Assessing benefits of developing a simulation model for sustainable constructions using Life Cycle Assessment (LCA) Approach in Sri Lanka

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***Abstract*— Using the Life Cycle Assessment (LCA)method to create a simulation model for sustainable projects in Sri Lanka can have a number of advantages. LCA is a methodical approach that assesses the environmental effects of a process or product throughout the course of its full life cycle, from the extraction of raw materials to the disposal at the end of its useful life. LCAis a tool that assists in identifying potential environmental costs associated with construction projects and enables well-informed decision-making to lessen these effects. This employs a a content anlaysis to conduct a comprehensive review on the national and international existing models/frameworks and data bases for modelling the sustainability of constructions and a questionnairesurvey to asses the feasibility of using LCAs with theprofessionals of the construction industry. Results prove that there very few information on widely used models by the design professionals Furthermore results indicate that in maintaing indoor air quality and energy aspects using LCAs need to be implemented with signifance in the Sri Lankan context. Findings also proved that the burden of a high cost requirement is needed to implement LCA in Sri Lanka, therefore exisiting database inventory from foreign countries need to be modified to suit local data. A LCA model can help Sri Lanka's construction industry transition to more environmentally friendly and sustainable practices, so the long-term benefits outweigh the short-term drawbacks.*

***Keywords*— Life cycle assessment, simulation model, sustainability**

I. INTRODUCTION

Construction activities contribute to pollution significantly in the contemporary era. These construction activities facilitate the urbanisation aspects of the world's population. In 30 years half the world population will be in Asian countries and 70% of Sri Lanka's population is to reside in urban settlements by 20230 (UN Report, 2014) . According to (Bribian and Capilla, 2011) civil and construction works contribute to 60% of the global raw material consumption, of which, 40% is related to the construction industry. Cement which constitutes an essential part of concrete contributes to 5-7% to the global anthropogenic carbon emissions. The construction industry utilises 16% of the total steel and iron productions. These industries contribute to 6-7% of the planet's carbon emissions (IEA, 2020).

It is very clear that the construction industry consumes the majority of the world's natural resources and emits significant loads of pollutants. GDP From Construction in Sri Lanka averaged 133,568.86 LKR Million from 2010 until 2017, reaching an all-time high of 200,970 LKR Million in the fourth quarter of 2016 (Trading Economics, 2017). There are various challenges faced by the construction industry prompting professionals to endorse the concept of sustainability by using resources efficiently.

Life cycle assessment (LCA) is a valuable tool for quantitatively evaluating the environmental impacts of a product or process. Unlike building environmental assessment schemes such as LEED and BEAM, which focus on specific impact areas and use semi-quantitative scoring methods(LEED, 2001), LCA considers a broader range of impact categories and provides a systematic quantification of environmental impacts throughout a product's life cycle. LCA takes into account the entire life cycle of a building, from raw material extraction and manufacturing of construction materials, through the construction phase, occupancy, maintenance, and eventually demolition and disposal(UNEP, 2004). It evaluates impacts across various categories, including but not limited to energy consumption, greenhouse gas emissions, water use, land use, waste generation, and toxicity(ECS, 2006).

LCA offers a more thorough understanding of a building's environmental performance by taking into account a variety of impact categories. It makes it possible to locate problem regions and places where adjustments can be made to lessen the total environmental impact. Additionally, LCA makes it possible to compare various design options and aids in the process of making decisionsthat will reduce environmental burdens (USEPA, 1993). According to Sonneman et al. (2003), implementing LCA in the building construction sector can assist overcome theshortcomings of the current environmental assessment frameworks. It offers a quantitative evaluation of construction-related emissions, which are frequently disregarded by existing rating systems. Stakeholders can better understand the environmental effects of their decisions and spot possibilities for improvement by including LCA into the design and decision-making processes.

There are many commericalised assessment tools which related with LCA, these include EcoEffect (Sweden), ENVEST (UK), BEES (US), and ATHENA (Canada) relate with the LCA. Some of these tools aim to simplify this for practical use within the design process, but this can make these tools inflexible to local design and construction practices in Sri Lanka. Hence, it would be very useful to develop a model that underlines the local construction techniques and approaches. Despite several studies from several other countries were focusing on the construction phase, none were specifically designed for Sri Lanka.

The objective of this research is to understand the requirement of a model to assess the sustainability aspects of constructions in Sri Lanka using Life Cycle Assessment approac

II. Methodology

Research design is constituted of the two major steps as follows;

1. Literature survey, a content anlaysis to conduct a comprehensive review on the national and international existing models/frameworks anddata bases for modelling the sustainability of constructions.

