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Appraisal Index System and Weights Determination for Green Campus

Bailu Ma[1, a],Xiaoping Feng[*2,b], Xiaoxia Lu[3,c], Chunping Wang[4, d],Hui Guo[5, e],Yilin Ding[6, f]

School of Environment and Civil Engineering, Jiangnan University, 1800 Lihu Avenue, Wuxi, China

[a]mabailu@foxmail.com, [b]fxp_99@126.com

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Abstract: Positioned on sustainable development philosophy, aiming to build a concise and systematic appraisal index system for green campus, the paper builds the index system and hierarchy structure model from perspectives of planning and ecology, energy and resources, environment and health, operation and management, education and promotion and etc. It adopts Analytic Hierarchy Process to analyze each factors' weights in the appraisal system thus providing a measurable analytic method for the appraisal of green campus deployment.

Introduction

Green campus was first mentioned in 1996 <The Action Outline of National Environmental promotion and education>, it put stress on placing environmental protection sense and actions into schools' overall management, education, teaching & learning and construction activities, and guiding teachers and students to pay attention to environment issues. Facing the pressing needs of talents and scientific technologies in the deployment process of sustainable development strategies as well as the realistic needs of higher education's sustained development, colleges should play critical roles in knowledge innovation, sustained development and environmental education. [1] In order to facilitate green campus development, a complete set of appraisal index system is needed in China for evaluation and guidance. The appraisal index system is supposed to embody special characteristics of education industry, to reflect the injected various resources and the relationship between different aspects, layers, forms and effects in the construction process. The green campus appraisal should apply a method that combines qualitative and quantitative indexes, adopts relatively unified criterion and suitable weights so as to make the quantitative calculation easy and meanwhile reflect various indexes' status and functions thus improving the appraisal's precision and its conclusion's objectiveness.

Establishing appraisal index system for green buildings

Basic principles of building index system

Scientific principle

Scientific nature is an important principle of building green campus's appraisal system, the appraisal indexes should be reached by theoretical knowledge applied analysis and from an objective angle. Firstly, pay attention to combining the theories and realities, define appraisal indexes' concepts as well as extension, avoid overlaps of indexes. Next, appraisal indexes' concepts must be clear and specific with scientific significance so as to ensure the appraisal's scientific nature and reliability, thus enabling the system to have universal applicability.

1. Systematic principle

Green campus appraisal index system is an organic whole formed by many complementary indexes and according to defined hierarchy structure. When design the index system, those that can comprehensively represent green campus construction and development aspects should be selected. In the hierarchy structure, every appraisal index represents the affiliation of each hierarchy, thus enabling horizontal and vertical irritation analysis of the indexes in the system, the indexes should be mutually independent and interconnected.

2. Operational principle

The operational principle requires finalized index system can be applied and executed very well. The key purpose of operability is to guide and standardize practices, it is a concrete deployment and implementation of theory construction. The requirements are when selecting appraisal indexes, pay attention to proportional relationship of subjective and objective indexes so it is easy to gather and collect indexes. Considerations should also be given to the appraisal indexes' sensitivity and reliability, hence selected indexes can precisely make evaluations on colleges.

3. Representative principle

Representative principle requires the selected indexes to highlight the subject's features during the evaluation process for green campus. Based on the theories of sustainable development, environmental ecology and economic applicability, to select representative indexes that can lead the construction of colleges' green campus.

Hierarchy structure of the appraisal index system for green campus

Hierarchy structure of the appraisal index system refers to affiliation between various indexes. Firstly, define the research object's target hierarchy, then set up several specific sub targets under the target hierarchy (i.e. intermediate hierarchy), the sub targets can be split into more concrete indexes, thus forming up an organic hierarchy structure for green campus and a system in which the indexes' relationship is clear.

