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Post-evaluation Method and Application of Green Campus

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Abstract. The paper is intended to create a relatively simple and clear post-evaluation system for green campus. From the aspects of planning and ecology, energy and resources, environment and health, operation and management, education and promotion, by use of the analytic hierarchy process, the paper aims to determine the weight, build a model and establish a post-evaluation system for green campus. With Jiangnan University as an example, adopting multi-level grey evaluation method, the paper makes an evaluation of Jiangnan University and gains according star grade.

Introduction

Green campus is referring to a cultural environment oriented toward green, environmental protection and sustainable development and aimed at saving energy, land, water, material and protecting environment within the life cycle of campus under the condition of ensuring its fundamental education function.[1] Up till now, there have been approximately four thousand institutions for higher learning all around the nation, whose energy consumption accounts for a large portion of the total of the society. However, China's construction of green campus is basically remaining at the level of conception without any large-scale practice and promotion. In order to boost the development of green campus and help construction of green campus ascend to practice from conceptual level, it is essential to build a complete evaluation index system to appraise and direct institutions of higher learning. For realizing the purpose of guiding the construction of green campus, China has attempted to establish several sets of evaluation standards for green campus. Nevertheless, by contrast with international-mature evaluation system for green campus, domestic evaluation standard is not as complete, and the practice and application is not as much. To accelerate Chinese construction of green campus, it is necessary to set up a scientific and effective post-evaluation system in line with national conditions.

Evaluation index system for green campus

Fundamental principles for establishing index system

Principle of scientificity

Selection of post-evaluation index for green campus shall follow the principle of objectivity and be based on theory of sustainable development and theory of economic applicability. The definition, computing method, data collection, coverage range and weight selection of scientific index shall be performed on scientific basis so as to enable index system to withstand repeat scrutiny and give expression to the nature and features of green campus to the best for the purpose of being applied extensively[2].

Principle of systematization

On account of the complexity of post-evaluation system for green campus, the establishment of system should comply with principles of systematization and hierarchy to realize both independence and connection between indexes in order to make a systematic evaluation to colleges and universities from the aspects of planning, emerging saving, operation management, education and promotion.

Principle of operability

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Principle of operability requires that the finalized index system can be fully used and applied, and that the selected indexes can receive reliable evaluation. In addition, it is essential to screen these indexes to select out those which are representative enough to lead the construction of green campus in colleges and universities.

Principle of comparability

To serve as an evaluation system, in order to acquire objective and effect assessment results, it is necessary to ensure that the indexes are quantizable, which on one hand, requires that the qualitative indexes can be indirectly quantized after being assigned, and on the other hand, means that quantitative indexes can be quantized directly. Quantifiability is a major factor to ensure the comparability of evaluation system.

Establishment of evaluation index system for green campus

According to the principles of comprehensiveness and systematization, select a number of factors as the first-level evaluation index, including the influence of environment and health, planning and ecology, operation and management, education and promotion, etc. on the construction of green campus, which summarizes all the factors influencing the construction of green campus. Each first-level contains lots of second-level indexes, and the like till the indexes are measurable and can reflect the overall state as detailly and roundly

Table 1: Post-evaluation index system for green campus

	First-level index	Second-level index	Third-level index
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

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.

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. The index is made up of resources consumption, energy efficiency optimization and use of non-traditional energy and puts emphasis on the principle of sustainable development and rational utilization of resources.

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. Environment and health contains acoustic environment, thermal and humid environment, outdoor environment and safeguard measures for teachers' and students' health.

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.

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. The items of evaluation include times of activities about the construction of green campus, total number of participants and the number of technology research and development projects about the construction of green campus.

Weight determination

After finishing the establishment of evaluation model for green campus, it is required to distribute weight to all levels of evaluation indexes so as to work out the total points of items according to the score of indexes, thus to determine campus's stars. In terms of weight determination, there are usually two categories, namely subject weighting evaluation method and object weighting evaluation 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 environment, filed and traffic planning, facilities and equipment management, operation and promotion of green campus. Therefore, to evaluate green campus is a comparatively blurry process difficult to be quantified accurately. 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.

