The benefits of life cycle assessment: A methodology for buildings in South Africa

Ngwepe, L.K.¹, Aigbavboa, C.O² and Thwala, W.D.³

¹ Department of Construction Management & Quantity Surveying, University of Johannesburg, lknwewe@gmail.com, Tel No. +27 11 559 6398.
² Department of Construction Management & Quantity Surveying, University of Johannesburg, caigbavboa@u.ac.za, Tel No. +27 11 559 6398.
³ Department of Construction Management & Quantity Surveying, University of Johannesburg, didibhukuli@u.ac.za, Tel No. +27 11 559 6398.

ABSTRACT

Purpose of this paper: The aim of this study was to investigate the benefits of Life Cycle Assessment (LCA) for buildings across their life-cycles in South Africa.

Design/methodology/approach: To achieve the objectives of the study, a critical review of the literature was undertaken, coupled with a questionnaire survey to collect the primary data on the benefits of the LCA methodology for buildings across their entire life cycle. Through the review of the literature; the five major benefits of LCA for buildings were identified. This provided the basis for the formulation of the questionnaire. The questionnaire was distributed to all the professionals involved in the construction industry. The targeted number of respondents was 150; but only 116 questionnaires were returned. After a careful examination of the received questionnaires, only 98 were usable; and these formed the basis of the data analysis for the study.

Findings: The findings from the questionnaire survey revealed that the participants agreed that the use of a life-cycle assessment would improve building designs by making them more environmentally friendly, thereby building construction-project efficiency amongst others. The lowest-ranked factor was construction business-marketing territory; and it was ranked number 15.

Value of the study: The study contributes to the body of knowledge on the benefits of life-cycle assessment in the South African construction industry.

KEYWORDS: Building Construction, Construction Industry, Environmental Impact of Construction Activities, Life Cycle Assessment, South Africa

1. INTRODUCTION

International Standard 14040 (2006) defines the Life-Cycle Assessment (LCA) as a technique for assessing the environmental aspects and the potential impacts associated with a product; and it does so by: compiling an inventory of all the relevant inputs and outputs of a product system; evaluating the potential environmental impacts, and interpreting the results of the support tool. It is a tool that is used to identify, determine, quantify and evaluate the total environmental loadings and impacts (inputs and outputs) of a particular service, product, as well as the process, or activity, from cradle to grave. This means that the environmental impacts of all the phases of the product’s life are assessed: from the time that the materials are extracted – through the manufacture, transportation, storage, use, recovery,
reuse/recycle and disposal (Crawford, 2011; Kohler & Moffatt, 2003; Khaseem, 2009). The LCA takes a systemic view of the interaction between human activities and the environment, (Grant & Hes, 2002).

LCA is also referred to as a measurement tool that measures the environmental performance of a product or process. It is a process of estimating the environmental burdens for the energy and the materials used, as well as the wastes released into the environment. It then identifies the opportunities for environmental improvements (Rehan & Faisal, 2006). In addition, the LCA methodology provides a quantitative basis for assessing the potential improvements in the environmental performance of a system throughout its cycle (Korones & Dompros, 2005). Furthermore, LCA enables the estimation of the cumulative environmental impacts, resulting from all stages in the product life cycle – often including impacts not considered in more traditional analyses – such as the transportation of the materials (EPA, 2006).

LCA is an industrial environmental-management approach that looks holistically and comprehensively at the products, processes, and activities (SAIC, 2006). In addition, LCA is the only science-based and credible tool that is designed to measure the environmental impacts of products (Schenck, 2005). This is because of its holistic approach on products, services, or activities, amongst others. Moreover, the system’s perspective of LCA avoids problem shifting from one life-cycle stage to another, from one type of problem to another, and from one location to another (UNEP, 1996). Instead, LCA evaluates all the stages of a product’s life cycle – from the perspective that they are interdependent – meaning thereby that one operation leads to the next (EPA, 2006). This tool allows decision-makers the opportunity to study the entire system of a product, hence avoiding sub-optimisation that could result when just one process is the focus of the study.

Hence, the present study aims to investigate the benefits of LCA methodology for buildings across their entire life cycles in the South African construction industry.

