Postprint of the Green Campus Construction Evaluation System

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Abstract

Campuses constitute an important component of society and serve as crucial cradles and bases for cultivating talent and providing developmental support for the nation. By leveraging campuses as drivers of social development, resource utilization efficiency can be enhanced, and issues such as energy shortages and environmental pollution can be alleviated, thereby promoting sustainable social development. As part of public infrastructure, campuses are characterized by diverse facilities, dense populations, and high energy and resource consumption, resulting in substantial pollution and energy usage. Green campus construction has garnered widespread attention. This paper completes the overall framework design and construction of a green campus evaluation system by comparing domestic and international green evaluation systems and integrating the "Green Campus Evaluation Standard" with a focus on scoring criteria applicable to computer technology platforms. The functions of various subsystems within the green campus evaluation system are discussed, and the application of this system will contribute to promoting green campus construction.

Full Text

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Green Campus Construction Evaluation System

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Abstract: Campuses are essential components of society and crucial cradles for nurturing talent, providing foundational support for national development. By

leveraging campuses as drivers of social progress, we can enhance resource utilization efficiency, alleviate energy shortages and environmental pollution, and thereby foster sustainable societal development. As part of public infrastructure, campuses are characterized by diverse facilities, dense populations, and substantial energy and resource consumption, generating considerable pollution and energy demands. Consequently, green campus construction has attracted widespread attention. This paper systematically examines green campus evaluation indices and systems through comparative analysis of domestic and international frameworks. Based on the *Green Campus Evaluation Standard*, we propose an evaluation index system applicable to computer-based platforms and complete the overall framework design and construction of a green campus evaluation system, discussing the functions of its various subsystems.

Keywords: Green; Campus; Evaluation; System

1. Overview of Green Campus Construction

According to the 2014 National Education Development Statistical Bulletin, China had 514,000 schools of all types and levels in 2014, with 260 million students enrolled and total school building floor area reaching 2.99 billion square meters, averaging approximately 11.5 m^2 per capita. With high population density and diverse facilities, campuses represent major energy consumers in society. National Energy Administration data show that total electricity consumption reached 5,523.3 billion kWh in 2014, a 3.8% year-on-year increase. University per capita energy consumption in China significantly exceeds the national average for residents, with preliminary statistics indicating that university students' per capita energy and water consumption are four times and twice the national averages, respectively. This substantial resource consumption has drawn increasing attention to campus energy conservation, emission reduction, and ecological construction, revealing tremendous potential for energy savings. Campuses can also provide standards and practical experience for low-carbon initiatives.

Internationally, the UK—pioneer of the low-carbon economy and the first nation to formulate sustainable development plans—has accumulated extensive successful experience in green campus development. In 2005, led by Nottingham Trent University (NTU) and supported by the Higher Education Funding Council for England (HEFCE), the UK developed the EcoCampus evaluation standard and award system for higher and further education institutions. EcoCampus provides a modular, phased approach to Environmental Management System (EMS) development based on BS8555 and ISO14001 standards, recognizing institutions with outstanding environmental sustainability performance while offering technical support to resource-constrained or inexperienced organizations.

In China, Tsinghua University first proposed the concept of creating a "Green University" in 1997, after which other institutions introduced ecological concepts

into campus construction. For example, Guangzhou University implemented ecological priority principles in planning and environmental design, conducting vegetation surveys and green space system planning to maximize natural ecological protection. However, green campus concepts remain insufficiently applied in Chinese campuses, with understanding often limited to greening and beautification. This superficial approach, combined with low management levels, severely constrains in-depth and sustained green campus development. A comprehensive, systematic, and sustainable construction standard is lacking to guide and regulate the development of environmentally friendly, energy-efficient, and comfortable green campuses from planning and design through operation. Regarding evaluation index systems, mature frameworks exist in the United States, United Kingdom, Australia, and other countries (see Table 1).

