Construction Industries’ LCA Adaptability: A Desk Study based SWOT Analysis

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Abstract

Life Cycle Assessment (LCA) is a method applied to enhance ecologically sustainable development in the construction industry. LCA is used extensively pertaining to the construction industry in developed countries rather than in developing countries. Accordingly, this study aimed to develop a literature-based SWOT analysis to examine the strengths and opportunities confronted by developed countries and weaknesses and threats faced by the developing countries in practicing LCA in the construction industry. The SWOT analysis is a data-driven, fact-based analysis used to overlooks internal and external factors to assist decision-making. Findings highlighted that developing Environmental Product Declarations (EPDs) for communication purposes in developed countries is the frequently claimed strength in implementing LCA. Lack of accurate LCA data in developing countries can be recognized as a highly reported weakness. Initiation of LCA software is the commonly stated opportunity to integrate LCA into the construction industry in developed countries. Lack of societies’ environmental awareness has created the greatest threat to the application of LCA in developing nations. The study emphasized that developed countries enjoyed a literature-based multiplicity of strengths and opportunities whilst developing countries faced a great proportion of weaknesses and threats, which need to alleviate to create LCA enabled built environments in developing countries.

Keywords: Developed countries, Developing countries, Strengths/weaknesses, Threats/opportunities, Life Cycle Assessment

1. Introduction

The construction industry is a prominent contributor to both economic and social development in the contemporary world (Behm 2008). Nevertheless, the construction industry has also been identified as the main source of substantial environmental impact locally, nationally, and globally (Kylili et al. 2017). Evidently, the construction industry contributes immensely to the adverse global environmental impacts: for instance, the construction industry is responsible for approximately 40% of the energy consumption, 33% of the global GreenHouse Gas (GHG) emissions, 30% of raw material usage, 25% of solid waste generation, 25% of water consumption, and 12% of land use globally (Antón and Díaz 2014). Concurring with Xing et al.’s (2011) there is an indication that current building stock and other structures will be further escalated by 1% per year due to new constructions. It is probable that these environmental issues will become adverse along the timeline (Grundel and Dahlström 2016). Hence, there is an urgent requirement to mitigate these formidable environmental challenges that are arising from the construction industry activities (Sharma et al. 2011). Subsequently, different methods and tools have come into the practice to alleviate undesirable environmental problems, which can address the issues with a multi-disciplinary approach such as energy-saving, reduction of material usage, and emissions control etc. (Atmaca 2016).

Consequently, a number of environmental management tools have been implemented over the last decades to assess the environmental impacts of construction activities and to identify opportunities for environmental improvements (Manuilova et al. 2009). Examples include LCA, Strategic Environmental Assessment (SEA), Environmental Impact Assessment (EIA), Ecological Footprint etc. (Manuilova et al. 2009; Todd 2012). Amongst several environmental management tools, the LCA approach can be identified as a globally recognized method used to assess all environmental inputs (i.e. raw material, energy and water) and all environmental outputs (i.e. solid waste generation, atmospheric emissions, and waterborne waste) throughout the expected lifespan of the construction (Stevenson and
Ingwersen 2012). Moreover, the LCA approach is a prominent analytical tool and a methodical environmental management technique, which is utilized to holistically assess and analyze potential environmental impacts covering the product life cycle from its raw material extraction to final disposal (Bilec et al. 2009). Hence, LCA is often called a “cradle-to-grave” assessment method, as it considers and assesses all the possible environmental effects over the Whole Life Cycle (WLC) (Yarramsetty et al. 2018). As an attempt to organize and harmonize LCA applications, LCA was formalized by the International Organization for Standardisation (ISO) and the Society of Environmental Toxicology and Chemistry (SETAC) under the umbrella of the ISO 14000 series. This series is based on life cycle thinking with the aim of quantifying all environmental influences assignable to the product life cycle (Saunders et al. 2013). According to International Organization for Standardization [ISO] (2006), the implementation process of LCA is structured into four interlinked phases such as, (i) ISO 14041:1998 - Goal and Scope Definition, (ii) ISO 14041:1998 - Life Cycle Inventory (LCI), (iii) ISO 14042:2000 - Life Cycle Impact Assessment (LCIA), and (iv) 14043:2000 – Life Cycle Interpretation. Moreover, it can be identified that LCA has been utilized as a worldwide standardized procedure for environmental assessments (Bjørn et al. 2018) as it has been applied as a significant tool utilized for environmental management and sustainable construction all over the world (Crawford 2011). Consequently, LCA has been applied to evaluate the environmental performance of different construction outputs throughout WLC with the aim of reducing remarkable life cycle environmental impacts (Basbagiil et al. 2013).

