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A SUSTAINABLE APPROACH FOR PARK BENCH BY USING STREAMLINED LIFE CYCLE ASSESSMENT: A CASE STUDY

Ruqayah Ali Grmasha[1,*], Osamah J. Al-Sareji[1], Hind Mufeed Ewadh[1,] Mohammed Hussein Nadhim Obaid[1] and Nawfel Amer Salih[2]

[1]Environmental Research and Studies Center, University of Babylon, Iraq
[2]University of Babylon, Hillah, Babylon, Iraq
*Corresponding Author Email : ruqayah.grmasha@uobabylon.edu.iq

Abstract

The main objective of employing a life cycle assessment tool is to obtain guidance in regard to the environmental implications of selected products, systems or services. However, this tool is still time-consuming as well as resource-intensive. Thus, Streamlined life cycle assessment (SLCA) has been developed to overcome this problem. The aim of this study is to assess the materials' environmental impact of park bench located in Sydney, Australia. The SLCA data were preformed according to the Valuation of Social Cost and Simplified Life Cycle Assessment Model (VSSM). Furthermore, Eco-indicator 99 method was carried out for the Life Cycle Impact Assessment. The results indicated that the material phase in particularly the concrete is the major contributor for the whole life cycle of a park bench with 25.9 points followed by transportation. Due to the lack of information regarding concrete SLCA point, the ceramic point was selected as it considered the best available option. According to sensitivity analyses, the high SLCA points for transportation mode was alleviated by selecting another transportation type.

***Keywords*:** Life Cycle Assessment; Eco-Indicator 99; Hot spot; Sensitivity Analysis.

Introduction

In the last few decades, there have been raising concerns worldwide regarding global challenges such as resource depletion, population growth as well as pollutions United Nations, Department of Economic and Social Affairs (2013). Authority's initiatives and awareness toward major environmental impacts are increased dramatically and becoming noticeable thought services, products as well as general behavior Chomkhamsri and Pelletier (2011). Thus, the Life Cycle Assessment (LCA) tool has been developed to identify the environmental issues of a product, service and system over a whole lifetime to support sustainable development in the organizations Hauschild *et al.* (2005). However, the step of data collection in LCA is a time-consuming Wenzel *et al.* (1997). One strategy to cope with this issue is to alleviate the required data quality and quantity via simplification/ streamlined life cycle assessment (SLCA) Fleischer *et al.* (1998), Hunt *et al.* (1998), Rebitzer and Fleischer (2000), Curran (1996) and Christiansen *et al.* (1995), to start with less detailed work towards complex once Lehtinen *et al.* (2011). This paper access the environmental impacts for a park bench located in Sydney, Australia by using a streamlined life cycle assessment method.

Goal and scope definition

From the perspective of sustainability, it is necessary to consider the whole life cycle stages of the park bench to improve energy and resource efficiency. Therefore, Streamlined Life Cycle Assessment (SLCA) will be used to evaluate the environmental impacts and four specific stages should be referred such as raw materials, manufacturing process, usage and the end of life (EOL). The goal is to assess the environmental impacts that occurred by producing 1 park bench using for 20 years with no maintenance. The functional unit, scope and system boundary are illustrated as follow:

a. **Functional unit**: 1 park bench using for 20 years with no maintenance.
b. **Scope:** Cradle to grave includes raw material, manufacturing process, usage, and end of life.
c. **System boundary**: In this paper, the system boundary type is the product system and environmental system, which is shown in figure 1. The park benches should be installed in Sydney, Australia. For sandstone, it is manufactured in Byron Bay, New South Wales, Australia. Furthermore, the raw material and manufacturing process are excluded in this system boundary, but the transportation is included.