2. Questionaire surevy rated on the likert scale. This questionnaire survey is derived from the framework available GREEN^{SL} Rating tool for new constructions version 2.1. Thus, the questions presented are the rating system categories of water efficiency, energy and atmosphere, materials resources and waste management and indoor air quality. Thequestions comply with requirement of LCAs under mentioned rating system categories. The questionnaire surevy is provided to architects, quantity surveyors and engineer professionals within the construction industry.

III. RESULTS AND DISCUSSIONS

From Literature- International

Dong and Thomas (2015) developed a LCA model to analyse the energy usage within commercial buildings.This model was further used to asses the impacts on the environment by construction materials used in the mass housing projects in Hong Kong

Dong and Thomas (2015) developed a life cycle assessment (LCA) model called the Environmental Model of Construction (EMoC). This model allows professionals to make decisions in order to asses the performance of the constructed buildings in Hong Kong from the initial stages to the final stage. The analaysis is extensive revolving aroung 18 categories of environmental impacts. **However, this model cannot be used in Sri Lankan construction industry due to differences in the usage of constrctution materials and varied construction practices.**

(Kumanayakea and Luoa, 2017) presented a framework for the development of a computerised assessment tool using the Life cycle assessment analysis. This LCA approach is used to indicate the the 'Building Sustainability Index'. Econmic and environmental condition of the embodied levels of carbon were taken into account while developing this tool and this tool was viable mainly for areas in China

(Roh et al., 2014 and Tae et al., 2011) life cycle inventory data bases for the building codes of particular countires based on building certification systems. However, these studies presented findings based on carbon footprint levels and embodied energy All of these studies are limited only to the calculation of carbon foot print, embodied energy or both.

Futhermore a study by Solís-Guzmán et al., (2018) developed a tool OERCO2 which is available online and this tool is feasible for users of all types therefore this LCA modelling tool is user friendly.

Financial constraints include perceptions of greater capital costs, investments focused on quick returns rather than lifecycle costs, and a lack of tenant demand, according to Wilson and Tagaza (2006). Similar to this, Durmus etal (2010) noted that firm budgets are typically not structured to track life cycle cost (LCC) for a project creating longer term benefit and that the return on investment needs more of a historical view to become more predictable.

From Literature-Local

It is important to note that there is no LCA database for construction practices in Sri Lanka. However several studies within the local context have carried out LCA studies using databases of foreign tools. This is practical to a certain level but there various limitations associated with using databases of foreign countries.

Edirisinghe(2013) had implemented a LCA on the Sri Lankan ceramic tile. The author had used the Ecoinvent database for acquiring data for the study.

Fernando(2017) carried out a LCA of the local cement industry. An analysis was done on the cement making process. Data for this research were collected through primary and secondary data sources.

Moreover Fernando (2017) stated that developing a new database with an LCA inventory needs to be done by developing the exisiting LCA database to suite local conditions. This needs to be done with available literature. Collection of new data needs to be minimised, except for the most vital data requirements. Therefore, Fernando (2017) collected primary and secondary data from various literature and in selected construction manufacturing processes such as sand and bricks. This is uses to develop the available exiting LCAs

Waidyasekara and Fernando (2012) stated that investors of green buildings focus particulary on reducuing the construction cost, however, they fail in considering the economic performances of the life cycle of construction materials. Therefore, investors ignore several benfits which can be obtained from green buildings such as reduced energy costs, inexpensive electricity and water bills, lesser waste management costs and reduced fuelcosts.

Questionaire Survey Analysis

The questionnaire was provided to a sample of 50 professionals in the construction industry. Questions were based on the categrories/sustainable features provided Green Rating Tool of the Sri Lanka Green Building Council. All questions revolved around the development of a simulation model to asses the Life Cycle Assesments of buildings in Sri Lanka. The data was analysed using descriptive statistics. Table 1 indicates the percentage of the population agreeing and disagree on developing a model for LCA.

Table 1- Professional opinion using LCA

Sustainable Feature	% Agreeing on using a simulation model for Life Cycle Cost Assessment(%)	% Disagreeing on using a simulation model for Life Cycle Cost Assessment (%)
water efficiency	63	37
energy and atmosphere	81	19
materials resources and waste management	65	35
indoor air quality	78	22

According to Table 1. Energy and atmosphere relevant criteria calls for majority in the agreement percentage of using LCAs for many projects. As in reality, these have extremely high starting costs with the easiest availabity of data for the calucation of being power, air conditioning and ventilation, gas meter readings, electricity meter readings, refrigerant equipment, loose appliances, repairs and décor, and built-in fittings.

Results indicate that in maintaing indoor air quality LCAs need to be implemented with signifance. As according to the construction industry professionals, due to the prolonged occupancy times for HVAC systems' service lives, it has also been determined that the potential for global warming represents the biggest environmental threat to the built environment .