Prevailing literature has witnessed a number of LCA applications in the construction industry, which support decision-making in the environmental sustainability context (Hauschild et al. 2017). LCA delivers a comprehensive panorama of potential environmental aspects of a building and creates a more precise picture of the exact environmental trade-offs by considering the WLC (Abd Rashid and Yusoff 2015). For example, according to the LCA study done by Carre (2011), the construction phase contributes to approximately 31-43% of GHG and 31-44% of Cumulative Energy Demand (CED) and when it comes to the operation phase it accounts to around 53-68% for GHG and 52-64% for CED, and maintenance accounts to around 4-6% of GHG and 5-6% for CED and the disposal phase only accounts for -1 to -5% for GHG and -1 to -3% for CED. With reference to studies carried out by Kutnar and Hill (2015), they pointed out that, LCA results are important in recognizing the ‘hot-spots’, which are the most significant environmental issues in the building life cycle, where improvements can be done to get the greatest environmental benefits. Moreover, as cited in Asif et al. (2007) it is highlighted that the materials used for the buildings are accountable for greater than 50% of the embodied energy in the building. In that sense, the utilization of alternative materials for instance; stabilized soil blocks, hollow concrete blocks, or fly-ashes, in place of the materials with a high embodied energy e.g. reinforced concrete is able to save approximately 20% of the cumulative energy used over a building life cycle (Huberman and Pearlmutter 2008). Likewise, LCA gives an overview of how different types of building materials contribute to adverse environmental impacts. Accordingly, LCA methodology helps in decision-making towards exploring more sustainable solutions. Therefore LCA can be identified as a tool for improving ecological sustainability within the construction industry (Ortiz-Rodriguez et al. 2010). Hence, it can be said that integration of LCA to the early design stage of building life cycle can bridge the gap between environmental challenges and socioeconomic development in the construction industry, by recognizing strategies for environmental improvement without the burden of shifting one life cycle phase to another (Asadollahfardi et al. 2015).

LCA has entered rapidly into developed countries with increased attention towards creating more environmental-friendly constructions (Guinee et al. 2010; Scheuer et al. 2003). Confirming the above view, LCA has been mostly engaged in the construction sector in developed countries like Europe, North America, Japan, and Korea (Islam et al. 2015). For example, Keoleian et al. (2000) conducted a study focusing on the building sector in the United States of America (USA). The results highlighted that the utilization phase of the building accounted for around 90% out of the total life cycle energy consumption. Aye et al. (2012) have conducted a similar study based on the Australian residential building sector, which is another example that can to be mentioned out of many reported studies. Supportively, prevailing literature indicates significant evidence of an extensive amount of building LCA being conducted in developed counties in comparison with the developing countries (Ortiz et al. 2009; Saunders et al. 2013). Compared to developed counties, developing countries have given less attention to implementing LCA within the construction industry. Also, the construction industry in developing countries has been in the position of high vulnerability to face environmental degradation, as a result of the booming nature of constructions, which drastically increases multi-faceted environmental and sociological challenges. This can be tackled and mitigated by integrating LCA into the construction industry in developing countries in making environmentally sound decisions.

The identified contradictory situation between developed countries and developing countries, emphasise the need to investigate as to why LCA has not been implemented in developing countries. Hence, this study in particular explores
the strengths and opportunities confronted by developed countries and weaknesses and threats faced by the developing countries in implementing LCA for the construction industry by conducting a desk study. Thereafter, identified strengths and opportunities confronted by developed were suggested to achieve the weaknesses and threats faced by the developing countries in implementing LCA. Finally, last section discusses about the overall conclusion of the study.