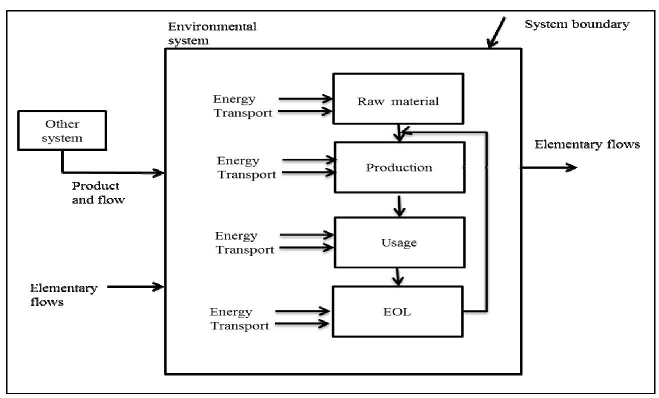

Fig. 1 : System boundary

Materials and Methods

Inventory Analysis

Input data

Most of the data were taken from the SLCA driver database as well as Ecoinvent and SIMAPRO version 7.1 software. In terms of the selection of SLCA drivers, all of them can derive from SLCA database exclude material, concrete with 25% fly ash, and concrete to be 100% landfill. As the major component of concrete is cement and it is kind of ceramic material, therefore, in this paper, assuming concrete with 25% fly ash in the category of ceramic and glass. Thus, the SLCA driver for raw material concrete and concrete to landfill will adopt the value of raw material ceramic (0.0270 points/kg) and landfill glass B250 (1998) (0.0013 points/kg). In addition, the required distance between cities and suburbs was taken from Google Maps. For product distribution distance in the Sydney area, it is assumed to be 350km. The disposal distance is assumed 30 km, but considering the distance of collection, so the final disposal distance used in the calculation is 380 km.

Drivers for Material stage

The raw materials of this product include steel, plastic and concrete with 25% ash. As for steel, the driver for No Ni Ferro has been chosen, while for plastic materials, choosing the M011: Rubber, Thermoplast and Thermoset, thermoset has been chosen as the plastic shell of the park bench for its flintiness and durability. Although it is still not applicable to find in the literature the accurate drivers of the concrete with 25%, the drivers of Ceramic applied as the substitutes.

Driver for Process stage

The manufacturing processes include electroplating zinc I, extrusion of PET/AU U, power saw (per hour) U and screwing GCCC-LCA. As aforementioned, all the drivers can be found in the SCLA database, and in the above order, they are G06: Electroplating Zinc I/Electric welding steel 5, G05: Deep drawing PS or PET or PET/RPET / Foil extrusion / Calandering. PVC foil, G02: Power saw (per hour) S and G05: Screwing and from the instruction. As the product is assumed to be assembled in Brisbane; therefore, the electricity using driver should choose Energy Asia/Australia.

Driver for Transportation

At the transportation stage, the plastic parts are typically made in Melbourne and transported to Brisbane. The distance from Melbourne to Brisbane is approximately 1676km. Because it is long-distance transportation and in order to reduce transportation times, 3.5t-delivery van is selected. As for the Sandstone, it is produced in Byron Bay and delivered to Brisbane (with a distance of 166 km) and the 40t-truck has been chosen to deliver it. For product transportation, the given 28t-truck to deliver it from Brisbane to Sydney and the distance between these two cities is 350km.

Driver for Usage stage

As these park benches distributed around Sydney, it assumed that the total delivery distance is 350km (the perimeter of the area if taking Sydney CBD as the central point). Thus, in order to reduce the transportation times and the GHGs produced by the truck, the 40t-truck has been selected.

Driver for End of life stage

Firstly, it supposes that all the benches need to be transported to a certain recycling point and the location of the disposal site is estimated at 30km away from the usage location. Therefore, the total distance should be 350km plus 30km which is 380km. Base on the emission reduction and the energy conservation principles, the 40t-truck has been chosen to deliver the waste scrapped benches.

Results and Discussion

Life Cycle Impact assessment (LCIA)

Up to date, there are several of LCIA methods that can be applied to assess the environmental impacts. Those methods are varying in the impact categories they included, in their geographical focus, and in their indicators selection Handbook, I.L.C.D. (2010). The selection of the most suitable LCIA method is case-specific and the Handbook I.L.C.D., 2010 offers some suggestions about appropriate methodology selection. The recommended methods include Eco-indicator 99, Goedkoop (1999). Environmental Priority Strategies (EPS) 2000. CML 2 baseline (2000) and Cumulative Energy Demand (CED). In the Eco-indicator 99 method, the impact category indicator results are calculated in the Characterization step. In addition, the three damage categories (human health, ecosystem quality and resources) are calculated in the Normalization and weighting step. In EPS 2000 method, four impact categories (human health, ecosystem production capacity, abiotic stock resource and biodiversity) are assessed by weighting, and the weighting factors mean the willingness of a company to pay to avoid changes. The CML 2 baseline 2000, a problem-oriented approach, focuses on category indicators at the middle point. Normalization scores of each baseline indicator are calculating to compare with the reference value. CED is applied to assess energy consumption (primary and secondary energy) involving characterization and weighting steps. The impact categories are a non-renewable fossil, non-renewable nuclear, renewable biomass, renewable wind, solar, geothermal, and renewable water.

