Applicability of Life Cycle Assessment (LCA) to Buildings: A Review

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ABSTRACT
Life Cycle Assessment (LCA) is globally recognized as an analytical tool that systematically and holistically investigates, compiles and evaluates potential environmental burdens attributed with products, processes or an activity by ascertaining and quantifying material usage, energy consumption and environmental releases. LCA methodology has increased in popularity in developed countries in recent years as a decision making tool, to assess the buildings' environmental impacts and energy consumption throughout its entire life cycle. Even though, building LCA is accomplished internationally, it is hard to find evidence in the Sri Lankan context. LCA has come to a standstill in the industrial sector, as relatively less attention has been paid to the implementation of LCA to the building sector. Therefore, this study is aimed with the perspective of closing this research gap by conducting an investigation on the LCA implementation process, barriers and possible strategies of applying LCA to buildings, for the better adaptation of LCA into the Sri Lankan building sector.

Key Words: Life Cycle Assessment, LCA for Buildings, Life Cycle Inventory Analysis, Life Cycle Impact Assessment

1. INTRODUCTION

The perpetual development and anthropogenic activities that occur with the growth of the economic sectors has aroused public concern on undesirable environmental problems (Li & Ma, 2014). Therefore, it is required to implement methods to assess and alleviate the environmental impacts and resource consumption by different sectors (Höjer et al., 2008).According to Jeswaniet al. (2010), various measures are used to evaluate environmental emissions, such as Life Cycle Assessment (LCA), Ecological Footprint (EF), Material Flow Analysis (MFA), Input Output Analysis (IOA), Environmental Impact Assessment (EIA) and Environmental Auditing.

Out of numerous environmental assessment methods, LCA has been accepted as the only legitimate process to evaluate products, processes and services from the environmental perspective throughout the entire lifecycle (Arena & De Rosa, 2003).LCA can be defined as a systematic set of process which targets to quantitatively evaluate the potential environmental burdens affixed with product or process by recognizing and quantifying the environmental impacts and resource consumption. Moreover, LCA enables the quantification of cumulative environmental impacts attached along the entire life cycle from "cradle to grave" (Ortiz-Rodríguez, Castells, and Sonnemann, (2010). According to Chau, Leung, and Ng (2015), implementation of LCA is ruled by ISO 14040-14044 standards and the implementation process is structured into four fundamental steps, such as Goal and Scope Definition, Life Cycle Inventory (LCI), Life Cycle Impact Assessment (LCIA), and Interpretation.

Currently, LCA has demonstrated its capability to deliver an analytical framework to evaluate buildings' and industrial processes' environmental performance throughout its expected lifespan

(Utama&Gheewala, 2009). Extensive amount of LCA studies have focused on industrial processes (i.e. cement manufacturing process and paper production process) rather than on the building sector (Huntzinger& Eatmon, 2009). Accordingly, application of LCA to the building sector is relatively recent and novel (Buyle, Braet, &Audenaert, 2013) due to increasing attention to assess building performances over the entire life cycle (Tian, 2013).

2. LCA IMPLEMENTATION PROCESS TO THE BUILDING SECTOR

LCA implementation phases along with its different stages can be described in the table 1, which was developed based on the literature.