2. Research Methodology
This paper adopts a desk study approach to locate strengths and opportunities confronted by developed countries and weaknesses and threats faced by the developing countries in implementing LCA for the construction industry. A desk study can be identified as a search of information using mainstream resources such as; published journal articles, published conference papers, analytical reports, books and other publications (Crisp 1981). In addition, a desk study can be recognized as a research method using secondary data, which is utilized to review the results of previous research outcomes for the purpose of obtaining a comprehensive understanding of the relevant research area (Bingham et al. 2012). The goals of the desk study were achieved by comprehensively evaluating published journal articles, books and other sources on problematic domains. This research has evaluated a total of 70 sources (1996–2018) containing 57 journal articles, 9 books and 4 unpublished doctoral dissertations from various databases including Springer, ScienceDirect, Emerald etc. were evaluated by covering developed and developing countries. Countries considered in the study present in Table 1.

Table 1: Developed and developing countries considered in the study

<table>
<thead>
<tr>
<th>Developed Countries</th>
<th>Developing Countries</th>
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<tbody>
<tr>
<td>Belgium</td>
<td>Argentina</td>
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<tr>
<td>Germany</td>
<td>China</td>
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<tr>
<td>USA</td>
<td>Colombia</td>
</tr>
<tr>
<td>Netherlands</td>
<td>Greece</td>
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<tr>
<td>Israel</td>
<td>India</td>
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<tr>
<td>France</td>
<td>Iran</td>
</tr>
<tr>
<td>Hong Kong</td>
<td>Libya</td>
</tr>
<tr>
<td>United Kingdom (UK)</td>
<td>Malaysia</td>
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<tr>
<td>Australia</td>
<td>Sri Lanka</td>
</tr>
<tr>
<td>Canada</td>
<td>Turkey</td>
</tr>
<tr>
<td>Spain</td>
<td></td>
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<tr>
<td>Sweden</td>
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</tbody>
</table>

The tool used to capture strengths, opportunities, weaknesses, and threats faced by developed and developing countries is the SWOT analysis. Accordingly, researchers in the field of strategic management, utilize SWOT analysis which is an acronym for (Strengths, Weakness, Opportunities, and Threats) that is used to identify internal factors (i.e. strengths and weaknesses) and external factors (i.e. opportunities and threats), which are favorable and unfavorable to achieve specific objectives of the particular project or an activity (Zueva 2019). Supportively, Zlatanova and Isikdag (2009) developed a SWOT analysis to outline the strengths, weaknesses, opportunities and threats in the application of BIM (Building Information System) to the field of Architecture, Engineering, and Construction (AEC) industry. Moreover, SWOT analysis is used to reveal the external macro-environmental factors along with the internal country-specific forces in the course of implementing Building Energy Efficiency (BEE) in rural China (Zhang et al. 2018). Accordingly, based on the prevailing perspectives and utilization of SWOT analysis, it can be used to examine the current and emerging strengths and opportunities confronted by developed countries and weaknesses and threats faced by the developing countries in implementing LCA for the construction industry. When taking into consideration the LCA integration to the construction industry, the SWOT analysis which is data-driven, fact-based and which realistically overlooks internal and external factors will facilitate and assist with accurate decision-making for successful LCA integration. Hence, the designing of SWOT can be utilized as an effective tool as it constitutes suitable parameters to diagnose prevailing problems on LCA integration to the construction industry in the developing countries, whilst recommending actions to prevent forthcoming problems from both the internal and external environments. Accordingly, this study has developed the SWOT analysis to investigate strengths and opportunities confronted by developed countries and weaknesses and threats faced by the developing countries in implementing LCA for the construction industry.

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3. Literature based SWOT Analysis and Discussion

The following sections focus on the detailed SWOT analysis for the purpose of identifying the strengths and opportunities confronted by developed countries and weaknesses and threats faced by the developing countries in implementing LCA to the construction industry. All strengths, opportunities, weakneses and threats were formulated by considering the descending order of timescale of the literature source.

3.1. SWOT Analysis: Strengths

When developing the SWOT analysis for the LCA integration of the construction industry, the construction industry itself can be identified as the “internal environment”. Favorable activities of the construction industry can be identified as “strengths”. Moreover, strengths encourage and enable the application of LCA to the construction industry. Strengths, which have been reported by the prevailing literature can be explained as follows. Summary of the findings of the strengths is tabulated in Table 2 with relevant references and the reported time period.

