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DEVELOPMENT OF SIMPLIFIED LCA MODEL FOR SMALL AND MEDIUM ENTERPRISES (SMES)

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ABSTRACT

Environmental Life Cycle Assessment (LCA), one of the most commonly used tools in industrial ecology, has several characteristics that make its use and application difficult in Small and Medium Enterprises (SMEs). Collection, elaboration and interpretation procedures of these numerous data require knowledge of standardized methodological aspects and supporting systems, such as databases and software. In addition, high quality LCA results require time-consuming studies. Although the LCA tool has been popular since 1990's until the present, implementation of the LCA tool in the Malaysian industry is still limited. A survey conducted in 2003 showed that 98% of the respondents were either not sure or do not know of any LCA performed in the Malaysia, reflecting on the very limited application of LCA on the whole in the country [1]. In this paper, a simplified LCA model using a checklist scoring system is proposed. The model developed, also known as the Simplified Scoring System (SSS) procedure, is a preliminary study in doing the assessment using a simplified LCA concept in SMEs especially for packaging industries. The results of the assessment is tabulated in a matrix form and presented in plots. The easier assessment using the developed model will be shown using data from the corrugated paper carton as a case study.

Keywords

Simplified Life Cycle Assessment, Small and Medium Enterprise, corrugated carton, Simplified Scoring System

1. INTRODUCTION

A survey conducted by Mansoni found that the common problem faced by SMEs when practicing, was the reluctance to adopt life cycle ideas and life cycle thinking in their environmental management [2]. In addition, SMEs have to manage an enormous quantity of environmental data to comply with licensing and operation rules, which make the practice become more difficult. As a result, SMEs perceive environmental aspects as constraints primarily in terms of costs, which are often unknown and hidden. SMEs also do not perceive environmental management system as an opportunity especially the idea of life cycle management. These obstacles may reduce the popularity of environmental management practicing especially LCA in SMEs in Malaysia.

The list below sums up some of the main issues and questions of the debate [2];

(a) Focus must be on simplified certification and validation systems.
(b) Voluntary instruments alone do not appear sufficient. Strong incentives for the application of command and control tools are needed.
(c) It is important to consider the strong market power of retailers and their influence on SMEs, as well as their potential to inform consumers about the environmental performance of products. This is especially relevant for energy consuming and waste intensive products.
(d) It is important to consider the information needs of end consumers, which typically are not related to LCA. Data need to be interpreted to demonstrate their implications for actual concerns like health issues, nature conservation, energy or cost issues.

With these issues identified issues, a simplified LCA which is applicable in current Malaysian SMEs is developed. The main conclusions regarding the new tool can be summarized as follows:

(a) SMEs need assessment procedures that allow them to perform LCA by themselves with minimal time and resource investments.
(b) A suitable tool should maintain the complex life cycle approach; however, clear and easy to understand calculation and visualization methods should be offered.

2. DEVELOPMENT OF SIMPLIFIED SCORING SYSTEM

The focus of this study is mainly on the self-assessment procedure. The important steps of self-assessment procedure in this study are:

(a) Completing the "Goal and scope definition" form
(b) Completing "Inventory" worksheets (collection of data)
(c) Calculating the score based on the "checklist" (impact assessment)

In this first step of the procedure, users define the goals, the functional unit and the system boundaries of the study. The next step is the filling in of the Inventory form. In this step, users collect and store all the life-cycle-based quantitative and qualitative information that are necessary for the following steps of the self-assessment procedure. Demand for data collection was limited as much as possible in order to minimize time requirement. The pre-defined form helps non-expert users to understand the life cycle concept and avoid unwanted skipping of important stages of the product system [3].

The product life cycle is divided into three main stages:
(a) Production : processing and transportation of raw and intermediate materials and manufacturing
(b) Distribution : product transportation from producer to consumer and to end user.
(c) Disposal: product disposal and recycling

The aim of the checklist is to prepare a general checklist adaptable for packaging products. The main environmental concerns to take into account are grouped into five main categories as tabulated in Table 1:

(a) Material choice
(b) Use of energy and water
(c) Solid waste emissions
(d) Waterborne emissions
(e) Airborne emissions