Table 1:- LCA methodology for Building Sector

Phase 1:- Goal and Scope Definition		
Requirements under the phase	**Method of achieving the requirements under the phase**	**Reference Code**
Defining goal of the LCA study	The goal of the extensive amount of LCA studies was to conduct a comprehensive assessment to realize potential environmental burdens and energy consumption of buildings across the entire lifecycle.	17,
Identification of Functional Unit	One square meter (1 m^2) of usable building floor area is the most common functional unit for the building LCA, which links all the flows of inputs and outputs, in line with the goal of the study.	30,
System boundary definition	It can be identified as cradle –to-grave (whole life cycle assessment) or partial lifecycle assessments, such as cradle-to-gate (building product assessment) and gate-to-gate (construction process assessment)	1,10
Identification of building lifespan	50 years has been used as the medium value as well as the commonly used standard building lifetime for the LCA study	33, 37,25
Presentation of assumptions	LCA based on the number of assumptions such as, all the waste was disposed to the landfills, 5% of materials have been wasted during the construction stage, transportation data is based on the average number of roundtrips from manufacture to site.	17
Presentation of limitations	Limitation of an extensive amount of LCA studies can be identified as exclusion of minor renovations and replacements (e.g. light bulbs, air filters, window glass, cleaning supplies, small electrical components, such as sensors and switches), interior decorations, local infrastructure impacts and site location characteristics due to the shortages in required data	17
Phase 2:- Life Cycle Inventory Analysis		
Identification of data collection method	Possible data collection sources are classified under different key building lifecycle phases, such as manufacturing phase, construction phase, use phase and EOL phase	1
Data collection	Typically LCI has identified upstream flows (raw material extraction, material production, transportation building construction and use), and downstream flows (deconstruction of building and disposal of building) which belongs to the system boundary of the study.	16
Calculation of collected data	Relevant flows of inputs and outputs within the defined system boundary has to be calculated in relation to the pre-determined functional unit	16
Phase 3:- Life Cycle Impact Assessment (LCIA)		
Selection of LCIA method	Selection of LCIA method (midpoint or endpoint) and impact categories has based on the goal and scope of the study.	8
Classification	Identified inputs and outputs in the phase of LCI, assigned into the numerous impact categories according to the influence which have been committed on the environment.	8
Characterization	Integrating impact categories to its category indicators.	24
Normalization	The most common normalization factor such as "person equivalents" which	4,5

	represents the amount of building emission with the mean value that is apportioned to each person of the population, from the selected region.	
Grouping and Weighting	Finally, significant impact categories are possibly ranked and prioritized by evaluating and comparing environmental impacts of different building lifecycle phases, according to its perceived severity of impact categories	4,5
Phase 4:- Life Cycle Interpretation		
Identification of significant problems	Further identified significant issues, which have emphasized the highest contribution to environmental problems throughout the WLC by narrowing down identified impact categories into the most significant impact categories on the basis of the results of previous phases.	24
Evaluation of results	Results are evaluated and examined from the building point of view and, therefore, the energetic and environmental burdens of each building's life cycle can be determined	24
Uncertainty analysis and sensitivity analysis	Uncertainty analysis and sensitivity analysis are utilized to evaluate the robustness and strength of the conclusions.	8,10
Provide conclusions and recommendations	Present conclusion and recommendations for environmental improvements.	34

3. DRIVERS IN IMPLEMENTING LCA TO THE BUILDING SECTOR

The foregone review of the LCA implementation process has indicated inherent different drivers of LCA methodology to the building sector. Drivers are the factors that encourage the LCA implementation. Summary of literature findings about the drivers can be tabulated as given in table 5 with relevant references.

Table 2: Drivers for LCA implantation to the Building Sector

No	Drivers	Reference Code
1	To identify opportunities for environmental improvements	27,40
2	To recognize cost saving opportunities	14, 27
3	To promote environmental targets for buildings	40
4	To recognize energy saving opportunities	27, 29
5	To emerge and introduce the green products	14, 27
6	Top management pressure to implement LCA	14
7	To compare the environmental impacts of alternative materials that can be used during the construction process	27
8	For the purpose of meeting eco-labeling criteria	14, 27, 29, 40
9	As an initiative through Research and Development	14
10	As a novel instrument for Research and Development	14
11	As an environmental legislation or political pressure	14, 29
12	Due to the application of LCA by other competing companies	14
13	Growing industrial interest	14
14	High energy consumption of building sector	29
15	To acquire marketing benefits	40
16	Introduction of a Simplified LCA method	40
17	To acquire subsidies on environmental impact reduction	40

4. BARRIERS IN THE IMPLEMENTATION OF LCA TO THE BUILDING SECTOR

Application of LCA to the building sector, as a decision making tool has been constrained by numerous barriers. Table 2 shows the identified barriers with its respective literature source.

