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IDENTIFICATION OF KEY ENVIRONMENTAL ISSUES FOR BUILDING MATERIALS

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Abstract

Manufacture, construction and use of buildings and building materials make a significant environmental impact internally (inside the building), locally (neighbourhood) and globally. Life cycle assessment (LCA) methodology is being applied for evaluating the environmental impact of building/or building materials.

One of the major applications of LCA is to identify key issues of a product system from cradle to grave. Key issues identified in an LCA lead one to the right direction in assessing the environmental aspects of a product system and help to identify the areas for improvement of the environmental performance of a product as well.

The purpose of this paper is to suggest two methods for identifying key issues using an integrated tool (LCADesign), which has been developed to provide a method of determining the best alternative for reducing environmental impacts from a building or building materials, and compare both methods in the case study. This paper assists the designers or marketers related to building or building materials in their decision making by giving information on activities or alternatives which are identified as key issues for environmental impacts.

Keywords: Key environmental issue, Building material, Life Cycle Impact Assessment, Characterization, Valuation

1. Introduction

There is a growing concern about environmental impacts from building and/or building materials since construction and use of buildings and building materials make a significant environmental impact internally, locally and globally [1, 2]. In the context of manufacturing processes of building materials, it is important to identify the environmental burdens in a processing sequence, where they originate, where they are greatest and how they might be reduced. Life cycle assessment (LCA) is an extremely useful tool for this purpose in that it can be used to calculate the environmental impact of a product, process or activity from the cradle to the grave. The impact can be expressed as a quantity of material emission or as a contribution to a known problem area [3, 4]. It thus supports the design of products that cause less harm to the environment.

One of the major applications of the LCA is to identify key issues of a product system from cradle to grave. Key issues identified in an LCA lead one to the right direction in assessing the environmental aspects of a product system and help to identify the areas for potentially significant improvement of the environmental

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performance of a product as well. The approach for identification of key issues can be divided into two types according to which impact applied to identification: characterization impact, valuation. The key issues may be different according to which approach is used for identification with the focus for improvement not resulting in the best outcome for the intended purpose.

The purpose of this paper is to describe two approaches for identifying key issues based on dominance analysis, and compare both approaches in case study. This study assists the decision making related to building materials for designers, or marketers by giving information on activities or alternatives which are identified as key issues for environmental impacts.

2. Identification of key environmental issue

A key environmental issue of building materials is a unit process or activity for which the potential impact to the environment is significant within a given unit process or activity. To develop an environmentally sustainable building material, it is generally required to reduce the environmental impact, which is caused from a process or an activity incurred in the manufacturing of a building material. Then, building material designers or manufacturers can suggest alternatives for the process or activity identified as the key environmental issue.

Identification of the key issue is generally carried out by dominance analysis. After making an environmental inventory list of a building material, the environmental impact for each environmental impact category is obtained by environmental impact assessment, which consists of three steps: characterization, normalization and valuation, based on the result of inventory analysis. A key environmental issue is identified by the following five sequential steps:

Step 1. Inventory analysis for a building material

Step 2. Calculating the environmental impact for a given impact category (Global warming, ozone depletion, etc.) by multiplying the environmental emissions by the corresponding factors for a given impact category

Step 3. Calculating total environmental impact by summation of each impact

Step 4. Dividing each environmental impact (result from Step 2) by total impact (result from Step 3)

Step 5. Identifying the key environmental issue after deciding the cut-off criteria as x % which are activities/inventory items contributing more than x % to the total impact of building materials.

Key environmental issues may vary according to which kind of environmental impact is selected (e.g. characterized impact, normalized impact or weighted impact).

2.1. Identification of key issue based on the characterization

Characterization is the mandatory element of life cycle impact assessment, where the environmental loads, after have being sorted into the different impact categories, are aggregated by calculating the size of their environmental impact [3]. The environmental loads are multiplied by their corresponding equivalency factors and then added together per impact category, which is called characterized impact.

