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Pavement Environmental Life Cycle Assessment Tool for Local Governments

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RESEARCH REPORT

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Pavement Environmental Life Cycle Assessment Tool for Local Governments

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16. Abstract
The processes in the pavement life cycle can be defined as: material extraction and production; construction; transport of materials and demolition; the use stage, where the pavement interacts with other systems; the materials, construction, and transport associated with maintenance and rehabilitation; and end-of-life. Local governments are increasingly being asked to quantify greenhouse gas emissions from their operations and identify changes to reduce emissions. There are many possible strategies that local governments can choose to reduce their emissions, however, prioritization and selection of which to implement can be difficult if emissions cannot be quantified. Pavement life cycle assessment (LCA) can be used by local governments to achieve the same goals as state government. The web-based software *environmental Life Cycle Assessment for Pavements*, also known as eLCAP has been developed a project-level LCA tool. The goal of eLCAP is to permit local governments to perform project-level pavement LCA using California specific data, including consideration of their own designs, materials, and traffic. eLCAP allows modeling of materials, transport, construction, maintenance, rehabilitation, and end-of-life recycling for all impacts; and in the use stage it considers the effects of combustion of fuel in vehicles as well as the additional fuel consumed due to pavement-vehicle interaction (global warming potential only). This report documents eLCAP and a project that created an interface for eLCAP that is usable by local governments.

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Pavement Environmental Life Cycle Assessment Tool for Local Governments

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Glossary

AADT	average annual daily traffic
AADTT	average annual daily truck traffic
AB	aggregate base
Caltrans	California Department of Transportation
eLCAP	environmental Life Cycle Assessment for Pavements
EPA	Environmental Protection Agency
ESAL	equivalent single axle loads
FHWA	Federal Highway Administration
GHG	greenhouse gas
GWP	global warming potential
HMA	hot mix asphalt
IPR	in-place recycled
IRI	International Roughness Index
LCA	life cycle assessment
LCI	life cycle inventory
LCIA	life cycle impact assessment
LRS	location reference system
PCC	portland cement concrete
RHMA-G	rubberized hot mix asphalt-gap graded
TRACI	Tool for Reduction and Assessment of Chemicals and Other Environmental Impacts
u-so	unit process, single operation (terminology in the application GaBi)
UI	user interface

Executive Summary

Executive Summary

The processes in the pavement life cycle can be defined as: material extraction and production; construction; transport of materials and demolition; the use stage, where the pavement interacts with other systems; the materials, construction, and transport associated with maintenance and rehabilitation; and end-of-life. The use stage currently typically focuses on the combustion of fuel in vehicles and the interaction of vehicles with the pavement, although other use stage processes include interactions with stormwater, heat island effects, active transportation use, and lighting.

Agencies that own and manage pavements have a growing need to be able to quantify their greenhouse gas (GHG) emissions and the other environmental impacts of pavement operations, and to consider GHG and those other impacts in pavement management, conceptual design, design, materials selection, and construction project delivery decisions. They also need to be able to evaluate the life cycle environmental impacts as part of policy and standards development. All these tasks can be performed using life cycle assessment (LCA). There are different constraints and requirements with respect to the scope of the LCA and the data available for each of these different applications. The web-based software environmental Life Cycle Assessment for Pavements, also known as eLCAP has been developed as a project-level life cycle assessment tool. This report documents eLCAP and a project that created an interface for eLCAP that is usable by local governments. eLCAP was designed for use by pavement engineers, managers, and policy personnel.

There are many possible strategies that local governments can choose to reduce their emissions, however, prioritization and selection of which to implement can be difficult if emissions cannot be quantified. Pavement LCA can be used by local governments to achieve the same goals as state government, including 1) quantification of environmental impacts from the pavement life cycle; 2) comparison of design alternatives and comparison of policy alternatives—such as changes in specifications for construction quality, materials, and pavement management decision trees; and 3) evaluation of pavement impacts in planning alternatives, provided that conceptual designs are available to sufficiently define details.

The eLCAP (environmental Life Cycle Assessment for Pavements) software is a web-based software project-level life cycle assessment tool that uses California-specific life cycle inventories and processes. The goal of eLCAP is to permit local governments to perform project-level pavement LCA using California specific data, including consideration of their own designs, materials, and traffic. eLCAP allows modeling of materials, transport, construction, maintenance, rehabilitation, and end-of-life recycling for all impacts; and in the use stage it considers the effects of combustion of fuel in vehicles as well as the additional fuel consumed due to pavement-vehicle interaction (global warming potential only).

eLCAP was developed with funding from the California Department of Transportation and internal funds from the University of California Pavement Research Center (UCPRC). All the data and functions of eLCAP are the same in the Caltrans and local government versions. The differences are in the input data needed by the user to

define the scope of the pavement project and traffic data for use stage calculations. The Caltrans version of eLCAP uses Caltrans definitions for defining the pavement structure and uses information in Caltrans databases such as the number of lanes, traffic data, and climate region data based on the project location on the state highway network. The development of the local government interface was funded with Senate Bill 1 funds from the University of California Institute of Transportation Studies (UC ITS).

eLCAP is intended to follow the Federal Highway Administration Pavement LCA Framework and International Standards Organization guidance for LCA. The data quality assessment approach developed by the US Environmental Protection Agency and used by the Federal LCA Commons program has been updated and used in eLCAP. eLCAP performs a formal mass-balancing procedure on a pavement LCA project model, and then computes 18 different impact indicator values (identified by their variable names), among which are Global Warming Potential (GWP), Human Health Particulate Air, Acidification, and different forms of Primary Energy. eLCAP also generates a detailed Excel report file to display graphs and tables of results.

eLCAP models the life cycle history of a pavement project by allowing a user to specify any number of construction-type events, occurring at a user-specified date, followed by an automatically generated Use Stage event that begins immediately afterward and lasts until the next construction-type event or the End-of-Life (EOL) date. Construction-type events require user input specifications for materials and their associated quantities, transport types and their associated distances, and construction equipment and their associated times of operation. eLCAP has built-in library versions for these processes based on California and Caltrans practices. These library-based processes allow a user to analyze a specific pavement project or create user-defined processes based on library versions, and then customize the amounts and sources of inputs that go into that user-defined process.

Use stage-type events, which are automatically generated for each user-defined construction-type event, have a start date immediately after the end of the construction event and an end date specified by the user. Currently, eLCAP is limited in that it only computes GHG for pavement-vehicle interaction for internal combustion engine vehicles in the Use Stage, using baseline fuel consumption for a very smooth pavement and excess fuel consumption from pavement roughness (in terms of International Roughness Index [IRI]). The tool models the environmental effects of “using” the pavement project by computing the GHGs from traffic (cars and trucks) driving over it during the time span of the Use Stage. eLCAP allows the user to report total emissions from vehicles, or only those caused by vehicle interaction with the pavement roughness.

eLCAP generates an Excel spreadsheet that contains bar and pie charts for 18 impact indicators, grouped into the following topics: Material Production, Transport, Construction Equipment, and Construction. This report is generated for each construction-type event defined in the life cycle. The Excel spreadsheet also contains data tables for all impacts. eLCAP generates several other, lower-level reports with details for each construction-type event. For use stage events, the local government eLCAP generates a detailed report containing the following information for each lane in a route segment for each year of analysis in the use stage period based on user input of car and truck traffic count data:

- Truck lane distribution factor
- Traffic volumes (cars and trucks)
- Equivalent single axle loads (ESAL)/year (for use in selecting IRI performance model parameters)
- ESAL category (for use in selecting IRI performance model parameters)
- IRI performance model parameters
- IRI
- GHG

The eLCAP software discussed and depicted in this technical memorandum represented the most recent version available at the time of the writing. However, as the development of eLCAP is continuous, the software's functions, user steps, and/or interface may differ at a later date.

Contents

1 Overview

1.1 Need for Local Government Version of eLCAP

The processes in the pavement life cycle can be defined as: material extraction and production; construction; transport of materials and demolition; the use stage, where the pavement interacts with other systems; the materials, construction, and transport associated with maintenance and rehabilitation; and end-of-life. The use stage currently typically focuses on the combustion of fuel in vehicles and the interaction of vehicles with the pavement, although other use stage processes include interactions with stormwater, heat island effects, active transportation use, and lighting.

The California Department of Transportation (Caltrans) has a growing need to be able to quantify its greenhouse gas (GHG) emissions and the other environmental impacts of pavement operations, and to consider GHG and those other impacts in pavement management, conceptual design, design, materials selection, and construction project delivery decisions. Caltrans also needs to be able to evaluate the life cycle environmental impacts as part of policy and standards development. All these tasks can be performed using life cycle assessment (LCA). There are different constraints and requirements with respect to the scope of the LCA and the data available for each of these different applications.

LCA considering only GHG emissions has been implemented in the Caltrans network-level pavement management system. The web-based software *environmental Life Cycle Assessment for Pavements,* also known as eLCAP, has been developed as a project-level life cycle assessment tool.

Local governments also are increasingly being asked to quantify GHG emissions from their operations and identify changes to reduce emissions. There are many possible strategies that local governments can choose to reduce their emissions, however, prioritization and selection of which to implement can be difficult if emissions cannot be quantified. Pavement LCA can be used by local governments to achieve the same goals as state government:

- Quantification of environmental impacts from the pavement life cycle
- Comparison of design alternatives
    - It is recommended that pavement decisions be made using life cycle cost analysis (LCCA) and LCA, in addition to the current typical consideration of initial cost; LCCA considers the long-term economic effects of decisions and LCA considers the long-term environmental impacts of decisions
    - It is essential that LCA comparisons of alternatives consider the full life cycle and not just initial impacts, because alternatives with lower initial impacts may have significantly greater impacts over the life cycle

- Comparison of policy alternatives, such as changes in specifications for construction quality, materials, and pavement management decision trees
- Evaluation of pavement impacts in planning alternatives, provided that conceptual designs are available to sufficiently define details.

This report documents eLCAP and a project that created a user interface for eLCAP that is usable by local governments.

1.2 Overview of eLCAP

The *environmental Life Cycle Assessment for Pavements* software (eLCAP) is a web-based software project-level life cycle assessment tool that uses California-specific life cycle inventories and processes (1, 2). The goal of eLCAP is to permit local governments to perform project-level pavement LCA using California specific data, including consideration of their own designs, materials, and traffic. eLCAP allows modeling of materials, transport, construction, maintenance, rehabilitation, and end-of-life recycling for all impacts; and in the use stage it considers the effects of combustion of fuel in vehicles as well as the additional fuel consumed due to pavement-vehicle interaction (global warming potential only).

eLCAP was developed with funding from the California Department of Transportation and internal funds from the University of California Pavement Research Center (UCPRC). All the data and functions of eLCAP are the same in the Caltrans and local government versions. The differences are in the input data needed by the user to define the scope of the pavement project and traffic data for use stage calculations. The Caltrans version of eLCAP uses Caltrans definitions for defining the pavement structure and uses information in Caltrans databases such as the number of lanes, traffic data, and climate region data based on the project location on the state highway network. The development of the local government interface was funded with Senate Bill 1 funds from the University of California Institute of Transportation Studies.

eLCAP is intended to follow the Federal Highway Administration Pavement LCA Framework (3), and International Standards Organization guidance for LCA (4,5). The data quality assessment approach developed by the US Environmental Protection Agency (EPA) and used by the Federal LCA Commons program (6) has been updated and used in eLCAP.

eLCAP performs a formal *mass-balancing procedure* on a pavement LCA project model, and then computes 18 different *impact indicator* values (identified by their variable names), among which are Global Warming Potential (GWP), Human Health Particulate Air, Acidification, and different forms of Primary Energy. eLCAP also generates a detailed Excel report file to display graphs and tables of results.

eLCAP models the life cycle history of a *pavement project* by allowing a user to specify any number of construction-type events, occurring at a user-specified date, followed by an automatically generated Use Stage event that begins immediately afterward and lasts until the next construction-type event or the End-of-Life (EOL) date.

Construction-type events require user input specifications for materials (e.g., hot mix asphalt [HMA], portland cement concrete [PCC], aggregate base [AB], and in-place recycled [IPR] materials) and their associated quantities, transport types and their associated distances, and construction equipment (e.g., pavers, rollers, lighting, etc.) and their associated times of operation. eLCAP has built-in library versions for these processes based on California and Caltrans practices. These library-based processes allow a user to analyze a specific pavement project or create user-defined processes based on library versions, and then customize the amounts and sources of inputs that go into that user-defined process. For example, the library process for Electricity Grid Mix uses 43.4 percent from Natural Gas, but a user can create a user-defined Electricity Process, based on the Electricity Grid Mix library process, which instead uses 20 percent from Natural Gas. Further, any custom, user-defined process set up—either by using the "Manage User Processes" page or within a project—becomes available globally to that user for any project.

Use stage-type events, which are automatically generated for each user-defined construction-type event, have a start date immediately after the end of the construction event and an end date specified by the user. Currently, eLCAP is limited in that it only computes GHG for pavement-vehicle interaction for internal combustion engine vehicles in the Use Stage, using baseline fuel consumption for a very smooth pavement and excess fuel consumption from pavement roughness (in terms of International Roughness Index [IRI]). The tool models the environmental effects of "using" the pavement project by computing the GHGs from traffic (cars and trucks) driving over it during the time span of the Use Stage. eLCAP allows the user to report total emissions from vehicles, or only those caused by vehicle interaction with the pavement roughness.

eLCAP includes models for roughness, in terms of International Roughness Index (IRI), that are used in the Caltrans pavement management system for different levels of truck traffic and different climate regions. The IRI models are used with previously developed life cycle inventories (LCIs) for fuel use as a function of IRI to calculate GHG emissions at the network level for planned scenarios of treatments versus "do nothing." The user inputs the initial IRI achieved from construction.

Users interact with eLCAP via a web browser that accesses its user interface (UI). The main UI web page contains the controls necessary to define the life cycle of a pavement project: Construction, Maintenance/Rehabilitation, Materials, Transport and Equipment. Data for a pavement project are grouped into a *project trial*. There can be an unlimited number of project trials for a project, and a user can have an unlimited number of projects. All user data are stored in a database, currently *SQL Server*. In addition, a user can save the data for a project trial to a local hard disk in a "json"-formatted file. These downloaded files can act as a backup to the user database or as project documentation; they can also be uploaded to eLCAP for processing. eLCAP permits users to function using metric and several types of US standard units.

eLCAP does not perform the following functions:

- Pavement design
- Life cycle cost analysis
- Network-level analysis

1.3 Basic Results

eLCAP is intended to make the complicated process of LCA modeling and analysis as simple as possible. Another objective is to provide specific and easy-to-understand results. To that end, eLCAP generates an Excel spreadsheet that contains bar and pie charts for 18 impact indicators, grouped into the following life cycle stages: Material Production, Transport, Construction Equipment, and Construction. This report is generated for each construction-type event defined in the life cycle. The Excel spreadsheet also contains data tables for all impacts.

eLCAP generates several other, lower-level reports for each construction-type event:

- Detailed process-level results from the *balancing* operation (see Balancing), showing scaled input and output flows[1] for every process in the pavement project model
- The input and output flows for the LCI for the pavement project
- The flows, the characterization factor, the LCI amount, and the resulting flow potential amounts for each impact indicator for each stage, e.g., Material Production, and for each impact method, e.g., *TRACI 2.1*[2], Primary Energy

For Use Stage events, the local government eLCAP generates a detailed report containing the following information for each lane in a route segment for each year of analysis in the Use Stage duration based on user input of car and truck traffic count data:

- Truck lane distribution factor
- Traffic volumes (cars and trucks)
- Equivalent single axle loads (ESAL)/year (for use in selecting IRI performance model parameters)
- ESAL category (for use in selecting IRI performance model parameters)
- IRI performance model parameters
- IRI
- Tool for Reduction and Assessment of Chemicals and Other Environmental Impacts (TRACI)GHG

1.4 Users

eLCAP was designed for several classes of users:

- Pavement engineers, managers, and policy personnel; with future versions intended to also be used by planners working in the conceptual-design stage
    - Local government practitioners

[1] Input flows are materials and energy entering a process, output flows are the product, waste, and emissions leaving the process
[2] Tool for Reduction and Assessment of Chemicals and Other Environmental Impacts (TRACI)

    - Caltrans practitioners
- Researchers
- Students

Users choose whether to use the local government interface, which requires the user to input traffic and climate information, or the Caltrans interface, which uploads traffic and climate information based on the district/county/route/post-mile/direction location reference input by the user.

1.5 Software Ownership, Hosting, and Management

eLCAP is a MicrosoftASP.NET/C# web application owned by the Regents of the University of California. The HTML (ASPX pages) and C# source files (and other support files, such as the Highway Log) are currently hosted on the servers of the UCPRC.

The contractual agreement between Caltrans and the University of California allows Caltrans to move the hosting to a Caltrans web server at any time, gives Caltrans unlimited California State Government use, and gives Caltrans the ability to modify the source code to create new state-owned software.

Local government users will be licensed by the University of California for use only.

1.6 A Note on this Technical Memorandum

The eLCAP software discussed and depicted in this technical memorandum represented the most recent version available at the time of the writing. However, as the development of eLCAP is continuous, the software's functions, user steps, and/or interface may be different at a later date.

2 Balancing, Model Generation, and Assessment

eLCAP*'s* main function is to simulate (i.e., to model) the life span of a pavement section (i.e., a project) to compute the environmental effects of traffic and of construction and maintenance (Use Stage). The software does this so that users can make informed decisions on the best course of action to pursue to minimize harmful environment effects and maximize pavement performance over the long term. This is important because sometimes what initially sounds like a good idea may turn out differently when all the processes in the life cycle—including extraction and production of materials, materials transportation, construction equipment use, maintenance, use, and the end-of-life—are taken into consideration.

2.1 Balancing

eLCAP models a pavement project as a series of *unit processes* that are described in life cycle inventories (LCI) with the output "flow" of one unit process or more going into another unit process as an "input" flow or flows, as Figure 2.1 illustrates. A unit process generates a *unit* amount of product flow (e.g., 1 kg of HMA). Each unit process has many inputs and outputs, and the outputs can be categorized as either the main *product flow* and/or one or more *emission flows.*

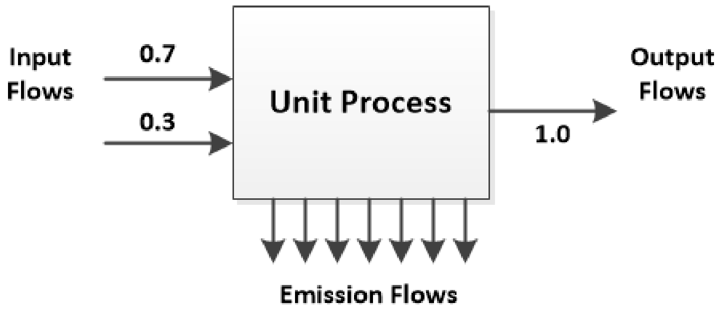


Figure 2.1. A Unit Process.

