Journal of Cleaner Production 193 (2018) 661–671

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Developing indicators for sustainable campuses in Taiwan using fuzzy Delphi method and analytic hierarchy process

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ARTICLE INFO

Article history:
Received 7 September 2017
Received in revised form
9 May 2018
Accepted 10 May 2018

Keywords:
Eco-schools
Sustainable development
Sustainable campus
Carbon dioxide emission
Energy consumption
School buildings

ABSTRACT

Education is an essential national policy, and developing sustainable campuses has been a goal of education environment policies. This study used a literature review to establish 55 initial for assessing a sustainable campus and performed inductive analyses, after which 28 final indicators were screened out by academic researchers and campus users using the fuzzy Delphi method. The indicators were divided into three major dimensions—policy management, buildings and equipment, and educational activities—which were further subdivided into nine subdimensions; subsequently, a hierarchical analysis expert questionnaire was used for consistency testing. The differences in weights between dimensions and indicators in addition to between expert groups (with distinct backgrounds) were analysed, and sustainable development strategies and priority orders were then inferred. Among the three dimensions, "Buildings and equipment" was recommended for the most immediate attention. The other two dimensions, "Policy Management" and "Educational Activities," were weighted differently by the two groups of experts. This study determined that resource recycling and energy efficiency generate benefits and that conserving energy and reducing carbon footprint are the core of sustainable school grounds.

1. Introduction

Taiwan is a resource-poor island, importing up to 98% of its energy (Bureau of Energy (BOE) of Taiwan (2016). In addition, its energy utilization efficiency is low. With an average of 10.68 tonnes per person, it is ranked 19th in the world in terms of CO_2 emissions, despite the global average emission being only 4.52 tonnes per person; additionally, it is ranked 45th in the world regarding its carbon emission concentration of 0.27 kg CO_2/US$, where the global average is 0.32 kg CO_2/US$ (IEA, 2016). In other words, Taiwan's average CO_2 emissions per capita is 2.36 times the global average, yet its economic output is merely 0.84 times the global average, demonstrating Taiwan's unsatisfactory energy efficiency. Energy saving and sustainable development topics have thus received broad attention in Taiwan in recent years. Taiwan's Ministry of Education began implementing a sustainable campus policy in 2004, which stated that, starting from 2009, new campus buildings must meet the design specifications for green buildings. The green building assessment system contains myriad tools, which can be applied to many building categories. However, it applies only to buildings. Numerous factors affect school grounds aside from their buildings. To date, their sustainable campus policy has been a crucial policy for and is highlighted annually by the Ministry of Education. However, varied opinions have been voiced on how campus sustainability should be assessed, including which indicators or assessment items should be adopted; thus, a broader and more in-depth discussion is required to achieve a consensus.

School and other education buildings have been the focus of building energy consumption in various countries. For example, school buildings account for 13% of all building energy consumption in the United States, where they consume the fourth highest percentage of power, preceded only by retail (32%), offices (18%), and hotels and restaurants (14%) (Pérez-Lombard et al., 2008). In terms of total electricity consumption in the United States, school

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https://doi.org/10.1016/j.jclepro.2018.05.082
0959-6526/

buildings account for 10.8% of all building electricity consumption and are ranked third in the sector, preceded only by offices (20.4%) and retails and malls (20.4%) (Energy Information Administration, 2012). School buildings are also ranked third in terms of category of building energy consumption in the United Kingdom, behind commercial and office buildings (Department of Energy and Climate Change, 2017). Relevant data on Taiwan is lacking, but according to the energy consumption data declared by high voltage customers in nonproductive industries as disclosed by the BOE, school building energy consumption accounts for 14.4% of all high voltage energy consumption, second only to that of hospital buildings (14.9%) (BOE of Taiwan, 2017), indicating the large amount of energy consumed by school buildings. Wang (2016) disclosed that in terms of energy consumption in Taiwan's schools, electricity accounts for 93% of the total energy consumption, implying that the topic of energy must be at the core of sustainable campus development.

2. Literature review

Energy has always been at the core of discussions on sustainable development; thus, saving energy has been regarded the principal subject in studies that assess sustainable campuses (Faghihi et al., 2015; Hasapis et al., 2017; Zhou et al., 2013). Most energy-themed research has used energy monitoring approaches to provide the objects of investigation (usually universities) with various valuable assessment results and recommendations (Deshko and Shevchenko, 2013; Kolokotsa et al., 2016; Yoshida et al., 2017). In addition, numerous studies have been based on energy-induced carbon emission, wherein the corresponding strategies adopted by sustainable campuses were weighted based on the amount of carbon emissions they resulted in (Li et al., 2015; Liu et al., 2017; Zen et al., 2017), providing many carbon reduction strategies based on local school features, which can be used as a reference for areas or schools with similar climatic conditions. Moreover, because of their high energy consumption, universities are encouraged by government units to employ renewable energy, and thus numerous sustainable campus studies have focused on renewable energy usage (Kumar et al., 2017; Park and Kwon, 2016; Talavera, 2014).