Domestic scholars continuously draw on international advanced experience to research "green campuses." Zang Shuliang et al. conceptualize green campuses as complete artificial green ecosystems formed under scientific ecological theory guidance. Zhang Fang understands green campuses as ecologically virtuous cyclic university environments constructed under sustainable development principles. Chen Yuetang defines green campuses as campuses with distinctive culture and connotation formed through rational planning, design, and construction under ecological principles. Jiang Wenjie et al. view green campuses as artificial ecosystems planned, constructed, managed, and operated using ecological principles to achieve efficient energy utilization. Although definitions vary, all embody sustainable development principles.

Based on these principles, green campuses constitute an essential component of ecological gardens and eco-city construction, representing an inevitable trend for 21st-century university campus environmental development. Green plant configuration design and artificial plant community construction not only determine the effective functioning of campus green ecological functions but also serve as crucial pathways and means for building green campuses. Since anthropologist Julian Steward proposed the concept of "ecological culture" in his 1953 book *Evolution and Process*, increasing scholars have focused on ecological planning and application, introducing "ecology" into campus planning and construction. Recent years have witnessed continuous attempts at "ecological campuses" internationally, such as the University of Nottingham' s Jubilee Campus, which transformed a derelict bicycle factory into a vibrant green campus while linking green campus construction to lean practices, and North Carolina State University' s new campus, which designed a drainage system considering downstream water impacts while protecting important local tree species and natural areas, increasing native plant communities to restore local biodiversity.

Green campus and ecological campus represent distinct concepts: ecological campuses apply ecological principles to construct artificial ecosystems, while green campuses typically refer to schools that fully embody environmental protection concepts in campus construction, management, and daily behavior of campus personnel. Consequently, ecological campus evaluation and green cam-

pus evaluation emphasize different aspects—ecological campuses focus on evaluating overall environmental energy input and output and systemic ecological construction, while green campuses emphasize the manifestation and implementation of green concepts in campus construction and operation. Both, however, share the core principle of sustainable development.

2. Green Construction Evaluation Index System

Different scholars hold varying perspectives on constructing green campus evaluation index systems. Xu Liyan proposed a green Olympics evaluation system with resource consumption, environmental load, indoor environmental quality, and outdoor physical environmental quality as indicators after analyzing popular color performance of buildings domestically and internationally. Chen Yuetang et al. constructed an evaluation index framework for Hunan Agricultural University covering structure, function, and coordination. Using Northeastern University as a case study, researchers proposed analyzing campus energy consumption through ecological footprint methodology, including energy, food waste treatment, and other aspects. Kim et al. used case studies to illustrate green campus applications and implementation methods while constructing corresponding management organizations. Jiang Xinpei et al. combined Analytic Hierarchy Process and fuzzy comprehensive evaluation methods with expert analysis to determine index weights. In the UK, a team led by Dr. Peter Redfern at Nottingham Trent University developed the EcoCampus system based on obstacles to green campus construction, such as lack of awareness of ISO and EMAS standards, insufficient staff knowledge and capacity, lack of implementation tools, time consumption, process complexity, increased documentation, unrecognized achievements, and lack of multi-level support and incentives. The system addresses these factors through targeted solutions, enabling institutions to progressively meet international standards from foundational levels, thereby building positive images, enhancing competitive advantages, achieving cost savings in key areas, optimizing energy use, realizing sustainable development, addressing climate change challenges, improving management levels, better controlling risks, and adapting to international laws and regulations. The system covers pollution, waste, energy, water, transportation, carbon emissions, legal compliance, and procurement, guiding assessment and awards through four phases: Planning (Bronze), Implementation (Silver), Operation (Gold), and Review and Correction (Platinum).