In this case, the Valuation of Simplified Life Cycle Assessment and Social Cost (VSSM) Model is applied to assess the environmental impacts of each stage, using the Eco-indicator 99 (unit: points). This model provides SLCA drivers to calculate the impacts. The equation about how to calculate the environmental impact by using the SLCA drivers is shown as follow:

Total environmental impact= SLCA drivers× Input data

= SLCA Driver for material × Material weight (kg) + SLCA Driver for process × Material weight (kg) + SLCA Driver for usage × Lifetime energy consumption (MJ) + SLCA for EOL options × Material weight (kg) + SLCA for transportation used in all stages × travel distance (km)

For the choosing of SLCA drivers, 40t truck and 3.5t van have two choices, so sensitivity analysis is adopted to analyze the difference of different SLCA drivers. As for the calculation of transportation, the unit should be transformed into tkm, for example, product (weight 991 kg) is transported from Brisbane to Sydney (923 km), transporting by 28 t truck (divers: 0.0176 points/tkm), then the design value will be (991×923) ÷1000 = 914.693 tkm, and the SLCA result is 914.693×0.0176 =16.1 points. 5. Interpretation

It can be seen from Figure 2 which illustrates the SLCA total results of each life cycle stage and the results of cradle to gate and cradle to grave that the material is the biggest contributor for the whole life cycle of a product. That is, material stage is the hot spot.

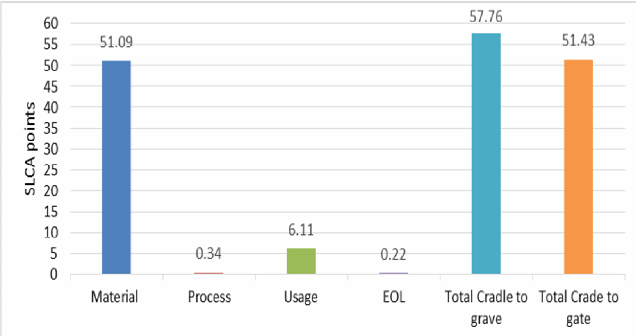

Fig. 2 : The SCLA results in different life cycle stages and the totals

Ecological hotspots analysis

In five main processes of the life cycle, each process has its own high point stage which means the production will pose high threats to the environmental impacts. It can be seen from Figure 3 that in the raw material stage, the concrete base has generated the highest point, which is above 25.9 points, the second one is a plastic structure (5.36 points) and third is the steel support of the bench (0.85 points). Refers to the supplier transportation process, the most obvious one is the product transportation stage, which means deliver the park bench from Brisbane to Sydney create the most environmental impacts compared with other stages. The output SCLA results generated by the manufacturing process is limited, compared with another process, the environmental impacts made by this process are not that significant. When it comes to the usage process, the SCLA result produced by the distribution of the product can be very notable which has 5.5 points ranked the third place in the total stages. The last process is the end of the park bench life. Although some stages in the disposal process get the negative results, which means these stages will reduce the environmental impacts generated in the whole life circle, there is still one stage creating very high SCLA results which are concrete and masonry blocks disposal. To conclude, a total of seven hot spots in the product life cycle create significant environmental impacts and should be paid more attention.