<table>
<thead>
<tr>
<th>No</th>
<th>Strengths</th>
<th>Reported Time Period</th>
<th>Ref. Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>Concern on developing eco-labeling criteria and EPDs for communication purpose within the construction industry</td>
<td>2018-1996</td>
<td>[2],[3],[4],[6]</td>
</tr>
<tr>
<td>S2</td>
<td>Intention for identifying opportunities for ecological improvements in the construction industry</td>
<td>2015-1996</td>
<td>[3],[4],[6]</td>
</tr>
<tr>
<td>S3</td>
<td>Growing industrial interest to apply LCA to the construction industry</td>
<td>2015-2000</td>
<td>[1],[2]</td>
</tr>
<tr>
<td>S4</td>
<td>Positive growth in the construction industry to achieve environmental sustainability</td>
<td>2009</td>
<td>[6]</td>
</tr>
<tr>
<td>S5</td>
<td>Organization of workshops and forums on LCA to make people aware and educate about LCA</td>
<td>2009</td>
<td>[5]</td>
</tr>
<tr>
<td>S6</td>
<td>Highest interest in developing benchmarks for different building types</td>
<td>2009</td>
<td>[6]</td>
</tr>
</tbody>
</table>


According to Table 1, LCA integration to the construction industry in developed countries has been strengthened due to the increasing interest in identifying opportunities for ecological improvements over its life cycle and due to the considerable attention on reducing environmental impacts generated by the construction industry (Bilec et al. 2009). Dewulf et al. (2009) highlighted that the construction industry in developed countries actively participates in organizing workshops and publishing several handbooks (i.e. International Reference Life Cycle Data System Handbook (ILCD) on LCA, which can be identified as strengths in implementing LCA within the construction industry in developed countries. Further, there is an indication of the increasing importance of LCA between the years, 1996 to 2018 is the development of the novel concept called “Environmental Product Declarations” (EPDs) with respect to the construction industry (Frankl and Rubik 2000). An EPD can be identified as a set of calculated environmental data of a particular product with pre-defined parameter categories based on the LCA methodology or ISO 14040 series. Moreover, EPD makes it easy for designers to select eco-friendly materials or products for the construction (Fava 2006). Further, there is also an increasing interest in developing more and more green buildings in developed countries to achieve environmental sustainability since the year 2009 approximately. The erection of green buildings requires complete LCA to assess harmful environmental impacts during the entire building life cycle (Singh et al. 2011). Hence, the increasing interest in developing green buildings provides a strong foundation for the adoption of LCA within the construction industry in developed countries. Likewise, a number of studies have divulged various strengths that encourage the adoption of LCA to the construction sector in developed countries.

Moreover, findings highlighted that some sort of strengths have arisen since the year 2000 but quite a few new strengths (i.e. initiation of EPDs) have emerged in recent years, which encourage the adoption of LCA for the construction industry in developed countries. Accordingly, it is highlighted that strengths that are enjoyed by the developed countries enhance the ability of LCA application since last the decade. Hence, developing countries should make an effort to embed the above-identified strengths to its construction industry in order to facilitate a resourceful background to support the LCA application.
3.2 SWOT Analysis: Weaknesses

This section comprises of the weaknesses that the construction industry faces whilst attempting to implement LCA, for the purpose of reducing environmental impacts. From the SWOT’s point of view, disadvantageous characteristics of the construction industry (internal environment) can be identified as “weaknesses”. The summary of weaknesses from the literature findings is shown in Table 3 with its respective literature source and reported time period.

Table 3: Weaknesses in integrating LCA for the construction industry in developing countries

<table>
<thead>
<tr>
<th>No</th>
<th>Weaknesses</th>
<th>Reported Time Period</th>
<th>Ref. code</th>
</tr>
</thead>
<tbody>
<tr>
<td>W1</td>
<td>Deficiencies in collecting accurate and high-quality LCA data with respect to the construction industry</td>
<td>2015-2000</td>
<td>[3], [4], [8], [9], [11], [12], [13]</td>
</tr>
<tr>
<td>W2</td>
<td>LCA for the civil engineering structures are more complex than LCA for conventional products</td>
<td>2015-2007</td>
<td>[2], [4], [5], [15]</td>
</tr>
<tr>
<td>W3</td>
<td>Financial constraints in allocating funds to initiate LCA within the construction industry</td>
<td>2011-2000</td>
<td>[6], [13], [14]</td>
</tr>
<tr>
<td>W4</td>
<td>The high cost of performing LCA (cost of purchasing data from commercial databases, the cost for the primary data collection and LCA professional fees)</td>
<td>2011-2000</td>
<td>[3], [7], [13], [14]</td>
</tr>
<tr>
<td>W5</td>
<td>Insufficient financial gains to the stakeholders compared with the costs of conducting LCA</td>
<td>2009</td>
<td>[16]</td>
</tr>
<tr>
<td>W6</td>
<td>Scarcity of adequate experienced professionals to perform LCA</td>
<td>2009-2000</td>
<td>[1], [3], [13]</td>
</tr>
<tr>
<td>W7</td>
<td>Confined stakeholder demand in performing LCA within the construction industry</td>
<td>2006</td>
<td>[10]</td>
</tr>
<tr>
<td>W8</td>
<td>Time taken to conduct building LCA is long</td>
<td>2000</td>
<td>[7], [13]</td>
</tr>
</tbody>
</table>