Table 2: Weight of all levels of indexes

First-level index	Weight	Second-level index	Weight	Third-level index	Weight
Planning and Ecology	0.2000	Land saving and Greening	0.3332	Land Utilization	0.4565
				Land for Greening	0.5435
		Safety Planning	0.3591	Urgent Evacuation System	0.4975
				Setting of Guide Sign	0.5025
		Traffic Planning	0.3077	Setting of Parking Lot	0.4924
				Public Traffic Networks	0.5076
Energy and Resources	0.2500	Energy Consumption	0.3333	Students' Average Energy consumption	0.5128
				Students' Average Water consumption	0.4872
		Energy Efficiency Optimization	0.3333	Water Saving of Equipment	0.4975
				Energy Saving of Equipment	0.5025
		Non-traditional Resources Utilization	0.3334	Recycle of Renewable Energy	0.3737
				Recycle of Rainwater	0.3241
				Middle-water System	0.3022
Environment and Health	0.2500	Environmental Comfort Level	0.3203	Acoustic Environment	0.4924
				Thermal and Humid Environment	0.5076
		Outdoor Environment	0.3121	Surface Water Environment	0.3201
				Greening Environment	0.3604
				Outdoor Wind Environment	0.3195
		Health of Teachers and Students	0.3676	Heath Education	0.3254
				Health-care Equipment	0.3298
				Public Health	0.3448
Operation and Management	0.2000	Technical Management	0.5192	Equipment Management	0.4444
				Intellectualized System	0.5556
		Environmental Management	0.4808	Greening Maintenance	0.3509
				Refuse Disposal	0.3229
				Pollutant Emission	0.3262
Education and Promotion	0.1000	Publicity and Promotion	0.5000	Propaganda	0.5039
				Course Setting	0.4961
		Achievements in Scientific Research	0.5000	Technology Research and Development	0.5238
				Award and Praise	0.4762

Building of evaluation model

Establish evaluation index set

Let U be evaluation index set, among which (referring to number i first-level evaluation index) is the first-level index set, (referring to number j second-level evaluation index under number i first-level evaluation index), (referring to number k third-level index under number j second-level index contained in number i first-level evaluation index).

Produce scoring standard and determine the weight of all indexes

Since evaluation index usually belongs to the range of subject index, it is required to quantify evaluated items and make evaluation. The paper adopts the pattern of scoring by experts in order to distinguish different grades: as to evaluation index , let the range of evaluation value be [9~7), [7~5), [5~3), [3~0), corresponding to the grades of evaluated items with three stars, two stars, one star and below grade respectively. For the weight of indexes, see Table 4.

Organize experts to grade and build sample matrix

After the weight of indexes is determined, invite p experts to grade the evaluated objects based on all listed indexes in the three levels according to the given scoring standard within the range of [0~9]. Calculate the score and then put the result into sample matrix:

In the matrix, refers to the score of evaluation index given by expert p.

Determine evaluation grey class

Determining evaluation grey class is to confirm its number of grades, the corresponding grey number and whitenization weight function. In accordance with the scoring standard, divide evaluation grey class into four levels, namely, e=1, 2, 3, 4, whose corresponding grey number and whitenization weight function are presented as below.