Table 1 Data and information elicited in the inventory form

Production
• Raw and ancillary materials (quality and quantity) • Transport of raw and ancillary materials to the manufacturing plant (type and distance) • Energy consumption • Water consumption • Solid wastes (quality and quantity) • Waterborne wastes (quality and quantity) • Airborne emissions (quality and quantity)
Distribution
• Material consumption (quality and quantity) • Transport of product – distribution to consumers (type and distance) • Energy consumption • Water consumption • Solid wastes (quality and quantity)

• Waterborne wastes (quality and quantity) • Airborne emissions (quality and quantity)
Disposal
• Material consumption of disassembly processes • Transport of product to final disposal/recycling site • Energy consumption • Water consumption • Solid wastes (quality and quantity) • Waterborne wastes (quality and quantity) • Airborne emissions (quality and quantity) • Recycling (quality and quantity of recycled materials)

The quantitative and qualitative aspects of the product under study are considered when assessing the data using the checklist. For quantitative aspects, data can be derived from product specific or site specific data collection. The assessments of qualitative aspects can be done by the supporting database, which have played an important role to ensure that the data input is well defined and accurate. As mentioned earlier, the supporting databases smoothen the progress of simplified life cycle assessment implementation.. There are three life cycle stages in this assessment; namely, production stage, distribution stage and disposal stage. For every life cycle stage, there are five elements; notably, material choice, use of energy and water, solid wastes, waterborne emissions and airborne emissions each of which contains sub-elements.

In the calculation of the environmental impacts, there are two types of scoring rules involved; namely, scoring rules for quantitative aspects and scoring rules for qualitative aspects.

2.1 Scoring Rules for Quantitative Aspects

The scoring rules for this study are mostly derived from the quantitative assessments that are suggested in Hui et al. [4] and Mansoni et al. [2]. However, some scoring rules have been modified to suit this study. Example of the modifications includes the range of percentages used in the disposal material choice. In this study, five point scoring scale is adopted. Zero means highest impact and four means lowest impact. Besides, the hazardous wastes scoring classification for solid waste emissions, waterborne emissions and airborne emissions; which is based on the guidelines for the classification of hazardous chemicals (DOSH, [5]) also included. Table 2 shows the themes of the checklist sub-elements and the related suggested rules for quantitative scoring.

Table 2 Scoring rules for quantitative aspects

Theme	Valuation rule
Mass of material input (raw and intermediate materials, ancillary materials, disposed and recycled materials)	4 if $R \leq 5$ 3 if $5 \leq R \leq 20$ 2 if $20 \leq R \leq 100$ 1 if $100 \leq R \leq 500$ 0 if $R \geq 500$ ** R= {Amount of materials (kg)/ functional unit (kg)} x 100
Type of materials	4: Recycled, renewable 3: (Recycled, non-renewable) or (non-recycled, renewable) 2: Virgin, renewable, recyclable 1: (Virgin, renewable, non-recyclable) or (Virgin, non-renewable, recyclable) 0: Virgin, non-renewable, non-recyclable
Efficiency in energy or water use	4: Extremely good efficiency 3: Good efficiency 2: Medium efficiency 1: Low efficiency

	0: Very low efficiency
Distance of transportation	4: Local 3: Regional 2: National 1: Asia 0: Worldwide
Type of transport	4: Passenger car 3: Van 2: Lorry or truck 1: Train 0: Ship
Waste water emissions	4: Emissions are under the limits of law standards into surface water without treatment processes 3: Emissions reach the limits of law standards into surface water without treatment processes 2: Emissions are under the limits of law standards into surface water after treatment processes or under the limits of law standards into sewage without treatment processes 1: Emissions are under the limits of law standards into sewage after treatment processes 0: Emissions are over the limits of law standards into sewage without treatment processes
Disposal material choice (Composting rate of material, combustibility of material, percentage of size reduction and degradation rate of material).	4: Very high (81-100%) 3: High (61-80%) 2: Moderate (41-60%) 1: Low (21-40%) 0: Very low (0-20%)
Type of hazardous wastes (refer to R-number)	4: Irritant 3: Harmful 2: Corrosive 1: Toxic 0: Very toxic
The compounds that affect environmental impact categories (toxic pollutants, particulate matter and toxic gases).	4: Lower than below regulatory limit 3: Below regulatory limit 2: Within regulatory limit 1: Above regulatory limit 0: Higher than above regulatory limit

In the calculation of environmental impacts in a sub-element, a score will be given for each substance and the quantity of each substance has to be presented in the relative form. Hence, the actual impacts of the substance can be identified by multiplying the score and relative of that particular substance. The averaged total score from every substance reveals the total impacts in that sub-element. Similarly, the averaged total score from every sub-element reveals the total impact in that element.