The eLCAP database currently contains over 50 different unit processes with over 1,600 different flows. A typical eLCAP-modeled pavement project may include several hundred unit processes for one construction-type event, and there may be many construction-type events in the overall life cycle. These collected unit processes form the *LCA balance model* for the construction-type event.

Each unit process has *input quantity* requirements as shown in Figure 2.2. As an example, an *HMA unit process* may need to have 0.06 kg of bitumen and 7.63e-3 MJ, etc., to produce 1.0 kg of HMA. Similarly, a *pavement* *project unit process* may need to have 100,000 kg of HMA (that is, it has an input quantity requirement of 100,000 kg of HMA).

Since each unit process generates a unit of product, a "scaling" or "balancing" procedure needs to be performed to get the final *balance model* in balance; this process starts at the pavement project unit process and traverses/climbs upstream for each input flow for each unit process in the model. All flows for a particular unit process are scaled by the quantity requirement of the unit process downstream. eLCAP accomplishes this balancing procedure by using a programming technique called *recursion*.

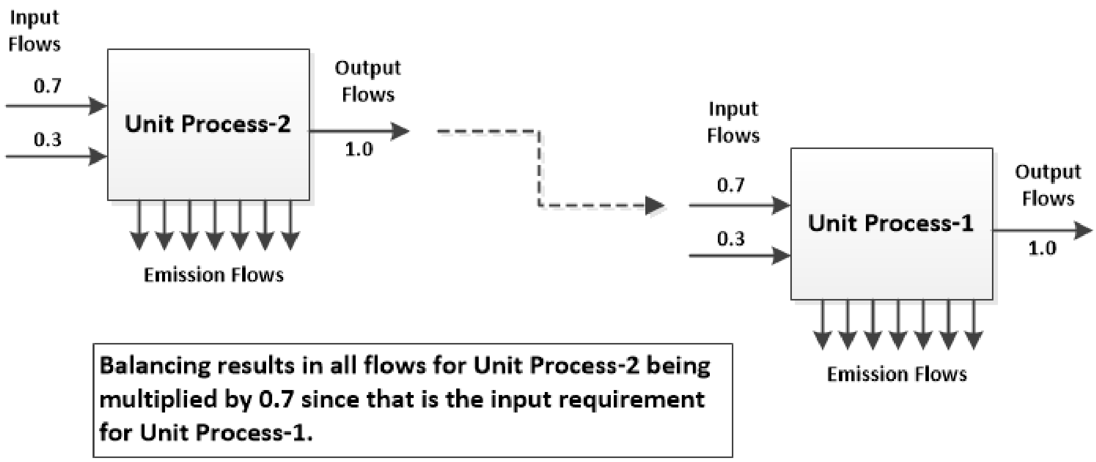


Figure 2.2. Two-Unit Process with Scaling.

Once this balancing process is complete, each *input flow type* (e.g., CO_2) for each process is summed, and the same is done for the output flows, starting at the pavement project and traversing/climbing upstream for each input flow. The result of this summation process is an *LCI* for the pavement project that reflects all upstream effects.

The final step is to compute the results for the various impact indicators. eLCAP computes 18 different impacts—most of which are based on *TRACI 2.1*—and others, primarily different categories of energy use, originating from the European Union document EN15804 (7). All of these are also included in the Federal Highway Administration (FHWA) Pavement LCA Framework (6). Each impact indicator consists of a list of relevant flows, each with a specific "characterization" factor (e.g., for GWP, CO_2 has a factor of 1.0 and CH_4 has a factor of 25.0). The flows for the final LCI for the pavement project are used to compute the impact results for the Construction Stage.

From the above discussion, it is evident that the building blocks of any LCA are *processes* and the *flows* into and out of those processes. Another way to state this is that the building block of any LCA is *data*. Specifically, if process-level data are representative of what is being modeled (e.g., a pavement project), then the LCA should result in an accurate estimate of the environmental impact of what was included in the LCA. But if the process-level data are not representative, if perhaps some of the data are for industries from a different country or region because “local” data are unavailable, then the LCA will result in less realistic assessments of what is being modeled.

The next sections provide an overview of the various data items in an eLCAP LCA: processes, flows, and models.

2.2 Process Data

As mentioned above, the basic building block of any LCA is the *unit process*, in which there is an object that has material input needs and which produces a product and emissions (i.e., output items). High-quality representative process-level data are key to obtaining representative results, since LCA is basically an accounting activity, that is, data items (flows) are simply multiplied by factors and then added up.

eLCAP has over 50 unit processes in its database. This data set was created by starting with basic LCI data from the LCA application from thinkstep AG called *GaBi* (2) and other databases. The UCPRC then adjusted the data to match California materials processes and types, construction processes, and construction equipment types. The end result is that the unit processes in eLCAP have been developed for LCA users in California.

2.2.1 GaBi-Generated Processes

The majority of the unit processes in the eLCAP database are the result of their first being modeled in *GaBi*, tailored to California’s needs, and then taken through an export process that generates an Excel file. In arriving at a unit process in this way, minor manual modifications are made to the Excel file which is then saved as a comma separated value (CSV) file. As noted above, a separate application processes these *GaBi* exported files and generates process definition files. GaBi data LCI cannot be seen by the users. The users can see the impacts generated using the GaBi data and the data sources are documented in the data quality assessment section of the software.

2.2.2 Manually Created Processes

eLCAP also has 15 or so process definition files that are manually generated. These are necessary for unit processes that consist entirely of inputs and a single product output, such as aggregate base (AB). In this way, the manually generated unit process acts as a basic aggregator of input flows and does not generate any emissions itself.

2.3 Flow Data

Intimately associated with the unit process discussed above are *flows*. *Flow objects* are used to model the flows of materials and emissions. Flows connect the input items of one unit process to the outputs of another unit process.

2.3.1 Description and Format

A file format was developed for eLCAP to capture the data associated with a flow so the application's database can be populated. The following data items are contained in a *flow definition file:*

- Name of the flow
- Description of the flow
- Reference Quantity (e.g., mass)
- Reference Unit (e.g., kg)
- Flow Property (used to convert a referenced flow in a unit process to units different from those used to define the flow)

2.3.2 GaBi-Generated Flows

Flow definition files are generated from the processing of GaBi-exported unit-process CSV files. Currently, over 1,600 flows have been generated from the GaBi-export process.

2.3.3 Manually Created Flows

eLCAP also has 25 or so flow definition files that are manually generated. This is necessary for unit processes that have a manually generated process definition file, since the output flow per unit of product flow for the process needs to be created for the aggregator-type process.

2.4 Models

The third concept used by eLCAP to build its LCA database is the *model*. An example model is shown in Figure 2.3 for "Crude Oil Refinery." The figure shows that a model consists of a main unit process that produces the product ("Crude Oil Refinery (u-so)") with a series of input flows. The "u-so" is GaBi terminology for a "unit process, single operation" model. This means that the emissions of upstream flows are not included.

The input flows can be satisfied by either "agg"-type unit processes or by another u-so model. In the figure, the "agg"-type unit processes are represented by "Crude Oil (agg)," "Transport Ocean (agg)," and "Transport Barge (agg)," which all have upstream effects in them. The other input flows in the figure are connected to the outputs of other models (i.e., "Natural Gas (Boiler), Electricity, Residual Fuel Oil, and Liquefied Petroleum Gas"). Connecting an input flow to another model allows users to customize the upstream model in the UI. Users cannot customize an "agg"-type unit process.

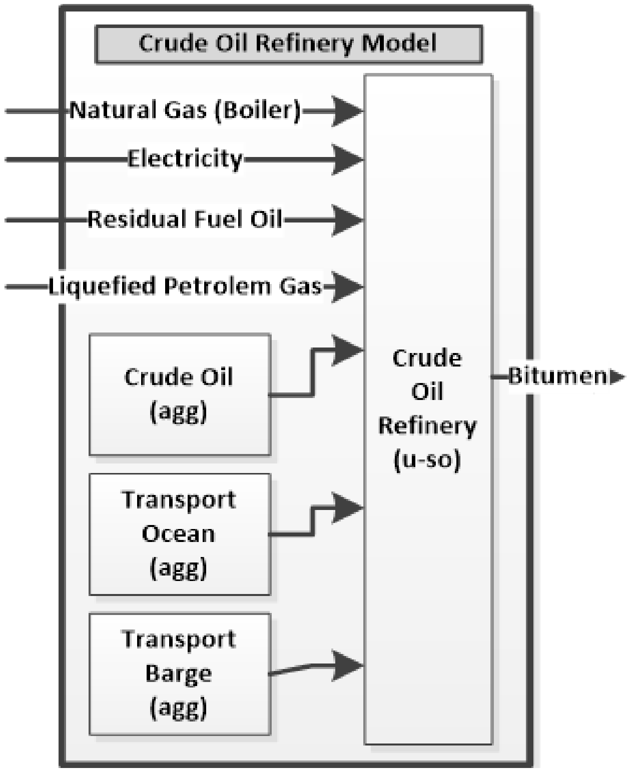


Figure 2.3. Example eLCAP Model.

2.4.1 Description and Format

Model definition files contain *named references* to unit processes, flows, and other models. Model definition files are processed into eLCAP memory at program start up. The following data items are contained in a model definition file:

- Name of the model
- Description of the model
- Named references to unit processes
- For a named reference that has input items (e.g., Crude Oil Refinery (u-so) in Figure 2.3):
  - A named reference to a model
  - A named reference to a process in that model
  - A named reference to a flow in that process; this is usually the output product flow

2.4.2 User-Defined Models

All model definition files are manually generated by the user in the UI.

2.5 Processing and Generation of the LCA Database

The left side of Figure 2.4 shows the processing procedure carried out to generate the eLCAP LCA database. The steps in the procedure are:

1. An LCA expert at UCPRC builds a California-specific model in GaBi and exports flows for the main process in the model.
2. A separate software tool, DB Gen, is used to process the GaBi-exported CSV files; this software tool reads these files and generates *process* and *flow definition* files.
3. DB Gen is next used again to process the generated *process* and *flow definition* text files, and the manually generated *definition* and *flow* files.
4. The above steps result in an XML database file that eLCAP loads when the application starts up. It has a structure shown at the center of Figure 2.4.
5. *Model definition* files are created. All sources of LCA data are now available for eLCAP.
6. A user accesses eLCAP via a web browser. eLCAP reads the LCA XML database file into memory and also reads and processes the model definition files into memory.
7. The structure for the in-memory version of the XML database file mimics the structure of the XML file.
8. When a user requests that an analysis be performed, eLCAP builds the *balance model*, balances it, and then computes the LCI for the construction-type event and the impact factors for it.

2.6 Model Generation

When a user requests that an LCA be performed, eLCAP starts a loop over all the *LcaEvents* in the life cycle defined by the user. The first step in that loop, for each *LcaEvent*, is for user data to be translated into an LCA model via a *model generation activity*. This activity is simple for a Use Stage *LcaEvent* but complex for a construction-type event. Before the model generation activity, eLCAP must perform some initial/preparatory work to assist the Use Stage procedure: the user defines the number of lanes, the traffic (cars, trucks) in terms of average annual daily traffic (AADT) and average annual daily truck traffic (AADTT), the annual traffic growth rate, and a selected climate region for each segment. This is necessary because the Use Stage has performance models that require these data.

2.6.1 Construction-Type Event

Figure 2.5 shows part of a construction-type model used to build the *balance model*. The process starts at the *pavement project model*, considers each named reference to a process, gets the actual process from the database, copies it, and adds it to the list of processes that will become the balance model. For each input flow for the process that produces the output product, the model that is referenced is obtained and the same process is followed. This continues until there are no more upstream models to address. A recursive implementation is used for this complex procedure. Once the balance model has been constructed it can be balanced was discussed under Balancing.

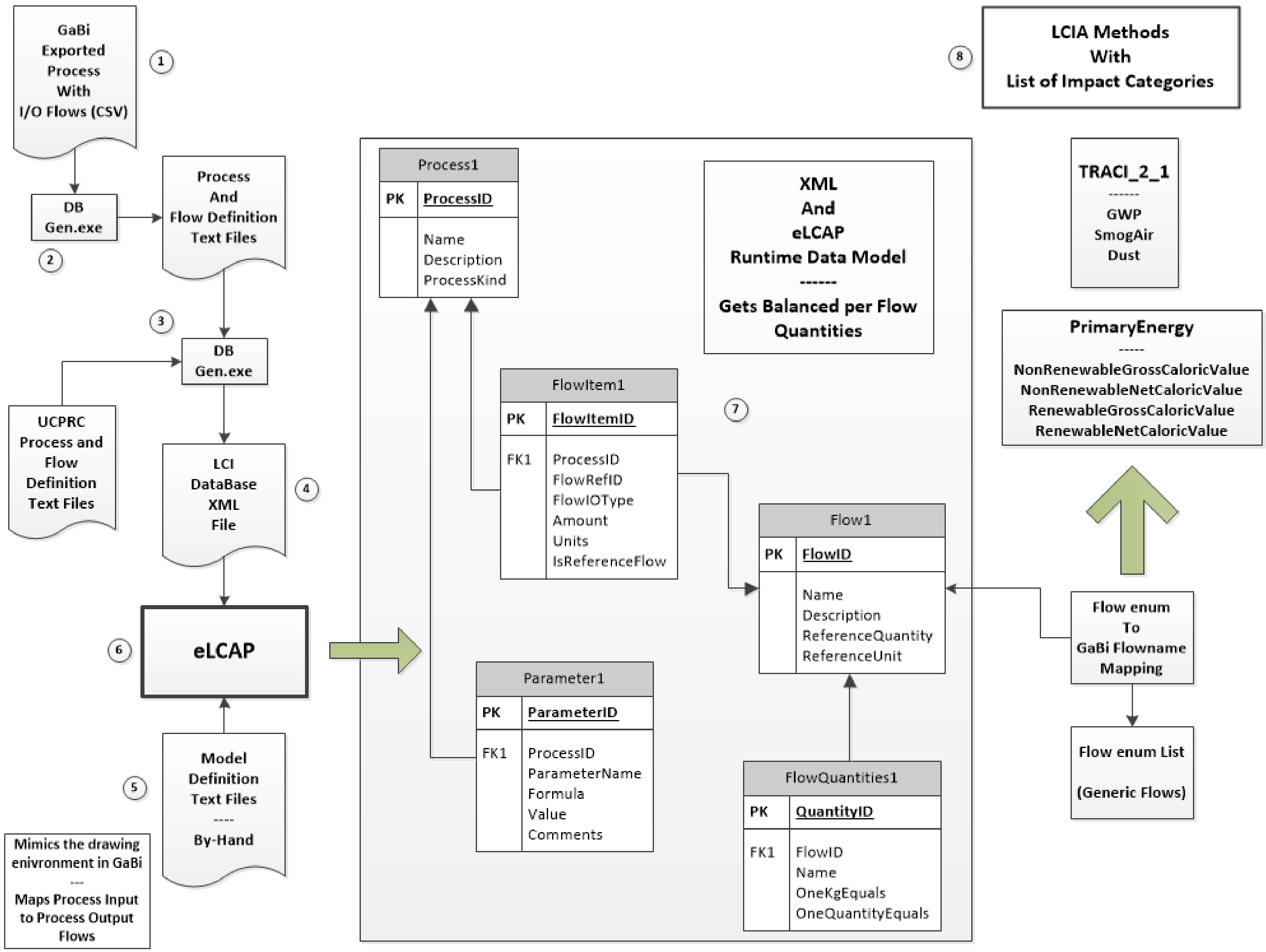


Figure 2.4. Overall eLCAP Data Processing and Operation.

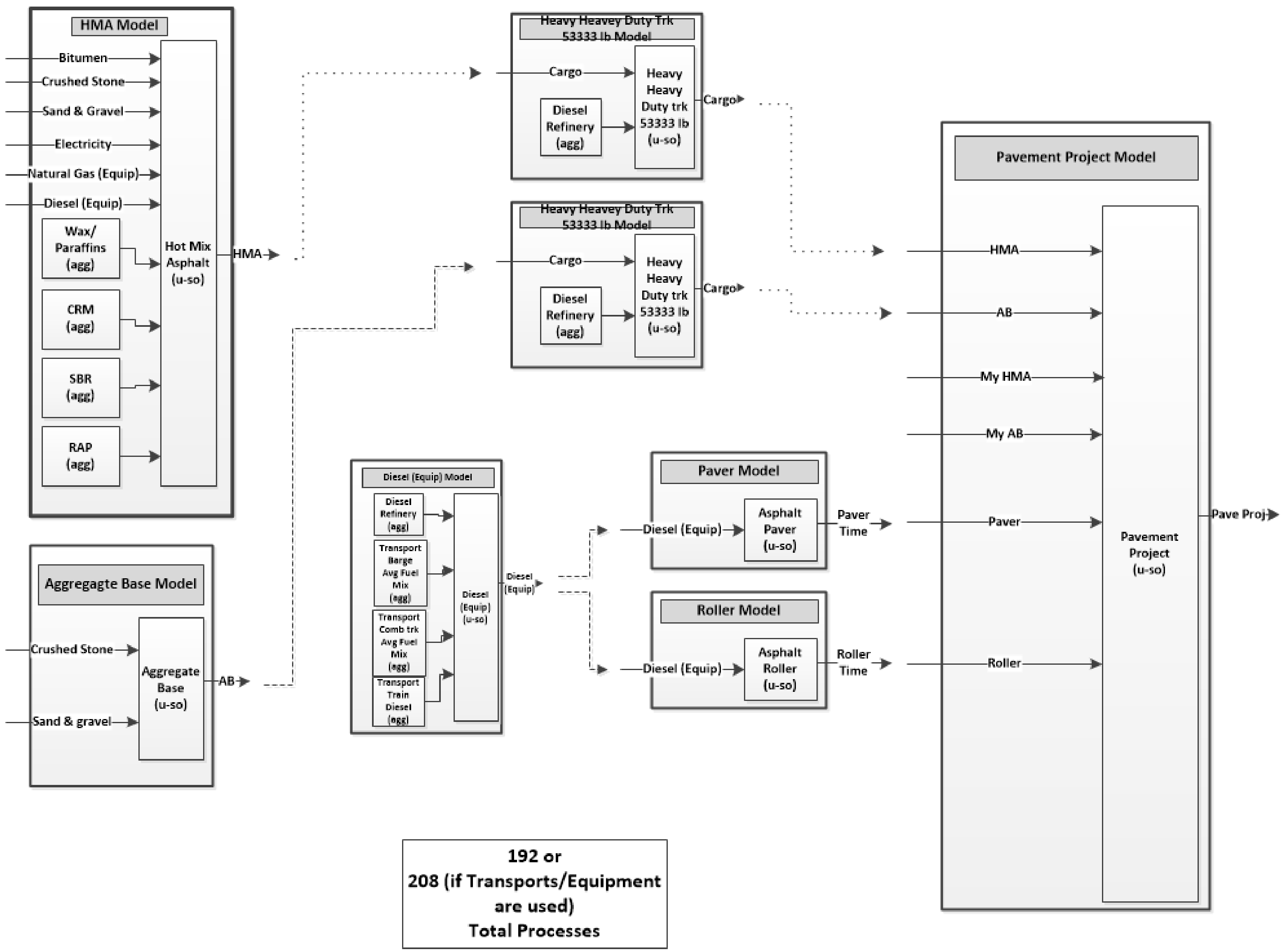


Figure 2.5. Pavement Project Model with Upstream Models.