Table 3:- Barriers in Implementing LCA to the Building Sector

No	Barriers	Reference Code
Barriers in conducting LCA for the building sector		
A1	Lack of knowledge on the LCA as a decision making tool, which can be used to assess building lifecycle	3, 11, 26
A2	Financial difficulties in the implementation of LCA to the building sector	11, 27
A3	LCA approach for the building sector is viewed as less practicable by stakeholders	11
A4	Unavailability of one mythology to perform LCA	3,18
A5	Less organizational commitment to perform LCA	3, 11, 26
A6	Lack of high quality and accurate data to conduct LCA	3, 7, 4, 13, 15, 26, 27
A7	Barriers related to the co-ordination of LCA into the building sector	18, 11, 26
A9	Lack of LCA data with respect to the Building sector	3, 9, 13, 27
A10	Lack of cultural understanding of LCA for the building sector	3, 11, 26
A11	Lack of training and awareness related to LCA	3, 11,
A12	Lack of modern integrated management skills with respect to LCA	11, 18
A13	Limited understanding about the environmental impacts caused by the building sector	27
A14	Improper organizational structure	11, 18
A15	Less transparency of LCA tool	11, 18, 26
A16	Little interest by top management on the application of LCA	18, 26
A17	Limited customer demand to perform LCA	9, 18
A18	High cost of performing LCA	4,27
A19	Lack of governmental incentives	27
A20	Lack of professionals to conduct LCA	3,4, 27
A21	LCA for the building sector is more complicated than LCA for conventional products	7
A22	Difficulties in communicating results to the top Management	12
Barriers within the LCA method		
B1	Time taken to conduct the LCA	27
B2	Prejudices about the complexity of LCA method	4, 9, 27
B4	Number of assumptions used in the LCA study has led to uncertainties	8,
B5	No consideration of data related to the indoor environmental quality	23
B6	Lack of capability of including building site specific data to the LCA process	2
B7	Due to the subjectivity of selecting impact categories	7, 13,27
B8	High resource requirements and time consumption for the data collection	23,27
B9	The inherent subjectivity of LCA in Building structures	26, 27

5. Strategies to Overcome the Barriers of LCA Implementation to the Building Sector

As per the observations in table 3, it is revealed that there is a tendency towards less applicability of LCA to the building sector. This has been continuously highlighted. Hence, it is important to identify the strategies which can alleviate all barriers. According to Seidel (2016), facilitating and incorporating the application of LCA into the public policy might improve utilization of LCA, as a decision-making tool, which can ultimately lead to enhancing the environmental outcomes by means of supporting and stimulating sound decisions. According to Scheuer et al. (2003) the building sector is required to take an active interest in implementing public LCA software and databases by getting the support of the government. Further, according to them, the development of public LCA databases can accommodate valid LCI and LCIA data in an accurate manner for this purpose, eradicating difficulties faced during data collection. According to Cooper and Fava (2008), it is suggested to increase the industry and governmental funding on LCA software. Seidel (2016) stated that, stakeholders of the organization have to be educated and be made well aware about the LCA process and its prospective potential contribution to the organization. Singh et al. (2011) has suggested to integrate social indicators with the traditional LCA approach.Arena and De Rosa (2003) has highlighted that, traditional LCA technique requires more data as well as time and resource to perform. Hence, it is recommended to perform streamlined LCA practice that requires less data.

6. CONCEPTUAL FRAMEWORK FOR LCA IMPLEMENTATION IN BUILDINGS

LCA methodology has increased popularity in recent years, as a decision making tool in the developed countries and is used to assess adverse environmental impacts created by the building sector to the surrounding environment throughout its entire life cycle. Hamidul et al. (2015) specified that the building sector in developing countries is lagging in adopting LCA practices to their decision making process. Moreover, Ortiz-Rodríguez (2010) emphasized that LCA has come to a standstill in developed countries, as relatively less attention has been paid to the implementation of LCA in developing countries due to barriers pertaining to the implementation of LCA for the building sector. Therefore, these numerous views stress that LCA implementation and adaptation has been limited in the building sector, which needs to be exposed in order to add value to the industry. Thus, there is a requirement for developing a framework to facilitate the effective and successful implementation of LCA for the building sector. The conceptual frame work developed is shown as figure 1, which highlights the drivers, barriers and strategies to overcome the barriers in implement LCA for buildings.

7. SUMMARY

The LCA concept has recently emerged for the building sector with the contemporary push towards assessing environmental impacts. A significant application of building-related LCA is increasing in developed countries rather than in developing countries. Consequently, barriers in implementing LCA for building sector has been examined under two categories. Moreover, the study further reviewed the strategies that can alleviate the barriers in implementing LCA to the building sector. When it comes to the Sri Lankan context, as a developing country it is required to identify the practice of LCA in buildings.

