International Journal of Engineering & Technology, 7 (3.7) (2018) 54-57

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Sustainability in the Product Design: A Review of Recent Development Based on LCA

Salwa Mahmood[1*], Mohd Fahrul Hassan[2], Abdul Rahman Hemdi[3], Muhamad Zameri Mat Saman[4]

[1]Department of Mechanical Engineering Technology, Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia, 84600 Pagoh, Johor, Malaysia
[2]Department of Material and Design Engineering, Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia, 86400 Batu Pahat, Johor, Malaysia.
[3]Faculty of Mechanical Engineering, Universiti Teknologi Mara, 13500 Permatang Pauh, Pulau Pinang, Malaysia.
[4]Department of Materials, Manufacturing and Industrial Engineering, Faculty of Mechanical Engineering, Universiti Teknologi Malaysia, 81310 Johor Bahru, Johor, Malaysia.
**Corresponding author E-mail: msalwa@uthm.edu.my*

Abstract

In order to achieve sustainable product design process, aspects such of environmental, economic and social should be balanced. This paper discussed on sustainability of product design, conceptual basis of life cycle assessment (LCA), review of LCA at several product design, methodology of proposed framework and discussion on strengths and limitations of LCA. This paper proposed to develop a framework for improving the product design process based on LCA tool. The aims is to calculate potential impact of environment, economic and social aspects during product design process. For environmental aspects, LCA tool will be used. For economic and social considerations, life cycle costing (LCC) and social life cycle assessment will be applied respectively. At the end, proposed framework are able to help designers to improve product design by considering all sustainability aspects.

Keywords: *Sustainability, Life Cycle Assessment, Sustainable Product Design*

1. Introduction

It is generally acknowledged that sustainable development can be described as enhancing the quality of life. Sustainable development helps human to live in healthy and comfortable environment. Thus, sustainable development able to improve social, economic as well as environmental conditions for present and future generations. Sustainable development has gained much attention in all nations since world commission on environment and development (WCED) introduced Our Common Future (1987).

This commission reported about sustainable development should focus as meeting the needs of present without compromising the need of future generations for their own need [1]. However, sustainability of humankind nowadays is threatened by dynamism of technology, economy, population acceleration and social rates of change over time [2,3].The notions of sustainable development and of planning for sustainable development have been closely scrutinized and redefined. The concept of sustainability is understood intuitively, but it remains difficult to express in operational terms [3,4]. Thus, sustainability is subjective because an environmentalist's definition of such a concept does not necessarily equate to the meaning of sustainability for the economist and socialist.

According to previous research work, planning for sustainable development should refer to long term development [5]. Thus, the path for achieving sustainability in product design should begin at the earliest stage. It might help such idea for implementing 6R approach in product design; Reduce, Reuse, Recycle, Recover, Redesign, Remanufacture [6]. Life Cycle Assessment (LCA) methodologies was applied by previous researchers in improvements of product design [7-11].

Several studies was combined LCA methodology with another method such Theory of Inventive Problem Solving (TRIZ) [12], Quality Function Deployment (QFD) [13], and Artificial Intelligence (AI) such fuzzy logic approach [6-15]. The aim of this paper is to review the previous LCA research on product design process for future research. Firstly, this paper provides details of LCA and its methodology which is based on ISO 14040. Secondly, the review on the previous research works by using LCA in product design process. Following that, the discussion of the perceived strengths and limitations of LCA presented. Finally, conclusion and future research work explained.

2. Literature Review

2.1 Conceptual Basis of LCA

For the last several decades, environmental awareness has been developing rapidly. The term environmental friendly was brought in order for shifting attitude towards the environmental consideration. However, it is difficult to determine which product is environmental friendly. It has been questioned on how people can access benefits by changing the mode of product design, production, usage and end-of-life of a product. Thus, answer for that such questions are important for a sustainable development. The envi-

ronment is a complicated network of many unexpected and unexplained interrelationship [16].