2.6.2 Use Stage Event

The model generation step for a Use Stage event is much simpler than for a construction-type event. The current Use Stage model computes the GHG generated from traffic driving over the pavement project for some user-defined time period. The GHG procedure used for this computation includes the effects of increasing IRI (and traffic) over time, so the Use Stage model-generation step obtains appropriate IRI performance model parameters, for each lane segment, based on Pavement Type, Treatment, Climate Zone. ESALs are calculated for local government projects using the AADTT, the traffic growth rate, and an assumed axle load spectrum. The assumed axle load spectrum is typical of the routes on the state highway network in urban areas and rural routes that are not heavy carriers of long-haul semi-tractor trailer combinations, referred to as WIM Spectrum 1.

2.7 Life Cycle Impact Assessment (LCIA)

eLCAP internally generates an appropriate set of 18 *LCA impacts* (e.g., GWP, primary energy, etc.) associated with several *LCA methods* (e.g., *TRACI 2.1)* to allow the user to make decisions on the environmental effects of a pavement project over its life cycle. No user involvement is necessary.

eLCAP includes two methods for computing impact factors:

1. A method based on a list of flows with an associated characterization factor
2. A method based on a performance model; currently, an IRI model is the only one available

eLCAP uses the first method for all impacts generated for *construction-type LcaEvents*, meaning all materials, construction, maintenance, and end-of-life processes. The second method is used for calculation of the GHG (GWP) emissions from pavement-vehicle interaction associated with roughness in the use stage (the variable *Use Stage-type LcaEvents)*, the only impact considered by eLCAP for the use stage at this time.

2.7.1 Flow-Based Impacts

As part of the *balancing* procedure in the balance model, the LCI for *appropriate processes* (see below) is generated using the methodology described in Process Data. The *LCI flow list* for a process and the list of *flows* (and characterization factors) for a particular impact of the process are used to compute the impact by simply matching up the flow names between the two lists, getting the balanced model LCI flow amount (which includes all upstream effects), multiplying it by a characterization factor, and summing over all flows defined for the impact.

The “appropriate processes” referenced above are those that are needed for reporting to the user, such as Construction and Material Production processes. The stages that appear in the following list illustrate the hierarchy of stages and processes for the examples shown (this is not a complete list of all the processes in eLCAP*)*. Some of the stages are normally associated with LCA, such as Material Production, and others are “virtual” stages used to obtain the impacts computed for reporting purposes. Recycled materials that are not allocated impacts do not have materials production processes. They only have construction and transport processes.

1. Construction Stage
    a. The Pavement Project Process
2. Material Production Stage
    a. HMA Process
    b. PCC Process
    c. Aggregate Base (AB) Process
3. HMA Production Stage
    a. HMA Process
4. HMA Aggregate Stage
    a. Crushed Aggregate Process
    b. Natural Sand and Gravel Process
5. HMA Bitumen Stage
    a. Bitumen Process
6. HMA Energy Stage
    a. Electricity Process
    b. Natural Gas Equipment Process
    c. Diesel Equipment Process
7. PCC Production Stage
    a. PCC Process
8. PCC Aggregate Stage
    a. Crushed Aggregate Process
    b. Sand and Gravel Process
9. PCC Cement Stage
    a. Cement Process
10. PCC Energy Stage
    a. Electricity Process
    b. Natural Gas Equipment Process
    c. Diesel Equipment Process
11. Aggregate Base Production Stage
    a. Aggregate Base Process
12. Aggregate Base Crushed Agg Stage
    a. Crushed Aggregate Process
13. Aggregate Base Natural Agg Stage
    a. Sand and Gravel Process
14. Transport Stage
    a. Transport Process

15. Construction Equipment Stage
    a. Paver Process
    b. Roller Process

As is shown, this list has 15 stages and many processes. There are many more stages and processes for other materials and equipment in eLCAP. Computing LCIs for a process is a computer-intensive activity since eLCAP needs to recursively climb the upstream tree, starting from a particular process and considering all the input flows into that process.

2.7.2 Performance Model-Based Impacts

eLCAP computes a single impact factor for Use Stage-type *LcaEvents:* GHG. Calculating that impact factor is done using an equation that accounts for traffic loads in each *lane segment* (cars and trucks) and uses an IRI performance model that predicts the increase of IRI over time (age from the date a treatment was applied).

The equation for calculating GHG emissions from vehicles in each year is:

$$
\begin{aligned}
GHG_{Vehicle}(IRI) = {} & (IRI \times RoughnessFactor_{Car} + Const_{Car}) \times CarVolumeLane\,i \times LaneMile \\
& + (IRI \times RoughnessFactor_{2Axle} + Const_{2Axle}) \times 2AxleVolumeLane\,i \times LaneMile \\
& + (IRI \times RoughnessFactor_{3Axle} + Const_{3Axle}) \times 3AxleVolumeLane\,i \times LaneMile \\
& + (IRI \times RoughnessFactor_{4Axle} + Const_{4Axle}) \times 4AxleVolumeLane\,i \times LaneMile \\
& + (IRI \times RoughnessFactor_{5Axle} + Const_{5Axle}) \times 5AxleVolumeLane\,i \times LaneMile
\end{aligned}
$$

The emissions from this equation are summed over the analysis period (from the end of a construction-type event to the start of the next construction-type event) using the IRI predicted for the pavement at the middle of each year. The variables used in the $GHG_{Vehicle}$ equation are described in the Table 2.1.

Table 2.1. GHG Equation Variable Definitions

Variable	Definition
$GHG_{Vehicle}$	GHG emissions from all vehicles in Lane i in a single year (metric tons of CO_2-e)
IRI	IRI of the segment in Lane i (m/km), 1 m/km = 63 inches/mile.
LaneMile	Total lane-miles of that lane in the segment (lane-mile)
RoughnessFactor	The averaged coefficient to convert the IRI to GHG emissions for cars and trucks due to rolling resistance. The unit is metric tonnes of CO_2-e/(IRI[m/km] x mile).
Const	Constant term in the equation, representing the GHG emissions due to other types of resistance that the energy needs to resist. The unit is metric tonnes of CO_2-e/mile.
CarVolumeLane i	Volume of cars in Lane i. It is readily available in the traffic table.
2/3/4/5AxleVolumeLane i	Volume of trucks in each class in Lane i. It is readily available in the traffic table.
$GHG_{VehicleAllYears}$	Total GHG emissions (metric tonnes of CO_2-e) from vehicles running on Lane i in the segment in the whole analysis period

The values for *RoughnessFactor* and *Const* used in the $GHG_{Vehicle}$ equation are shown in Table 2.2.

Table 2.2. Roughness Factor and "Const" for GHG Equation

Vehicle Classification	RoughnessFactor	Const
Car	0.003577	0.133451
2-Axle Truck	0.003628	0.400894
3-Axle Truck	0.0073	0.657537
4-Axle Truck	0.012107	0.957231
5-Axle Truck	0.012808	1.046075

The performance model equation for IRI as a function of the age of a treatment is shown below:

$$IRI(t) = a+b*age^c \quad \textbf{[1]}$$

The parameters in Equation [1], a, b and c, are selected based on *Pavement Type* (indicating surface type: Flexible or Rigid [jointed plain concrete at this time]), *Treatment*, an *ESAL category*, and a *Climate category*. A partial table of IRI performance model parameters is shown in Figure 2.6. The full set of IRI performance model parameters is included in Lea, et al, 2021 (1).

				IRI (IRI_L+IRI_R)/2 = a+b*Age^c Age = ((Average_IRI-a)/b)^(1/c) (in/mi)			
Pavement Type	Treatment	ESAL/yr*	Climate**	Node ID	a	b	c
	1. Full Depth Reclamation	A	severe	1	157.3	3.4	1.0
			mild	2	88.8	2.0	1.0
		B	severe	3	143.0	5.1	1.0
			mild	4	88.3	2.2	1.0
		C	severe	5	139.6	5.4	1.0
			mild	6	87.8	2.5	1.0
	2. Thick Overlay or Reconstruct	A	severe	7	157.3	3.7	1.0
			mild	8	88.8	2.3	1.0
		B	severe	9	143.0	5.4	1.0
			mild	10	88.3	2.5	1.0
		C	severe	11	139.6	5.7	1.0
			mild	12	87.8	2.8	1.0
	3. Very Thin Overlay	A	severe	13	89.5	3.8	1.0
			mild	14	90.8	2.4	1.0
		B	severe	15	77.3	5.5	1.0
			mild	16	92.5	2.6	1.0
		C	severe	17	76.4	5.8	1.0
			mild	18	94.3	2.9	1.0

Figure 2.6. Excerpt from the table of IRI performance model parameters.

When a user defines the materials for a construction-type event, a selection is made for *Pavement Type* and *Treatment*. The other two data items needed to make the IRI model parameter selection are *ESAL Category* and *Climate Category*. Table 2.3 and Table 2.4 show how to obtain both categories from actual data.

The three ESAL categories: A, B and C, are determined by the value of ESALs/year.

Table 2.3. ESAL Categories

ESALs/yr	Category
< 100,000	A
> 100,000 and < 500,000	B
> 500,000	C

The two climate categories are determined from the *Climate Zone*. The assignment of climate regions to the Mild or Severe categories is based on observation of trends in IRI on the state highway network.

Table 2.4. Climate Categories

Climate Zone	Category
North Coast	Severe
High Desert	Mild
Inland Valley	Mild
Central Coast	Mild
Desert	Mild
South Coast	Mild
High Mountain	Mild
South Mountain	Severe
Low Mountain	Severe

2.8 Data Quality

eLCAP includes metadata that the user can access in the software to better understand the data, and a data quality assessment using a data quality matrix. The metadata approach and the data quality matrix in *eLCAP* were updated in 2020. The metadata are now more complete.

2.8.1 Metadata

eLCAP includes fields for three kinds of metadata: administrative, descriptive, and structural. A description of each item within each metadata field is presented in Table 2.5.

Table 2.5. Metadata Fields Included in eLCAP

Administrative Metadata – *Information that helps in managing the data*	
Recorder/Reviewer/Organization	Names or initials of who records the data, who reviews the data, and their affiliations
Data Source	Source from which the data were acquired. This could be a webpage link, published report, literature, or the name of the organization/person from whom the data was obtained.
Publication Date	Date the data was produced or published (YYYY)
Data Accessed	Date the data was accessed (MM/DD/YYYY)
Descriptive Metadata – *Information that describes the data*	
Original Process Name	Name of the product or process
Data Produced Location	Location where the data was produced. If the information is available, it is preferred that the city, state, and country be reported.
Descriptive Properties	Any helpful descriptive information about the product or process (e.g., shapes and sizes of aggregates, cement type, PG binder grade, etc.)
Structural Metadata – *Information that identifies the content of the data*	
Quantity	Quantity of product (1, 10, 100, etc.)
Units	Units of the quantity (US tons, gallons, BTU, etc.)
Structural Properties	Information that shows the content of the product/process (e.g., compressive strength value of concrete, mix design/job mix formula of asphalt concrete, aggregate gradation information, etc.)
Other Information	Miscellaneous information about the product/process that is helpful for identifying and reproducing the data, and that can increase confidence in acceptance of the data

2.8.2 Data Quality Assessment

All data for materials, unit processes, energy resources, equipment, and transportation have been evaluated using a data quality assessment matrix similar to that used for the FHWA *PaveLCA* tool *(8)*, that is in turn based on the US EPA's pedigree matrix *(9)*. This was done by the *PaveLCA* team working with a parallel FHWA project team that was developing a database framework for pavement LCA *(10)*, which was partially informed by the framework in eLCAP. The US EPA's pedigree matrix was enhanced for the FHWA tool to standardize the practice of data quality assessment for use in pavement LCAs. Table 2.6 shows the data quality assessment matrix that was used in eLCAP.

Table 2.6. Data Quality Assessment Matrix in eLCAP

Criterion	Description	Excellent (1)	Very Good (2)	Good (3)	Poor (4)	Unsatisfactory (5)
Reliability	**Inventory data checked for mass balance, recalculation, etc.**	Verified data based on measurements	Verified data based on a calculation or non-verified data based on measurements	Non-verified data based on a calculation	Documented estimate	Undocumented estimate
	Organizational Continuity and Support	Hosts and Owns	Owns but does not host	Hosts but does not owns	Hosts and owns partially	Does not host or own
	Regular updates, Statistically established confidence intervals	Regular Updates	Less frequent updates	No Updates	-	-
Data Collection Methods	**Relevant coverage of the market**	Representative data from >80% of the relevant market, over an adequate period	Representative data from 60–79% of the relevant market, over an adequate period OR representative data from >80% of the relevant market, over a shorter period of time	Representative data from 40–59% of the relevant market, over an adequate period OR representative data from 60–79% of the relevant market, over a shorter period of time	Representative data from <40% of the relevant market, over an adequate period of time OR representative data from 40–59% of the relevant market, over a shorter period of time	Unknown OR data from a small number of sites and from shorter periods
	Relevant time period coverage to capture seasonal variations	Seasonal variations captured	Seasonal variation not captured	-	-	-
	TRACI impact indicators compatible	100% TRACI compatible	75% TRACI compatible	50% TRACI compatible	25% TRACI compatible	TRACI incompatible

Criterion	Description	Excellent (1)	Very Good (2)	Good (3)	Poor (4)	Unsatisfactory (5)
Time period	**Data age**	Less than 3 years of difference	Less than 6 years of difference	Less than 10 years of difference	Less than 15 years of difference	Age of data unknown or more than 15 years
	Correlated to relevant time periods	Data fully adjusted for relevant time periods of analysis	Data fully adjusted for relevant time periods but with medium level of uncertainty	Data fully adjusted for relevant time periods but with high level of uncertainty	Some data adjusted for relevant time periods but with high level of uncertainty	Data unadjusted for relevant time periods
Geography	**National and/or regional data (Detail the level of resolution, i.e., required Data Quality in Goal and Scope)**	Data from same resolution AND same area of study	Within one level of resolution AND a related area of study	Within two levels of resolution AND a related area of study	Outside of two levels of resolution BUT a related area of study	From a different or unknown area of study
Technology	**Data from processes and materials under study**	All technology categories are equivalent	Three of the technology categories are equivalent	Two of the technology categories are equivalent	One of the technology categories is equivalent	None of the technology categories are equivalent
	Relevant technology covered	Yes				No
Process Review	**Goal and scope definition of a dataset, raw data, life cycle inventory (LCI) methods, life cycle impact assessment (LCIA) methods that are applicable, unit process inventory, aggregated process inventory, and dataset documentation**	Documented reviews by a minimum of two types of third-party reviewers	Documented reviews by a minimum of two types of reviewers, with one being a third party	Documented review by a third-party reviewer	Documented review by an internal reviewer	No documented review

Criterion	Description	Excellent (1)	Very Good (2)	Good (3)	Poor (4)	Unsatisfactory (5)
Process Completeness	**Evaluate the flows within the inventory**	>80% of determined flows have been evaluated and given a value	60–79% of determined flows have been evaluated and given a value	40–59% of determined flows have been evaluated and given a value	<40% of determined flows have been evaluated and given a value	Process completeness not scored

3 Association with GaBi

As mentioned in Process Data, the majority of processes and flows in the eLCAP LCA database originate in *GaBi*. Models are built in the *GaBi* application using its LCIs, and then customizations are made to tailor the results for California. Last, the input and output flows for the process are exported to a file and then processed for use in eLCAP.

As was mentioned previously, two types of processes are exported from *GaBi*: “agg” and “u-so.” These are discussed in further detail below.

3.1 Process Type: “agg”

An “agg”-type process is one that has all upstream effects included. They can be considered as “leaf” nodes in the Balance Model since nothing is upstream from them. The “Crude Oil (agg)” process in Figure 2.3 is an “agg”-type process, which has no input flows. Further, once all the input flows to an “agg”-type process have been aggregated, it is impossible to disaggregate them back into the processes used to build the “agg”-type process. An “agg”-type process, exported from *GaBi*, typically has several hundred input and several hundred output flows since all flows from upstream processes have been aggregated into it.

From a user perspective, this type of process is the least flexible since it cannot be customized. But practically speaking, there have to be “agg”-type processes at some point going upstream in the LCA model; the point where they appear depends on the sources of data and level of effort required to get the data.

3.2 Process Type: “u-so”

A “u-so”-type process is one that does not include any upstream effects; it has input flows that need to be connected to upstream models. The “Crude Oil Refinery (u-so)” process in Figure 2.3 is a “u-so”-type process. A “u-so”-type process exported from *GaBi*, typically has a handful of input flows and very few output flows: the *main product flow* and a few *emissions flows*.

A “u-so” process is more flexible than an “agg”-type since it allows flow-based connections to upstream models and thus permits an eLCAP user to customize the “u-so” process by changing the amounts of flows into the process and the actual source of the flows.