2.2 Scoring Rules for Qualitative Aspects

In this study, the scoring rules for qualitative aspects refer to the identified substances identified especially in waterborne and airborne emissions. Basically, different type of emissions has different environmental impact potentials categories. For example, substances in Global Warming Potential (GWP) can only be found in the form of airborne emissions.

Calculation of the potentials contributions from an emission to an environmental impact requires knowledge of how strongly the substances emitted, contribute to the type of environmental impact in question. The equivalency factors expresses the substance's strength measured relative to a reference substance, and this method of expressing the equivalency factor is common for most types of environmental impacts (Wenzel et al., [6]). For global warming the reference substance is carbon dioxide (CO2), the impact factors thus express the substances' potential impacts as grams of CO2 equivalent per gram of substance. When methane has an impact factor of 25, it means that emission of 1 g of methane contributes as much to global warming as the emission of 25 g CO2.

There are five environmental impact potentials in this scoring rules; namely, nutrients, greenhouse gases, ozone depletors, acidic gases and volatile organic compounds. These environmental impact potentials are based on their individual equivalency factors as given in EDIP method. Table 3 shows the general scoring rules for qualitative aspects.

Table 3 General scoring rules for qualitative aspects.

Theme	Valuation rule
The compounds that affect environmental impact categories (nutrients, greenhouse gases, ozone depletors, acidic gases, volatile organic compounds)	4: Lower than below equivalency factors 3: Below equivalency factors 2: Within equivalency factors 1: Above equivalency factors 0: Higher than above equivalency factors

In the calculation of an environmental impact potential, the characterization factor for a substance will be multiplied with its amount released and the relative score can be calculated for that substance. Therefore, the impact of that substance's contribution will be identified. Next, a qualitative score for the substance can be found by using the scoring scale interpolation. This is followed by the averaged score from every substance, which indicates its total impacts of the sub-element. Finally, the averaged total score from every sub-element indicates its total impacts of that element.

The developed SSS model covered 3 parts; namely, goal and scope definition, life cycle inventory and scoring checklist. They are revealed at different layout but have interrelation among each other. The SSS was developed using visual C++ programming. The results will be shown in a matrix form and presented in plots to reveal the easy-assessment of the findings.

3. CASE STUDY – CORRUGATED PAPER CARTON

The SSS procedure was tested using a case-study where a simplified LCA of a corrugated product was carried out [3]. Table 5 shows the data in SSS procedure where the goal and scope of the case study are defined.

Table 5: SSS case study- goal and scope definition

Functional unit	1000 units of RSC 1000 with double walls BC flute for 2m² layout.
Goal of the study	Identify the strengths and weaknesses of product system
System boundaries	The processes included within the product life cycle are: production of raw materials, corrugated production, transportation, distribution, disposal of packaging materials.

Generally, LCA is a tool that requires a wide range of data in order to complete a detailed assessment. Thus, it takes a long period of study. Due to cost and time issues, a few assumptions have been made during the case study assessment. These assumptions will be discussed in the following paragraph.

The results from the SimaPro 5.1 database will be used as the inventory data input in this case study. The results from SimaPro are presented according to the compartment categories. However, only raw material compartment, air compartment, water compartment and solid compartment are chosen to further the assessment. We have ignored the other minor compartments due to their non-significant appearances. Besides, only the significant amounts of substances in each compartment were assessed. In order to ensure that the SSS procedure is developed to assess the impacts of the product under study, the negative values obtained from the SimaPro 5.1 software assessment were ignored. This means that the avoided products or processes during reuse or recycling practices are not included in this study. However, the total assumptions of reuse, recycling and landfill impacts are considered in this study. It is also assumed that water and energy will be used efficiently. Therefore, no comparison should be made between the energy and water usage except for distance and types of transportation, which were in the same category. With the above assumptions made, the developed SSS procedure will be more easily assessable and the outcome could be presented later in the matrix form and target plot form.