The built environment is one of the largest sectors in any nation; and it contributes significantly to the environmental impacts. The built environment contributes to the environmental impacts – for example, through the emission of Greenhouse gases by burning fossil fuels during the transportation of materials during the construction activities; or by the incineration of waste that is generated from construction, as well as the demolition activities. Buildings are one of the major products of the built environment; and they comprise six life-cycle stages. These include: extraction of raw materials; manufacturing; construction; operation; as well as maintenance, demolition, and disposal.

The six life-cycle stages of a building make the undertaking of LCA for the buildings almost impossible; since it involves a considerable number of stakeholders, companies, personnel, and much legislation amongst others. Buildings are developed to provide for human needs, such as shelter; but they are found to be contributors to the environmental impacts. Buildings are a significant component of the human environment; and, accordingly, they contribute to the economy and the environmental impacts, including global climate change (Horne et al., 2009).

One of the major ways that building developments affect the environment is through the use of non-renewable natural resources, such as land and minerals. The utilization of non-renewable resources compromises the quality of life of humans; since land and other resources are depleted at a rate that is not sustainable (Carpenter 2001).
According to Crawford (2011), once the non-renewable resources have been completely exploited, or when they are considered to be too costly, or too difficult to extract from the earth, there would be a need to look for, or to develop alternative solutions to meet our needs. However, due to the difference in developments, Aglionby et al. (2001) maintain that each project is built and operates in a different socio-economic, political and physical environment; and therefore, it may improve some lives; whilst it diminishes the quality of others.

2. THE BENEFITS OF LIFE-CYCLE ASSESSMENT IN THE BUILDING SECTOR

The central motivation of LCA is the belief that products, processes, and other economic activities cause environmental harm that is not adequately controlled, together with the use of natural resources that are not properly priced (EPA, 1993). Hence, LCA is one of the tools or solutions that have been developed because of the increase in environmental awareness. It is a tool that was originally developed, in order to encourage organisations to be environmentally friendly, when embarking on production processes/activities. Furthermore, societies have become concerned about issues of natural-resource depletion and environmental degradation (EPA, 2006). In the light of the built environment sector, the White paper (2005) informs us that architects, engineers, contractors, building owners, environmentalists and government officials want the assurance that the products and materials they are using to design and construct buildings are the most beneficial to the environment from the "cradle to the grave".

In addition, Ampofo-Anti (2001) argues that to place construction on a truly sustainable path of green building, the movement needs a method, which goes beyond any subjective checklist of green features. Ampofo-Anti (2001) further informs us that such methods must provide objective guidelines for a comprehensive assessment of the environmental impacts of a product or process. Hence, the SAIC (2006) informs us that many businesses have responded to the reduction of environmental concerns by providing greener products and by using greener processes.

Studies have shown that LCA solves many environmental problems associated with a product. For instance, Ampofo-Anti (2009) informs us that the LCA procedure investigates a wide range of environmental impacts associated with industrial products, such as climate change, acidification, ozone depletion and human toxicity. However, there are significant positive differences that the use of LCA brings to the environmental performance of buildings, both new and existing. Khasreens et al. (2009) maintain that LCA has become a widely used methodology, because of its integrated way of treating the framework, impact assessment and data quality. Furthermore, any identified problems can also be traced through all the environmental media, namely, air, water and soil, (Ampofo-Anti, 2009). Another benefit of LCA is that it is based on a chosen functional unit; and one can factor in many geographical, technological and temporal variations in the assessment thereof (Crawford, 2011).

Overall, LCA covers the whole developmental story (Schenck, 2005) from the cradle to the grave.

2.1 Environmental Performance benefits of Life-Cycle Assessment

The EPA (1993) informs us that by performing LCA, analysts can: i) Develop a systematic evaluation of the environmental consequences associated with
a given product; ii) analyze the environmental trade-offs associated with one or more specific products/processes, to help gain stakeholder (state or community, etc.) acceptance for a planned action; iii) quantify any environmental releases to air, water, and land – in relation to each life stage and/or major contributing process; iv) assist in identifying any significant shifts in the environmental impacts between the life-cycle stages and the environmental media; v) assess the human and ecological effects of material consumption and environmental releases to the local community, region, and world; vi) compare the health and ecological impacts between two or more products/processes, or identify the impacts of a specific product/process; and vii) identify the impacts to one, or more specific environmental areas of concern.

