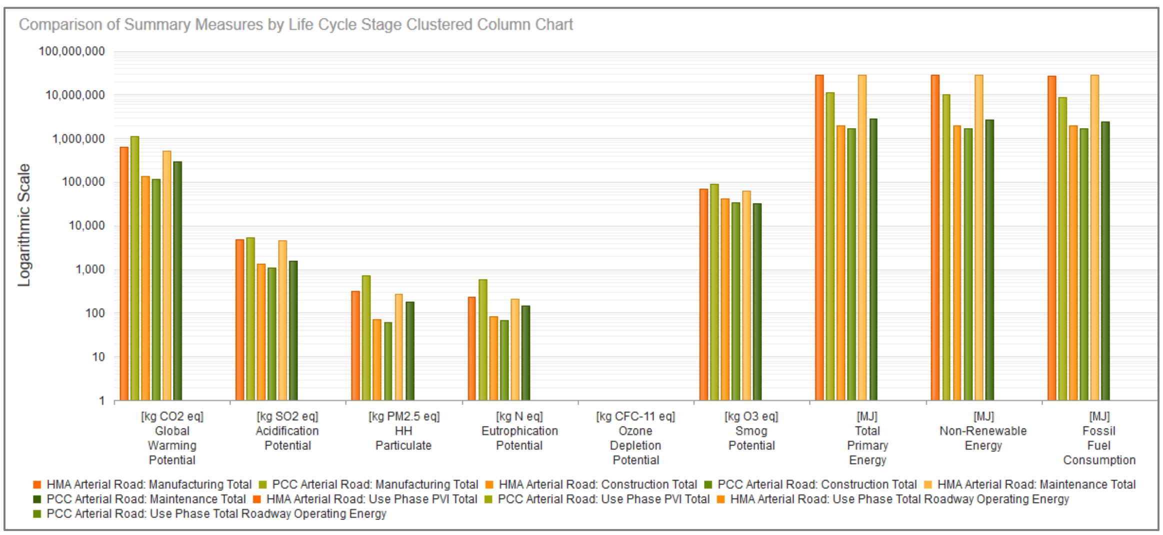
Click on the Summary Measures Comparison Report Configuration tab, and like single project reports, you can choose which summary measures that you wish to include in the report by turning each measure on or off. There are two format options and two ways to group the results in the comparison reports.

If you choose "**Grouped Totals**" under Report Group Type Options, the results will be condensed into the major life cycle stage group totals for the Manufacturing, Construction, Maintenance & Rehabilitation, Embodied Totals, Roadway Operating Energy and PVI life cycle stages. If you group by "**Individual by Life Cycle Stage**" the table will be expanded to include all the typical life cycle stages including the material, transportation, equipment, annual operating energy, PVI IRI, PVI deflection and Totals columns. For the graphs at least, all of the individual columns can create a very busy graph with so many data columns that it becomes difficult to read, especially if you are comparing three or more projects and all of the summary measures. Our table and graph examples below show only the Grouped Totals reports.

Under Report Format Options you have two options. "**Absolute Value**" will present the actual value of each summary measure of each project side by side.

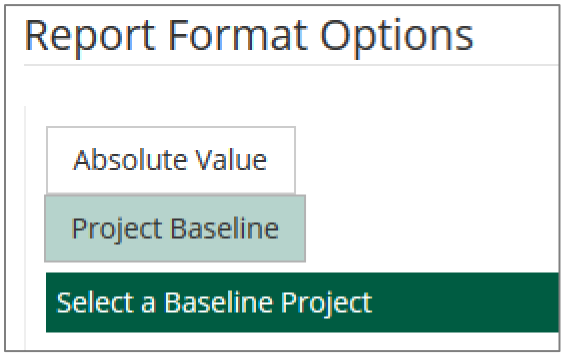
Comparison of Summary Measures by Life Cycle Stage

Project Name	Summary Measure	Unit	Manufacturing	Construction	Maintenance & Rehabilitation	Embodied Totals	Use Phase: Roadway Operati... Energy
			Total	Total	Total	Total	Total
HMA Arterial Road	Global Warming Potential	kg CO2 eq	6.267e+5	1.361e+5	5.200e+5	1.283e+6	0.000e+0
PCC Arterial Road	Global Warming Potential	kg CO2 eq	1.141e+6	1.138e+5	2.909e+5	1.546e+6	0.000e+0
HMA Arterial Road	Acidification Potential	kg SO2 eq	4.775e+3	1.309e+3	4.567e+3	1.065e+4	0.000e+0
PCC Arterial Road	Acidification Potential	kg SO2 eq	5.391e+3	1.095e+3	1.536e+3	8.021e+3	0.000e+0



Project Baseline reports compare all the reports to a baseline project on a percentage basis. In other words, the baseline project will appear in the report as 100% for all measures, and the other projects will show their percentages compared to the baseline.