Table 1: index system for green campus

Target hierarchy A	Rule hierarchy B_1	Rule hierarchy B_2	Scheme hierarchy
Evaluation Index System for Green Campus	Planning and Ecology	Land saving and Greening	Land Utilization
			Land for Greening
		Safety Planning	Urgent Evacuation System
			Setting of Guide Sign
		Traffic Planning	Setting of Parking Lot
			Public Traffic Networks
	Energy and Resources	Energy Consumption	Students' Average Energy consumption
			Students' Average Water consumption
		Energy Efficiency Optimization	Water Saving of Equipment
			Energy Saving of Equipment
		Non-traditional Resources Utilization	Recycle of Renewable Energy
			Recycle of Rainwater
			Middle-water System
	Environment and Health	Environmental Comfort Level	Acoustic Environment
			Thermal and Humid Environment
		Outdoor Environment	Surface Water Environment
			Green Environment
			Outdoor Wind Environment
		Health of Teachers and Students	Heath Education
			Health-care Equipment
			Public Health
	Operation and Management	Technical Management	Equipment Management
			Intellectualized System
		Environmental Management	Greening Maintenance
			Refuse Disposal
			Pollutant Emission
	Education and Promotion	Publicity and Promotion	Propaganda
			Course Setting
		Achievements in Scientific Research	Technology Research and Development
			Award and Praise

1. Target hierarchy

Target hierarchy is an overall evaluation of green campus: the green campus's general environmental protection, energy saving and sustained development status.

2. Rule hierarchy

Rules hierarchy is a summary of affecting factors on green campus including planning and ecology, energy and resources, environment and health, operation and management, education and promotion and the like affecting factors.

3. Scheme hierarchy

Scheme hierarchy stays at the bottom of the hierarchy structure, it is a refinement of its above layer called intermediate hierarchy and is a more specific expression of affecting factors on green campus. Constant refinement enables every index to be measurable, can reflect overall status more detailly and comprehensively.

Analysis of the rule hierarchy

1. Planning and ecology

The index is used to evaluate the overall planning and ecological environment of campus. Campus planning is a determinant factor to campus' future plasticity and overall style, including land saving and greening, safety planning, traffic planning and filed construction.

2. Energy and Resources

The index of energy and resources is applied to assess campus' overall effect of energy saving. In respect to utilization of energy and resources, institutions of higher learning are supposed to keep in line with the principle of sustainable development and serve as an example to influence their surroundings in the aspect of energy saving and utilization of sustainable resources.

3. Environment and health

The index is adopted to evaluate the overall environment of campus. Campus environment will greatly impact the comfort of the major groups, teachers and students. Favorable campus environment is able to provide both teachers and students with pleasant feelings and has positive effects on their working and learning.

4. Operation and management

As a whole, campus needs to be equipped with a complete operation and management system, which is roughly divided into system management, technical management and environment and used to observe operation and management effect and whether management system is complete.

5. Education and promotion

During constructing green campus, institutions of higher learning should get the utmost out of its major functions and features, formulate related regulations and policies, implement education and promotion, research and popularize relevant results in scientific research so as to push forward nationwide construction of green campus.

Basic theory of Analytic Hierarchy Process

Analytic Hierarchy Process short named as AHP is about decomposing decisions invariably associated factors into targets, rules and schemes, then make qualitative and quantitative analysis for decision making. The specific process is building judgement matrix for every identified hierarchy, do consistency inspection and get the feature vector, finally define prioritized weighting of every subordinate layers toward their upper layers, i.e. the sum up of all subordinate layers weighting equals to the upper layer's weighting. After summarizing all layers, final weight of every scheme for the overall target can be determined, the one with highest weight is the best scheme.

Analytic Hierarchy Process is a decision-making method with multiple principles that are easy, agile and practical and able to do quantitative analysis on qualitative problems. [3]Its strength is that it views the entire system as a whole without neglecting any factor's impact, and the setting of every weight can eventually impact the results in a direct or indirect way, and the impact degree of every factor in every hierarchy is quantitative.