4 User Interface

This chapter discusses the user interface (UI) from a user's perspective. Figure 4.1 shows the eLCAP home page, which has a set of useful links and log-in controls on the left-side pane. The different pages in the UI are accessed via menu links, shown at the top in the figure. The buttons at the bottom are used to display PDF files of the various LCA models in eLCAP.

The following are the top menu items:

1. *Home:* this menu item is used to display the home page.
2. *Instructions:* this menu item is used to display the Instructions page, which contains information on how to use eLCAP.
3. *Projects:* this menu item is used to display the Projects and Project Trials Management page (see Projects and Project Trials Management)
4. *Input*: this is a hierarchical menu with the following menu items:
    a. *Manage User Processes:* links to the page used to manage user-defined processes, such as a customized version of HMA (see User-Defined Processes).
    b. *Project Information:* links to the page used to define the pavement cross section and to input traffic information (see Project Information).
    c. *Life Cycle:* links to the page used to define the life cycle of the pavement project, including events when construction/maintenance occurs, the list of activities, and the list of Materials and Equipment for each event (see Life Cycle Definition).
5. *Analyze & Results:* this page is used to perform the LCA and obtain results (see Life Cycle Definition).
6. *About:* this menu item is used to display the About page, which contains information about the application.

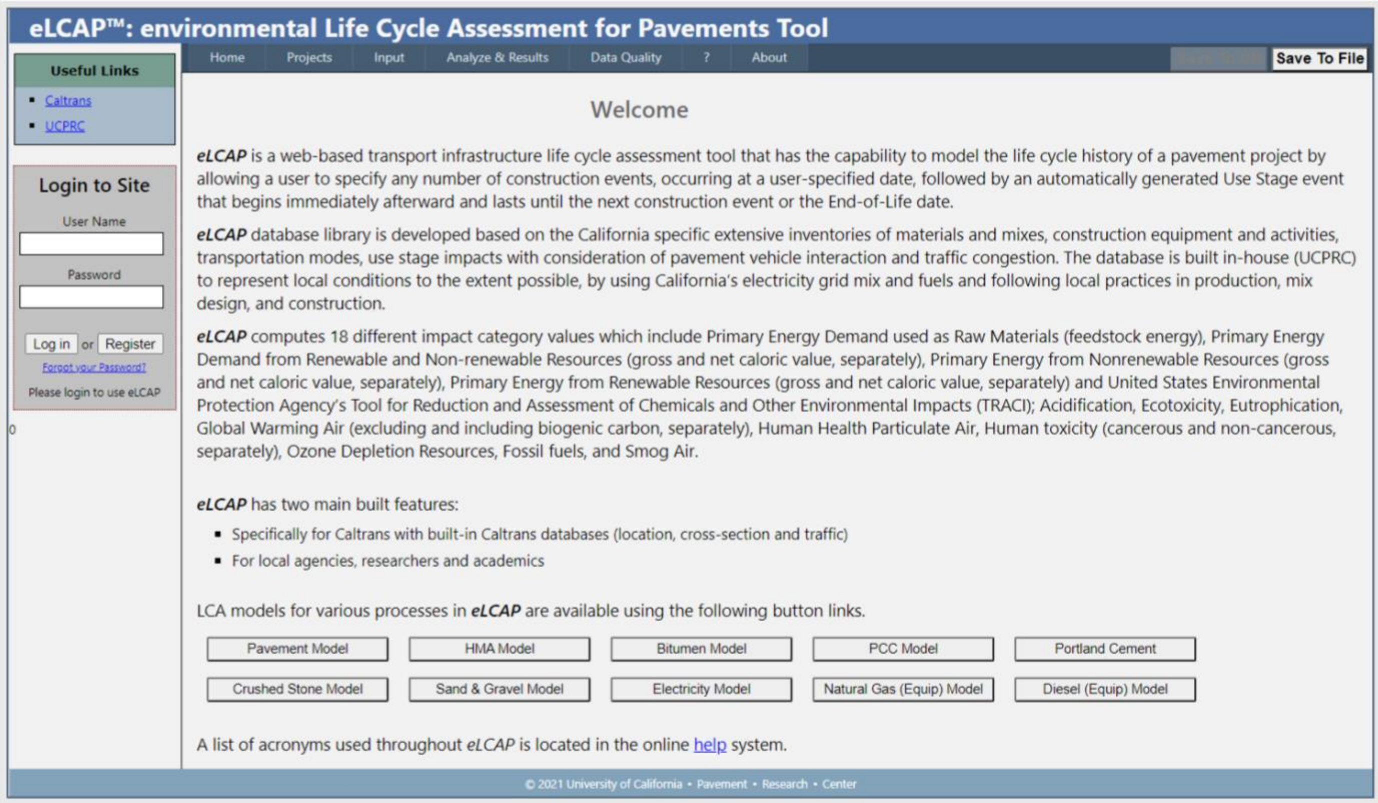


Figure 4.1. The eLCAP Home Page.

4.1 Authentication and Authorization

eLCAP requires a user to be registered and approved before they can use the program. Once approval is granted, users are associated with a particular eLCAP user group or groups. Specific user permissions are controlled via user groups.

The eLCAP registration page is accessed by clicking the “Register” button shown in Figure 4.2 (it appears on the left side of the home page). Clicking that button brings up the dialog box shown in Figure 4.3. Once a user fills in all the empty fields and clicks “Create User,” both the user and the eLCAP administrator will receive an email. After receiving the email, the administrator can approve the user and assign them to the appropriate user group.

eLCAP also has a mechanism for obtaining a temporary password if a user forgets theirs. To obtain a temporary password, a registered user just has to click the “Forgot your Password?” link on the home page (as shown Figure 4.2), and this will bring up the Password Recovery page shown in Figure 4.4. After entering a user name and clicking “Submit,” the user will receive an email containing a temporary password for logging in. After doing so the user can change the password to something else, as shown in Figure 4.5. Clicking the “Change your Password” link will bring up the registration page shown in Figure 4.6.

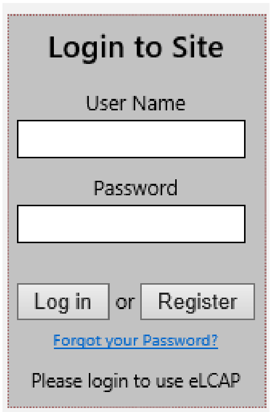


Figure 4.2. Accessing the Registration Page.

Figure 4.3. Registration Page.

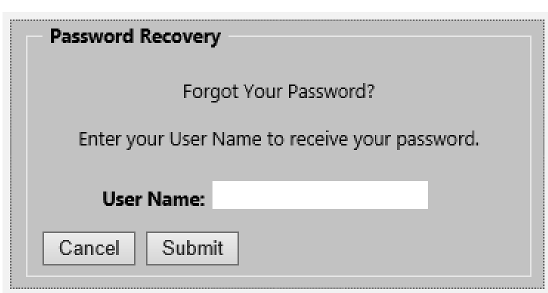


Figure 4.4. Password Recovery Page.

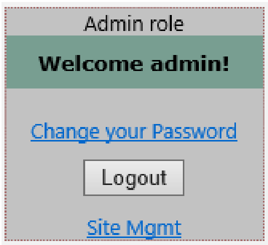


Figure 4.5. Accessing the Password Change Page.

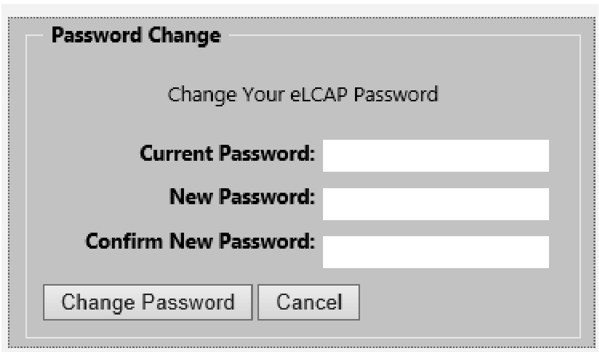


Figure 4.6. Password Change Page.

4.2 Projects and Project Trials Management

eLCAP uses the concepts of “projects” and “trials.” A user can create any number of projects, and a project can have any number of trials. A trial contains the data for the life cycle of a pavement project. User-defined processes (see User-Defined Processes), such as a custom HMA or custom Transport, are common across all trials. All user data are saved in an SQL database on a server.

eLCAP allows a user to generate a text file version of Trial data to act as backup to database data or for project documentation. These files may be uploaded to eLCAP and used to perform an LCA as well.

The Project and Trial Management page is shown in Figure 4.7. The corresponding number-labeled areas that appear in the figure are discussed below.

1. This button allows the user to browse a local hard disk for an eLCAP input file, upload it, edit it, and then run it.
2. This field shows the current project.
3. This field shows the current project trial.
4. This is a link to the trial, which allows the title to be edited and a description to be entered

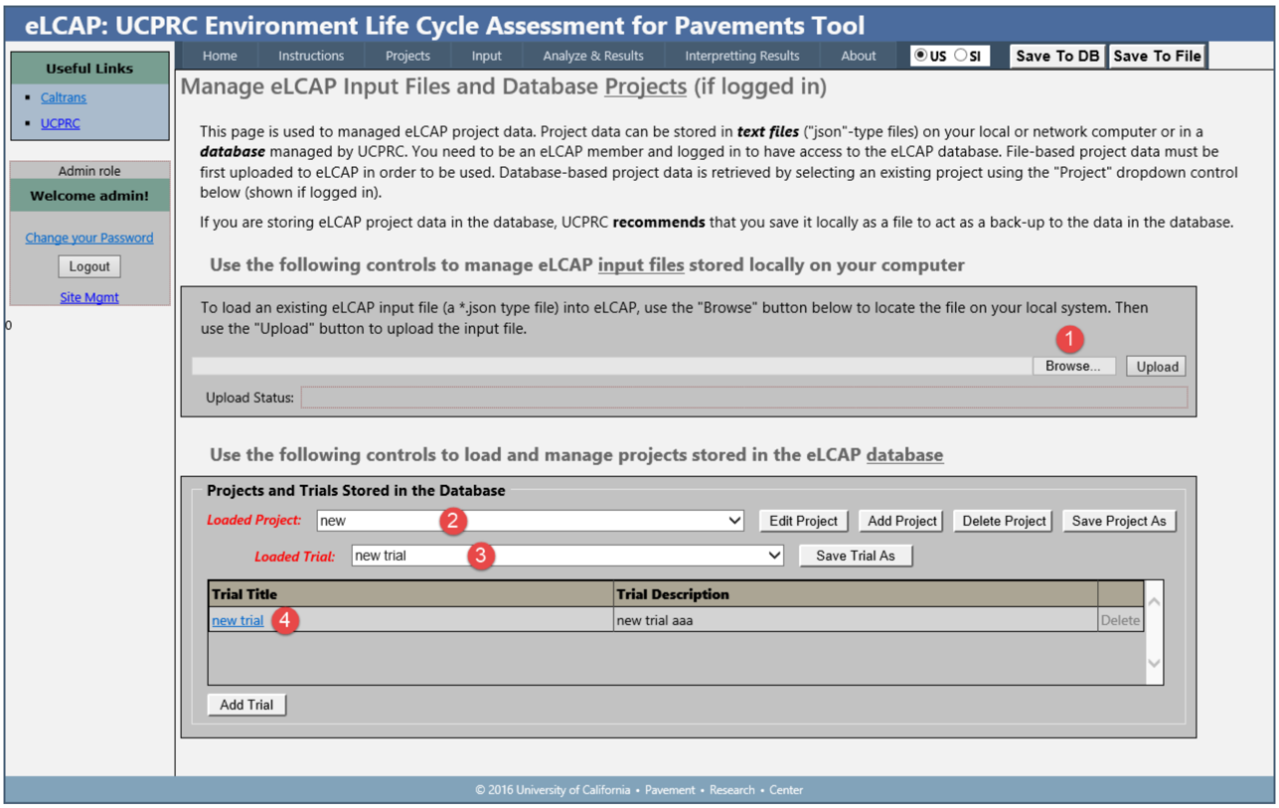


Figure 4.7. Projects and Trials Management Page.

The buttons on this page allow users to perform the following activities:

1. *Edit Project:* edit the current project. The kind of project (Caltrans or Local Agency) will be shown next to the name of the project.
2. *Add Project:* add a new project. A new trial will automatically be added to the new project. When a new project is added, a second page asks the user whether it is a Local Government project or a project on the Caltrans Managed network (Figure 4.8). Local government users should select “No.”
3. *Delete Project:* delete the current project. If there is only one project, this button is disabled.
4. *Save Project As*: creates a new project based on the current project.

5. *Save Trial As*: creates a new trial for the current project based on the current trial.
6. *Add a Trial*: add a new trial to the currently selected project.
7. *Selected Trial Comparison Report*: allows a user to select two or more trials and generate a report showing impact indicators for each trial to assist in trial comparisons.

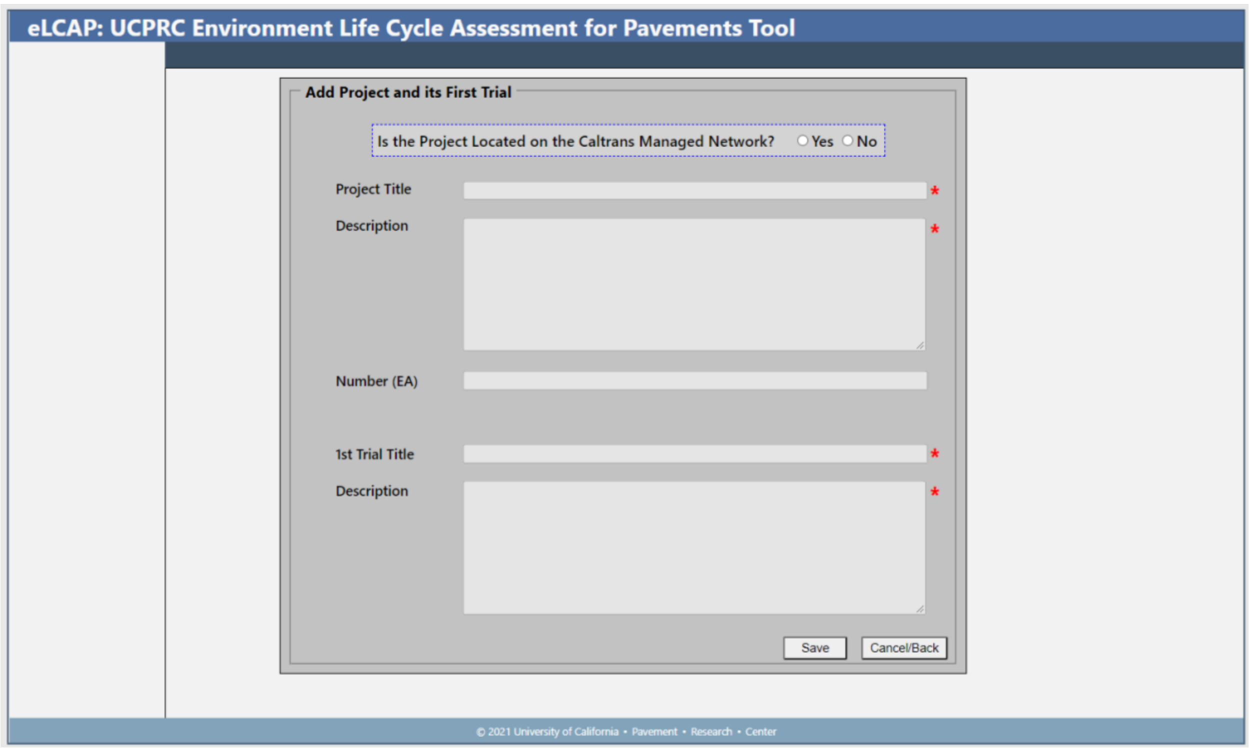


Figure 4.8. Project type Definition (local or state) when Adding New Project

4.3 Project Information

The Project Information page is accessed via the Input menu. Hovering the mouse cursor over the Input menu will reveal three submenu items (see Figure 4.9), one of which is "Project Information."

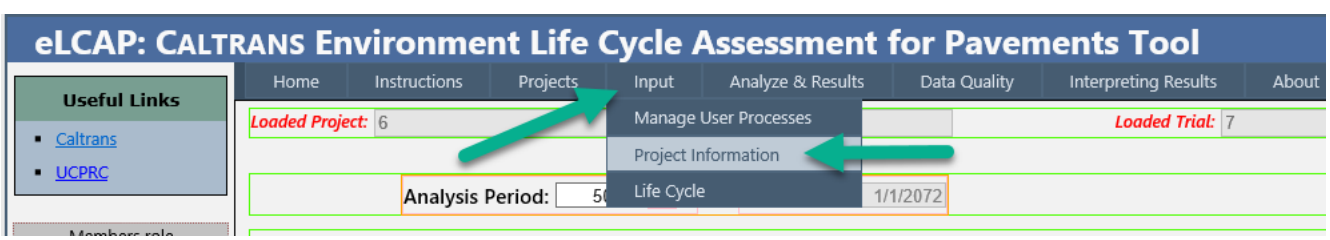


Figure 4.9. The Menu Item that Opens the Project Information Page.

Clicking Project Information for a local government project will bring up the local government Project Information page (Figure 4.10).