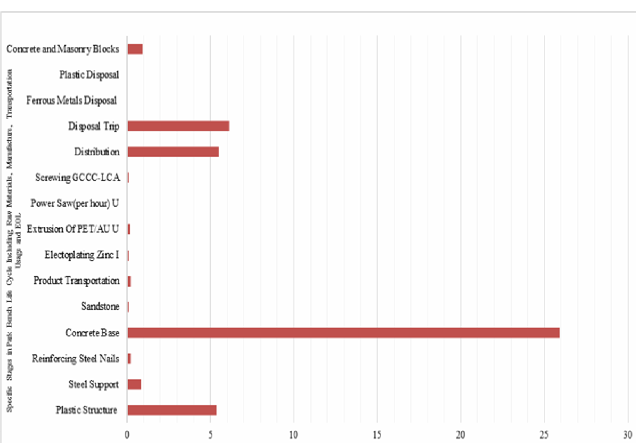

Fig. 3 : Hot spot in each life cycle stages

Sensitivity analysis

In this paper, the SLCA driver for concrete is assumed due to the limitation of the database, therefore the actual results will be less or more than the calculated value. Furthermore, the functional unit stated that there is no maintenance for the park bench. If there is annual maintenance, the total SLCA result of usage will increase as certain materials and energy will be involved.

Another assumption is the distribution transportation distance in the Sydney area. It assumed the transportation radius is 50 km, in the calculation, distance 350 km is adopted. However, when changing this value to 7850 km (the area), usage will become the hot spot of the whole life cycle of the product. For the transport mode, in this case, truck and vans are used, if transport mode changes to train, water or plane, there will have a great difference. It can be seen from figure 4 that the change of transport mode has a great impact on the final results, especially for air traffic. In this case, only choose one type of different transport mode to compare the result, and the transportation between the factory and port are neglected. Therefore, the sensitivity analysis might be only demonstrated that air traffic has the biggest environmental impact in this case. On the other hand, choosing trucks and vans are take economic and convenience into account. As the transportation distance is not exactly what it is, so the actual SLCA result for transportation might be bigger than the calculated value.

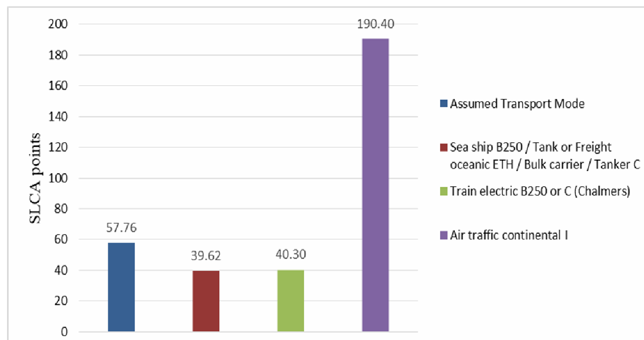

Fig. 4 : Results of using different transport mode

In the SLCA driver's database, there are alternative drivers for truck and van. Thus, sensitivity analysis is made to compare the influence of different drivers for same transport mode. Figure 5 show that changing the type of delivery van will have a great impact on the cradle-to-grave results, while the change of 40 t truck has slight difference.

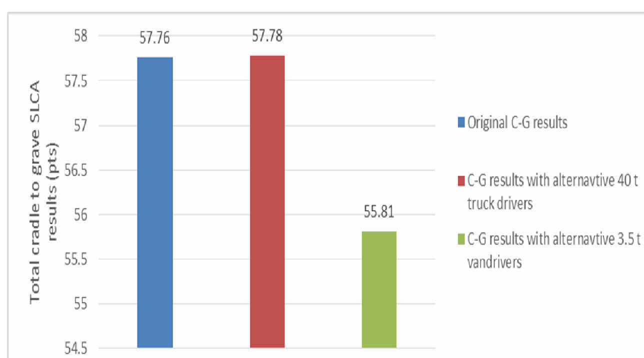

Fig. 5 : Comparison of overall cradle to grave (C-G) results with alternative divers

Conclusion

In this paper, the Life Cycle Assessment of a park bench was presented using the Simplified/ Streamed Life Cycle Assessment (SLCA) method and the results from hot spot analysis as well as sensitivity analysis were discussed. The usage phase had the highest environmental impacts during the product life cycle due to concrete use. The exact

SLCA point for the concrete has not been published yet in the literature; therefore, the ceramic was used instead. In terms of transportation, carrying out the sensitivity analysis proved that the alternative transport mode could reduce the total environmental impact compared current used mode.

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