Hierarchy judgement matrix

Every factor's weight reflects the important degree of it in the green campus appraisal system, generally 1~9 scaling method is applied. Assume in a certain hierarchy, there's n factors, X={x1,x2,…,xn}，conduct paired comparison of factors and form the judgement matrix.
Target hierarchy A 's judgement matrix toward rule hierarchy B

A	B_1	B_2	B_3	B_4	B_5
B_1	a_{11}	a_{12}	a_{13}	a_{14}	a_{15}
B_2	a_{21}	a_{22}	a_{23}	a_{24}	a_{25}
B_3	a_{31}	a_{32}	a_{33}	a_{34}	a_{35}
B_4	a_{41}	a_{42}	a_{43}	a_{44}	a_{45}
B_5	a_{51}	a_{52}	a_{53}	a_{54}	a_{55}

Table 2: Importance levels of each index

Scores	Meanings
1	Means comparing two factors, they are equally important
3	Means comparing two factors, the former one is slightly more important than the later one.
5	Means comparing two factors, the former one is moderately more important than the later one.
7	Means comparing two factors, the former one is much more important than the later one.
9	Means comparing with two factors, the former one is absolutely more important than the later one.
2,4,6,8 means the intermediate value of aforementioned judgement.	

Consistency Inspection

1. Single ordering and consistency inspection
Because the importance degree's value of every index is defined by experts, the judgment matrix has certain subjective nature, therefore need to do consistency inspection on the matrix i.e. to calculate the deviation index C.I.:

$$C.I. = \frac{l_{\max} - n}{n-1}$$

According to different orders in the judgment matrix to reach average random consistency index R. I.

1	2	3	4	5	6	7	8	9
0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.14	1.45

Then random consistency index C. R.:

$$C.R. = \frac{C.I.}{R.I.}$$

When CR<0.1, the consistency of the judgment matrix is considered acceptable, otherwise need to revise the matrix.
2. Hierarchy overall ordering and consistency inspection

$$CR = \frac{a_1 CI_1 + a_2 CI_2 + \mathbf{L} + a_m CI_m}{a_1 RI_1 + a_2 RI_2 + \mathbf{L} + a_m RI_m}$$

Calculate the bottom toward top hierarchy's overall ordering vector, inspect CR<0.1 by using overall ordering consistency ratio C.R.

If it gets passed, then make decisions according to the results indicated by overall ordering vector, otherwise need to reconsider the model or rebuild those matrixes to ensure C.R is bigger in paired comparison.

Index system's weights analysis

Weighted analysis method

Post-evaluation system for green campus, a multi-level and multi-factor evaluation system, not only involves energy saving and environmental protection of equipment inside campus, but reflects the main users' satisfaction with the overall operation of green campus. Therefore, to evaluate green campus is a comparatively blurry process difficult to be quantified accurately. In the determination of the weight, there are usually two categories—subjective empowerment evaluation method and objective empowerment evaluation method.

Compared with the objective empowerment evaluation method, the subjective empowerment evaluation method is more inclined to the experts through the experience to measure the relative importance of each index, to a certain extent and can reflect the needs of users. So the paper adopts the analytic hierarchy process in subject weighting evaluation method to determine weight. In addition, in order to improve accuracy of calculation, the case applies analytic hierarchy process software, YAAHP, as a tool to calculate the weight and gains the weight of all levels of indexes as below.

Before undertaking analytic hierarchy process, in order to ensure every index's importance level is relatively reasonable, we released questionnaires to experts, after statistics we got every index's importance degree values, after paired comparison we were able to build judgment matrix.

AHP defines index's weighting

Take outdoor environment for example, a judgment matrix is built on the basis of importance degree value derived from questionnaires.

A=

①Classify every column of the judgment matrix $M_i = \prod_1^j a_{ij}$, $\overline{W_i} = \sqrt[3]{M_i}$, wi= $M_i / \sum_1^3 \overline{W_i}$

M1=0.5，$\overline{W_1}$=0.7937，w1=0.25

M2=4，$\overline{W_2}$=1.5874，w2=0.5,；

M3=0.5，$\overline{W_3}$=0.7937，w3=0.25

By calculation, the outdoor environment's weight is 0.05, final weight is:w={0.0125,0.0250,0.0125}.

② λ_{max} calculation. λ_{max} W=AW . Put into data and can get the judgment matrix's λ_{max}=3.000。

③Inspect for consistency. λ_{max}=3.000， $CI = \frac{\lambda_{max}-n}{n-1}$ ， n=3， CI= 0。

CR=CI/RI=0.000<0.10，Meet consistency requirements.