4. RESULTS

Table 6 summarizes the scores for each sub-element in every life cycle stage. The amounts of quantity for the most significant substances were listed under the relevant sub-element categories. For instance, there were so many substances in each sub-element and in each sub-element there were also a few choices that can be considered under each element category. Thus, the quantity of sub-elements in each element category was different. The choices depend on sub-element needed in the study.

Table 6 SSS case study- checklist scores for each sub-element in every life cycle stage

Checklists	Mean	Note
1.Production		
Type of raw materials	1.94	Virgin, non-renewable, recyclable
Ancillary materials	2.96	Non-renewable, recyclable
Use of water	3.00	Good efficiency
Use of energy	3.00	Good efficiency
Transport distance of materials to production plant	0.03	Within worldwide and Asia
Quantity of solid waste emissions	1.26	R= 23.98% , virgin, non-renewable, non recyclable
		High content of nitrate
Nutrients in waterborne emissions	2.91	High content of NOX
Nutrients in airborne emissions	1.81	High content of CO2
Greenhouse gases emissions	3.61	High impact of Halon-1301
Ozone depletory gases emissions	4.00	High content of SO2 and NOX
Acidic gases emissions	2.63	High impact of methane and CO
Volatile organic compound gases emissions	4.00	
2. Distribution		
Type of raw materials	0.98	Virgin, non-renewable, non-recyclable
Use of energy	3.00	Good efficiency
Transport distance of materials distribution	3.11	Within local and regional
Quantity of solid waste emissions	4.00	R = 0%
Nutrients in waterborne emissions	3.98	High impact of N-tot and NH4+
Nutrients in airborne emissions	3.44	High impact of NOX
Greenhouse gases emissions	3.83	High content of CO2
Ozone depletory gases emissions	4.00	High impact of Halon-1301
Acidic gases emissions	3.44	High impact of SOx and NOX
Volatile organic compound gases emissions	3.99	High impact of CO
3. Disposal		
Type of materials	0.43	Virgin, non-renewable, non-recyclable
Use of water	3.00	Good efficiency
Use of energy	3.00	Good efficiency
Transport distance of materials to be disposed	4.00	Local
Solid waste emissions	1.01	Virgin, Non-renewable, recyclable

Nutrients in waterborne emissions	2.69	High impact of nitrate and NH4+
Greenhouse gases emissions	4.00	High impact of methane
Acidic gases emissions	4.00	High impact of HF
Volatile organic compound gases emissions	4.00	High impact of methane and CO

These different choices of sub-elements were identified and calculated for each element category in the ratio scale, as can be seen in Table 6. The maximum point is four and the minimum point is zero. The results of the case study were shown in matrix form (Table 7) and target-plot form (Figure 1).

Table 7: The results in matrix form

	Material choice	**Use of energy**	**Solid waste emissions**	**Waterborne emissions**	**Airborne emissions**	**Total values**
Production	245/400	201/400	126/400	346/400	334/400	1252/2000
Distribution	98/400	306/400	400/400	399/400	378/400	1581/2000
Disposal	43/400	333/400	101/400	335/400	400/400	1212/2000
Total value	386/1200	840/1200	627/1200	1080/1200	1112/1200	4045/6000

SSS is an environmental impact assessment system, which employs the three stages of a product life as the basis for analysis. With the maximum point of 2000 per stage, the results indicated more comprehensive outcome with the total maximum point of 6000 for three life stages. Therefore, the total point for this product under study is 4045/6000. Among all the life cycle stages, the highest score at 1581/2000 is distribution stage, followed by production and disposal stage, which are 1252/2000 and 1212/2000 respectively (Table 7).

The higher the generated score, the lower is the negative impact contribution to the environment. Thus, the disposal stage was found to be the weakest stage in product system towards the environmental concepts. Material choice and solid emissions are among the main cores in the disposal stage. This could be due to the usage of the virgin and non-renewable materials during waste disposal activities. The product under study is one of the common packaging materials used in the market. Therefore, the high impact of this product in the disposal stage is expected.

The highest impact in the production stage occurred in the solid emissions, which has a total score of 126/400. In this element, the process wastes contributed the most impacts to the environmental by producing 550 kg of waste during the production process. The distribution stage has the least impact to the environment compared to other stages. The total generated score for this stage is 1581/2000. Although there is no solid waste emission in this stage, a maximum point of 400 is given for that element in order to fulfill the requirement of the matrix approaches. The overall result is considered above average with the generated score of 4045/6000 for 1000 units of RSC paper carton. Thus, one RSC carton will contribute 0.03% of its negative impact to the environment. This packaging material is considered to have a low impact if compared with other packaging materials, which have a higher contributory percentage.