After collecting data for life cycle inventory (LCI) analysis of a building material, the characterization impact can be obtained by multiplying the corresponding factors by the amount of each material in the inventory. Key issues can be defined as activities or inventory items with rates of contribution to the characterization impact of more than x%. The contribution rate (%) is defined as the characterized impact for each activity or process divided by the total characterization impact, as in the following equation.

$$\text{Contribution rate (\%)} = \frac{CI_{i,j,k}}{CI_i} \times 100 \qquad (1)$$

where, CI_i is a characterized impact for the i^{th} environmental impact category (g-eqv/f.u) [$CI_i = \sum_j C_{i,j} = \sum_j (Load_{j,k} \times \text{eqv}_{i,j})$] (i: global warming, ozone depletion, eutrophication, etc.) and $CI_{i,j,k}$ is a characterized impact for the k^{th} activity of the j^{th} inventory in the i^{th} environmental impact category, which is obtained by multiplying the environmental emission ($Load_{j,k}$, g/f.u) by its corresponding equivalency factor ($\text{eqv}_{i,j}$, g-eqv/g).

If the cut-off criteria is 10%, then activity or process of selected building material is identified as the key environmental issue, if it contributes more than 10% to the total characterization impact.

2.2. Identification of key issue based on the valuation

Valuation is the optional element of life cycle impact assessment, which the environmental parameters are aggregated to form a single parameter [3].

Identification of a key issue based on the valuation is carried out by dividing the valuation result (weighted impact) for each activity by that for building material. This approach gives relative contribution rate (%) of each activity and environmental impact category to the total impact of building material. This is represented by the following equation.

$$\text{Contribution rate (\%)} = \frac{WI_{i,k} \;\; (= \sum_j NI_{i,k} \times W_i)}{\sum_i (\sum_k WI_{i,k}) \;\; (= \sum_i (\sum_k NI_{i,k} \times W_i))} \times 100 \qquad (2)$$

where, $WI_{i,k}$ is the weighted impact for the k^{th} activity of the i^{th} impact category and $NI_{i,k}$ is a normalized impact for the k^{th} activity of a given impact category i. W_i denotes the weighting factor for environmental impact category i.

If the cut-off criteria is 10%, then activity or process of selected building material is identified as the key environmental issue, if it contributes more than 10% to the total valuation (weighted impact).

3. Illustrative example

To illustrate how these approaches are applied to the building materials, Portland cement, which is one of most popular building material used in construction activity, is considered as an example. Figure 1 shows a general Portland cement production process in Australia [5]. To simplify the calculation, the production process is divided into three steps (Quarrying and raw milling, Clinkering, and finishing, see Figure 1).

The input data for life cycle inventory analysis for Portland cement production were taken from the literature [5, 6], and the enviornmental emission data due to electricity, oil, water consumption, and resource consumption are taken from the commercial enviornmental life cycle assessment tool (LCADesign) which is used for building/building materials in Australia [7].

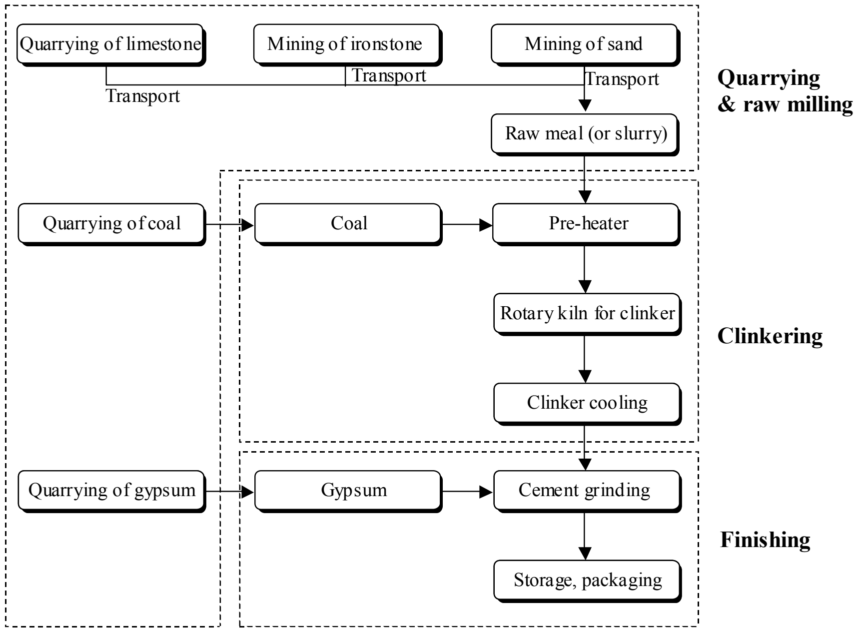

Figure 1 Portland cement production process

Environmental substances considered in the analysis were energy consumption, raw material consumed, air-/water-borne emissions, and wastes generated. Environmental emissions were calculated based on the 1 kg of Portland cement production (called functional unit, f.u). Figure 2 shows the environmental inventory results for Portland cement production during the life cycle, which was obtained using the LCADesign Tool.

