

DESIGN AND DEVELOPMENT OF ONLINE LIFE CYCLE ASSESSMENT SOFTWARE

Vijaya Rajeswaran S P^{#1}, Anandhan M^{#2}, Prabakaran T^{#3}

^{1,2,3}Department of Mechanical Engineering, Mepco Schlenk Engineering College, India

Abstract

In this work the web-based Life Cycle Assessment (LCA) software has been proposed for LCA beginners. The objective of the online proposed LCA software is to simplify the LCA study. The proposed LCA software is web based which avoids the installation of LCA software in local systems. The user can access the LCA software by following simple steps. The software uses CML and Recipe method to calculate the environmental impacts of product system. The LCA software was tested in the Local Area Network mode with two computers. The result was comparable with reference case study chosen. The Hyper Text Markup Language was used to design the Graphical user interface. JavaScript is used for client side and PHP is used for server side.

Keywords: Life Cycle Assessment (LCA), Web-based LCA Software, Life Cycle Assessment Software, Environmental Assessment Tool, Online Software, Environmental Impacts.

INTRODUCTION

The activity of the industries have major impacts on the environment and it is necessary to carry out environmental studies [1]. Environmental impact assessment, environmental risk assessment, multi-criteria decision analysis and risk management, and life cycle assessment (LCA) are various tools used in industries for Environmental studies [2]. Among the various analysis method, the LCA is mostly used to find the impact of the product throughout its life cycle. The LCA method is used by the various sectors in the industry. LCA method is also used for business decisions and policy making. LCA is a calculation of the environmental impacts of a product system during its entire lifetime [3].

A. Life Cycle Assessment (LCA)

LCA is a procedural framework for evaluating environmental impacts of product for all its life cycle stages starting with raw material extraction, through manufacturing, distribution, use, maintenance, reuse, recovery and to final disposal of the product [4]. LCA principles and framework are described in ISO

14040 Standard titled: Environmental Management – Life Cycle Assessment – Principles and Framework [5]. The requirements and guidelines for conducting LCA are described in ISO 14044[6].

There are various LCA software currently used by the LCA practitioner throughout the world. LCA software are available in both web-based and application-based format. Most of the LCA software are developed of generic purpose type and some are used for specific domain. SimaPro is a generic LCA software. It is one of the commonly used LCA software developed by PRé [7]. GaBi is a generic LCA Software developed by GaBi Solutions [8]. The LCA software openLCA emerged in 2006 was developed by GreenDelta.[9]. CCaLC2 is the second generation of the CCaLC carbon footprint tool [11]. The eVerdEE is the web-based LCA Software. It is mainly used by the small and medium scale industries [10][11][12]. SENSE tool is used to find the environmental impacts of food products [13][14]. The software e-DEA was developed by EVEA and GreenDelta and is mainly developed for the non-expert user [15]. The Toovalu has been developed by the EVEA is mainly used to find the carbon footprint in the industrial environment [16]. The PackageSmart was developed by the EarthShift. The main purpose of this tool is to estimate environmental impacts of the packaging unit [17]. This tool can also be used by the non LCA experts and is highly flexible [18].

LCA methodologies used in the environmental impact assessment vary by the set of impact categories chosen. There are various methodologies available to perform LCA. They are Recipe 2016, Impact 2002+, Eco-indicator 99, CML, impact world+, IPCC, LIME, TRACE, CED and so on [19] [20] [21][22]. The following are a brief introduction to the LCA methodologies used for the development of software. CML is a method developed by the Institute of Environmental Sciences of the University of Leiden [23][24]. Recipe 2016 is the method for life cycle impact assessment. The latest version of the recipe is 'Recipe 2016'. This method

consists of both the midpoint and endpoint approach [25][26].

METHODOLOGY

B. LCIA methodology

The developed LCA software followed the general requirements described by the N. Unger et.al [27]. The appropriate properties and structures of commercial LCA software tools are incorporated from the study by Gareth Rice et.al [28]. The CML 2001 [29] and Recipe 2016 [26] were the LCA methodologies used for the proposed software. Most impact categories available in CML and Recipe 2016 were used in the developed LCA software.

The main aim of newly developed LCA software was to provide a user-friendly environment and the non-LCA expert can also be able to use the LCA software.

C. Modules of LCA Software

The proposed LCA software consists of five modules namely

1. Functional Module.
2. Product Module.
3. Stage Module.
4. Result Module.
5. Compare Module.

1) **Functional Module:** In this module, the user has to fill the data related to the functional units. All the fields in this module have to be filled without fail. This module is used to compare two LCA projects. The sample screenshot of the functional modules is shown in the figure 1.