8. CONCEPTUAL FRAMEWORK FOR THE SUCCESSFUL IMPLEMENTATION OF LCA TO THE BUILDING SECTOR

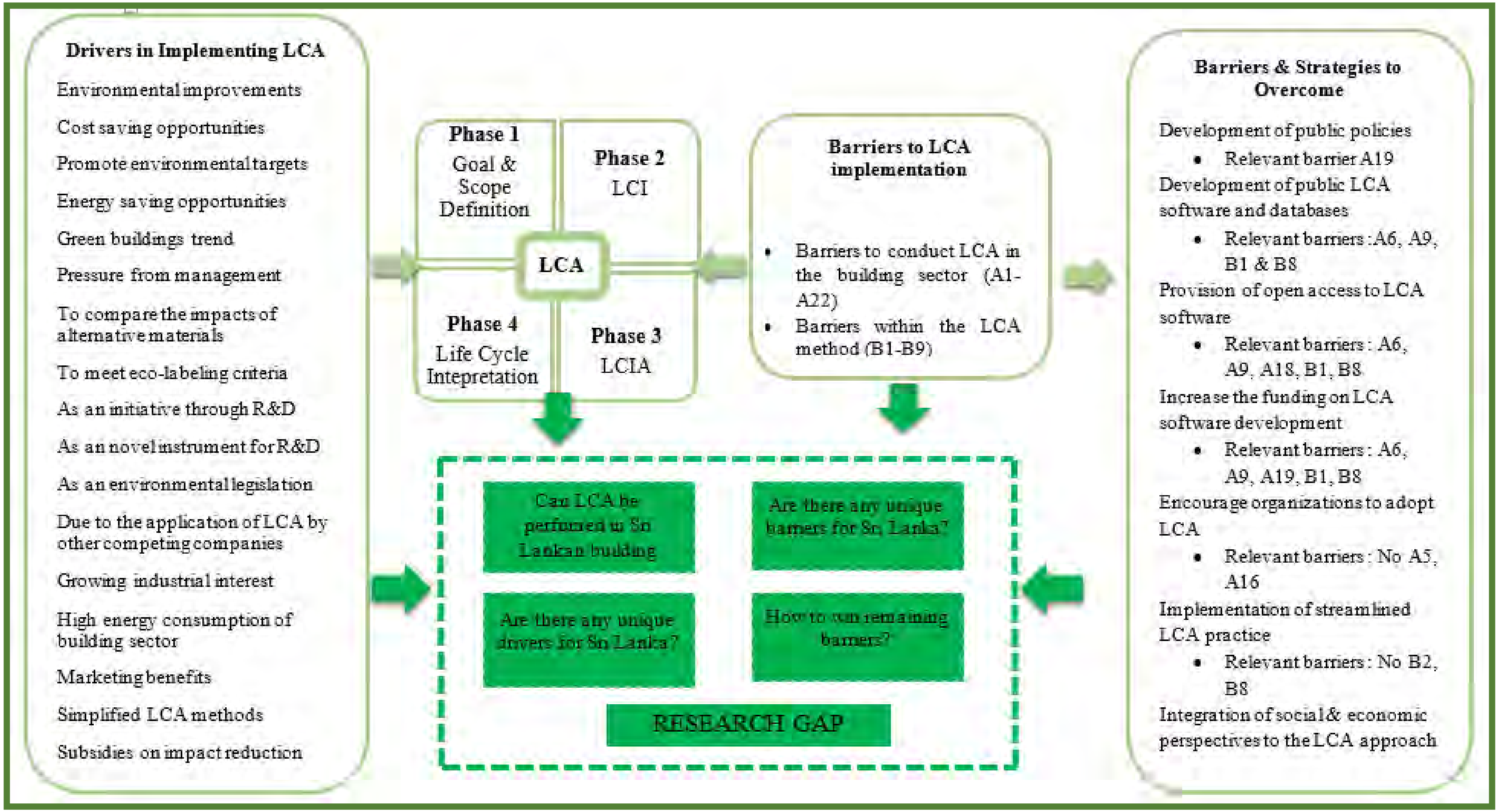

Figure 1: conceptual framework for the successful implementation of LCA to buildings

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