LCA Methodology

A Weighting Method for the Korean Eco-Indicator

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Abstract

A weighting factor proposed in this paper is a product of a reduction factor \( \left( \frac{N}{T_i} \right) \) and a relative significance factor \( f_i \). A politically determined critical impact \( \left( \frac{T}{f_i} \right) \) is assumed to cause a critical damage defined as a level of damage acceptable to a society. A graph showing the relationship between relative damage and normalized impact indicates that the weighting factor \( \left( \frac{NFF}{f_i} \right) \) is the slope of this graph. It shows further that the relative damage is the same as the weighted impact.

Keywords: Critical impact; damage; reduction factor; relative damage; relative significance factor; weighting

1 Background

In 1998, the Korean government launched a project that develops Korean Eco-Indicators for typical materials, processes and waste disposal methods. This project is similar to the Eco-Indicator 95 project in the Netherlands [1]. The Korean Eco-Indicator development requires a weighting method that allows aggregating impact from various impact categories into a single score.

Weighting is defined as an optional element of the Life Cycle Impact Assessment (LCIA) phase in which the data from the Life Cycle Inventory (LCI) analysis or the indicator results are ranked and possibly aggregated, and may include the use of subjective judgement and value choices [2]. In general, environmental impacts of a product system in LCA may be classified into three different types: characterized, normalized and weighted impact [3]. The first two types of the impact are associated per impact category and the last per product system.

A characterized impact \( (CI) \) is an impact calculated by multiplying \( \text{Load}_i \) by its equivalency factor, \( eqv_{i,j} \), for a given impact category \( i \), i.e.

\[
CI_{i,j} = \text{Load}_i \times eqv_{i,j}
\]

\[
CI_i = \sum_j \text{Load}_i \times eqv_{i,j}
\] (1)

A normalized impact \( (NI) \) is an impact calculated by dividing the characterized impact \( (CI) \) by a normalization reference \( (N) \) for a given impact category \( i \). [A normalization reference is the total characterized impact calculated on the basis of an inventory of all the society’s activities over a reference period of time [3]. Thus,

\[
NI_i = \frac{CI_i}{N_i}
\] (2)

A weighted impact \( (WI) \) is an impact calculated by multiplying the normalized impact by a weighting factor \( W_i \). That is:

\[
WI_i = NI_i \times W_i
\] (3)

Fundamental question resides in the selection of \( W_i \). There are three general approaches in selecting \( W_i \) values. They are the panel method, the monetization method and the distance-to-target method [4]. From these, the distance-to-target method has been used rather widely.

Typical examples would include the Eco-Indicator 95 [1], the Dutch and Swedish Environmental Theme method [5] and the Danish EDIP method [3]. The weighting method for the Korean Eco-Indicator is based on the concept of the Dutch Eco-Indicator 95 and the Danish EDIP method; thus, the weighting schemes used in those methods are the starting point for the development of a weighting method for the Korean Eco-Indicator. Each of these two methods adopted a weighting scheme based on the distance-to-target method.

2 Analysis of the Distance-to-Target Method

The distance to target method defines \( W_i \) as:

\[
W_i = \frac{N_i}{T_i}
\] (4)

where

\[
T_i = \text{Target reference of an impact category } i: \text{An impact where no discernable impact is observed in a given environment.}
\]
Frequently $N/T$ is termed as a reduction factor. Substituting $NI$ in equation (2) and $W_i$ in equation (4) into equation (3) gives:

$$WI_i = \frac{CI_i N_i}{T_i} = \frac{Cl_i}{T_i} \quad (5)$$

From equation (5), it is evident that the distance-to-target method is in fact not a weighting method. Dividing $CI_i$ by $T_i$ results in an expression which is another form of normalization [4]. The denominator has changed from a normalization reference ($N_i$) to a target reference ($T_i$). Thus, weighted impact in equation (5) is not a weighted impact but a normalized impact. The reason for using $N_i / T_i$ is because of difficulties in estimating $T_i$; while a reduction factor is relatively easy to obtain. Most of the time, $N_i / T_i$ is a politically determined reduction factor.

In addition to the problem described above, there is a fundamental problem in using $N_i / T_i$ as a weighting factor in calculating the weighted impact. By using $N_i / T_i$ as a weighting factor, we implicitly assume that each impact category is equally important. This is because $N_i / T_i$ only indicates the degree of seriousness of a given impact category. It does not indicate anything in terms of relative significance among different impact categories.

Let's take an example. A reduction factor for eutrophication, which is a local impact, indicates the distance between current impact ($N_i$) and target impact ($T_i$). The distance between these two values reflects the seriousness of that specific impact category, in this case eutrophication, in a given environmental condition, here, local environment. Thus, a reduction factor does not provide any indication as to the relative significance among different impact categories. This suggests that the distance-to-target method alone should not be used as a weighting method.

There are several specific problems in using $N_i / T_i$ as a weighting factor. One of the specific problems is that receiving environment affected by a given impact category is different from one impact category to another. For global impacts, the receiving environment is the global environment. For regional and local impacts, the receiving environments are regional and local environments, respectively. Furthermore, global impacts are considered more serious than regional and/or local impacts.

Other specific problems include the degree or rate of reversibility and scientific uncertainty of a given impact category. In general, reversible impacts are considered less serious than irreversible impacts. A reversible impact with a shorter recovery time is considered less serious than that with a longer recovery time. Those impacts with scientifically known consequences are considered less serious than those with scientifically uncertain consequences [6].

The above-mentioned viewpoints are called the precautionary principle. This principle has frequently been applied to determine the relative significance of impact categories in the panel method. Giving a weighing factor to each impact category is the same as comparing the relative significance among different impact categories. From these discussions, it is evident that the distance-to-target method is not a weighting method. This is because the method only deals with the degree of seriousness within a given impact category.

### 3 Method Development

Weighing between safeguard areas requires the selection of the types of safeguard area. This selection may be made based on the goal of today's human society. "Our Common Future" [7] may indicate that realization of a sustainable society would be the goal. If this were the case, the resource and ecosystem would be a good choice for the safeguard areas. These safeguard areas suffer damages resulting from activities such as resource consumption and environmental emissions of a product system.

It is quite subjective to judge whether resource or ecosystem is more important to the realization of a sustainable society. Giving equal weight to these two safeguard areas may be acceptable, although it may never be agreed, in light of the fact that both are essential components for a sustainable society. However, it is controversial as to the selection of safeguard areas. For example, whether health is a separate safeguard area or belongs to the ecosystem still needs to be resolved. Because of reasons cited above, no attempt was made to develop a weighting scheme between safeguard areas. Rather, an emphasis was given to resolving the weighting issue between impact categories within a given safeguard area.

A panel method such as the Delphi-like method has been used widely in giving a weighting factor to an impact category: however, it lacks a specific consideration of each impact category. In other words, the Delphi-like process did not consider the degree of seriousness of a given impact category as in the case of the distance-to-target method. Thus, a new approach is needed to give a weighting factor to each impact category.

The new approach proposed in this paper is to combine a reduction factor in the distance-to-target method and a relative significance factor based on the precautionary principle in giving a weighting factor to each impact category. The relative significance factor may be determined based on methods such as the Analytical Hierarchy Process [8] or Multiple Hierarchy Process [8]. These methods are subjective in nature because value judgement is involved; however, it is inevitable to exercise value judgement because the relative significance between impact categories in itself requires value judgement.

Thus, a proposed weighting factor is expressed in equation (6):