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A model for evaluating the environmental benefits of elementary school facilities

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ABSTRACT

In this study, a model that is capable of evaluating the environmental benefits of a new elementary school facility was developed. The model is composed of three steps: (i) retrieval of elementary school facilities having similar characteristics as the new elementary school facility using case-based reasoning; (ii) creation of energy consumption and material data for the benchmark elementary school facility using the retrieved similar elementary school facilities; and (iii) evaluation of the environmental benefits of the new elementary school facility by assessing and comparing the environmental impact of the new and created benchmark elementary school facility using life cycle assessment. The developed model can present the environmental benefits of a new elementary school facility in terms of monetary values using Environmental Priority Strategy 2000, a damage-oriented life cycle impact assessment method. The developed model can be used for the following: (i) as criteria for a green-building rating system; (ii) as criteria for setting the support plan and size, such as the government's incentives for promoting green-building projects; and (iii) as criteria for determining the feasibility of green building projects in key business sectors.

1. Introduction

According to the U.S. Energy Information Administration (EIA), buildings are key factors affecting energy consumption and global warming (EIA, 2011a,b). Famous politicians, celebrities, and journalists have continuously stressed the effects of buildings on environmental issues such as global warming and resource depletion (Robichaud and Anantatmula, 2011). Accordingly, many countries have exerted efforts to reduce the environmental impact of their buildings by diffusing environment-friendly buildings such as sustainable or green ones. South Korea has also been exerting efforts to reduce the environmental impact of its buildings by establishing the "*Framework Act on Low Carbon, Green Growth*" and the "*Act on the Promotion of Green Buildings*" (MOLEG, 2010; MLTM, 2012).

Generally, green buildings incur higher initial costs compared to conventional buildings, so many countries, including South Korea, promote government-led green-building projects using the green-building rating systems (Baldwin et al., 1998; USGBC, 1999) or incentive programs (Marmen and Clark, 2000; Office of Sustainability and Environment, 2013). Many key business sectors including developers, bankers, and appraisers, however, want to know the benefits of transforming new and existing buildings into green buildings (Ries et al., 2006). In particular, they want to see such benefits in monetary terms. The government also needs to come up with a clear set of criteria for granting appropriate financial incentives to new green buildings.

Therefore, a model for evaluating the environmental benefits of new buildings was developed in this study. By comparing the environmental impact of a new building with those of a benchmark building that has similar characteristics to the new building, the developed model can evaluate the environmental benefits of the new building. This study used case-based reasoning (CBR) and life cycle assessment (LCA) for developing the model.

CBR, one of the most popular data mining methods, allows retrieving similar cases from the database (Doğan et al., 2008). This method was used to determine the benchmark building for comparison with the new building. LCA, a representative method of assessing the environmental impact of products and systems during their life cycles (ISO, 2006), has been used to assess the potential environmental impact of a building (Asif et al., 2007; Kofoworola and Gheewala, 2008; Yan et al., 2010) or as a tool for analyzing the building's components in the building industry (Amick, 1999; Hong et al., 2012a; Iyer-Raniga and Wong, 2012; Li, 2006). Therefore, this study also used LCA to assess the environmental impact of a new and a benchmark building.

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The scope of the model developed in this study was set to elementary school facilities. According to the *2010 Educational Statistical Yearbook*, over 1600 educational facilities have been constructed per year since 2000 (MEST, 2010). Considering that much cost and effort are consistently being invested in the construction of elementary school facilities, it is very important to evaluate the environmental benefits of such facilities. Thus, this study aimed to develop a model for evaluating the environmental benefits of elementary school facilities.

2. Method

Fig. 1 shows the framework of the proposed model for evaluating the environmental benefits of a new elementary school facility: (i) using CBR, retrieve from the database the elementary school facilities with similar characteristics as the new elementary school facility to be evaluated; (ii) create the energy consumption and material data of the benchmark elementary school facility using those of the retrieved similar elementary school facilities; and (iii) assess the environmental impact of the new and the benchmark elementary school facility, and by comparing the results, determine the environmental benefits of the new elementary school facility. CBR was used to create the data of the benchmark elementary school facility, while LCA was used to assess the environmental impact of the elementary school facilities.