In other word, sometimes when a problem can be solved might only shift another problem at different stage of product life cycle. It is generally acknowledged that LCA is the most suitable tools for answering questions for product environmentally friendly. In addition, according to previous research, LCA has become a widely used methodology because of its integrated way of developing frameworks, data quality as well as impact assessment [15-18].

Based on ISO 14040:2006, LCA is a tool for analyzing the environmental burdens of products or services at all stages of production, consumption and disposal. Environmental burdens include all types of impacts on the environment, including depletion of resources, energy consumption, and emissions to land, water and air [15].

LCA consists of four distinct analytical steps; defining the goal and scope, creating the inventory, assessing the impact and lastly interpreting the results. Firstly, defining goal and scopes will defining purpose and determining system boundary. Secondly, for life cycle inventory (LCI), it involving collecting data such inputs and outputs that crossing the system boundary. Thirdly, the life cycle impact assessment (LCIA) evaluates potential environmental impacts occurred. Finally, the last steps is the interpretation that identifies issues, evaluates finding for reaching conclusions and generate recommendations.

2.1 Review of LCA at Several Product Design

A good design of a product with its improved life cycle is a reason towards sustainability. The design of products and their use are major concerns to improve environmental performance. This can be achieved by applying LCA, environmental management and eco-design. This means that the environment influenced the decision making in the design process. Hence it is influences the final product design. With eco-design, designer should aware the need of environmentally friendly product development. Next, clarify the design results by involving the environment in product development process. Then, acknowledge the availability of methods for environmentally friendly product development. LCA is one of the method mentioned. This section discussed about previous research works on product design based on LCA methodology.

Several previous research works focused on the use of software tools that based on LCA [7-11,19]. The purpose is to evaluate the environmental aspects and potential impacts associated with the product design. In the product design, environmental aspects evaluated from the previous research work such waste management strategies, strategies for optimizing resources, strategies for optimizing product EOL and analysis of EOL products . As for potential impacts, most of researchers focus on evaluated the global warming potential, acidification potential, eutrophication potential and waste potential.

After obtained amount of potential impacts mentioned, researcher suggested way how to reduce the impacts for each product's life cycle. However, most of research done do not show the amount of potential impacts after suggestion had been done for comparison purpose. Comparison before and after improvement suggestion should be done to show the effectiveness of the improvement option given.

In the other hand, several studies was combined LCA methodology with another method such TRIZ, QFD and AI such fuzzy logic approach. Most of previous research proposed framework for assessing the environmental with combination another methodology. For an example, there was a framework proposed by adopted LCA, QFD and TRIZ for improvement in the product design [12]. The aim of the framework developed is to support environmental awareness in product design development. Different scenario shown by previous work, a framework was proposed to aid a product design concerning environmental aspects [13]. Here, LCA was applied as a tool for assessing environmental aspects before a framework developed using Artificial Neural Network (ANN). As we can see that LCA was applied for environmental assessment in framework developed from previous research works.

This paper proposed to develop a framework for improving the product design process based on LCA tool. The proposed framework aim to calculate potential impact of environment, economic and social aspects during product design process. Hence the proposed framework should be able to determine the improvement options for improving product design process in sustainability perspective. By developing this framework, designers able to choose the improvement options towards sustainability consideration at the early design process. This research are focusing on environmental, economic and social considerations towards achieving sustainability life cycle assessment (SLCA). For economic and social considerations, life cycle costing (LCC) and social life cycle assessment will be applied respectively. A case study on automotive part will be conducted.

3. Proposed Framework Methodology

Figure 1 shows the proposed framework for improving the product design process based on LCA tool. The assessment begins with a selected product and reviews the product specifications or bill of material (BOM) include the materials and processes for getting the sustainability parameters or input data by using LCI. After parameters had been collected, parameters need to be classified into their respective categories; environmental, economic and social aspects by using respected tools; LCA, LCC and social LCA.