This paper develops a green campus evaluation system index framework applicable to computer-based assessment by referencing China's *Green Campus Evaluation Standard* and mature domestic and international index systems. Computer-based evaluation systems can effectively handle the systematic complexity arising from interacting requirements and high utilization rates. Following systematic and concise scientific principles, we derived computer-applicable indices from the *Green Campus Evaluation Standard* (CSUS/GBC04-2013). We categorized land conservation and outdoor environment as "ecological environment"

; energy conservation and energy utilization, water conservation and water resource utilization, and material conservation and material resource utilization as "resource utilization" ; indoor environmental quality as "environmental quality" ; while retaining construction management and operation management unchanged; and adding innovation items referencing Hong Kong' s HKBEAM. The overall evaluation indices are shown in Figure 1 [Figure 1: see original paper]. Evaluation references are divided into "design evaluation" and "operation evaluation." Indices comprise prerequisite items and scoring items, with prerequisite items evaluated as "satisfied" or "not satisfied" and scoring items as point-based.

The scoring rate for each of the five indicator categories (Q1, Q2, Q3, Q4, Q5) should be calculated as the ratio of actual scores obtained to theoretically obtainable total scores. Q6 represents innovation item scores. Considering relative importance differences among indicator categories, weights are introduced in total score calculation. The total score rate should be the weighted sum of the five indicator scoring rates plus the additional scoring rate for bonus items (Q6): $\Sigma Q = W1Q1 + W2Q2 + W3Q3 + W4Q4 + W5Q5 + Q6$. Indicator weights reference the *Green Campus Evaluation Standard*. When total green building scores reach 50, 60, and 80 points respectively, green building ratings correspond to one-star, two-star, and three-star levels.

3. Design and Development of Green Campus Construction Evaluation System

3.1 Design Purpose

Green campus evaluation can guide public attention toward environmental sustainability while campuses disseminate environmental concepts externally, enabling more people to continuously focus on energy conservation and emission reduction. By establishing a small-scale ecological system on campus and educating students in ecological concepts, sustainable development principles can be promoted throughout society. The evaluation index system reveals that assessment work is a highly comprehensive systematic endeavor requiring not only evaluation processes but also generating substantial valuable data. Therefore, designing and developing a green campus construction evaluation system is essential.

3.2 Function Design

Green campus construction evaluation is divided into "design evaluation" and "operation evaluation" —two independent assessment phases. The green campus construction evaluation system implements overall green construction system assessment for campuses, comprising three main components: basic database, project scoring and rating, and results publication and analysis. The overall system framework is shown in Figure 2 [Figure 2: see original paper].

3.3 Architecture Design

The system framework forms the foundation for green campus evaluation system implementation. Based on functional requirements and overall planning for implementation and operation, the architecture follows software architecture layering principles for overall planning, as shown in Figure 3 [Figure 3: see original paper].

(1) User Interface Layer
This layer primarily handles user interaction, facilitating human-computer interaction. Evaluation objects are responsible for inputting data materials, scoring experts review and score submitted materials, and system maintenance personnel possess full system permissions for daily maintenance and data processing. In this system, the layer is implemented through Web Form interfaces.

(2) Data Access Layer
According to instructions from the business logic layer, this layer communicates with corresponding databases and processes data feedback to the business logic layer. It provides unified data access interfaces, completely encapsulating databases within the platform. The data access layer directly manages database connections and communication, rendering databases transparent to other layers, minimizing security risks while maximizing data processing efficiency.

(3) Database
This primarily comprises the evaluation index system database formed through index input, expert information database, and project information database.

3.4 Subsystem Functions

3.4.1 Basic Database

The basic database includes evaluation index maintenance, scoring expert database, evaluation standards, and document downloads. Evaluation index input comprises project basic information, ecological environment, resource utilization, environmental quality, operation management, education promotion, and innovation items. The evaluation indices are divided into qualitative and quantitative indicators. Qualitative indicators require no specific algorithms for data analysis and are typically determined through expert assessment of indices or design drawings and textual descriptions. Quantitative indicators require professional algorithms for analysis or software extraction and analysis of specific performance values for campus buildings, which are then scored according to evaluation criteria.