Table 3

Grey class	Grey number	Whitenization Weight Function f_e
Three-star (e=1)	$\otimes_1 \in [9,7)$	$f_1(d_{ijk}) = \begin{cases} \frac{1}{9} d_{ijk} & 0 \le d_{ijk} \le 9 \\ 1 & d_{ijk} > 9 \\ 0 & Others \end{cases}$
Two-star (e=2)	$\otimes_2 \in [7,5)$	$f_2(d_{ijk}) = \begin{cases} \frac{1}{7} d_{ijk} & 0 \le d_{ijk} \le 7 \\ \frac{14 - d_{ijk}}{7} & 7 < d_{ijk} \le 14 \\ 0 & Others \end{cases}$
One-star (e=3)	$\otimes_3 \in [5,3)$	$f_3(d_{ijk}) = \begin{cases} \frac{1}{5} d_{ijk} & 0 \le d_{ijk} \le 5 \\ \frac{10 - d_{ijk}}{5} & 5 < d_{ijk} \le 10 \\ 0 & Others \end{cases}$
Unqualified (e=4)	$\otimes_4 \in [3,0)$	$f_4(d_{ijk}) = \begin{cases} 1 & 0 \le d_{ijk} \le 3 \\ \frac{6 - d_{ijk}}{3} & 3 < d_{ijk} \le 6 \\ 0 & Others \end{cases}$

Apply matrix operation to make an overall evaluation of all levels of indexes

Let the whitenization weight function of the third-level index U_{ijk} under number e grey class be $x_{ijke} = \sum_{k=1}^{p} f_e(d_{ijke})$, the total evaluation coefficient of that belonging to every grey class $x_{ijk} = \sum_{e=1}^{4} x_{ijke}$. Let the whitenization weight coefficient vector of the third evaluation index U_{ijk} be $r_{ijk} = (r_{ijk1}, r_{ijk2}, r_{ijk3}, r_{ijk4})^T$, among which $r_{ijke} = \frac{x_{ijke}}{x_{ijk}}$. Based on r_{ijk}, build a whitenization weight coefficient matrix of the third-level index $R_{ij} = [r_{ij1}, r_{ij2}, \mathbf{L}, r_{ijk}]^T$, and make a comprehensive assessment of U_{ijk}: $B_{ij} = W_{ij} * R_{ij}$. Based on B_{ij}, establish a whitenization weight coefficient matrix of the second-level index $R_i = [B_{i1}, B_{i2}, \mathbf{L}, B_{ij}]^T$. Make an overall evaluation of U_{ij} as $B_i = W_i * R_i$ and create a whitenization weight coefficient matrix of the first-level index $R = [B_1, B_2, \mathbf{L}, B_i]^T$ based on B_i. Make a comprehensive evaluation of U_i and reach the result $B = W * R$.

At last, suppose the valued vector of evaluation grey class as $C = (9,7,5,3)$, and make an overall assessment of target S with the result G=$B * (9,7,5,3)^T$. According to the final result G and the given scoring standard, three stars [9~7), two stars [7~5), one star [5~3), under grade [3~0), it comes to the final result.

Case analysis

Jiangnan University is situated in Wuxi City, Jiangsu Province and directly under the Ministry of Education. The campus covers an area of 3,125mu with a floorage of more than 1,000,000 square meters. In 2008, Jiangnan University proposed the target of establishing low carbon and green campus and bettering water saving and energy saving. In addition, the university independently developed and designed a “digital energy supervision” platform, which comprises of electric power measurement, water supply measurement, smart lighting, fire control and other monitoring sub-systems and achieved scientific management and efficient energy saving by an integrated application of cutting-edge technologies including network, communication, information, control, etc. what’s more, the school has set up specialized an organization to oversee the power consumption of major buildings. Besides, the university has carried forward energy saving and cost reducing by real-time monitoring of the water supply and drainage pipeline network through nearly 20,000 sense monitoring points and is successful in constructing Jiangnan University as an energy-saving green campus. In the paper, Jiangnan University is taken as an example for the post-evaluation of green campus.