According to Table 3, people are prejudiced to apply LCA during the years 2015 to 2007 due to the complexity of civil engineering structures in comparison to conventional products. In developing countries, it has been confirmed that a high proportion of LCA studies have addressed product development processes (i.e. paper production process and cement manufacturing process) rather than focusing on the construction sector. As per the explanation of Basbagill et al. (2013) compared to products manufactured in industries, civil engineering structures are unique in their nature, its lifetime is long and civil structures are complicated with multiple functions, hence the adoption of LCA to the areas of AEC industry have been restricted and it weakens the application of LCA to the construction industry in developing countries. Moreover, it was pointed out that there is a scarcity of LCA expertise to perform LCA studies in developing countries (Arena and Rosa 2003).

Jonker and Harmsen (2012) emphasized that a complete life cycle assessment generally requires months to complete even by a qualified and experienced LCA professional, as data collection consumes more time and resources. Unavailability of high-quality LCA databases in developing countries during the period, 2015 to 2000 has created a major practical bottleneck in LCA studies (Arena and Rosa 2003; Saghafi et al. 2011). Scheuer et al. (2003) interpreted that less LCA data on the upstream and downstream impacts of buildings limited the LCA application. Accordingly, far less information on regional specific LCA data, scarcity of professionals in the field of LCA, and high level of specialized knowledge needed by the complex LCA have weakened the LCA application to the construction industry in developing countries (Abeyesundara et al. 2009). Hence, it has been emphasized that the application of LCA to the construction industry is more complex and expensive and also it limits the demand in applying LCA by stakeholders such as; contractors, consultants, architects and engineers (Hendrickson et. 2006).

Findings reveal that several weaknesses have been reported in the last decades. Also, some of the weaknesses are still prevailing over several years. Hence, developing countries should endeavor to minimize the above-identified weakness to implement LCA within its construction industry.
3.3 SWOT Analysis: Opportunities

“Opportunities” are the “external factors”, which motivate the application of LCA to the construction industry. When considering the development of SWOT analysis for the construction industry LCA integration, external factors can arise due to the effects created by external parties such as government, civil society, environmental societies, and academia etc. Opportunities, which have been reported by prevailing literature can be explained as follows. The summary of the literature findings is depicted in Table 4.

Table 4: Opportunities in integrating LCA for the construction industry in developed countries

<table>
<thead>
<tr>
<th>No</th>
<th>Opportunities</th>
<th>Reported Time Period</th>
<th>Ref. Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>O1</td>
<td>To obtain marketing benefits</td>
<td>2018</td>
<td>[4]</td>
</tr>
<tr>
<td>O2</td>
<td>Provision of tax reduction benefits for the reduction on environmental impacts</td>
<td>2108</td>
<td>[1]</td>
</tr>
<tr>
<td>O3</td>
<td>Empirically proved the benefits of conducting LCA</td>
<td>2018</td>
<td>[1]</td>
</tr>
<tr>
<td>O4</td>
<td>LCA as a novel approach for Research and Development</td>
<td>2015</td>
<td>[2]</td>
</tr>
<tr>
<td>O5</td>
<td>Due to the initiation of environmental policies which embeds LCA</td>
<td>2015-1996</td>
<td>[2], [3]</td>
</tr>
<tr>
<td>O6</td>
<td>Development of LCA software packages developed for the construction industry</td>
<td>2015-1996</td>
<td>[2], [3]</td>
</tr>
<tr>
<td>O7</td>
<td>Initiation of Simplified LCA method</td>
<td>2009</td>
<td>[5]</td>
</tr>
<tr>
<td>O8</td>
<td>Incorporation of LCA into green building certification processes</td>
<td>1996</td>
<td>[3]</td>
</tr>
<tr>
<td>O9</td>
<td>Favorable interest to initiate the green building implications</td>
<td>1996</td>
<td>[3]</td>
</tr>
<tr>
<td>O10</td>
<td>Integration of LCA with novel software such as Building Information Modeling</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(BIM)</td>
<td></td>
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</table>