The scoring expert database inputs experts' basic information and reviews historical scoring records, providing reference for project evaluation. Evaluation standards and other document downloads primarily include the *Green Campus Evaluation Standard* series documents. The common materials download module serves as an auxiliary module, providing users with resources and standard documents to support expert scoring. This information collects previous green

campus evaluation research cases and results and relevant standards, which are classified and organized into a downloadable module. When needed, experts can access this module, select required cases or standards from the list, and download them for reference during scoring. This module provides additional reference information, facilitates scoring work, and significantly improves efficiency.

3.4.2 Project Scoring and Rating

This module' s primary function is to complete various source documents and evaluation data input and manage information. Based on actual project conditions, data entry personnel input project data into the scoring system, after which the process advances to the expert scoring phase. Various system information undergoes unified management and processing to ensure accuracy, uniqueness, and security. All project scoring standards follow the *Green Campus Evaluation Standard* (CSUS/GBC04-2013).

For modules requiring on-site expert evaluation, relevant scoring standard explanations can be accessed anytime from the system. Based on evaluation standard document period information, team members can select documents for review. After reviewing project materials, experts select evaluation results in a scoring table displayed in the system—for example, "satisfied" or "not satisfied" for prerequisite items and specific scores for scoring items.

Scoring result processing is a critical system component that aggregates various indicator results to determine campus green ratings. After scoring, scoring tables are submitted to the server, and the system aggregates scores according to established evaluation indices to calculate a final total score. During system design, evaluation indices are reasonably configured to facilitate data processing and result aggregation, which is crucial for obtaining results.

3.4.3 Results Application and Publication

This module allows querying historical data by region and city, displaying project rating levels. Data analysis and comparison can reveal regional differences in scoring, and direct comparison between two projects is also possible. Analysis result reports can be downloaded.

3.5 Case Demonstration

The login interface is shown in Figure 4 [Figure 4: see original paper]. Users log into the system with accounts and passwords assigned according to different permission levels, where system administrators possess full permissions.

Under Basic Database—Expert Database, experts input their basic information to ensure scientific rigor and seriousness of evaluation work, including name, gender, ID number, workplace, and professional title, as shown in Figure 6 [Figure 6: see original paper].

Under Project Scoring and Rating—Project Basic Information, project basic information is input for subsequent review and modification. The project is the

evaluation object, and its basic information forms the most fundamental data for system establishment, as shown in Figure 7 [Figure 7: see original paper].

After basic information is input, evaluation object data is entered according to the evaluation index system, as shown in Figure 8 [Figure 8: see original paper]. Based on several indicators from the planning and ecological sections of the evaluation index system, data is entered according to the evaluation object' s actual conditions, with functions for data deletion, modification, and review.

After project data input, experts enter the scoring interface to evaluate projects. According to scoring rules, experts review project data and assign scores, as shown in Figure 9 [Figure 9: see original paper] and Figure 10 [Figure 10: see original paper].

After expert scoring, each sub-item score is aggregated into a total score record table with a rating level, as shown in Figure 11 [Figure 11: see original paper].

After total score calculation, the Results Publication and Application interface displays scoring results. Clicking Wuhan on the map shows all scored projects in the Wuhan area on the right side, with results viewable and a pie chart displaying regional rating distributions, as shown in Figure 12 [Figure 12: see original paper].

Green campus evaluation can enhance overall environmental awareness, promote sustainable development of campus ecological systems, and leverage campuses' educational and leading roles in society to advance sustainable development throughout society. Developing and implementing a green campus construction evaluation system is an essential tool for ensuring efficient, scientific, and orderly evaluation work.

However, China' s green environmental work started late with insufficient promotion, and public environmental awareness remains weak. The campus green evaluation system is not yet perfect, and evaluation process management systems lack uniformity. China still has considerable room for improvement in campus green evaluation management systems and methodologies.

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Note: Figure translations are in progress. See original paper for figures.