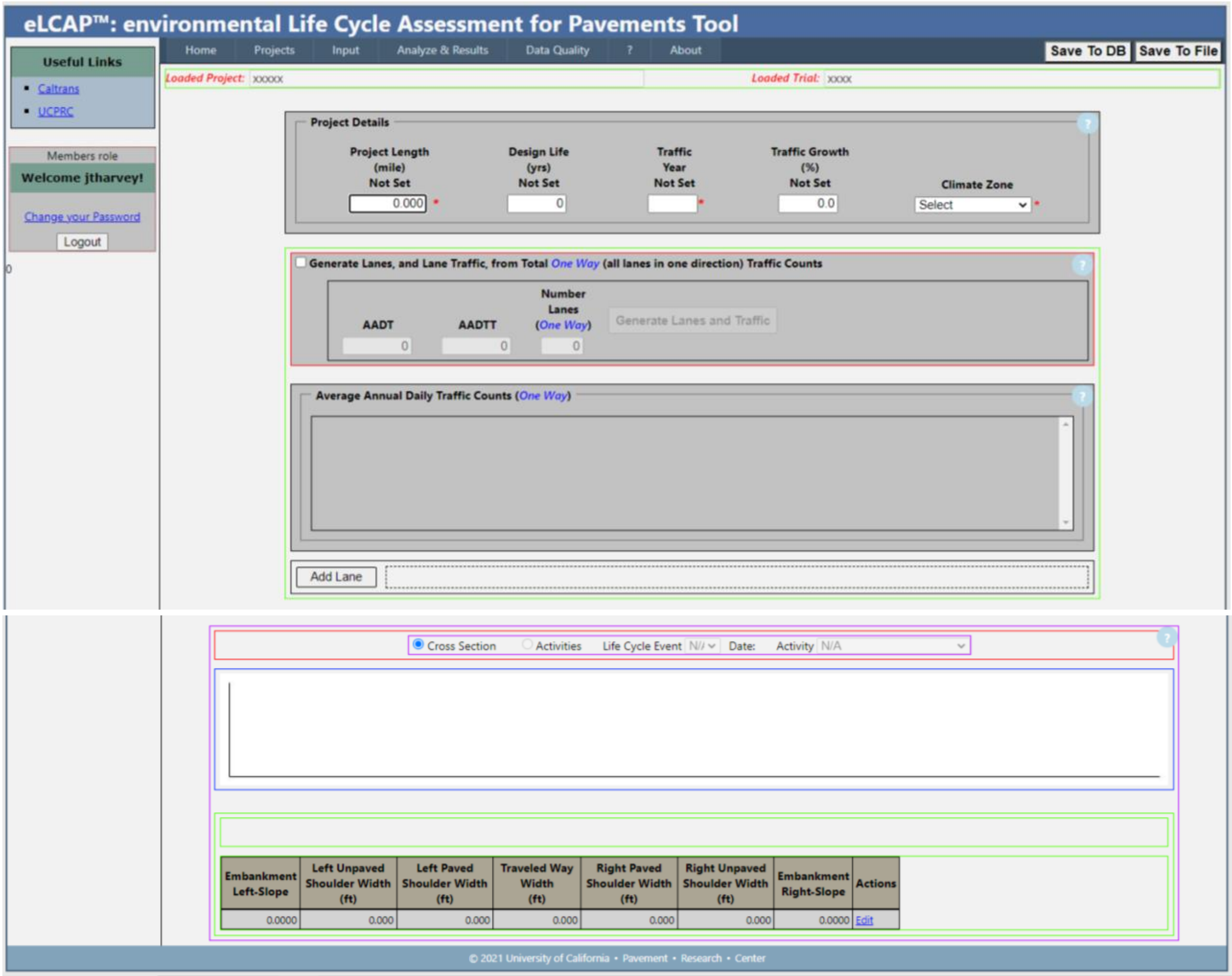


Figure 4.10. Local Government Project Information Page.

At the top of this page, a user defines the project length, the number of lanes, the design life, the initial year of traffic, the traffic growth rate. At the bottom of this page, a user defines the pavement cross section in terms of dimensions of the embankments, the unpaved shoulders, the paved shoulders, and the traveled way lanes.

4.4 Life Cycle Definition

The Life Cycle page is accessed via the same Input menu used to access the Project Information page (as discussed in Project Information). Hovering the mouse cursor over the Input menu will reveal three submenu items (see Figure 4.11), one of which is “Life Cycle.”

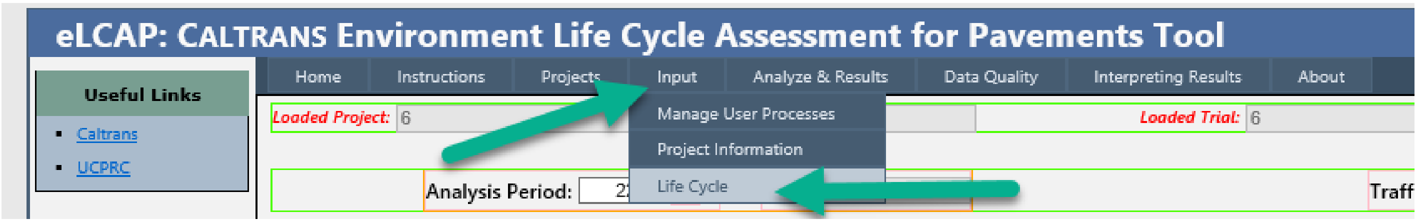


Figure 4.11. The Menu Item that Opens the Life Cycle Page.

Clicking Life Cycle will bring up the page on which a user defines the series of construction events that will model the project's life cycle. The top portion of the Life Cycle page, showing the Life Cycle grid, is shown in Figure 4.12. A Life Cycle Event is defined by the date of the event, the service life of the activities performed for the event, and the IRI roughness equation coefficients to use for the Use Stage that occurs between successive events. Each of the treatment options shown in the dropdown in Figure 4.12 has an associated set of IRI roughness equation coefficients that determines the rate of growth of IRI over time. The full Life Cycle page is shown in Figure 4.13.

Selecting a treatment type for the Use Stage Roughness Equation tells eLCAP to do two things: to include a use stage and to select the IRI roughness equation coefficients associated with the selected treatment. By default, "None" is selected, indicating that the user does not want to include a Use Stage for the life cycle event. A user should select the treatment that best represents the end result of the set of activities defined for the life cycle event. Major pavement treatment thickness definitions for the roughness equations include:

- Very Thin Overlay: ≤ 0.1 ft.
- Thin Overlay: > 0.1 ft, ≤ 0.2 ft
- Medium Overlay: > 0.2 ft, ≤ 0.5 ft
- Thick Overlay: > 0.5 ft

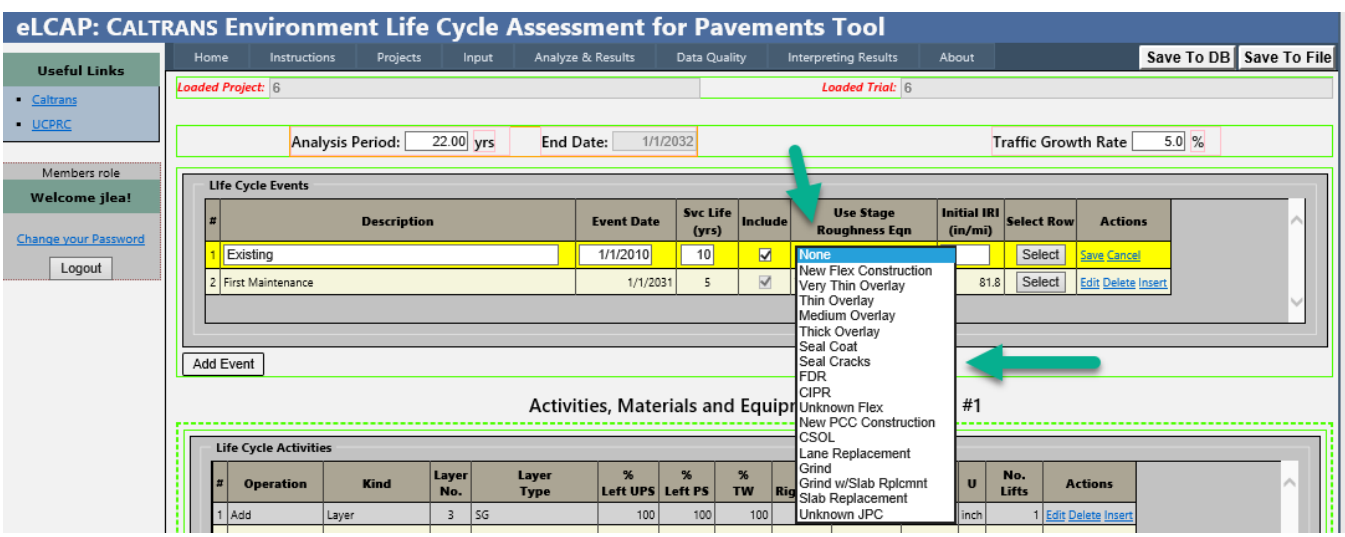


Figure 4.12. Selecting a Treatment for the Use Stage Roughness Equation.

As shown in Figure 4.13, the Life Cycle page is divided into four panes:

1. *Life Cycle Events:* the grid in this pane allows a user to add any number of life cycle events. The associated activities, materials, and equipment for the selected event (highlighted in yellow in Figure 4.13) will appear in the lower three panes.
2. *Life Cycle Activities*: the grid in this pane allows a user to add any number of activities for the selected event. The following is the list of activities and the various options for each:
    a. *Add*
        i. <u>Layer</u>: hot mix asphalt (HMA); portland cement concrete (PCC); aggregate base (AB); lean concrete base (LCB); cement treated base class A (CTB) class A and class B; asphalt treated permeable base (ATPB); cement treated permeable base (CTPB); cold central plant recycling (CCPR); full-depth recycling (FDR); partial-depth recycling (PDR); aggregate subbase (AS); lime treated subgrade (LTS); crack, seat and overlay (CSO); subgrade (SG)
        ii. <u>Seal Coat</u>: Chip Seal, Slurry Seal, Fog Seal, Cape Seal, Sand Seal, Tack Coat, Prime Coat
        iii. <u>Reflective Coating</u>: Bisphenol A, Polyester Styrene, Styrene Acrylate
    b. Remove
        i. Mill asphalt
        ii. Mill concrete
        iii. Grind & Groove
        iv. Cold plane
        v. Excavate
        vi. Haul Soil
3. *Materials and Transports to the Site:* the grid in this pane shows the eLCAP-generated materials, quantities, and means of transport for all the activities for the selected event; it also allows a user to manually add and delete materials.
4. *Equipment Used at the Site:* the grid in this pane shows the eLCAP-generated equipment and time of operation for each, for all activities for the selected event; it also allows a user to manually add and delete equipment.

When a life cycle event is added, the activities, materials, and equipment grids will be empty. eLCAP uses a default duration of 10 years between successive events to assist in constructing a life cycle. Users can edit the dates as necessary.

Each of the grids on the life cycle definition page consists of rows and columns. When the page first opens, the rows appear in *display* mode, allowing data items to be viewed but not edited. To enter *editing* mode to make changes, the user must click the “Edit” link in a particular row. After making changes, clicking “Save” will keep the changes and clicking “Cancel” will discard them.

When an activity is defined and saved, eLCAP will generate a default material to be used (e.g., a specific kind of HMA when adding an HMA layer) and a list of the construction equipment necessary to implement the activity.

eLCAP will also compute the quantities of material using the project limits (post mile start/end and number of lanes), the cross section defined on the Project Information page, and the thickness (add layer or remove material) specified for the activity. eLCAP will also provide construction time estimates for each piece of equipment. The default material and the computed material quantities and equipment time estimates may be edited.

A user can delete any or all of the items generated for an activity. In addition, a user can manually add materials and equipment. In fact, the user can skip defining any activities at all and directly add materials and their associated quantities, and equipment and its associated times of operation. But in most cases, defining activities for an event is more efficient than manually building lists of materials and equipment.

Clicking the links in the Source Name column in the two lower grids—Materials and Transports to the Site and Equipment Used at the Site—will display a form page with the data for the item. For example, if a user clicks the “HMA with 15% Binder Replacement, no Rejuv” in the Source Name column of the Materials and Transports to the Site grid, the HMA form page will be displayed. Listed on that form page will be all the input flows and their associated quantities needed to produce 1 unit of HMA. If the HMA is an eLCAP library material, no changes can be made to it, but if the HMA is a user-defined/custom HMA mix, changes can be made.

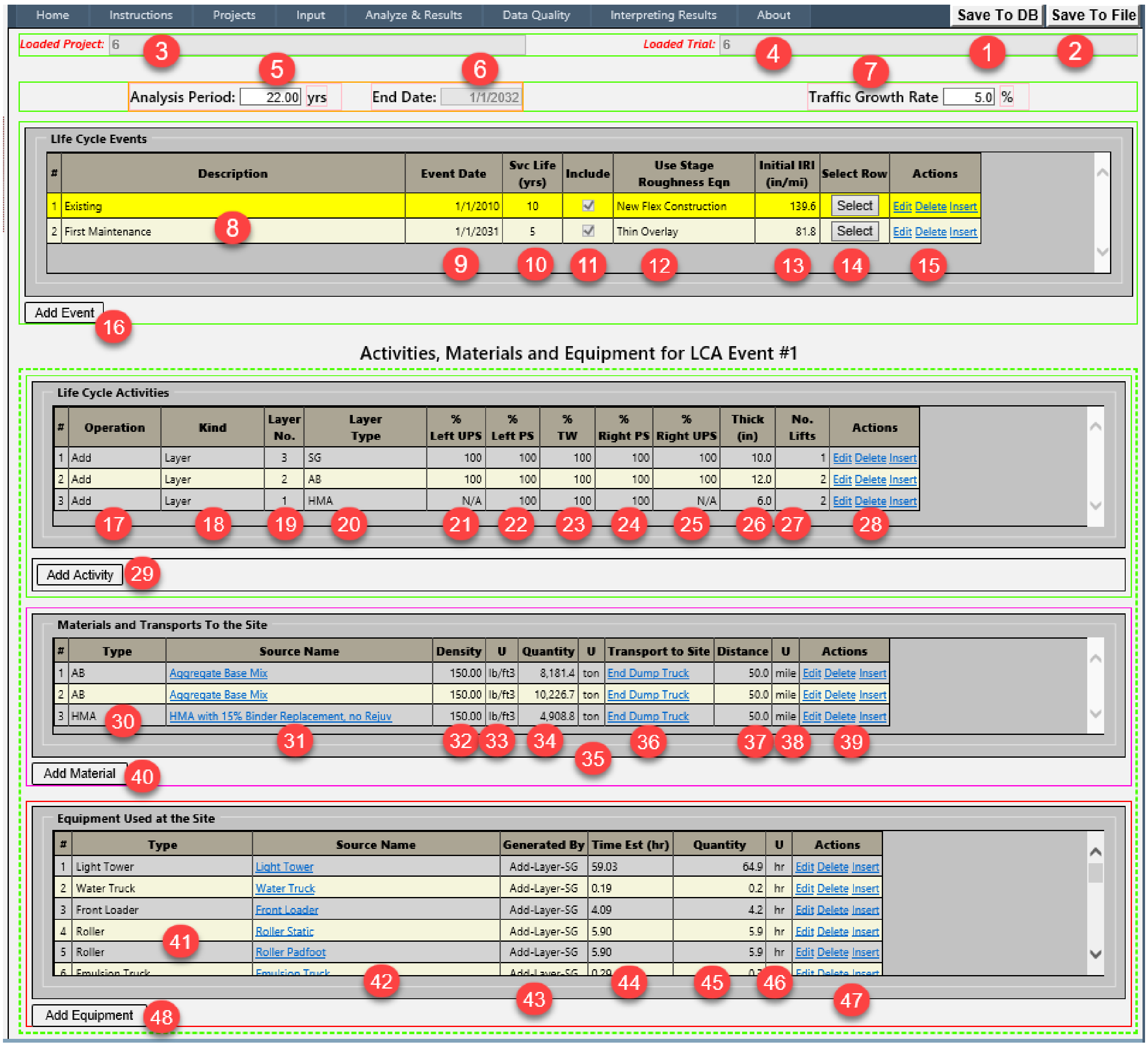


Figure 4.13. Life Cycle Definition Page.

The following list discusses the numbered items in Figure 4.13.

1. Button to click for saving the trial data to the database. Data are saved automatically when the user goes to the "Analyze & Results" page.
2. Button to click to save the trial data to a file on the computer.
3. Field that shows the current project (i.e., the "Loaded Project").
4. Field that shows the current trial (i.e., the "Loaded Trial").
5. Field to set the analysis period.
6. End date, generated by eLCAP.
7. Field to set the traffic growth rate (traffic counts are used between events in the Use Stage).
8. Field to enter text that describes what the event is modeling in the life cycle.
9. Field to set the date for the event.
10. Field to set the service life of the event in years.
11. Checkbox used to tell eLCAP if the event should be included in the LCA.
12. Dropdown list to select the treatment type that best represents the end result of the event.
13. Field to change the default Initial IRI for the event.
14. Used to select the event that will have its activities, materials, and equipment lists displayed in the lower three grids.
15. Buttons used to edit, delete, or insert an event.
16. Button used to add an event.
17. Dropdown list to select the operation for the activity (e.g., Add/Remove).
18. Dropdown list to select the kind of operation for the activity (e.g., Layer).
19. eLCAP-generated layer number.
20. Material type of the layer.
21. Percent of Left Unpaved Shoulder (UPS) width to include for the activity.
22. Percent of the Left Paved Shoulder (PS) width to include in the activity.
23. Percent of the Traveled Way (TW) width to include in the activity
24. Percent of the Right Paved Shoulder (PS) width to include in the activity.
25. Percent of the Right Unpaved Shoulder (UPS) width to include in the activity.
26. Thickness of the layer or the amount to remove in the activity.
27. eLCAP pre-populates this with the number of lifts required, per Caltrans rules.
28. Buttons used to edit, delete, or insert a life cycle activity.
29. Button to add a life cycle activity.
30. Shows/selects the type of material for the activity.

31. Shows/selects the source of the material; also used to select a custom material.
32. Field that is pre-populated with the density of the layer material.
33. Dropdown list to select the units for the density of the material.
34. Shows/selects the amount of the material.
35. Shows/selects the measurement units associated with the amount.
36. Show/selects the transport for bringing the material to the project.
37. Shows/selects the distance for the transport of the material to the project site.
38. Show/selects the measurement units for distance.
39. Buttons used to edit, delete, or insert a material.
40. Button used to add a new material to the material grid.
41. Shows/selects equipment type to be used at the site.
42. Shows/selects the piece of equipment to be used.
43. eLCAP-generated to indicate which activity generated the equipment.
44. eLCAP-generated estimate of how much equipment time will be needed.
45. Shows/selects the amount of time that the equipment at the site will operate.
46. Shows the measurement units (U) for the amount of time.
47. Button used to edit, delete, or insert a piece of equipment.
48. Button used to add a piece of equipment.

4.5 User-Defined Processes

eLCAP has many built-in materials, also referred to as *library materials,* that a user can select to define a construction-type event. The library materials are organized by type, e.g., HMA, PCC, etc., and there are several individual processes per type. For example, there are three different types of HMA on which to base a user-defined, custom HMA.