This approach is the key to the sustainable-construction concept (Kohler and Moffatt, 2003). Moreover, the system’s perspective of LCA avoids problem-shifting from one life-cycle stage to another, from one type of problem to another, and from one location to another (UNEP, 1996). Instead, according to the LCA; it evaluates all the stages of a product’s life – from the perspective that they are interdependent, meaning that one operation leads to the next. This tool allows decision-makers the opportunity to study the entire system of a product; hence, avoiding sub-optimisation that could result when just one process is the focus of the study.

Basically, what LCA does, for example, when comparing two products, in order to choose the one with less environmental impacts, it would inform the underlying impacts that are not easily thought of, rather than just choosing a product on the basis of what we see.

Here is a summary of the environmental performance benefits of LCA (EPA, 2006):

- Management of building stages;
- Building designs by making them more environmentally friendly;
- Building construction methods by making them more environmentally friendly;
- Building construction project efficiency;
- Building operation efficiency;
- The use of renewable energy technologies;
- Demolition strategies for buildings, by making them more environmentally friendly; and
- Disposal methods for demolished building materials, by making them more environmentally friendly.

2.2 Strategic planning benefits of Life-Cycle Assessment

LCA is also used to assist producers to make decisions about alternative processes – in an attempt to improve industrial-environmental performance, (EPA, 1993). LCA studies guide regulatory agencies and other stakeholders for decision-making in the design, selection and evaluation of a process (Rehan & Faisal, 2006), amongst others. According to Grant and Hes (2002), LCA can be seen as a way of thinking; because it broadens our understanding of the environmental impacts of products, to include both the upstream and downstream effects of decisions. Environmental improvements of a product, process, or service, gained from LCA can lead to environmental and financial benefits to an organisation. Additionally, they may provide an organisation with a competitive advantage over competing products – with environmentally preferred choices – thus, providing a pathway to significant reductions in global environmental impacts (Crawford 2011).
Consequently, decision-makers are able to prioritise improvement strategies and to allocate funding, in order to maximise any potential environmental benefits. Values are thus maximised; since inefficient processes or services may be modified or replaced on the basis of informed environmental analysis. LCA can also be used to identify potential opportunities for a business that could otherwise have been overlooked; and this, in turn, would improve the credibility of the business. By modifying the existing systems, processes, or services, the organisation would also, in turn, be more susceptible to complying with future environmental policies, thereby possibly minimising future liabilities, risks or costs associated with compliance, or shifting the market demands. Other benefits of LCA in strategic planning include: The targeting and tracking of environmental improvement and progress towards ecologically sustainable patterns of consumption of building materials.

2.3 Policies and legislation benefits of Life-cycle Assessment

LCA can be used to help inform the development, implementation, and management of public policy. Such policies could be any policy related to the built environment, or the building sector, as singular. LCA can inform policy across or for each of the stages of a building, i.e. for the extraction of raw materials, for the purposes of manufacturing building materials, manufacturing processes, construction methods, operation laws for the buildings, demolition laws for building, as well as recycling and re-use laws for building materials. When such policies are made public, significant environmental impacts may be achieved, compared with when individual organisations have their own way of dealing with the relevant issues. For example, if the recycling and re-using of building materials is standard policy across all the building construction industry, this would afford the government ways to measure the number of environmental impacts, for which the organisation is accountable, based on the amount of material they recycle or reuse.

LCA can also be used to measure the potential impact of any existing or proposed future policy decisions may have on achieving beneficial environmental outcomes (Crawford, 2011). By modifying the existing systems, processes, or services, the organisation would, in turn, be more susceptible to complying with future environmental policies, or possibly minimising any future liabilities, risks or costs associated with compliance or shifting market demands. Example of existing environmental laws in South Africa include the Environmental Management Act, which has specifications across all sectors. This includes the construction industry, and manufacturing, amongst others.

Other policy frameworks include: The White Paper on the following: i) National Climate Change Response; ii) Integrated Pollution and Waste Management; iii) Environmental Management; iv) Conservation and the Sustainable Use of Biodiversity; v) Sustainable Coastal Development in South Africa. Other benefits of of LCA to policies and legislation include: policy-formulation for buildings, construction-business conformity to green building practices, and construction business conformity to construction environmental laws and policies.
2.4 Marketing benefits of Life-Cycle Assessment

LCA can be used to label the environmental attributes of a product, service, or product. This would help improve the competitive advantage of an organisation. This labelling leads to green, and clean, information transfer to consumers; and thus many people become aware of what their use of certain products means or costs to the environment. This also informs value for money, as consumers of products become aware that by buying a product that is relatively expensive, but environmentally friendly; it would cost less to the environment. Examples of environmental labelling include fuel-consumption labels that disclose the fuel efficiency of motor vehicles and energy; or water-rating labels indicating the energy or water efficiency of domestic appliances (Crawford, 2011).