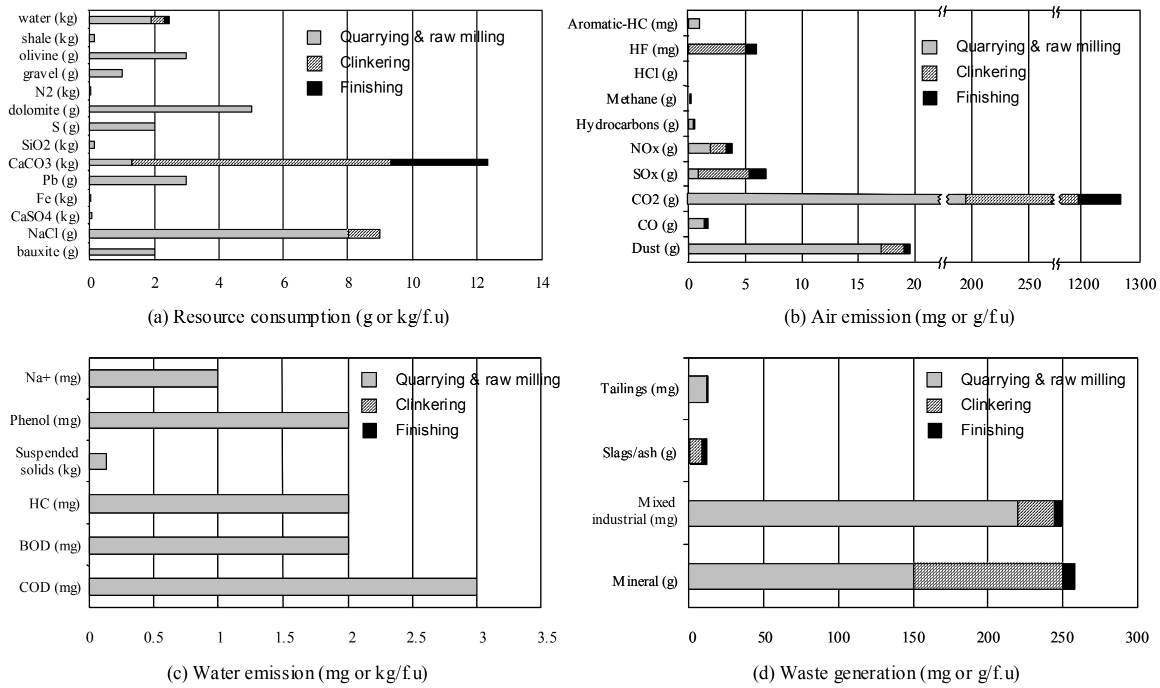

Figure 2 Environmental emission for Portland cement (unit of emissions/f.u)

The Eco-indicator 99 method [8] has been used to convert the inventory data into the environmental impact for Portland cement production. Normalization factor data was taken from European weight factors between categories and was applied without any modification [8].