Figure 4.14 shows the page for managing user-defined processes. The “Add New” button is used to add a new user-defined process for the type of material shown in the drop-down to the left of the button. The grid lists all user-defined processes.

The link in the Source Name column will display the edit form page for the process. The # Refs column indicates how many times the user-defined process is referenced by any trial. If the user-defined process is referenced, it cannot be deleted and the “Delete” button will be disabled.

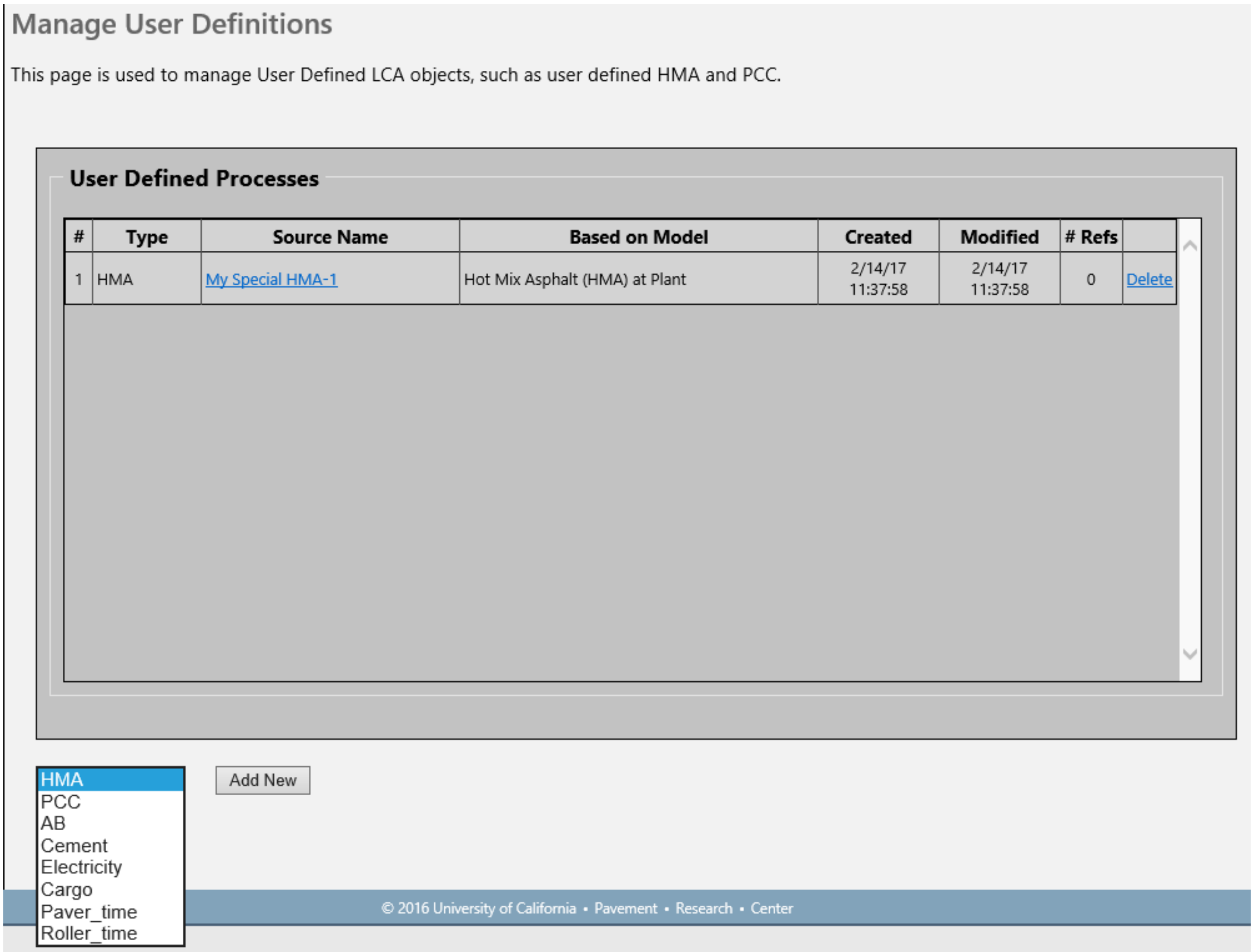
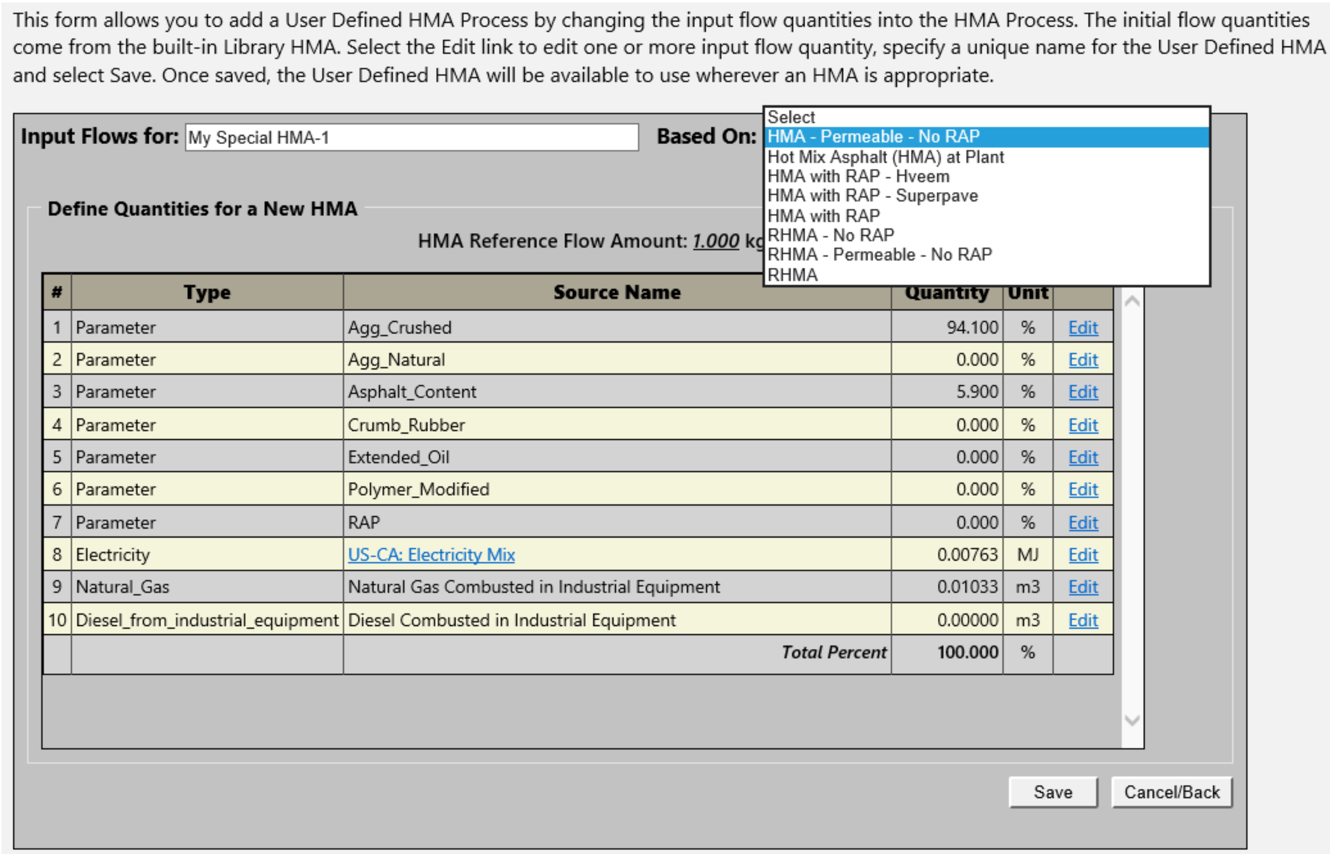


Figure 4.14. The Page to Manage User-Defined Processes.

Clicking the “Add New” button when HMA is shown in the dropdown menu brings up the HMA edit form page shown in Figure 4.15. Once this page appears, the user supplies a unique name to the user-defined HMA and then selects one of the HMA types in the eLCAP library by using the “Based on” drop-down menu. Next, the user edits individual rows to customize the HMA. For example, a user might want to have a special HMA that uses 4 percent “Asphalt Content” instead of the library’s version of 6 percent, or maybe they want to use a user-defined process (previously defined) for electricity for this new user-defined HMA.

Once a user-defined process has been created, it may be referenced when constructing the life cycle (see Life Cycle Definition).


This form allows you to add a User Defined HMA Process by changing the input flow quantities into the HMA Process. The initial flow quantities come from the built-in Library HMA. Select the Edit link to edit one or more input flow quantity, specify a unique name for the User Defined HMA and select Save. Once saved, the User Defined HMA will be available to use wherever an HMA is appropriate.

Input Flows for: My Special HMA-1 **Based On:**

Select
HMA - Permeable - No RAP
Hot Mix Asphalt (HMA) at Plant
HMA with RAP - Hveem
HMA with RAP - Superpave
HMA with RAP
RHMA - No RAP
RHMA - Permeable - No RAP
RHMA

Define Quantities for a New HMA

HMA Reference Flow Amount: *1.000* kg

#	Type	Source Name	Quantity	Unit	
1	Parameter	Agg_Crushed	94.100	%	Edit
2	Parameter	Agg_Natural	0.000	%	Edit
3	Parameter	Asphalt_Content	5.900	%	Edit
4	Parameter	Crumb_Rubber	0.000	%	Edit
5	Parameter	Extended_Oil	0.000	%	Edit
6	Parameter	Polymer_Modified	0.000	%	Edit
7	Parameter	RAP	0.000	%	Edit
8	Electricity	US-CA: Electricity Mix	0.00763	MJ	Edit
9	Natural_Gas	Natural Gas Combusted in Industrial Equipment	0.01033	m3	Edit
10	Diesel_from_industrial_equipment	Diesel Combusted in Industrial Equipment	0.00000	m3	Edit
		Total Percent	100.000	%	

Save Cancel/Back

Figure 4.15. Adding User-Defined HMA Process Page.

4.6 Default/Min/Max Values

eLCAP has a few default values that minimize user time when creating a new project trial. The following are the default values:

- Years added to the start of first life cycle event to establish the end-of-life date: **50 years**
- Construction time duration for a life cycle event: **6 months**
- Use Stage time duration between construction events: **10 years**
- Traffic Growth Rate: **0.0%**

eLCAP also makes range checks on data items so that unreasonable numbers/results are avoided. The minimum value is usually "0.0" and the maximum value is usually a large number so as not to constrain the user too much.

4.7 Data Quality Assessment

Metadata and data quality assessment information are available on the Data Quality tab as can be seen in Figure 4.16.

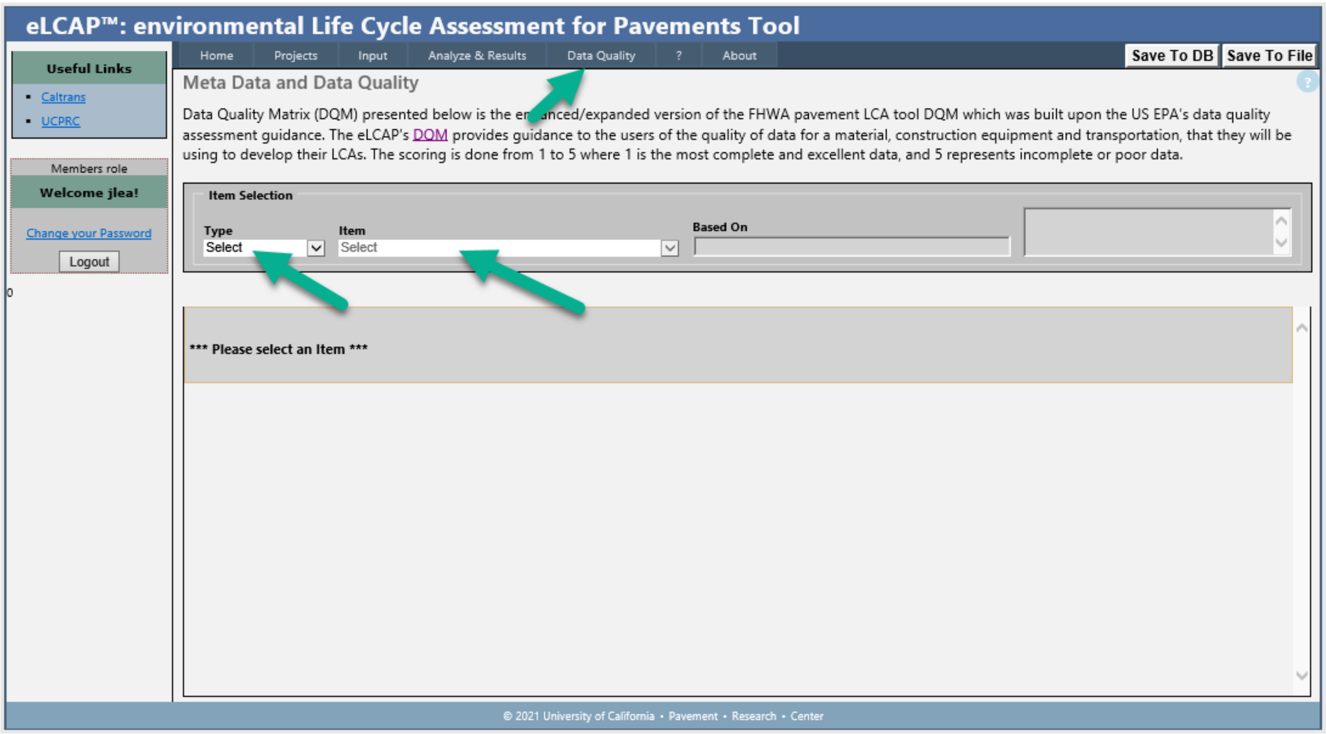


Figure 4.16. Data Quality Tab Location on the eLCAP Page.

The type of process and the specific item (material, equipment, or transport) whose metadata and data quality are to be assessed are first selected on this page. If it is a composite material (made with different materials), the metadata and data quality for the component materials are accessed individually. Figure 4.17 is shown for the component materials of RHMA-G (rubberized hot mix asphalt-gap graded).

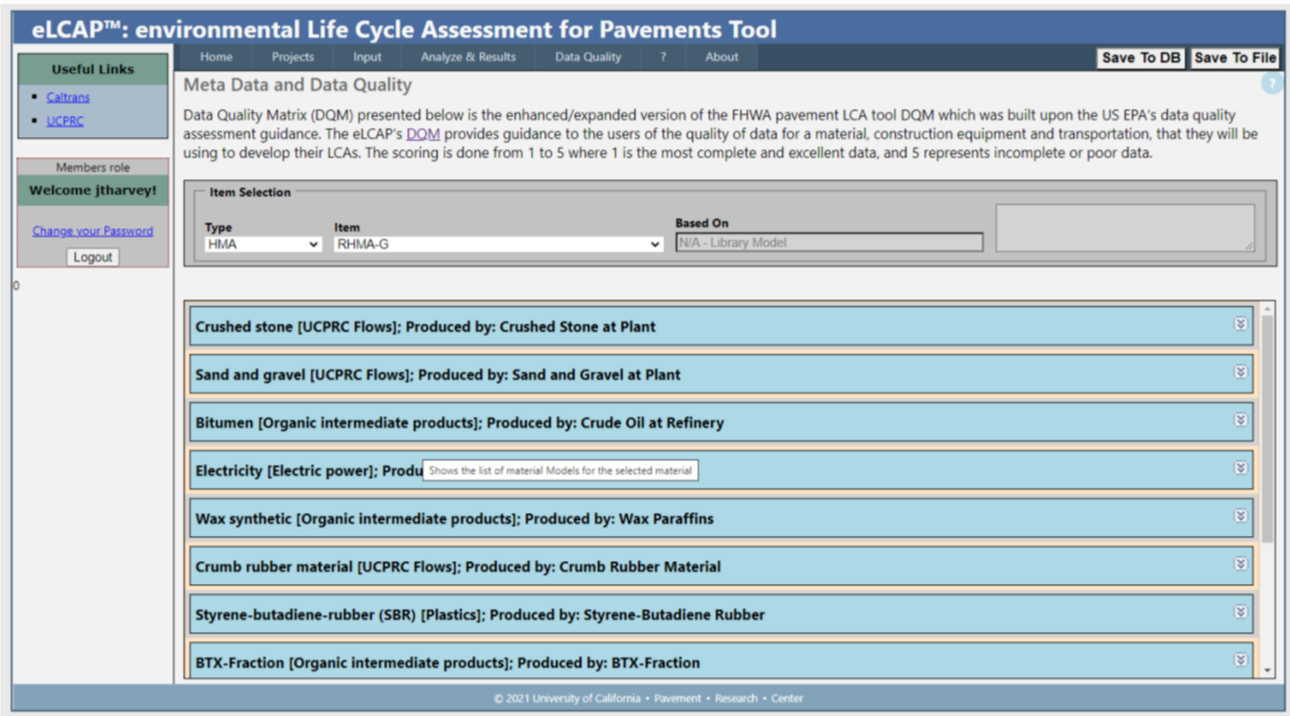


Figure 4.17. Example Showing Metadata and Data Quality Assessment Information (embedded under blue boxes) for Each Ingredient of RHMA-G (rubberized hot mix asphalt-gap graded).

Once an item is selected, the metadata and data quality assessment described in Data Quality Assessment can be seen, as shown in Figure 4.18.