Or alternatively put index's judgment matrix into software to calculate, the software can automatically calculate every index's weight and do consistency inspection.

The determination of intermediate hierarchy's indexes also applies the same method, hereby a summary of various indexes' weights.

Table 3: Various Indexes' Weights

First-level index	Weight	Second-level index	Weight	Third-level index	Weight
Planning and Ecology	0.2000	Land saving and Greening	0.0500	Land Utilization	0.0125
				Land for Greening	0.0375
		Safety Planning	0.1000	Urgent Evacuation System	0.0500
				Setting of Guide Sign	0.0500
		Traffic Planning	0.0500	Setting of Parking Lot	0.0250
				Public Traffic Networks	0.0250
Energy and Resources	0.2500	Energy Consumption	0.0833	Students' Average Energy consumption	0.0417
				Students' Average Water consumption	0.0417
		Energy Efficiency Optimization	0.0833	Water Saving of Equipment	0.0417
				Energy Saving of Equipment	0.0417
		Non-traditional Resources Utilization	0.0833	Recycle of Renewable Energy	0.0458
				Recycle of Rainwater	0.0200
				Middle-water System	0.0175

Table 3 Continued: Various Indexes' Weights

Environment and Health	0.2500	Environmental Comfort Level	0.0500	Acoustic Environment	0.0250
				Thermal and Humid Environment	0.0250
		Outdoor Environment	0.0500	Surface Water Environment	0.0125
				Greening Environment	0.0250
				Outdoor Wind Environment	0.0125
		Health of Teachers and Students	0.1000	Heath Education	0.0390
				Health-care Equipment	0.0491
				Public Health	0.0619
Operation and Management	0.2000	Technical Management	0.1000	Equipment Management	0.0250
				Intellectualized System	0.0750
		Environmental Management	0.1000	Greening Maintenance	0.0500
				Refuse Disposal	0.0250
				Pollutant Emission	0.0250
Education and Promotion	0.1000	Publicity and Promotion	0.0500	Propaganda	0.0250
				Course Setting	0.0250
		Achievements in Scientific Research	0.0500	Technology Research and Development	0.0333
				Award and Praise	0.0167

Hierarchy overall ordering

Summarize three hierarchy's weights, get the final hierarchy's overall ordering as below form shown: -

Table 4: Overall ordering of the final hierarchy

Index	Weight	Ranking	Index	Weight	Ranking
Land Utilization	0.0125	28	Heath Education	0.0390	12
Land for Greening	0.0375	13	Health-care Equipment	0.0491	6
Urgent Evacuation System	0.0500	3	Public Health	0.0619	2
Setting of Guide Sign	0.0500	3	Equipment Management	0.0250	15
Setting of Parking Lot	0.0250	15	Intellectualized System	0.0750	1
Public Traffic Networks	0.0250	15	Greening Maintenance	0.0500	3
Students' Average Energy consumption	0.0417	8	Refuse Disposal	0.0250	15
Students' Average Water consumption	0.0417	8	Pollutant Emission	0.0250	15
Water Saving of Equipment	0.0417	8	Propaganda	0.0250	15
Energy Saving of Equipment	0.0417	8	Course Setting	0.0250	15
Recycle of Renewable Energy	0.0458	7	Technology Research and Development	0.0333	14
Recycle of Rainwater	0.0200	25	Award and Praise	0.0167	27
Middle-water System	0.0175	26	Surface Water Environment	0.0125	28
Acoustic Environment	0.0250	15	Greening Environment	0.0250	15
Thermal and Humid Environment	0.0250	15	Outdoor Wind Environment	0.0125	28

We can tell from the form green campus appraisal result is mostly affected by the index called intelligent system followed by the public hygiene.

Conclusion

In this paper, the Analytic Hierarchy Process method is used to determine the weight of the green campus appraisal, while ensuring the objectivity, makes the evaluation process more considerate

about the users' subjective will. Through the scores of different schools about the index, the corresponding score can be obtained after the calculation, so that the evaluation of green campus can be quantified. It meets the demand of different colleges and universities on the green campus construction management and maintenance requirements, and has great significance in evaluation of green campus and its promotion.

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