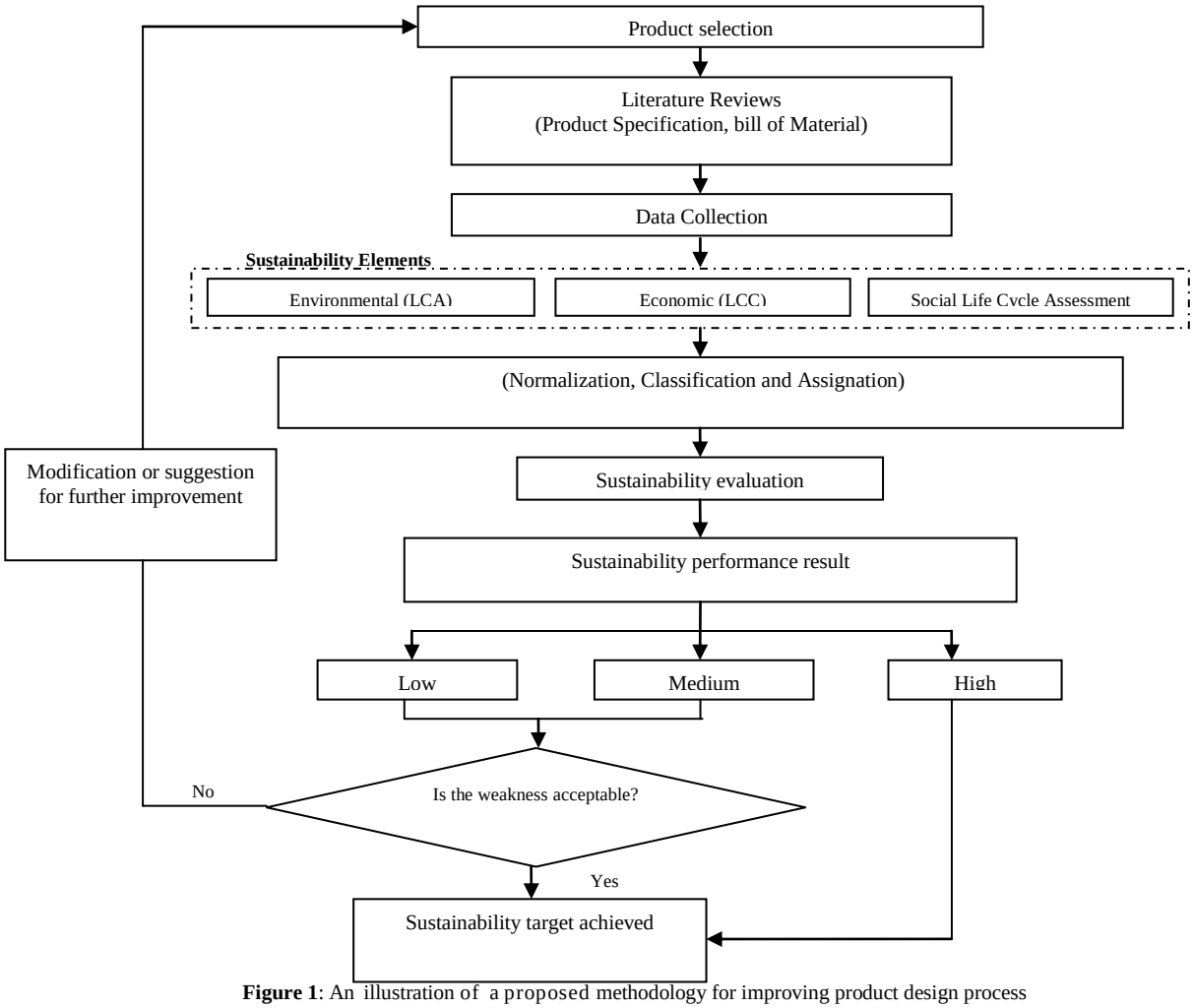

Figure 1: An illustration of a proposed methodology for improving product design process