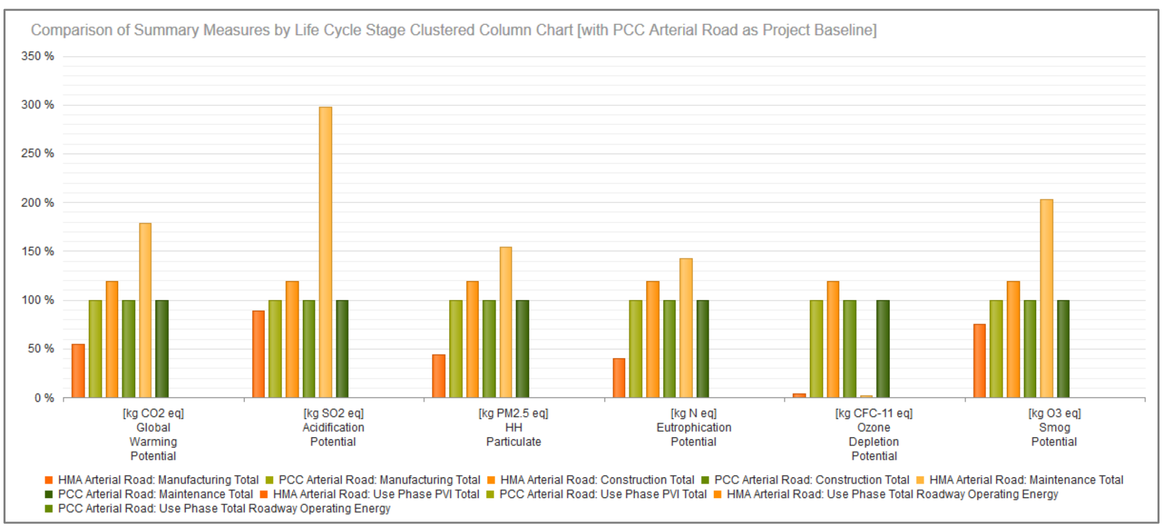
If you choose "**Project Baseline**", a drop down box will appear asking you to select a baseline project.



Select the project that you want to be represented as 100% in the report then click "**Submit Report Request**". A table and bar graph will be created in a new tab in your browser.

Comparison of Summary Measures by Life Cycle Stage [with PCC Arterial Road as Project Baseline]

Project Name	Summary Measure	Unit	Manufacturing	Construction	Maintenance & Rehabilitation	Embodied Totals	Use Phase: Roadway Operati... Energy
			Total	Total	Total	Total	Total
HMA Arterial Road	Global Warming Potential	kg CO2 eq	54.9 %	119.6 %	178.8 %	83.0 %	0.0 %
PCC Arterial Road	Global Warming Potential	kg CO2 eq	100.0 %	100.0 %	100.0 %	100.0 %	0.0 %
HMA Arterial Road	Acidification Potential	kg SO2 eq	88.6 %	119.6 %	297.4 %	132.8 %	0.0 %
PCC Arterial Road	Acidification Potential	kg SO2 eq	100.0 %	100.0 %	100.0 %	100.0 %	0.0 %



The report exported to Excel will include the table and two versions of the bar graphs.

2.5.2.2 - Life Cycle Cost Analysis (LCCA)

Click on the Life Cycle Cost Comparison Report Configuration tab, and like single project reports, you can change your currency, exchange rate, inflation rate and discount rates before producing the report. Any changes to these values are for this report only and will not change in the project information page. If you have different rates in the projects that you have selected, the values from the first project that is selected will be defaulted to this page. The projects must all be compared at the same rates, and the first project selected is just the default on this page; you can change these rates to the ones you wish for the analysis without altering the individual projects. If the wrong project's values are showing, click the Select Projects tab, unselect the projects and then reselect starting with the correct project. Click on the Life Cycle Cost Comparison Report Configuration tab again and the rates from the first project will be showing. Or, just change them manually.

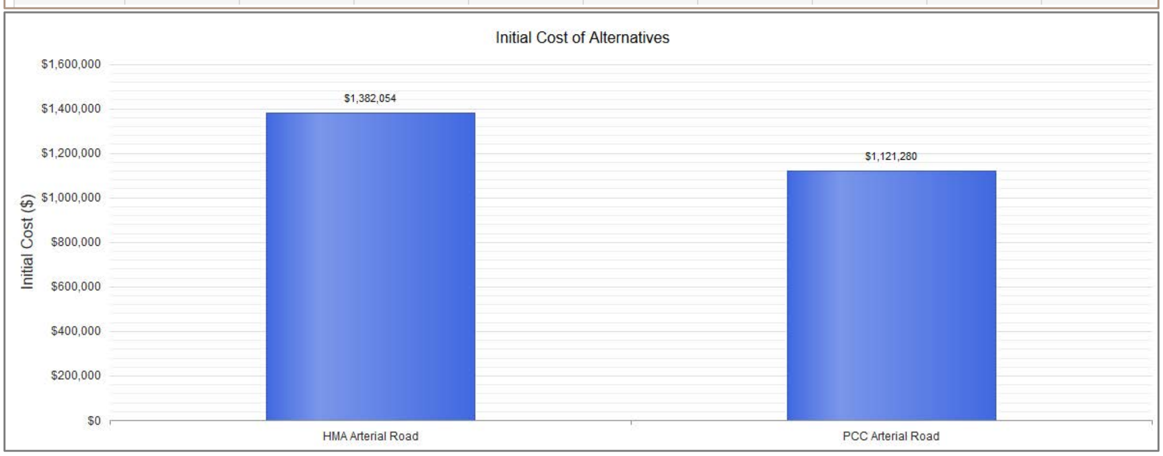
Click "**Submit Report Request**" to create an NPV table comparing the selected projects for each life cycle stage, a bar graph comparing the Initial Costs and a stacked bar graph comparing the Total NPV costs.