The results of the questioanire futher indicated that the quantification of sustainable features would enable our nation's finite resources to be used sustainably. When creating infrastructure, one should consider the available materials, although price is still often the deciding factor. A conventional building typically lasts between 50 and 100 years, at the least. The choices made by the architects, quantity surveyors and engineers during the design and construction phases are always used to determine how the building can be used and maintained.

A majority of the professionals agree upon using a model LCA approach for the sustainable features as this LCA model can be coupled with various visualisation softwares. These will aid architects, quantity surveyors and engineers in the decision making process when it comes to material selection, type of energy used, type of wastemanagement system. The mechanism with the lowest levels of environmental impact can be selected.

Results explicitly proved that the disagreement arose in each sustainable feature when implementing LCA in the construction industry industry was with the enormous costing and time that is required to implement a LCA model. This is a major drawback in developing a LCA. To undertake life cycle assessment (LCA) research, a lifecycle inventory (LCI) database is required. Due to the task's complexity, which requires a lot of time and resources in addition to being difficult, only a few complete LCI data bases have been created in the world today. There are currently few thorough LCIs available from regions like Europe and the United States. One ofthe top databases created in Switzerland, Ecoinvent offers trustworthy information in a variety of industries, including manufacturing, construction, and agriculture. Agri-footprint, Green Delta, Simapro, EASETECH, and EASETECH are a few other databases with specialized uses. Every database uses information particular to a given nation or area.

To cater the above mentioned issue, the professionals indicated that exisiting information from foreign models need to be used to develop and modify a database for the local due high cost issues. They further stated to increase sustainability in the construction industry, governments and environmental authorities should implement building codes and other environmental regulations.

The suggested LCA-based model will enable inclusion in additional environmental impact categories in Building Information Modeling (BIM) settings and also have a user-friendly interface allowing non-specialized users to evaluate sustainable usage of various construction materials, water, and energy.projects and enable improved construction and operation of those facilities for all parties concerned.

III. CONCLUSION

A thorough evaluation of the environmental effects linked to construction projects is made possible through LCA. The simulation model can pinpoint areas for improvement by evaluating the environmental costs of various materials, designs, and construction techniques. This information gives stakeholders the power to choose sustainable options, cut back on resource use, cut carbon emissions, and protect natural resources.

Based on their environmental performance, several design options and building methods can be assessed using the simulation model. A developed LCA model can be used by contractors, engineers, and architects to assess several options and determine which ones are the most environmentally friendly. This makes it possible to create buildings that perform better overall in terms of sustainability, waste generation, indoor environmental quality, and optimized energy efficiency.

Like many other nations, Sri Lanka is progressively emphasizing sustainable development and putting environmental laws and certifications into place. The creation of a simulation model based on LCA makes it easier to adhere to these rules and certifications. The model can offer the information and understanding required to satisfy environmental criteria, such as obtaining green construction certifications or adhering to particular environmental norms.

It is important to keep in mind that creating a simulation model for environmentally friendly buildings requires knowledge of LCA methodology, data collection, and integration with design and building procedures. The concept can assist in the development of Sri Lanka's building sector toward more sustainable and ecologically responsible methods, so the long-term advantages outweigh these initial difficulties.

REFERENCES

LEED. Reference package. Version 2.0. (2001). US Green Building Council, June 2001.

Wilson, J Land Tagaza, E (2006) Green buildings in Australia: Drivers and barriers. *Australian Journal of Structural Engineering*

Durmus-Pedini, A and Ashuri, B (2010) An overview of the benefits and risk factors of going green in existing buildings. *International Journal of Facility Management*,

Waidyasekara, K G A S and Fernando, W N (2012) benefits of adopting green concept for construction of buildings in Sri Lanka. *2nd International Conference on Sustainable Built Environment 2012 (ICSBE)*, December, Kandy, Sri Lanka,

Dong Ya Hong, S. Thomas Ng (2015). A life cycle assessment model for evaluating the environmental impacts of building construction in Hong Kong. Building and Environment 89

Edirisinghe J (2013). Life Cycle Assessment of a Ceramic Tile Produced in Sri Lanka. Available at:http://www.ejournalofscience.org/archive/vol3no11/vol3no11_7.pdf [Accessed 3rd July 2023].

4. Fernando, K. (2017). Life cycle assessment (LCA) analysis towards a sustainable cement industry for Sri Lanka: an analysis of three process pathways. [online] Dl.lib.mrt.ac.lk.
Available at: http://dl.lib.mrt.ac.lk/handle/123/2057 [Accessed 3rd July 2023].

Jaime Solís-Guzmán, Cristina Rivero-Camacho, Desirée Alba-Rodríguez and Alejandro

Martínez-Rocamora (2018). Carbon Footprint Estimation Tool for Residential Buildings for Non-Specialized Users: OERCO2 Project. Sustainability 218