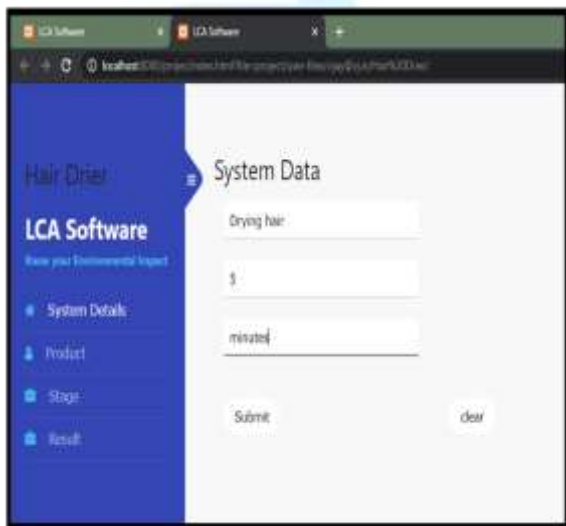


Fig.1 Functional Module

2) **Product Module:** In this module, initially the name of the product to be defined. The separate space will get open for each product name on that space and the user has to add the inventories. The inventory data for each product has to be selected from the given list with its quantity and unit. The selected inventory, its quantity and unit are displayed in the table format.

There is a provision to delete the data in each product and also it is possible to delete the product in the product module. The sample screenshot of the product module is shown in the figure 2.

3) **Stage Module:** In this module initially the name of the stage has to be defined. The separate space will get open for each stage name as shown in figure 3. On that space, there are two blocks one for input and other for output. The input and output products and its quantity of each stage are having to be selected from the given list in both blogs. The selected product in the input and output blogs are displayed in the table format. The built-in separate space for the waste management and Transport are get generated.

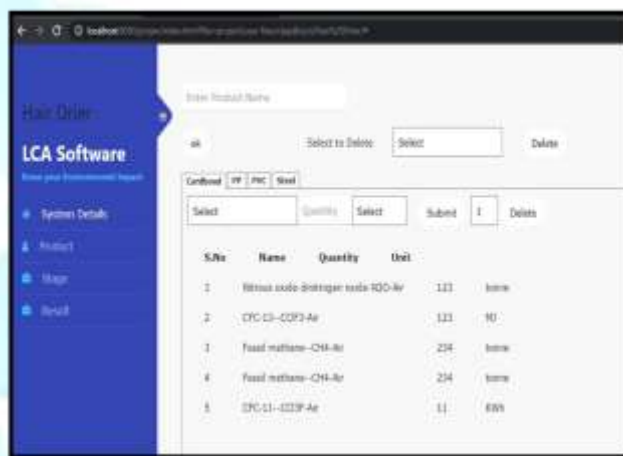


Fig. 2 Product Module

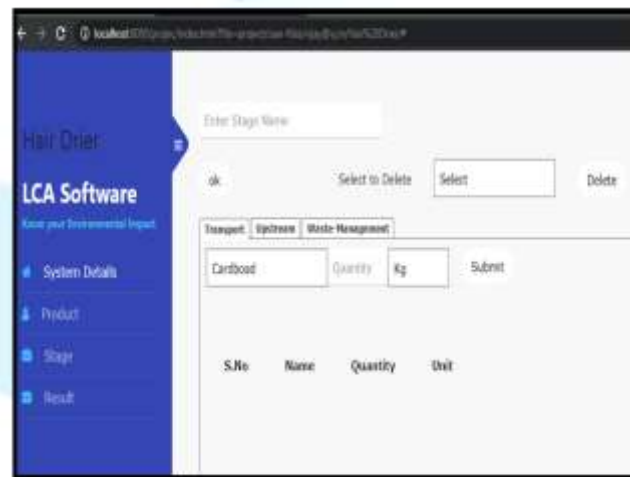


Fig. 3 Stage Module

4) **Result Module:** In this module the Environmental impacts of the product systems can be obtained as shown in figure 4.

5) **Compare Module:** This is the additional module in the developed LCA Software. Any two different product system with the same functional unit can be compared. There is a provision to select project files from their personal online account or they can

upload the file from the personal system but the file should be downloaded from the developed LCA software. The other data will not be accepted by the software. The overall environmental impact of the both projects are compared and the results are shown in the graphical format. The user is able to select the less environmental impacts process from this module. The sample screenshot of the result module is shown in the figure 5.

D. Software Specification

The LCA software was developed as the web-based application. HTML and CSS are used for designing the front-end phase of the application and JavaScript was used as client-side scripting language. The PHP was used as the server-side scripting language. MYSQL was used to store the data about the impacts used in the process. The advantage of using the web-based application was that, it can be accessed from the remote location.

The LCA software takes the data given by the user from the various modules in the software to perform LCA. The software has feature to add new inventories into the LCA software to improve the impact result of the product system.