In combination with evaluation index system and experts’ scoring, the evaluated values of all indexes are as below.

$$D^T = \begin{bmatrix} 8&8&7&7&5&5&7&7&8&7&8&9&9&7&7&8&8&7&6&6&6&8&8&8&7&6&6&5&7&7 \\ 9&9&7&6&7&6&8&8&8&8&9&9&9&6&7&8&9&6&7&7&7&8&9&9&8&7&5&6&7&6 \\ 8&9&6&6&7&7&8&8&8&8&8&8&9&7&6&7&9&7&6&7&8&7&9&8&8&7&6&5&8&7 \\ 8&9&7&6&6&7&9&9&7&7&9&9&9&7&8&8&8&7&6&6&8&9&9&9&7&6&5&6&7&7 \\ 9&8&6&7&7&7&8&8&8&8&9&8&8&8&8&8&9&6&6&6&7&8&9&8&8&7&5&5&7&6 \end{bmatrix}$$

Result of the grey coefficient of all indexes and whitenization weight coefficient are presented in the table

Table 4. the weight of indexes

Grey Class Coefficient	e=2	e=3	e=4	sum	Grey Class Weights	e=1	e=2	e=3	e=4
X_{111e}	4.29	2.00	0.00	10.73	R_{111}	0.4140	0.3996	0.1863	0.0000
X_{112e}	3.86	1.40	0.00	10.04	R_{112}	0.4760	0.3845	0.1395	0.0000
X_{121e}	4.71	3.40	0.00	11.78	R_{121}	0.3112	0.4002	0.2886	0.0000
X_{122e}	4.43	3.43	0.33	11.63	R_{122}	0.2961	0.3807	0.2948	0.0284
X_{131e}	4.57	3.60	0.33	12.06	R_{131}	0.2949	0.3792	0.2986	0.0274
X_{132e}	4.57	3.60	0.33	12.06	R_{132}	0.2949	0.3792	0.2986	0.0274
X_{211e}	4.29	2.00	0.00	10.73	R_{211}	0.4140	0.3996	0.1863	0.0000
X_{212e}	4.29	2.00	0.00	10.73	R_{212}	0.4140	0.3996	0.1863	0.0000
X_{221e}	4.43	2.20	0.00	10.96	R_{221}	0.3953	0.4041	0.2007	0.0000
X_{222e}	4.57	2.40	0.00	11.19	R_{222}	0.3772	0.4083	0.2144	0.0000
X_{231e}	3.86	1.40	0.00	10.04	R_{231}	0.4760	0.3845	0.1395	0.0000
X_{232e}	4.14	1.80	0.00	10.50	R_{232}	0.4340	0.3945	0.1715	0.0000
X_{233e}	3.86	1.40	0.00	10.04	R_{233}	0.4760	0.3845	0.1395	0.0000
X_{311e}	4.71	3.00	0.00	11.60	R_{311}	0.3353	0.4061	0.2586	0.0000
X_{312e}	4.57	2.80	0.00	11.37	R_{312}	0.3518	0.4019	0.2463	0.0000
X_{321e}	4.43	2.20	0.00	10.96	R_{321}	0.3953	0.4041	0.2007	0.0000
X_{322e}	3.86	1.40	0.00	10.04	R_{322}	0.4760	0.3845	0.1395	0.0000
X_{323e}	4.43	3.80	0.33	12.00	R_{323}	0.2870	0.3690	0.3166	0.0275
X_{331e}	4.29	4.00	0.33	11.95	R_{331}	0.2790	0.3587	0.3348	0.0276
X_{332e}	4.43	3.80	0.33	12.00	R_{332}	0.2870	0.3690	0.3166	0.0275
X_{333e}	4.57	2.80	0.00	11.37	R_{333}	0.3518	0.4019	0.2463	0.0000
X_{411e}	4.29	2.00	0.00	10.73	R_{411}	0.4140	0.3996	0.1863	0.0000
X_{412e}	3.71	1.20	0.00	9.80	R_{412}	0.4989	0.3786	0.1225	0.0000

Table 4. Cont. the weight of indexes

X_{421e}	4.00	1.60	0.00	10.27	R_{421}	0.4545	0.3896	0.1558	0.0000
X_{422e}	4.57	2.40	0.00	11.19	R_{422}	0.3772	0.4083	0.2144	0.0000
X_{423e}	4.43	3.80	0.33	12.00	R_{423}	0.2870	0.3690	0.3166	0.0275
X_{511e}	3.86	4.60	1.00	12.46	R_{511}	0.2408	0.3096	0.3693	0.0803
X_{512e}	3.86	4.60	1.00	12.46	R_{512}	0.2408	0.3096	0.3693	0.0803
X_{521e}	4.86	2.80	0.00	11.66	R_{521}	0.3431	0.4168	0.2401	0.0000
X_{522e}	4.71	3.40	0.00	11.78	R_{522}	0.3112	0.4002	0.2886	0.0000