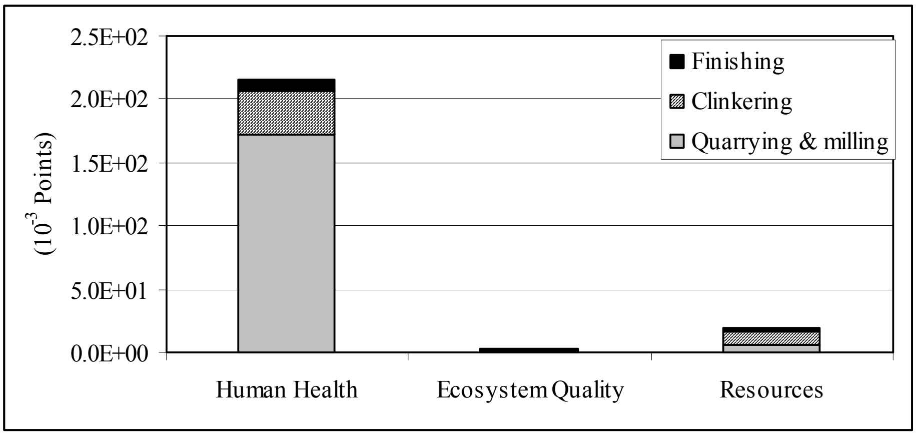

Figure 3 Environmental impact for Portland cement production

The total environmental impact of Portland cement production is shown in Figure 3. Key issues based on the characterization impact are shown in Table 1. A key issue is defined as an activity or substance contributing more than 10% to an environmental impact category. As seen in Table 1, major activities, which influence each of the impact categories, were identified as quarrying and milling process and clinkering. In addition, key substances which contribute more than 10% in each activity, were identified as hydrocarbons, dust, CO_2, NO_x and SO_x as air-borne emissions.

Table 1 Key issues for each impact category based on characterization result

Impact category	Key issue	
	Activity	**Substance**
Carcinogens	-	-
Respiratory organics	Quarrying & milling (78.6%)	Hydrocarbons (78.1%)
	Clinkering (16.7%)	Hydrocarbons (16.5%)
Respiratory inorganic	Quarrying & milling (82.0%)	Dust (79.3%)
	Clinkering (13.7%)	-
Climate change	Quarrying & milling (15.0%)	CO2 (14.8%)
	Clinkering (75.5%)	CO2 (75.3%)
Radiation	-	-
Ozone layer	-	-
Ecotoxicity	-	-
Acidification /Eutrophication	Quarrying & milling (40.3%)	Nitrogen oxides (as NO2) (37.0%)
	Clinkering (44.6%)	Nitrogen oxides (as NO2) (28.5%)
		Sulfur dioxide (16.1%)
	Finishing (15.1%)	Nitrogen oxides (as NO2) (10.1%)
Land use	-	-
Minerals	Quarrying & milling (89.5%)	Iron (ore) (74.8%)
Fossil Fuel	Quarrying & milling (32.4%)	Oil crude (27.3%)
	Clinkering (54.4%)	Coal hard (49.2)
	Finishing (13.2%)	-

An alternative approach to identifying key issues is based on valuation result (weighted impact), which is calculated by dividing the impact of each activity by the weighted total impact. A key issue is defined as an activity or impact contributing more than 10% to the total impact.

The result is shown in Figure 4. 80% of the total impact is caused by the quarrying and milling process, and 16% by the clinkering. The finishing process contributes only 4% to the total impact. On the other hand, the environmental impact, which contributes more than 10% to the quarrying and milling and clinkering processes, is identified as human health impact in both activities having a contribution of 95% and 75% respectively.