The literature thus demonstrates that a suitable energy strategy is at the core of a sustainable school; however, implementing sustainable school ground strategies still requires various additional strategies (Berzosa et al., 2017; Gomez et al., 2017). Numerous studies have been conducted using surveys of user opinion to yield concrete and feasible strategies (Arroyo, 2017; Dlouhá et al., 2018; León-Fernández et al., 2017). Some studies have investigated survey-distributed samples (Jorge et al., 2015; Li et al., 2015) and some have discussed the relationship between sustainability and regional planning (Grindsted, 2018). Other studies have consulted on sustainable school ground strategies or energy-related topics by using analytic hierarchy process (AHP) expert questionnaires (Heo et al., 2010; Kumar et al., 2017), gradually obtaining expert consensus through hierarchical analysis, through the Delphi method (Disterheft et al., 2015), or by focusing on methodological tools, such as fuzzy AHP and fuzzy Delphi method (FDM) (Deb et al., 2017; Suganthi et al., 2015).

Table 1 lists the methods used to assess eco-schools worldwide; some assessment indicators are committed to evaluating technology (CASBEE of Japan), but the majority of indicators assess the overall process of complete implementation (UNEP; Australian Government; Eco-Schools USA; MEP of China; MECSST of Japan). Taiwan has developed EEWH assessment tool for evaluating green buildings, however it is not design for campus. Energy efficiency (carbon emission reduction) is undoubtedly one of the core indicators and is affected by school building design and the air conditioning or other ancillary equipment used within buildings. Environmental-protection-related topics, as well as others such as those on water resources, waste reduction, and indoor environment, are also common key items. To facilitate the implementation of policies, forming eco committees in schools, formulating and implementing plans, holding regular meetings and checking progress, calling for community integration, and even incorporating eco-school topics into curricula can contribute to sustainable campus policy implementation. Each country differs in their assessment indicators or implementation strategies because of their distinct national conditions, hence the necessity for adapting the assessment method according to local conditions.

3. Methodology

Taiwan has 2630 elementary schools, 735 junior high schools, 506 senior high schools, and 158 universities, with a total of 3,946,639 students (Department of statistics, 2017). A more sustainable and comfortable campus environment must be provided for education. To define the indicators of a sustainable campus, it is necessary to gather scholars and experts and determine consensus through discussion. To perform the literature review, this study first established an expert committee, including authors, two experts, and two scholars, divided sustainable school ground indicators into three dimensions: policy management, buildings and equipment, and educational activities. After the committee was formed, Taiwan's current green building assessment indicators were referenced to formulate three major dimensions comprising 55 original indicators. The indicators were developed over 5 years (Taiwan Architecture and Building Center, 2012) and were designed for almost every possible building design and use. However, some are unsuitable for school grounds. They must be modified and classified, and through weighting hierarchical analysis, the appropriate ones can be determined. These assessment indicators applicable to sustainable campuses in Taiwan were then established through FDM, and the relative weight of each indicator was finally determined through the AHP.

3.1. Questionnaire respondents

This study invited 32 experts and scholars to complete the FDM questionnaire (Table 2); additional 16 experts and scholars were invited to complete the AHP questionnaire (Table 3). The scholars and experts include two groups: the first group includes managers who engage in sustainable school grounds affairs, including head teachers, assistant heads of general affairs, heads of general affairs, and heads of environmental education; the second group are university professors and researchers who specialise in related fields, including environmental engineering, environmental education, and green buildings. Additionally, the scholars come from both town centre schools and suburban schools, and school locations are evenly distributed around Taiwan. Compiling the indicators was a multicriteria decision-making process that required the inductive analysis of expert and scholar opinions. The questionnaire was designed for use by experts, who must determine what measures or policies are necessary and how they should be implemented on school grounds. The students were not consulted. The questionnaire respondents were individuals who were responsible for operations related to sustainable campuses or were academic researchers in that particular field. In Taiwan, the director of general affairs of elementary or secondary schools is generally in charge of planning school buildings and supervising their construction, as well as maintaining campus buildings and supervising