Eco-labelling should, consequently, be associated with value-for-money; consumers would realize the necessity of being environmentally friendly, rather than seeing value-for-money being related to cost only. In the light of buildings, LCA may be used to inform green-building ratings that are already in place. Since green-building ratings are largely based on energy, LCA can provide more underlying information that includes the total environmental impacts associated with the product. For example, LCA would review the reasons behind the use of glass-curtain walling, as an incentive to reduce energy – by allowing in natural daylight, by assessing environmental impacts involved during the production processes, etc. Other associated benefits of LCA to marketing include: it improves the construction business-marketing territory; it improves the construction business-competitive advantage; and it improves the construction industry’s credibility.

3. THE RESEARCH METHODOLOGY

This research followed a quantitative design. Unlike the qualitative approach, a quantitative approach is deductive in nature; and it attempts to adopt an objective, detached approach to observing phenomena and conducting experiments (Kothari, 2004; Gray, 2009). A questionnaire survey-research design was used to collect the primary data for the study. Close-ended questions were used for the purposes of this research. The use of close-ended questions provided the participants with a multiple of options, from which to choose – without allowing them to form personal opinions in their own words (Picardi & Masick, 2014).

The main advantage of using close-ended questions is their simplicity for data collection and analysis; thus, they are less time-consuming.

A questionnaire survey was conducted in the Gauteng Province of South Africa. The survey was conducted on the South African building construction sector; and hence, the targeted respondents were construction professionals, such as architects, engineers, quantity surveyors, construction-project managers, amongst others in the construction sector. The targeted number of respondents was 150 from the construction professionals currently working in the Gauteng Province of South Africa. These were sent an online Google-Form survey. From the distributed questionnaire, 116 questionnaires were received back. However, after a careful examination of the received questionnaires, only 98 were usable; as 18 returned questionnaires were not properly completed.

These formed the basis of the analysis for the study. The respondents had the leisure of completing the questionnaires in their own time and space; and they were well informed of the purposes of the study, the importance of their participation in the study; and where they could find the results – if they are interested in knowing the outcomes of the study. The secondary data for
the study were derived from the review of the literature, both published and unpublished, that formed the basis of the questionnaire design.

Survey research can yield data that are versatile; and they can be analysed from a multitude of different perspectives, depending on the actual data collected and the sources (Picardi and Masick, 2014). The data for the study were analysed by using descriptive and multivariate statistics (Factor Analysis). A number of variables were selected and/or formulated, based on the literature that was reviewed; and then analysed to find out whether they comprise a structure: by assessing the correlation between them. Hence, the Principal Axis Factoring Extraction Method and the Varimax with Kaiser Normalization Rotation Method were used in the Factor analysis for this study (the multivariate statistics are not fully reported on this paper).

4. FINDINGS AND DISCUSSIONS

4.1 Background information of the participants

The findings on this aspect of the study revealed that a majority of the participants were Quantity Surveyors, accounting for a little over half of the participants (51.02%). The 51.02% represents a total of 50 out of 98 participants. The least frequency was 4%, i.e. 4 out of 98 participants, which represents Architects, which were in the same range, as the frequency for Facilities Manager, with 5%. Along the same range of frequency are the occupations: Construction Manager with 8%; Civil Engineer 9.18%; Site Engineer with 12%. The average number of working experiences of the participants was 7.35. This is supported by the huge gap between the lowest (minimum) and highest (maximum) number of years worked, i.e. 1 and 30, respectively.