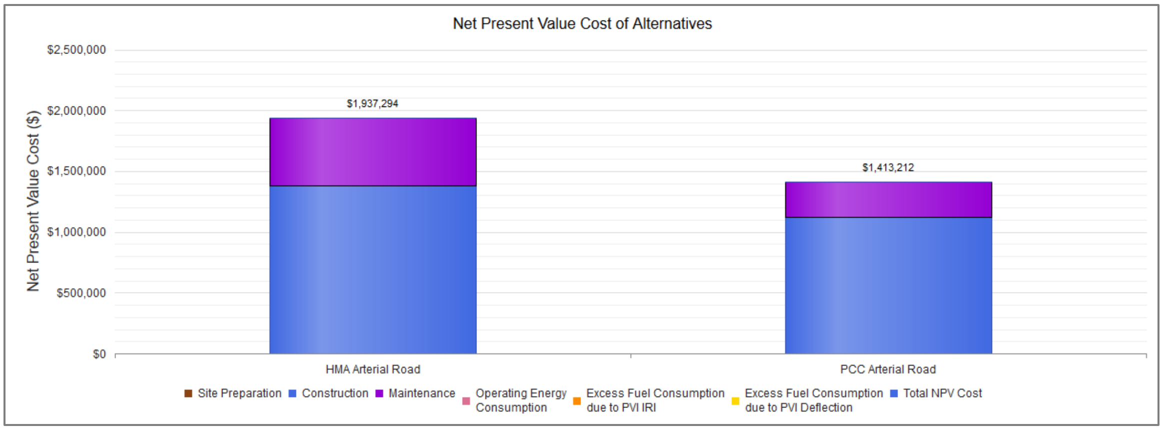
Life Cycle Cost Analysis Comparison Report - Net Present Value Summary

Currency: CAD **Inflation Rate:** 0.90 % **Discount Rate:** 3.90 % **USD to CAD Exchange Rate:** 1.0000

Export To Excel

Project Name	Site Preparation	Construction	Maintenance	Operating Energy Consumption	Total Agency Cost	Excess Fuel Consumption due to PVI IRI	Excess Fuel Consumption due to PVI Deflection	Total User Cost	Total Cost
HMA Arterial Road	$0.00	$1,382,054.00	$555,240.37	$0.00	$1,937,294.37	$0.00	$0.00	$0.00	$1,937,294.37
PCC Arterial Road	$0.00	$1,121,280.00	$291,932.39	$0.00	$1,413,212.39	$0.00	$0.00	$0.00	$1,413,212.39





3.0 - Support

This document is the primary help file for the tool. There are occasional links to help documents in the tool appearing as Question mark icons "?". Click on the icon and a link to a webpage or PDF file will give you access.

In the navigation pane on the left, click on the down arrow next to **Support** and 4 choices are available, Knowledge, History, Issues and Contact.

3.1 - Knowledge

This page will be augmented over time to include information as features are added or changed as the tool evolves.

At present it includes a link to the latest version this document on our software web site at https://calculatelca.com/software/pavement-lca/user-manual/.

Information about our database in general, and some specific LCA reports can be found at our corporate web site www.athenasmi.org

Tutorial videos can be accessed from this page or from a link on the top frame of the site which is visible at all times.

3.2 - History

Release Histories are shown here and document what changes have been made between versions of the tool. Results are exported with version numbers, and if you return to a project and a new version has been released, your results may have changed depending on what revisions may have been made. You can check here to see what has changed since you produced your results.

Note: With the desktop version of the tool, you had to download and install any new versions that came out, and if you wanted to preserve your projects and reproduce your results, you may have chosen to not update the tool to the new version. You no longer have this option. Being a web tool means that there is only one version, the latest, available at any one time. If you come back to the tool after an update that alters your results, you cannot revert to the previous version.

3.3 - Issues

This page lists the bugs and enhancements that have been submitted by users and their status. Click on “**Add a Bug, Issue or Enhancement Request**” button at the top of the page to submit an issue to the team.

3.4 - Contact

All questions, requests and contacts can be made at info@athenasmi.org .