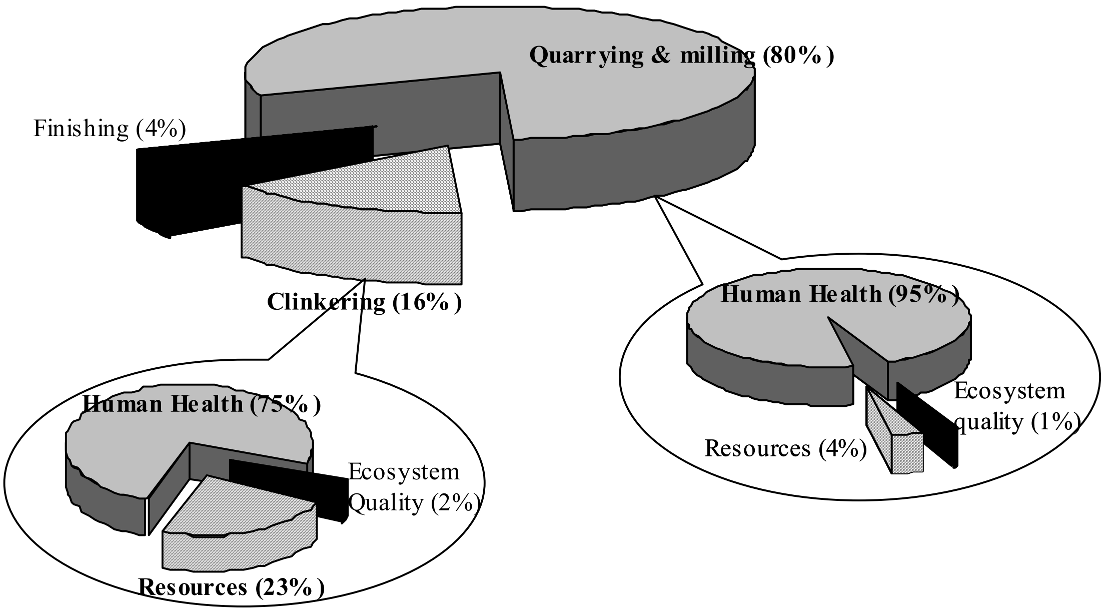

Figure 4 Contribution of key issues to the system

Table 2 Contribution of activity for each impact category and the whole system

Table 2 summarizes which activity contributes to the each environmental impact category and then a whole system. As shown in this table, the first approach based on the characterized impact can give a number of key issues, which contribute to each environmental impact category. However, it is not clear how to identify the key issue from the viewpoint of the whole system.

Identification of a key issue based on the weighted impact can make analysis easy to understand but less key issues are identified. That is, the identification of a key issue based on the weighted impact may overlook the more detailed key issues that are identified for each environmental impact category.

Activity	A* (%)											B* (%)
	Carcinogens	Respiratory organics	Respiratory inorganics	Climatic change	Radiation	Ozone layer	Ecotoxicity	Acidification/Eutrophication	Land use	Minerals	Fossil Fuel	Whole system
Quarrying & milling	0	78.6	82.0	15.0	0	0	0	40.3	0	89.4	32.4	75.5
Clinkering	0	16.7	13.7	75.4	0	0	0	44.5	0	7.6	54.4	19.1
Finishing	0	4.8	4.2	9.5	0	0	0	15.1	0	2.8	13.1	5.2

A: Contribution of each activity based on characterization
B: Contribution of each activity based total impact

4. Conclusion

Identification of key environmental issues or activities for building material production can give clues to obtain environmental sustainable building production. This paper compares two approaches for identifying key issues in the given environment. The main features of this study include that:

- The first approach, identification of key issues based on the characterization results, can give a number of key issues but it is difficult to grasp the key issue for whole system.
- The second approach, based on the weighted total impact, can give a consistent result from the whole system, but key issues identified are less.
- The illustrative example has shown that the first approach is useful to identify the key issues in the micro-level such as environmental substances, but the second approach is better to identify key issues in the macro-level such as human health, resources. Thus, both approaches will be used in order not to overlook relevant key issues though the selected approach would depend on the purpose of the intended LCA study.

The use of both approaches can support decision makers to identify sustainable options by taking into consideration their specific data to evaluate the building materials.

5. References

1. **AboulNaga, M., and Amin, M.** (1996). Towards a healthy urban environment in hot-humid zones- information systems as an effective evaluation tool for urban conservation techniques. *In: Proceedings of 24th IAHS World Congress*; Ankara, Turkey.
2. **Kim, J. J. and Rigdon, B.** (1998). *Sustainable Architecture Module: Qualities, Use, and Examples of Sustainable Building Materials*. Sustainable Architecture Compendium, National Pollution Prevention Center, University of Michigan.
3. ISO (2000) ISO 14042: Environmental management-Life cycle assessment-Life cycle impact assessment. Geneva, CH: ISO
4. **Seo, S.** (2002). *Environmental Weightings: concepts, methods and applications*, Report 2001-006-B-4, CRC for Construction Innovation, CSIRO.
5. **Seo, S.** (2002). *Process modeling for concrete and reinforcing*, Report 2001-006-B-9, CRC for Construction Innovation, CSIRO.
6. **QCL** (1998) *Australian Standard for Portland and Blended Cements*, QCL Technical note No.13, 1998.
7. **Tucker, S. N., Ambrose, M. D., Johnston, D. R., Newton, P. W., Seo, S., and Jones, D. G.** (2003). LCADesign An integrated approach to automatic eco-efficiency assessment of commercial buildings. In Amor, R. (Ed.), *Construction IT Bridging thedistance*. Auckland, 23-25 April. (CIB Report Publication 284, pp. 403-412.) (University of Auckland Auckland). ISBN 0-908689-71-3.
8. **Goedkoop, M. and Spriensma, R.** (1999). *The Eco-Indicator 99. A damage oriented method for life cycle impact assessment*. PRé Consultants, Amersfoort. http://www.pre.nl