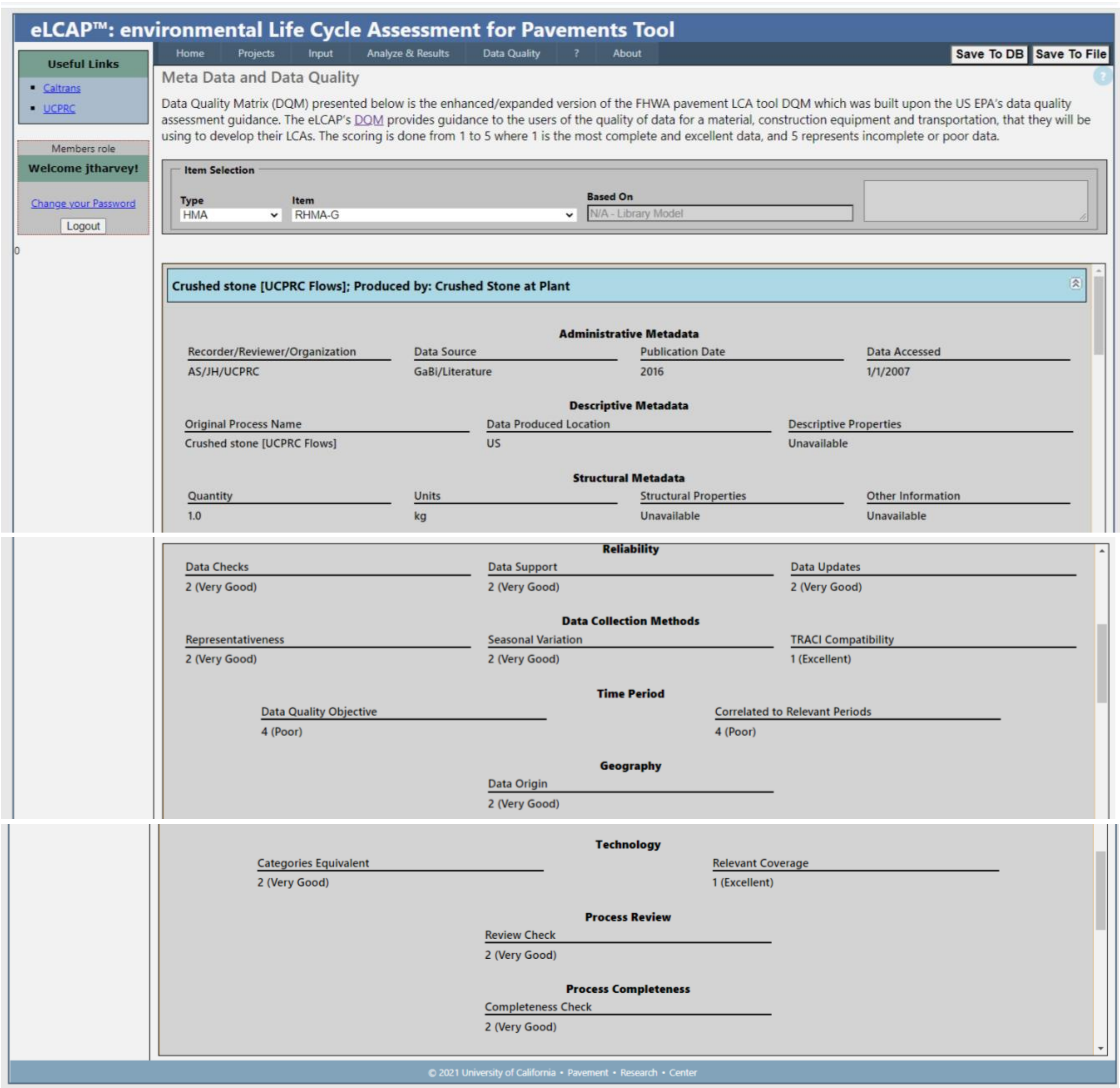


Figure 4.18. Example Showing Metadata and Data Quality Assessment of Crushed Stone that is being used in the RHMA-G (rubberized hot mix asphalt-gap graded).

4.8 Analyze & Results

The Analyze & Results page is used to perform an LCA and to obtain results. Figure 4.19 shows the Analyze & Results page. During a life cycle analysis, total GHG is displayed in the graph as it is computed for each construction-type event and each Use Stage event. Summary results appear in a scrollable window after the LCA is completed: there is a summary section for each construction-type event (Figure 4.19) and each Use Stage event in the life cycle (Figure 4.20). Report files *(Excel* and *PDF)* can be downloaded to a local computer by clicking the "Get Results" button.

The read-only fields at the top indicate the Project and Trial that will be used for the LCA.

The Balance Selection Controls are for expert users and do not appear for most users. The Model drop-down menu is used to select the LCA model that will be used for the balancing, and the Process drop-down menu is used to select the process in the model that will be the starting point for balancing. The default selection for the model is "Pavement Project" and the default selection for the process is "Pavement Project (u-so)." See Balancing for a discussion of balancing.

Balancing for a process (i.e., starting at and traversing/climbing upstream from the process) results in the generation of the LCI for the process. Expert LCA users may want to generate the LCI for a different process in the Pavement Project LCA model other than the Pavement Project process and these controls allow that to be done.

To initiate the LCA, the user clicks the "Balance" button. eLCAP will perform the LCA by looping over all the events (Construction Stage and Use Stage) in the life cycle, building an LCA model for each, balancing, and then performing the Life Cycle Impact Assessment (LCIA).

The "progress" message area immediately below the buttons on the page provides feedback to the user during the LCA. There are messages for each event. Construction-type events typically take more time to execute so the messages are easier to read; Use Stage events happen very quickly so the messages pass by quickly. For longer-executing events, there will be numbers visible in the message area as eLCAP sends second counts to the browser during the LCA.

The last messages shown for an LCA are "Report Generation Started" and "Report Generation Done." When these appear the "Get Results" button is enabled and generated report files can be downloaded.

The LCA may be stopped before it is complete by clicking the "Cancel" button.

Figure 4.19. Analyze & Results Page. (Note: example page, results not associated with other figures.)

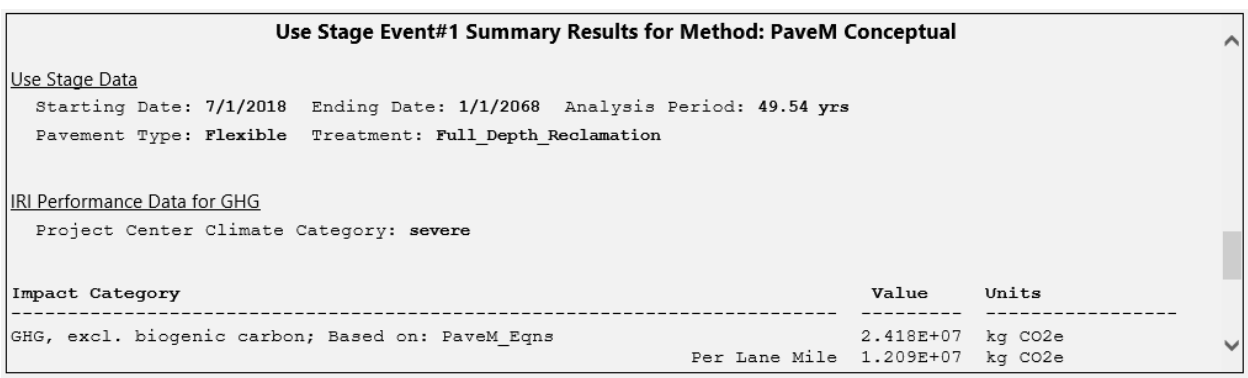


Figure 4.20. Analyze & Results Page Showing Use Stage Event Summary Results. (Note: example page, results not associated with other figures.)

4.8.1 Results Generation

A set of reports is generated automatically for each construction event–Use Stage pair of events. Detailed/debug level reports are generated as well as a standard Excel report. The list of reports for a single construction event and a single Use Stage life cycle event is shown in Figure 4.21. The Excel file is the standard report and all others are detailed/debug level reports.

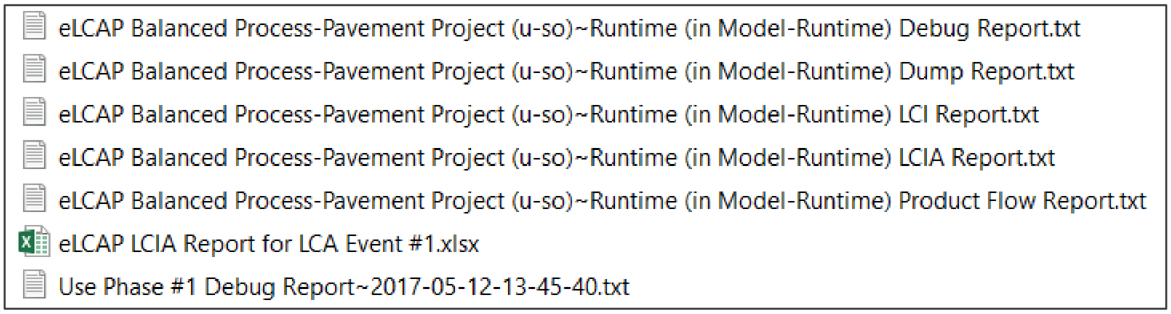


Figure 4.21. Generated Reports Ready for Download.

4.8.1.1 Detailed/Debug Level Reports

Figure 4.21 shows the reports generated by eLCAP for a single construction event–Use Stage pair of events. The first five reports shown in the figure are detailed/debug level construction-type event reports. The first one listed is the most comprehensive of the reports: it gives input/output flows for every process in the Pavement Project Model (there can be hundreds of them) with the following data for each flow:

1. Flow name
2. Amount of flow “as collected”
3. Amount of the flow normalized to produce a unit value for the output product flow
4. Amount of the flow scaled as required by the Pavement Project Process to produce a single pavement project

Since the process of balancing starts at the Pavement Project Process and “climbs” upstream for each input flow into that process, the Pavement Project Process is the last one to be completed, and thus it appears at the end of the report. Figure 4.22 shows the sample results for that process.

The figure shows that there were 108 processes in the LCA model and that the Pavement Project Model has a single input flow (907.185 kg of HMA, which is a user input value of 1 ton of HMA) and one output flow (a pavement project).

Since the user specified 1 ton of HMA for the example pavement project, all flows in the HMA Process upstream from the Pavement Project Process are scaled by 907.185. The scaling is performed, recursively, upstream for each model attached to each input flow in each process.

```
Process (108) Information for: Pavement Project (u-so)~Runtime              This Process is FIXED;   Model Scale Factor: 1.000
     This is a Pavement Project (u-so) Process


                                        All Techsphere and Nature flows are scaled by: 1.000000e+00

                                                                                                                Normalized to #
                                 Flows                      As Collected             Normalized to *       Techsphere Flows    Nature Flows
---------------------------------------------------- ---------------------- --------------------------- ---------------- ------------------
Inflows
  Hot Mix Asphalt (HMA) [UCPRC Flows]-1                 907.185 kg             907.185 kg/pcs             907.185 kg/pcs

Outflows
  Pavement Project [UCPRC Flows]*#                        1.000 pcs              1.000 pcs/pcs                                         1.000 pcs/pcs
```

Figure 4.22. Debug Level Report Results for the Pavement Project Process. (Note: example page, results not associated with other figures.)

Figure 4.23 shows some of the detailed information in the Use Stage event report.

The top section shows the three route segments for the example of a US 101 in del Norte County (DN-101-North) with their associated post miles. The second section shows some high-level Use Stage data. The third section shows route segment and lane data for the first year on the Use Stage. The information in this section is discussed in Performance Model-Based Impacts.

```
Segment List AFTER Project Limit Trimming (Traffic Volumes are for BOTH Directions)

                                    MgmtSegment List for Pavement Project Get Segments
---------------- Beg Segment Boundary ------------  ------- Segment ------   ---------------- End Segment Boundary ------------
   Event            CODM(m)      SODM          PM      Lanes   AADT  Trks Yr      Event           CODM(m)      SODM          PM
---------------  ----------  ----------  ---------  -----  ------ ----- --   ---------------  ----------  ----------  ---------
BegProj               0.0     763.637     M0.000       2    4450   507 00   LaneRange               0.0     767.317     R3.647
LaneRange             0.0     767.317     R3.647       1                       Traffic                 0.0     768.308     R4.638
Traffic               0.0     768.308     R4.638       1                       EndProj                 0.0     768.670     R5.000



Use Stage Data
          Starting Date: 1/1/2019    Ending Date: 7/1/2029    Analysis Period: 10.50 yrs
          Pavement Type: Flexible    Treatment: Full_Depth_Reclamation
          Project Length: 5.033 miles    Total Lane Miles: 8.713 miles    Avg # Lanes 1-Dir: 1.73

          Project Center Climate Zone: North Coast    Climate Category: severe
          Traffic Growth Rate: 0.0%



Use Stage GHG Due To IRI (Traffic Volumes Reflect Growth Rate Effects from Midpoint of Traffic Count Year to Date Shown in 'Date' Column)

Yr#     Date     Year Seg#  Seglen C WIM Ln#   DF     AADT    CarVol  TrkVol 2-Axle 3-Axle 4-Axle 5-Axle ESAL E   A     B   C   IRI       GHG
                             (mi)                                                                    (k)                     (ipm)      (kg)
--- ---------- ---- ---- ------- - --- --- ----- ------- ------- ------- ------ ------ ------ ------ ---- - ----- ---- --- ----- ------------
  1   7/1/2019  0.5    1    3.680 s  1b   1 0.190   1,152   1,104      48     17      8      0     20   24 A 157.3  3.4 1.0 159.0 7.343863E+05
                                          2 0.810   1,072     868     204     75     37      2     89  101 B 143.0  5.1 1.0 145.6 1.006404E+06
                          Segment Totals:   1.000   2,224   1,972     252     92     45      2    109                              1.740790E+06

                       2    0.991 s  1b   1 1.000   2,225   1,972     253     93     46      3    110  124 B 143.0  5.1 1.0 145.6 4.707014E+05
                          Segment Totals:   1.000   2,225   1,972     253     93     46      3    110                              4.707014E+05

                       3    0.362 s  1b   1 1.000   2,300   2,063     237     61     31     50     94  117 B 143.0  5.1 1.0 145.6 1.787601E+05
                          Segment Totals:   1.000   2,300   2,063     237     61     31     50     94                              1.787601E+05
                                                                                                                  Year Total:  2.390251E+06
                                                                                                    Year Total Per Lane Mile:  2.743316E+05
```

Figure 4.23. Debug Level Report Results for the Use Stage. (Note: example page, results not associated with other figures.)

4.8.1.2 Standard Excel Report

The following sections show some of the results for the standard Excel report.

Sample Project-Level bar chart. Figure 4.24 shows 6 of the 18 computed impact indicators, with each chart showing results for “Material Production,” “Transport,” “Construction Equipment,” and “Construction.”

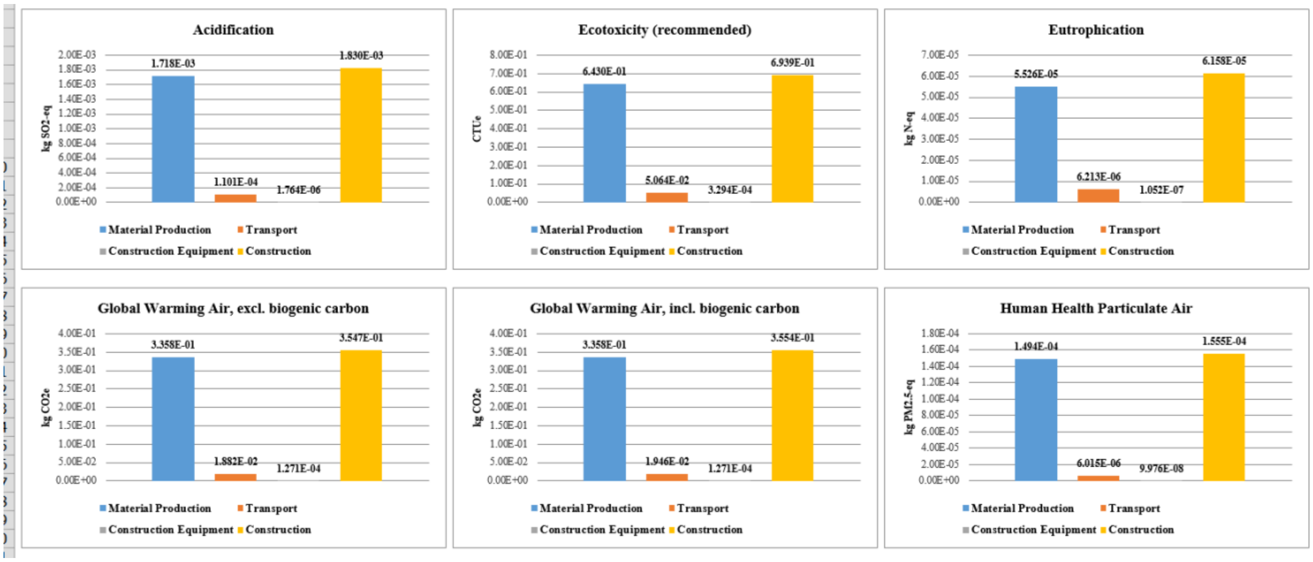


Figure 4.24. Excel Report Showing Bar Charts.

Sample Material-Level bar chart. Figure 4.25 shows 2 of the 18 computed impact indicators, with each chart showing several different types of grouped results.

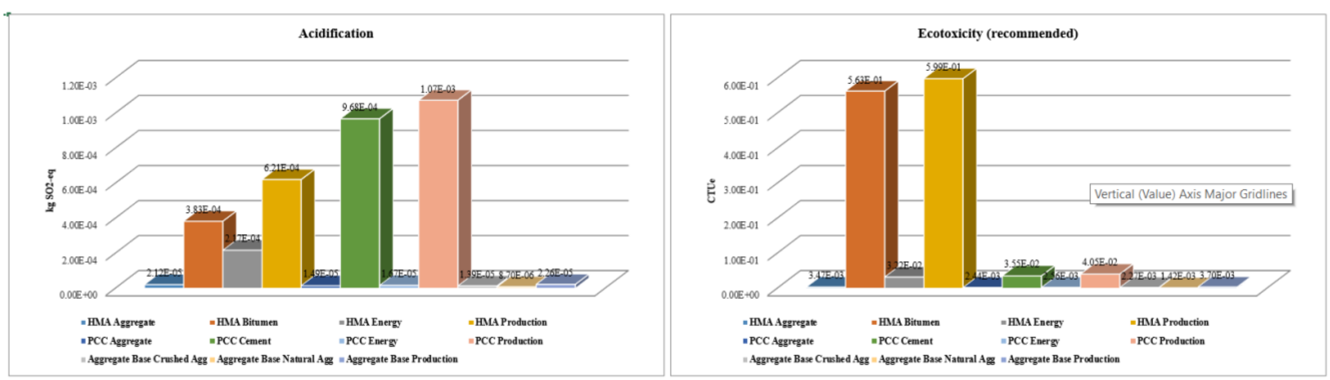


Figure 4.25. Excel Report Showing 3D Bar Charts.

Sample result table. Figure 4.26 shows the Project Totals table.