2.1. Case-based reasoning

As a method that retrieves similar cases from the stored database and determines the value predicted from such (Doğan et al., 2008), CBR can guarantee high reliability as it shows historical data at the same time, which are used to present the predicted value (Ji et al., 2010; Koo et al., 2010). Thus, many previous studies used CBR to estimate the construction cost or the required material quantity (Hong et al., 2012b,c,d; Koo et al., 2011).

The developed model in this study presents the environmental benefits of a new elementary school facility by comparing the environmental impact of the new and the benchmark elementary school facilities. CBR is used to create the benchmark elementary school facility for comparison with the new elementary school facility. The benchmark elementary school facility is created by considering only the facilities whose characteristics are similar to those of the new elementary school facility. By considering only the similar elementary school facilities rather than all elementary school facilities, more accurate environmental benefits of the new elementary school facility can be presented.

The data of the benchmark elementary school facility can be created as follows: (i) defining the attributes that explain elementary school facilities; (ii) developing a CBR model for retrieving the similar elementary school facilities based on the database on the existing elementary school facilities; (iii) creating the data of the benchmark elementary school facility by retrieving the similar facilities using CBR.

2.1.1. Defining the attributes

To retrieve similar elementary school facilities using CBR, the attributes that explain elementary school facilities should be defined. The environmental impact of a building for the duration of its life cycle is attributed to the energy consumed in the use and operation phase and the material used in the construction phase. Therefore, the energy consumption and material data of the elementary school facilities should be collected to assess the environmental impact of both a new facility and a benchmark elementary school facility. Thus, two databases for retrieving the energy consumption and materials data of the benchmark elementary school facilities were established separately. To establish the databases, the attributes of the energy consumption and the material data of the existing elementary school facilities were defined in this study, respectively.

First, the attributes for retrieving energy consumption data were defined. Hong et al. (2012b) defined the number of students, number of teachers, number of people, number of classes, number of people per class, number of stories, building area, total floor area, region, client type, and structure type as the factors affecting the energy consumption of an elementary school facility. Based on the elementary school facilities data collected, correlation and variance analyses were conducted on 11 attributes and energy consumption data. The results showed that all the attributes were meaningful. Therefore, the 11 building characteristics were used as the attributes for retrieving similar elementary school facilities for energy consumption data in the developed model.

Second, the attributes for retrieving construction material data were defined, but since it is impossible to establish databases for

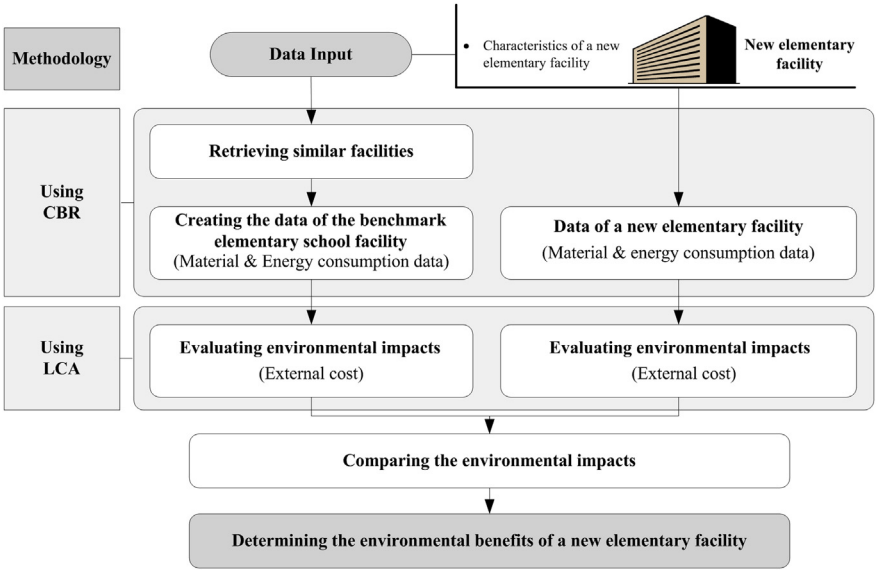

Fig. 1. Framework of the proposed model for evaluating the environmental benefits of a new elementary facility.