In line with the Table 4, most of the governments across the world promote and encourage the environmental assessments to predict possible environmental impacts through the whole value chain, since the year 1996. Subsequently, LCA has been widely embedded in the context of environmental regulations as a core element to take voluntary actions to build an ecologically sustainable construction industry in the US the European Union, Canada, Australia, Japan, Korea, and forthcoming booming economies such as India and currently China (Güine et al. 2010), as LCA plays a leading role in promoting the principles of sustainable construction. Kögler and Goodchild (2017) reveal that government bodies promote and encourage the utilization of LCA by incorporating LCA into different policies and regulations such as Construction Products Regulation (CPR), European Commission on Integrated Product Policy (IPP), European standards for sustainable construction, and in the certification schemes for sustainable building constructions.

Furthermore, increasing awareness of environmental impacts generated by buildings, coupled with pressures from numerous stakeholders such as legislative bodies, government regulators, and environmental activist groups have been keen on introducing “the green building movement” in connection with the LCA since 1996 (Singh et al. 2011). Also, application of LCA provides a significant amount of credit in the green building certification processes such as Building Research Environmental Assessment Method (BREEAM), Leadership in Energy and Environmental Design (LEED) version IV. Furthermore, the German Sustainable Building Council (DGNB), Green Building Initiative (GBI) and Green Globes rating system in the US can be identified as other programs that use LCA to analyze building life cycles whilst promoting LCA application within the construction industry. The purpose of LCA integration to the certification processes, standards and green building codes are to encourage professionals in the construction industry to compare and analyze different types of building materials and structural designs on the basis of its environmental impacts to make informed decisions during the building construction processes (Lewis and Demmers 1996).

When it comes to the perspective of academia, LCA is still becoming an active field for research. Hence, academics are interested in doing research-related activities on LCA with respect to the construction industry (Haes et al. 2004). Apart from that, Asadollahfardi et al. (2015) identified that environmental modeling software packages have recently been introduced as a collaborative activity of the academia and construction industry, which makes it easy to integrate LCA to the building sector. Szalay (2007) further elaborated that academia, government and construction industry are collaboratively involved in developing different LCA databases such as, ATHENA for US and Canada and GaBi and

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SimaPro for Europe, which can be identified as opportunities in implanting LCA for developed countries. Additionally, Arena and De Rosa (2003), highlighted that the traditional LCA technique requires more data as well as time and resources to perform. Hence, a novel approach has been developed by stakeholders in academia and construction industry viz. “streamlined LCA” that requires fewer data to perform LCA. As well as academia, government and natural environment together initiate Institute for Environmental Research and Education (IERE) in America, in order to undertake and disseminate fact-based and comprehensive research on the area of LCA (Amarasinghe 2018). Not only that, but parties in the environment also play a prominent role in Europe and North America by promoting LCA through the United Nations Environmental Programme.

Accordingly, it can be noted that developed countries have taken advantage to implement LCA due to the number of different opportunities. Moreover, developed countries are enjoying benefits for the last several years, which reinforces the application of LCA in the construction area in developed countries. Hence, developing countries should also try to reap these benefits by embedding the abovementioned opportunities in their construction industry.

3.4 SWOT Analysis: Threats

Unfavorable “external factors” that may create the potential harm or limit the integration if LCA to the construction industry can be identified as “threats”. Summary of literature findings regarding threats is shown in Table 5 with its respective literature source and reported time period.