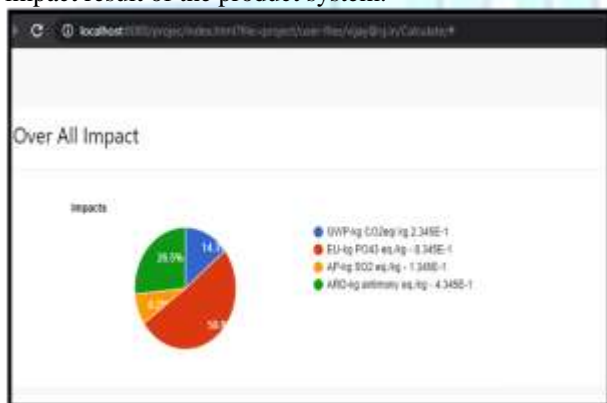


Fig. 4 Result Module



Fig. 5 Compare Module

E. Testing of LCA software

The testing is the essential part of the software development process because it will show the consistency of the software. The validation of the developed LCA software was done by comparing the

Life Cycle Impact Assessment (LCIA) profile with the LCIA results of reference study chosen. tool was based on performance of environmental impact assessment. Less than 10 % is the acceptance level of variation in the impact characterization for the LCA study [4]. The reference study chosen for validation of the software was LCA study of hair drier mentioned in the Life Cycle Assessment Best Practices of ISO 14040 Series [9].

The functional unit of the product system is Drying hair in 5 minutes. The system boundaries of the product system is from assembling to disposal of the product.

The following table shows the overall result obtained from the Reference case-study [9] and the developed LCA software.

TABLE 1

RESULT FROM PROPOSED LCA SOFTWARE AND REFERENCE CASE STUDY

Stages/Impact Assessment	Output from Software	Reference Case Study
GWP g CO ₂ eq/ hair drier	31718.61	3.17E+04
AP g SO ₂ eq/ hair drier.	123.739	1.24E+02
EP g PO ₄ - eq/ hair drier	0.26	2.60E-01
ARD g/ hair drier-yr	25.4891	2.56E+01

The result from the above table was found to be comparable with the reference case study chosen.

F. Steps for conducting LCA in the developed LCA Software

1. The user has to create new account in the website to access the LCA software.
2. After creating account, the user has to login.
3. After login in the web page project and compare tag will get enable.
4. Select project tag to perform LCA calculation.
 - 4.1. After select the project tag new page is get open. Click new button and enter the name of the new project and click ok button. The existing projects are also listed below with open, delete, download option in the webpage.
 - 4.2. Click Add button and select the LCA file to import from the local computer and add into your project list.
 - 4.3. Click open button new tab get open in browser and LCA get opened.
 - 4.4. The user has to fill the System data and press select button.

4.5. Select the product tag to create multiple product for the process.

4.5.1. User has to enter product name and select ok button.

4.5.2. New tab gets opened with the name of the Product name. On that the user has to select the inventory data, quantity and unit. The selected inventories are shown in the table format with quantity and unit.

4.5.3. The right side of the tag there is a select option to delete the particular inventory of the product.

4.6. Select the created product in the list and press delete button to delete the product.

4.7. After creating all the product for the project select the stage tab.

4.7.1. The user has to enter the stage name and press ok button.

4.7.2. In the input division user has to select the input product, quantity and unit. The selected products are shown in the table format.

4.7.3. The right side of the tag there is a select option to delete the particular product in the stage.

4.7.4. In the Output division the user has to select the output product, quantity, unit and belongs to other stage or waste management or by product. The selected products are shown in the table format with quantity and unit.

4.7.5. The right side of the tag there is a select option to delete the particular product in the stage.

4.8. Select the created product in the list and press delete button to delete the product.

4.9. After adding all the products to the stages select the result tab.

4.10. In the result tab the overall impact of the product is shown in the graphical representation.

5. Select the compare tab in the main page to compare to LCA project.

5.1. There are three options to select the project to compare.

5.1.1. Select two projects from the existing project list.

5.1.1.1. After selecting the projects from the list and press compare button.

5.1.1.2. The overall impact of the two projects are shown in the graphical representation.

5.1.2. Import two projects from the local system to compare.

5.1.2.1. After importing the projects from the local system press the compare button.

5.1.2.2. The overall impact of the two projects are shown in the graphical representation.

5.1.3. Select one project from the existing project list and other project has to be imported from the local system.

5.1.3.1. After selecting the projects to compare press the compare button.

5.1.3.2. The overall impact of the two projects are shown in the graphical representation.

6. After completing all the work press the logout tab to exit from the website.

RESULT

The newly developed LCA software was tested with the reference case study. The results of Global Warming Potential (GWP), Acidification Potential (AP), Eutrophication Potential (EU), Abiotic resource depletion (ADP) are shown in the table 1. The deviation ratio of results is comparatively very less. The developed LCA software can also be used to find other environmental impacts of the product system such as Ozone layer Depletion Potential (ODP), Human toxicity Potential (HTP), Fresh water Eutrophication Potential (FEP), Ionizing radiation Potential (IRP).

CONCLUSION

The CML and Recipe 2016 method are used in the developed Life Cycle Assessment software. The software is used to find the environmental impact of the process or products and to compare two different projects with same functional unit. This LCA software is developed with the basic options in the LCA tool. The result of the LCA software depends upon the quality of the inventory data. The software was tested with the reference case study chosen and the result was found to be comparable.

ACKNOWLEDGMENT

The authors acknowledge the Department of Mechanical Engineering, Mepco Schlenk Engineering College, Sivakasi, Tamil Nadu, India for providing the laboratory facilities to carry out this research work.

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