Product design for a selected product is characterized by intensive use of materials, energy, and the potential for environmental pollution due to intensive processes along it is life cycle. Furthermore, if a product consume in chemicals it may result in toxicity that should be calculate in environmental consideration. For LCC, cost optimization is important involving reducing the use of chemicals, energy and resources, transportation, labor, treatment cost and operating and management cost based on activity. Less energy and material consumption indicates a higher level of sustainability [5].

As for social aspect, the framework developed is consider controlling the hazardous material used, ergonomics factors and safety and control the emission that may have potential to human health by applying social LCA. Next, normalization, classification and assignation will be conducted in order to obtain the sustainability evaluation. After obtaining the result of product design in term of sustainability, such as low, medium or high sustainability, action can be taken for a designer. If the weakness of the product design is not acceptable, designer can choose the modification or suggestion for further improvement. However, if the sustainability performance is high means the sustainability target is achieved. So that, designer can proceed the product design to the next step such prototype or production.

4. Discussion of Strength and Limitation of LCA

This paper shows the proposed framework for improving. LCA is a well described and standardized structure that is widely applied. To the present review regarding on the product design process, it has been shown that most analyses of LCA focused on the evaluation of potential impacts at the final stage, where a product was completely produce. Environmental burden identified such global warming, acidification, eutrophication and waste that are commonly analyzed. Previously, most of the developed framework do not show the improvement options in the framework.

This framework should become a user friendly framework, which able to calculate the sustainability impact hence determine the improvement options should be taken. It generally depends on product at the early design stage. By using LCA, there are several advantages discussed. Firstly, LCA able to evaluate environmental burden for the product design process. Weak areas related to environmental aspects can be easily identified. After obtaining the environmental results, an improvement option need to be chosen for improve product design itself such minimize wastes, optimize consumption of energy and eliminate hazardous materials. Thus, this environmental labelling during product design with the used of the LCA can be the most logical approach to encourage users towards minimum environmental impacts. There are several limitations of LCA.

According to expertise, LCA focuses only on environmental aspects, which does not consider other important criteria such economic and social perspective [20]. Since LCA is not a complete assessment from the sustainability perspective, assessment for economic and social can be done separately [21,22]. In future, research need to be done for this two aspects by using LCC for economic assessment and social life cycle assessment for social assessment. Hence all three aspects can be integrated towards sustainability assessment.

5. Conclusion

The aim of this paper is to propose the research direction for developing a framework for improving the product design process based on LCA tool. The aim of the proposed framework is to evaluate the environmental burdens of an automotive parts during the product design process. In the framework proposed, the improvement options can be determined for improving the environmental consideration at the early design phase. Towards sustainability perspective, LCC and social life cycle assessment will be applied for consideration of criteria such economic and social, respectively.

Acknowledgement

The authors wish to thank for funding by Universiti Tun Hussein Onn Malaysia (UTHM) under Incentive Grant Scheme for Publication (IGSP) Vote No. U411 and Universiti Teknologi Malaysia (UTM) under Fundamental Research Grant Scheme (FRGS) Vote No. 4F570.

