Impact Estimator for Highways: User Guide

Last updated: April 2013

The Athena Impact Estimator for Highways is an LCA-based software package that makes life cycle assessment data easily accessible to transportation engineers. The Impact Estimator for Highways is built using the same methodology as the well-established Impact Estimator for Buildings. It provides a cradle-to-grave life cycle inventory profile for a given area of paved roadway. 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 tool was intended for freeways and major arterials, but can be applied to any roadway.

How it 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 Athena Institute and from Simapro. Material data represent national or industry averages for the extraction, processing and manufacturing of each material. Regional energy grids and transportation distances are applied to the average data to arrive at regional data profiles.
**Inputs**

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.

Lifespan default is 50 years but can be changed to 30 to 100 years. This figure dictates rehabilitation events such as scheduled resurfacing.

The gross roadway paved surface area is the functional unit. Results are reported for this area of roadway, and it is calculated automatically from the roadway assembly designs.

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.
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). The Impact Estimator 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.

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.

A table is available if custom mixes are required for asphalt or concrete. Create custom mixes by entering component materials as a percentage of weight.
On the roadway design page, users will describe the roadway cross-section. The purpose of this screen is to determine the geometry of the roadway so that the software can calculate material volumes.

Choose a pre-defined design from the database or begin a new design. Although this is not a life cycle costing tool, the user can input costs for initial construction and rehabilitation/maintenance tasks, and then export them for use in a life cycle costing tool.

Select a pavement type: flexible or rigid and reinforcing steel if appropriate.
Define right and left shoulders and rounding.

A schematic cross-section of the roadway will appear (not to scale). Assign materials, widths and thicknesses of each element in the schematic.

Click the Rehabilitation Schedule tab to enter a rehabilitation/maintenance schedule. These screens address materials added and taken away over the service life of the roadway. Note that the environmental impacts of maintenance activities with a life span longer than the
service life are prorated. Greyed-out text fields contain values that are read from the Athena databases or are calculated values from the roadway design. The first table shows a summary of all the rehabilitation steps, one per row, and by clicking on the edit button in the leftmost column, the second table appears with the details of each rehabilitation step.

Click the Pavement Vehicle Interaction (PVI) tab to enter PVI data for each roadway assembly. The PVI module calculates the increase of fuel consumption of a roadway over...
an ideal case, according to the stiffness and roughness of the top layer of the roadway surface, according to a model developed at MIT. The user can choose to ignore PVI results and not include them in the final results.

### Results
The software reports footprint data for the following 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. The Impact Estimator additionally reports fossil fuel consumption.

The Impact Estimator 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 replacement 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.

### Summary Measure Table By Life Cycle Stages

**Project:** Concrete Highway

<table>
<thead>
<tr>
<th>Material</th>
<th>Quantity</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete PC 30 MPa (flyash 25%)</td>
<td>265.7913</td>
<td>Tonnes</td>
</tr>
<tr>
<td>Concrete PLC 30 MPa (flyash 25%)</td>
<td>54150.3401</td>
<td>Tonnes</td>
</tr>
<tr>
<td>Granular A</td>
<td>184.2489</td>
<td>Tonnes</td>
</tr>
<tr>
<td>Granular B Type I</td>
<td>23580.0000</td>
<td>Tonnes</td>
</tr>
<tr>
<td>Granular B Type II</td>
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<td>Tonnes</td>
</tr>
<tr>
<td>Granular C</td>
<td>13221.9622</td>
<td>Tonnes</td>
</tr>
<tr>
<td>Reinforcing Dowel Epoxy Coated Steel</td>
<td>22.5282</td>
<td>Tonnes</td>
</tr>
<tr>
<td>Silicone Sealant</td>
<td>179.7048</td>
<td>Tonnes</td>
</tr>
</tbody>
</table>

Graphical results can also be produced, to compare two or more projects, by life cycle stage, on a project baseline basis (one project is set at 100%, and the other projects are compared to it on a percentage basis), or on a per square metre of roadway basis, or by the absolute values of each life cycle stage.
Comparison Of Global Warming Potential
By Life Cycle Stages
Concrete Highway #1 as Project Baseline

Percent


[Legend]
- Concrete Highway #1
- Concrete Highway #2
The LCA calculation excludes some aspects of roadway design as they are assumed to be largely common for all designs: site preparation, water management and utility infrastructure.

(1) US Environmental Protection Agency, Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts, 2007.
**Future Work**
Operating energy such as roadway lighting and vehicle fuel consumption is addressed in the LCA only if the user supplies annual energy consumption – the tool will not calculate this value.

The Impact Estimator can be further customized for specific regions.

[Contact the Athena Institute for more information.](#)

**IMPORTANT NOTES**
**THIS IS NOT A STRUCTURAL DESIGN TOOL. IT SHOULD NOT BE USED TO MAKE STRUCTURAL DESIGN DECISIONS.**