Project Totals

Selected Impact Categories and Inventories	Material Production	Material Production as % of Construction	Transport	Transport as % of Construction	Construction Equipment	Construction Equipment as % of Construction
Acidification	1.7178E-03	93.89%	1.1011E-04	6.02%	1.7637E-06	0.10%
Ecotoxicity (recommended)	6.4297E-01	92.66%	5.0638E-02	7.30%	3.2940E-04	0.05%
Eutrophication	5.5258E-05	89.74%	6.2132E-06	10.09%	1.0523E-07	0.17%
Global Warming Air, excl. biogenic carbon	3.3580E-01	94.66%	1.8821E-02	5.31%	1.2715E-04	0.04%
Global Warming Air, incl. biogenic carbon	3.3581E-01	94.49%	1.9461E-02	5.48%	1.2715E-04	0.04%
Human Health Particulate Air	1.4940E-04	96.07%	6.0149E-06	3.87%	9.9763E-08	0.06%
Human toxity, cancer (recommended)	2.2114E-10	97.77%	5.0047E-12	2.21%	4.3398E-14	0.02%
Human toxity, non-cancer (recommended)	5.2534E-08	94.94%	2.7842E-09	5.03%	1.8156E-11	0.03%
Ozone Depletion	1.1043E-09	99.93%	7.9885E-13	0.07%	5.1961E-15	0.00%
Resources, Fossil fuels	5.5400E-01	93.65%	3.7342E-02	6.31%	2.4289E-04	0.04%
Smog Air	2.4085E-02	88.74%	3.0006E-03	11.06%	5.6148E-05	0.21%
Primary Energy Demand used as raw materials (Feedstock Energy)	2.4120E+00	100.00%	0.0000E+00	0.00%	0.0000E+00	0.00%
Primary energy demand from ren. and non ren. resources (gross cal. value)	5.1562E+00	94.67%	2.8825E-01	5.29%	1.8749E-03	0.03%
Primary energy demand from ren. and non ren. resources (net cal. value)	4.8278E+00	94.68%	2.6936E-01	5.28%	1.7520E-03	0.03%
Primary energy from non renewable resources (gross cal. value)	5.0339E+00	94.55%	2.8825E-01	5.41%	1.8749E-03	0.04%
Primary energy from non renewable resources (net cal. value)	4.7055E+00	94.55%	2.6936E-01	5.41%	1.7520E-03	0.04%
Primary energy from renewable resources (gross cal. value)	1.2232E-01	100.00%	0.0000E+00	0.00%	0.0000E+00	0.00%
Primary energy from renewable resources (net cal. value)	1.2232E-01	100.00%	0.0000E+00	0.00%	0.0000E+00	0.00%

Figure 4.26. Excel Report Showing Data Table.

5 Summary of Changes to Support Local Agency Users of eLCAP

The underlying issue for local agency users of the Caltrans version of eLCAP is that the location of the project is not on the Caltrans location reference system (LRS) highway system, which pulls traffic and other data from Caltrans databases using the District-County-Route-Direction-Lane-Postmile LRS. eLCAP makes use of the specific traffic counts and climate zones needed for the Use Stage when computing GHG using the LRS. The basic LCA compute engine (combining flow-based LCIs for materials, transports, and construction equipment in order to compute 18 impact factors) did not require any changes. Changes were required in the UI, reports, database schema, and online help.

The first change was to add a project type control on the Add New Project page (Figure 5.1) This change required a change to eLCAP's database schema, handling of existing data sets, and also coordination with *CalME* code (UCPRC supported Caltrans pavement design software), since they share project and trial code. Once a selection is made for project type, it cannot be changed for the project: all trials added to the project share the project's project type (local or Caltrans managed network).

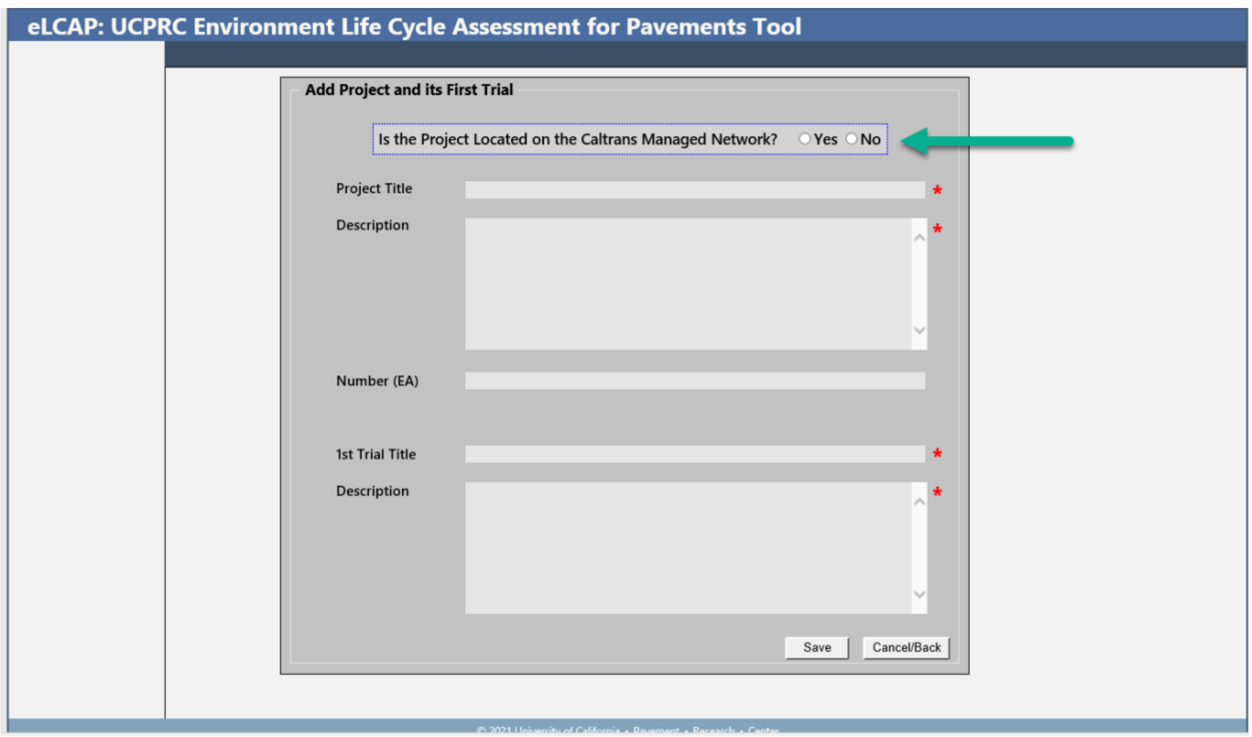


Figure 5.1. New Page to Identify Local Government Projects.

This new project type gets used at various locations in eLCAP, such as when computing GHG (IRI roughness equation) for the Use Stage (traffic for Local Agency comes from the user, not the Caltrans traffic database) and generating reports.

The note was added about the type of project currently loaded on the Projects page as well (Figure 5.2).

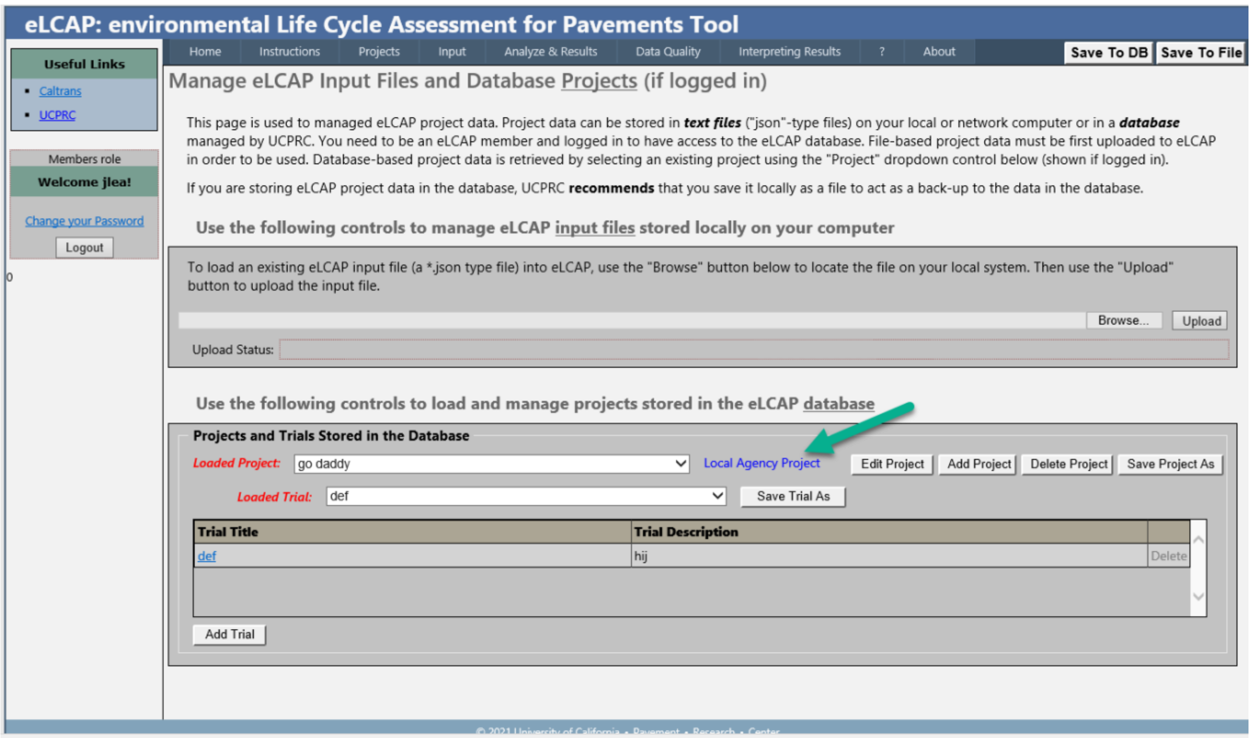


Figure 5.2. Project Type Indicator on Projects Page.

A new input page was developed for local government users to input traffic data (Figure 5.3). The user inputs project details including:

- Project Length
- Design Life
- Traffic Year
- Traffic Growth
- Climate Zone

Local agency traffic is specified by the user (Caltrans projects use the Caltrans traffic database), using one of two methods. In the first method the user inputs simple information:

1. One-way route traffic
    - AADT
    - AADTT
    - Number of Lanes

For this approach eLCAP uses truck lane distribution factors to spread total trucks across to the lanes, and new, Local Agency specific 2/3/4/5 axle distribution factors are applied to the user specified total trucks.

Users who have detailed truck type information can use a second approach to directly input traffic data.

1. Lane-based traffic
    - AADT – total traffic (cars and trucks)
    - AADTT – total trucks
    - 2/3/4/5 axle truck counts
    - ESALs/yr – computed by eLCAP
    - Checks are made on each lane's counts
    - Totals are summed and presented

The equivalent single axle loads per year are calculated from both sets of data using the Caltrans load equivalence factor exponent of 4.2 and the Caltrans ESAL equation.

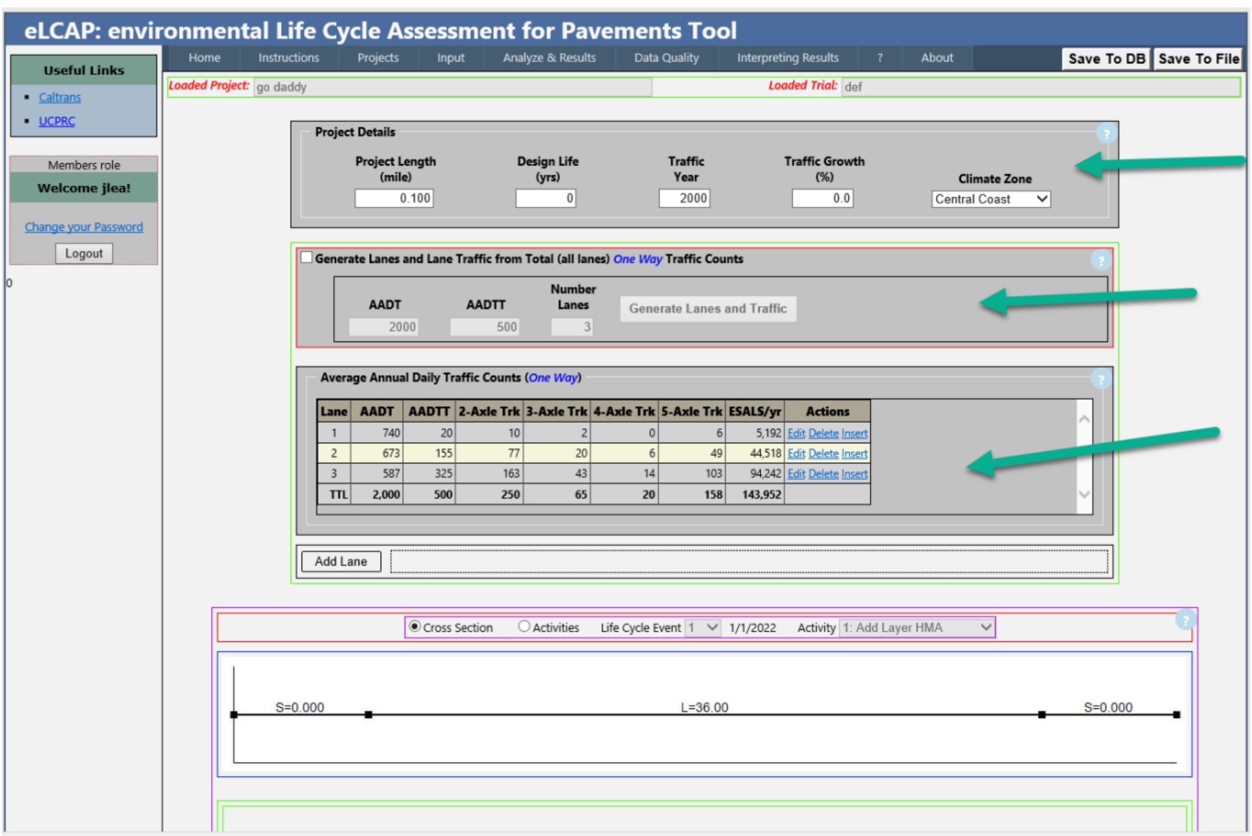


Figure 5.3. New Traffic and Climate Region Data Input Page for Local Government Projects.

The reports in eLCAP have been updated to identify the type of project (Figure 5.4) and display the traffic data used for the use stage (Figure 5.5).

***eLCAP* v1.DD001.0** **User:** Jon Lea **Report Time Stamp:** Tuesday, March 30, 2021, 9:45 AM

On Caltrans Network: No

Project: go daddy

Description: abc

Trial: def

Description: hij

Output Time Stamp: Tuesday, March 30, 2021, 9:44 AM

Figure 5.4. Local Government Project Identification in Report.

Traffic Counts (Single Direction)

Growth Rate: **0.0%**

Year: **2000**

Lane	AADT	AADTT	2-Axle	3-Axle	4-Axle	5-Axle
		--------- Average Annual Daily Truck Counts --------				
1	740	20	10	2	0	6
2	673	155	77	20	6	49
3	587	325	163	43	14	103
TTL	2,000	500	250	65	20	158

Figure 5.5. Calculated Traffic Data from User Input Assuming Weigh-In-Motion Spectrum 1.

The online help in eLCAP has been updated to provide information to the user about the local agency version of the program (Figure 5.6).

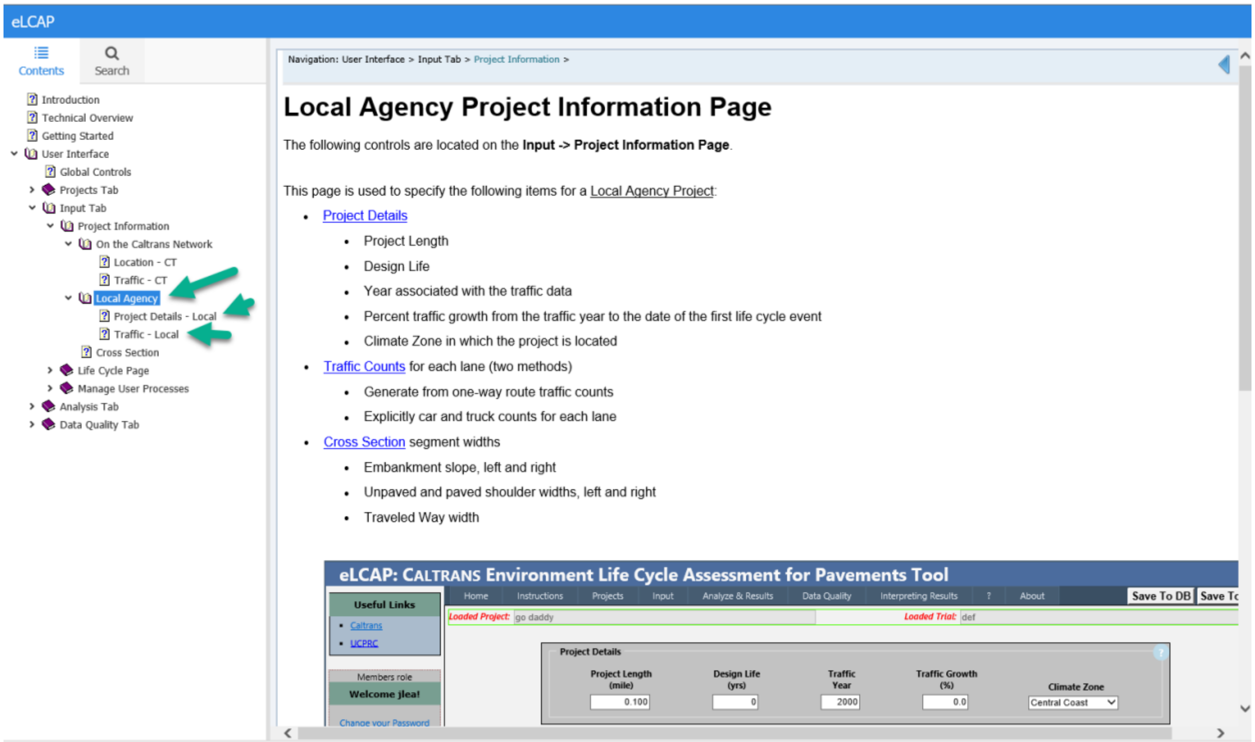


Figure 5.6. Local Agency Project Information Page in On-line Help.

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