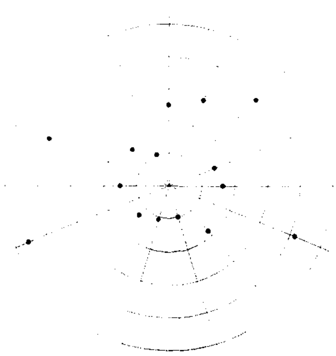

Figure 1: Results shown in the target plot form

The matrix provide a useful overall assessment of the product under study, but a more succinct display of SSS attributes is provided by the "target plots" as shown in Figure 1 There are five rims from zero point at the outer rim to four points at the inner rim. The highest point represents a better environmental impact. A good product or process appears as a series of dots bunched in the center, like rifle target in which each shot was aimed accurately. In this study, the dots are not really bunched in the center (Figure 1). Hence, steps can be taken to reduce the environmental impact of the product in the areas where the dots are further away from the center.

5. DISCUSSIONS

The main concept of presenting the results is derived from the study carried in Graedel et al [7]. The study emphasized on the concept of simplified LCA. The developed SSS also emphasized on the simplified LCA. Unlike classical inventory assessment and perhaps impact assessment, overall LCA as presented here is less quantifiable and less thorough. It is also more practical and utilitarian. The developed SSS required less input data with only three life stages. Supporting database like SimaPro 5.1 was used in this assessment in order to treat the data gap problems due to unavailability of data. Thus, an assessment of the product under study can be carried out with the support of a little background knowledge of LCA. In addition, the amount of time and money consumed will be small enough that the assessment has a good chance of being carried out and its recommendations implemented. With this development, we can actually develop baseline information of life cycle preliminary studies among those environmentally concern parties or people to get an overview of the whole product system from a green perspective.

However, there are also some shortcomings of this method. The life cycle stages were limited to only three. Further work needs to be incorporated to extend to as many life cycle stages as required in the product system. More reliable life cycle inventory data from Malaysian industries or sectors would result in a more reliable score. Currently, reliable life cycle inventory data is difficult to get. Thus, assumptions to fill up data gaps may result in erroneous scores.

6. CONCLUSIONS

A Simplified Scoring System was developed to introduce the life-cycle concept into product system assessments of the Malaysian SMEs. The main characteristic of this system is the use of checklists to enter and evaluate assessment scores, which would require minimal amount of time and effort for SMEs. Results of the assessment were tabulated in a matrix form and target plots for easy comprehension. The scores obtained would give the SMEs a general idea on how they fare in the assessment.

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REFERENCES

[1] Sumiani, Y & Nik Meriam, N. S. (2003) Strategies for the use and adoption of life cycle assessment for environmental management in Malaysia. Proceedings of International Conference of Environmental Management and Technology "A clean environment towards sustainable development". Malaysia: 4-6 August, pp 90-95.

[2] Mansoni, P. Sára, B. & Raggi, A. (2004) VerdEE: a tool for adoption of life cycle assessment in small and medium sized enterprises in Italy. Journal of Industrial Ecology. Vol, pp 1-3.

[3] Ang, Chai Tew (2005), Simplified Life Cycle Assessment in Environmental Management: Case Study in Packaging Industry (MSc Thesis), University Sains Malaysia.

[4] Hui, I. K., Lau, H. C. W., Chan, H. S. & Lee, K. T. (2002) An environmental impact scoring system for manufactured products. The International Journal of Advanced Manufacturing Technology, Vol 19, pp302-312.

[5] DOSH (1997). Guidelines for the classification of hazardous chemicals. Department of Occupational Safety and Health: Ministry of Human Resources Malaysia

[6] Wenzel, H., Hauschild, M. & Alting, L. (1997) Environmental assessment ofproducts-Methodology, tools and case studies in product development., Vol.1. USA: Kluwer Academic Publishers
[7] Graedel, T. E., Allenby, B. R. & Comie, P. R. (1995) Matrix approaches to abridged life cycle assessment. Environmental Science Technology. 29(3), pp 134A-139A