Table 5: Threats in integrating LCA for the construction industry in developing countries

<table>
<thead>
<tr>
<th>No</th>
<th>Threats</th>
<th>Reported Time Period</th>
<th>Ref. Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>Limited availability of platforms to publicize the LCA concept</td>
<td>2018-2015</td>
<td>[1], [4]</td>
</tr>
<tr>
<td>T2</td>
<td>Absence of proper legislative initiatives and competent authorities to encourage the application of LCA</td>
<td>2016</td>
<td>[12], [2]</td>
</tr>
<tr>
<td>T5</td>
<td>Limited society awareness on LCA as a decision-making tool to assess building environmental performances</td>
<td>2013-2001</td>
<td>[3], [8], [9], [10]</td>
</tr>
<tr>
<td>T6</td>
<td>Lack of favorable governmental incentives</td>
<td>2012-1996</td>
<td>[7], [10], [13]</td>
</tr>
<tr>
<td>T7</td>
<td>The emergence of different types of environmental management tools</td>
<td>2010-2006</td>
<td>[5], [6]</td>
</tr>
<tr>
<td>T8</td>
<td>Non-integration of LCA with building management software</td>
<td>2009</td>
<td>[13]</td>
</tr>
</tbody>
</table>


According to the findings of Table 5, generally, a lack of societies’ environmental awareness has created a threat to the application of LCA in developing nations, due to the deficiencies in current understanding about the concept and gaps between industry requirements and academic researches, since the year 2000 (Pour-Ghaz 2013). Furthermore, Amarasinghe (2018) stressed that lack of a platform to coordinate government authorities, LCA practitioners, environmentalists, scientists, and users, to share knowledge for the continuous improvement of LCA will threaten the spread of LCA within the construction sector in developing countries. Optimizing the environmental impacts of the construction industry is a must in the contemporary world. Despite common targets, national and international roadmaps related to the implementation of LCA, most of the developing countries experience obstacles when applying this knowledge practically due to the lack of integration of LCA with modern management software packages such as Building Information Molding (BIM) (Oviir 2016). Additionally, the lack of legislative governance measures in order to encourage building developers and designers to apply LCA in the early design stage barricades the application of LCA to the construction industry. Findings reveal that a number of threats have been reported for many years. Accordingly, it can be stated that in order to apply LCA within the construction industry in developing countries, threats that are reported through several years have to be minimized immediately to assist in implementing LCA.

The summary of the research findings is portrayed in Figure 1.
### ‘Strengths’ of developed countries

- **S1.** Concern on developing eco-labeling criteria and EPDs for communication purpose within the construction industry
- **S2.** Intention for identifying opportunities for ecological improvements in the construction industry
- **S3.** Growing industrial interest to apply LCA to the construction industry
- **S4.** Positive growth in the construction industry to achieve environmental sustainability
- **S5.** Organization of workshops and forums on LCA to make people aware and educate about LCA
- **S6.** Highest interest in developing benchmarks for different building types

### ‘Weaknesses’ inherited by developing countries with recommended actions to achieve ‘Weaknesses’

- **W1.** Deficiencies in collecting accurate and high-quality LCA data with respect to the construction industry *(Recommended Actions to undertake - O5)*
- **W2.** LCA for the civil engineering structures are more complex than LCA for conventional products *(Recommended Actions to undertake - O6 & S5)*
- **W3.** Financial constraints in allocating funds to initiate LCA within the construction industry *(Recommended Actions to undertake - O2)*
- **W4.** The high cost of performing LCA (cost of purchasing data from commercial databases, the cost for the primary data collection and LCA professional fees) *(Recommended Actions to undertake - O6 & O7)*
- **W5.** Insufficient financial gains to the stakeholders compared with the costs of conducting LCA *(Recommended Actions to undertake - O2)*
- **W6.** Scarcity of adequate experienced professionals to perform LCA *(Recommended Actions to undertake - S5)*
- **W7.** Confined stakeholder demand in performing LCA within the construction industry *(Recommended Actions to undertake - S5)*
- **W8.** Time taken to conduct building LCA is long *(Recommended Actions to undertake - O6 & O7)*

### ‘Opportunities’ of developed countries

- **O1.** To obtain marketing benefits
- **O2.** Provision of tax reduction benefits for the reduction on environmental impacts
- **O3.** Empirically proved the benefits of conducting LCA
- **O4.** LCA as a novel approach for Research and Development
- **O5.** Due to the initiation of environmental policies which embeds LCA
- **O6.** Development of LCA software packages developed for the construction industry
- **O7.** Initiation of Simplified LCA method
- **O8.** Incorporation of LCA into green building certification processes
- **O9.** Favorable interest to initiate the green building implications
- **O10.** Integration of LCA with novel software such as Building Information Modeling (BIM)