Part of the calculation process is as follows:

Land Utilization $R_{111} = [0.4142 \quad 0.3994 \quad 0.1864 \quad 0]^T$

Land for Greening $R_{112} = [0.4761 \quad 0.3844 \quad 0.1395 \quad 0]^T$

And then a comprehensive evaluation of the secondary indicators, $B_{ij} = w_{ij} * R_{ij}$, take Planning and Ecology as an example:

$$B_{11} = (0.4565, 0.5435) * \begin{bmatrix} 0.4142 & 0.3994 & 0.1864 & 0 \\ 0.4761 & 0.3844 & 0.1395 & 0 \end{bmatrix}$$
$$= (0.4478, 0.3912, 0.1609, 0)$$

Create a whitenization weight coefficient matrix for the second-level index based on B_{ij} :

$$\begin{bmatrix} 0.4478 & 0.3912 & 0.1609 & 0.0000 \\ 0.2990 & 0.3845 & 0.3027 & 0.0138 \\ 0.2949 & 0.3792 & 0.2986 & 0.0274 \end{bmatrix}$$

and then give a comprehensive evaluation of the first-level index , $B_i = w_i * R_i$

$$B_1 = (0.3332, 0.3591, 0.3077) * \begin{bmatrix} 0.4478 & 0.3912 & 0.1609 & 0.0000 \\ 0.2990 & 0.3845 & 0.3027 & 0.0138 \\ 0.2949 & 0.3792 & 0.2986 & 0.0274 \end{bmatrix}$$
$$= (0.3473, 0.3851, 0.2542, 0.0134)$$

Build a whitenization weight coefficient matrix for the first-level index according to

$$B_i : \begin{bmatrix} 0.3473 & 0.3851 & 0.2542 & 0.0134 \\ 0.4209 & 0.3978 & 0.1813 & 0.0000 \\ 0.3445 & 0.3884 & 0.2577 & 0.0094 \\ 0.4197 & 0.3885 & 0.1875 & 0.0043 \\ 0.2843 & 0.3592 & 0.3163 & 0.0401 \end{bmatrix}$$

The final comprehensive evaluation results:

$$B_{总}=(0.2 \quad 0.25 \quad 0.25 \quad 0.2 \quad 0.1)*\begin{bmatrix}0.3473 & 0.3851 & 0.2542 & 0.0134\\ 0.4209 & 0.3978 & 0.1813 & 0.0000\\ 0.3445 & 0.3884 & 0.2577 & 0.0094\\ 0.4197 & 0.3885 & 0.1875 & 0.0043\\ 0.2843 & 0.3592 & 0.3163 & 0.0401\end{bmatrix}$$

$$=(0.3732 \quad 0.3872 \quad 0.2297 \quad 0.0099)$$

The green building comprehensive evaluation value is:

$$W=B\times C^{T}=[0.3732 \quad 0.3872 \quad 0.2297 \quad 0.0099]*\begin{bmatrix}9\\7\\5\\3\end{bmatrix}=7.2474$$

The evaluation evaluation index score of the four sections, the comprehensive evaluation value in the three-star range $[9,7)$, it can be assessed as a green campus.

Conclusions

The AHP and Multi-Level Gray Comprehensive Evaluation Method are used to conduct post project evaluation of the green campus. In the process of weight distribution, the satisfaction of the users is taken into account, which can quantify the qualitative problems, so the index system is more scientific and comprehensive. The appliance of multi - level gray comprehensive evaluation method in analyzing the data improved the accuracy of the final result, which also provided theoretical and practical support for the post project evaluation of the green campus.

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