References

[1] Brundtland Commission Report. 1987. Our common future: from one earth to one world. Oxford University Press, World Commission on Environment and Development, 5: 22-23.
[2] Bossel, H., 1999. Indicators for sustainable development: theory, method, applications: a report to a Balaton Group. International Institute for Sustainable Development.
[3] Markard, J., Raven, R. and Truffer, B., 2012. sustainability transitions: an emerging field of research and its prospects. Research Policy. 41 (6): 955-967.
[4] Briassoulis, H., 2001. Sustainable development and its indicators: through a (planner's) glass darkly. Journal of Environmental Planning and Management. 44(3): 409-427.
[5] Hemdi, A. R., Mat Saman M. Z., and Sharif S., 2011. Sustainability evaluation using fuzzy inference methods. International Journal of Sustainable Energy. 2011: 1-17.
[6] De Silva, N., Jawahir, I. S., Dillon, J. O., and Russell, M., 2009. A new comprehensive methodology for the evaluation of product sustainability at the design and development stage of consumer electronic products. International Journal of Sustainable Manufacturing. 1(3): 251-264.
[7] Schneider, F., Salhofer, S., Schiffleitner, A., and Stachura, M. 2008. The development of an ecodesign product – the ecomouse case study. Progress in Industrial Ecology – An International Journal. 5(1/2): 102-123.
[8] Maruschke, J., and Rosemann, B., 2005. Measuring environmental performance in the early phases of product design using life cycle assessment. Environmentally Conscious Design and Inverse Manufacturing, Fourth International Symposium on. Tokyo, 12-14 Dec, 2005, pp 248-249.
[9] Bevilacqua, M., Ciarapica, F. E., Giacchetta, G., 2007. Development of a sustainable product lifecycle in manufacturing firms: a case study. International Journal of Production Research, 45(18-19):. 4073-4098.
[10] Gehin, A., Zwolinski, P., and Brissaud, D., 2009. Integrated design of product lifecycles – the fridge case study. CIRP Journal of Manufacturing Science and Technology 1 (4): 214-220.
[11] Vinodh, S., 2010. Environmental conscious product design using CAD and CAE. Clean Technology and Environmental Policy. 13(2): 359-367.
[12] Trappey, A. J. C., Chen, M. Y., Hsiao, D. W. and Lin, G. Y. P., 2009. The green product eco-design approach and system complying with energy using products (EuP) directive. Advanced Concurrent Engineering. 5: 243-254.
[13] Kuo, T. C., Wu, H. H. and Shieh, J. I., 2009. Integration of environmental considerations in quality function deployment by using fuzzy logic. Expert Systems with Applications. 36: 7148-7156.
[14] Mahmood, S., Hemdi, A. R., Saman, M. Z. M., Yusof, M. N., 2015. Graphical user interface for assessing sustainability by using fuzzy logic: a case study on hollow fiber membrane module. Jurnal Teknologi. 76: 207-220.
[15] British Standard Institution (2006). Environmental Management – Life Cycle Assessment – Principle and Framework BS EN ISO 14040. London: British Standard Institution.
[16] Zbicinski, I., Stavenuiter, J., Kozlowska, B., Van De Coevering, H. P. M., 2006. Product design and life cycle assessment. The Baltic University Press ISBN 91-975526-2-3. Uppsala, Sweden.
[17] Klopffer, W., 2006. The role of SETAC in the development of LCA. International Journal of Life Cycle Assessment. 11(2006): 116-222.
[18] Hillary, R., 1995. Life cycle assessment. Centre for Environmental Technology, Imperial College of Science and Technology: Great Britain.
[19] Russo, D., 2011. A computer aided strategy for more sustainable products. In.: Proceedings of the 4th IFIP WG 5.4 Working Conference, CAI 2011, Strasbourg, France, June 30 – July 1, 2011: 149-162.
[20] Balkema, A. J., Preisig, H. A., Otterpohl, R., and Lambert, F. J. D., 2002. Indicators for the sustainability assessment of wastewater treatment systems. Urban Water. 4: 153-161.
[21] De Silva, N., Jawahir, I. S., Dillon, J. O., and Russell, M., 2009. a new comprehensive methodology for the evaluation of product sustainability at the design and development stage of consumer electronic products. International Journal of Sustainable Manufacturing. 1(3): 251-264.
[22] Zamagni A. and Pesonen H., 2013. From LCA to life cycle sustainability assessment: concept, practice and future directions. International Journal Of Life Cycle Assessment. 18: 1637-1641.