### ‘Threats’ inherited by developing countries with recommended actions to achieve ‘Threats’

- **T1.** Limited availability of platforms to publicize the LCA concept *(Recommended Actions to undertake - S5)*
- **T2.** Absence of proper legislative initiatives and competent authorities to encourage the application of LCA *(Recommended Actions to undertake - O5)*
- **T3.** Problems in credibility of LCA results *(Recommended Actions to undertake - O6)*
- **T4.** Problems in understanding LCA results *(Recommended Actions to undertake - O6)*
- **T5.** Limited society awareness on LCA as a decision-making tool to assess building environmental performances *(Recommended Actions to undertake - O6)*
- **T6.** Lack of favorable governmental incentives *(Recommended Actions to undertake – O2)*
- **T6.** The emergence of different types of environmental management tools *(Recommended Actions to undertake – O2)*
- **T9.** Non-integration of LCA with building management software *(Recommended Actions to undertake – O10)*

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*Figure 1: SWOT Analysis in integrating LCA into the construction industry*
4. Research Findings

According to Figure 1, it can be highlighted that the developed countries partake of a vast majority of internal strengths as well as external opportunities. When considering the perspective of the developing countries, they are in the position of facing a great number of internal weaknesses, as well as external threats for several years. Based on this study, it is revealed that developing countries should try to minimize the internal weaknesses and external threats whilst appending internal strengths and external opportunities enjoyed by developed countries to enhance LCA application within the construction industry. Moreover, the findings of this study may be useful for developing countries to determine and implement mitigation mechanisms to alleviate identified weaknesses and threats faced by the developing countries in implementing LCA for the construction industry. Also, developing countries can take further actions to embed strengths and opportunities confronted by developed countries with the purpose of facilitating LCA enabled the construction industry in developing countries. Thereby, this research contributes to the growing international body of knowledge by recommending suitable measures to achieve internal weaknesses and external threats. Identified internal strengths and external opportunities can be used to mitigate and eliminate internal weaknesses and external threats as described in the Figure 1.

For example, one of the weaknesses faced by the developing countries can be identified as ‘deficiencies in collecting accurate and high-quality LCA data with respect to the construction industry’ that can be eliminated by integrating the strength of ‘development LCA databases and software packages specially for the construction industry’. Moreover, the research outcome would be highly significant to the stakeholders such as academia, government bodies, and environmentalists to identify their essential contribution towards the implantation of LCA to the construction industry in developing countries. Accordingly, it is proved that the developing countries have to perform particular activities in advance to implement LCA for the construction industry in developing countries.

5. Conclusions

LCA is a globally recognized structured method applied particularly to enhance ecologically sustainable development in the construction industry by assisting in the erection of environmentally-conscious buildings and other structures. Over the last decades, LCA has evolved significantly in developed countries (i.e. Europe, America and Australia), as a sophisticated assessment procedure used for eco-efficient designs, to strengthen the decision-making process in the built environment. Although the building LCA is well-rooted in developed countries, comparatively it is difficult to find shreds of evidence on LCA implementation in developing countries. The above-identified contradictory situation in developed countries vs. developing countries, emphasize the need for investigating as to why LCA has not been implemented in developing countries particularly, for reasons addressed throughout this study. The SWOT analysis was developed for the purpose of identifying the strengths and opportunities confronted by developed countries and weaknesses and threats faced by the developing countries in implementing LCA to the construction industry. Designing, SWOT can be utilized as an effective tool as it has constituted suitable parameters to diagnose prevailing problems on LCA integration to the construction industry in developing countries whilst helping to take action to prevent forthcoming problems posed by both the internal and external environments.

Findings highlight that out of six strategies, developing EPDs (Environmental Product Declaration) and eco-labeling criteria for communication purposes within the construction industry is the frequently claimed strength in implementing LCA in developed countries. Lack of accurate LCA data in developing countries can be recognized as a highly reported weakness. Initiation of LCA software packages is the commonly stated opportunity, which makes it easy to integrate LCA into the construction sector in developed countries. Lack of societies’ environmental awareness has created the greatest threat to the application of LCA in developing nations, due to the deficiencies in the current understanding of the LCA concept. This study emphasized that developed countries enjoyed a multiplicity of strengths and opportunities whilst developing countries faced a great proportion of weaknesses and threats, which need to be alleviated to create LCA enabled built environments in developing countries.

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