4.2 The benefits of LCA methodology for buildings

This section of the questionnaire explored the benefits of making use of the LCA for buildings. A 5-point Likert scale: (where 1 = Strongly Disagree (SD); 2 = Disagree (D); 3 = Neutral (N); 4 = Agree (A); 5 = Strongly Agree (SA)) was used to record the respondent’s level of agreement with the identified factors, as the benefits of using LCA for buildings across their life-cycle stages. Descriptive statistics, as well as factor analysis, was used to analyse the data. The findings from the results of the factor analysis revealed that no item needed to be reverse-scored. Prior to performing PCA, the suitability of the data for factory analysis was assessed. The inspection of the correlations matrix revealed that all the coefficients had a score of 0.30. The Kaiser-Meyer-Oklı value was 0.853, exceeding the recommended value of 0.6; and the Bartlett’s Test of Sphericity achieved statistical significance, supporting the factorability of the correlation matrix. Lastly, for the Commonalities; all the factors in question had Extraction values of more than 0.3, which renders them all acceptable for factor analysis.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Benefits of Life-Cycle Assessment for buildings</th>
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<tbody>
<tr>
<td>Factors</td>
<td>Mean</td>
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<tr>
<td>1</td>
<td>Buildings designed by making them more environmentally friendly</td>
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<td>2</td>
<td>Building construction methods by making them more environmentally friendly</td>
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<td>No.</td>
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<td>3</td>
<td>The use of renewable energy technologies</td>
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<td>4</td>
<td>Construction business conformity to green-building practices</td>
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<td>5</td>
<td>Construction-business conformity to construction-environmental laws and policies</td>
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<td>6</td>
<td>Progress towards ecologically sustainable patterns of building-materials consumption</td>
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<td>7</td>
<td>Targeting and tracking of environmental improvement</td>
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<td>8</td>
<td>Demolition strategies for buildings by making them more environmentally friendly</td>
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<td>9</td>
<td>Building operation efficiency</td>
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<tr>
<td>10</td>
<td>Disposal methods for demolished building materials by making them more environmentally friendly</td>
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<td>11</td>
<td>Building construction project efficiency</td>
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<tr>
<td>12</td>
<td>Management of building stages</td>
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<td>13</td>
<td>Policy settings for buildings</td>
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<td>14</td>
<td>Construction business-competitive advantages</td>
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<td>15</td>
<td>Construction-industry credibility</td>
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<tr>
<td>16</td>
<td>Construction-business marketing territory</td>
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</table>

Table 1 represents the scores of the calculated mean item score when the respondents were asked to rank the benefits of LCA to the building industry. Table 1 shows building designs can be used, by making them more environmentally friendly with a mean of 4.30; building construction methods by making them more environmentally friendly (M=4.25), The use of renewable energy technologies (M=4.23); Construction-business conformity to green building practices (M=4.20), and conformity to construction environmental laws and policies (4.19) were ranked as the top-five benefits of LCA contributions to the South African building industry. Whilst, Construction industry credibility (M=3.86) and Construction business marketing territory (M=3.52) were ranked as the lowest benefits of LCA. However, a major input from the study revealed that all the factors, as assessed in Table 1.1, were all considered significant by the respondents. These were found to be in agreement with previous scholarly works, as discussed in the literature section of the paper.

For instance, the EPA (2006) report on the benefits of LCA to environment performance revealed that LCA is useful for the management of building stages, as well as building designs – by making them more environmentally friendly, building construction methods by making them more environmentally friendly, building construction-project efficiency, as well as building-operation efficiency.

5. CONCLUSION

According to the reviewed literature, the LCA methodology, if undertaken for buildings, can be beneficial in four major ways, namely: environmental performance; construction business-strategic planning; policy-formulation,
and marketing. Most of the participants agreed that the use of life-cycle assessment would improve the building designs, by making them more environmentally friendly, in addition to building construction-project efficiency and the management of building stages. The lowest-ranked factor was construction-business marketing.

Because LCA is one of the tools or solutions developed because of the increases in environmental awareness, this study thus adds to the body of knowledge on the adaptation of LCA by construction organizations for the design of environmentally friendly products and buildings, when embarking on production processes/activities. Furthermore, societies have become concerned about issues of natural-resource depletion and environmental degradation. In the light of these findings, it is recommended that construction stakeholders, such as the architects, engineers, contractors, building owners, environmentalists and government officials should ensure that the design and construction of buildings most beneficial to the environment from – the “cradle-to-the-grave”. Further, in order to place construction and its related activities on a truly sustainable path of green building movement, LCA, which goes beyond any subjective checklist of green features, should be adopted.

REFERENCES


SACQSP, Professional Skills Module No. 18


