A multi-attribute decision model for performance assessment of eco-village construction in China

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Abstract: The eco-village is an idealized model for the establishment of internationally sustainable human settlements. To evaluate the performance of eco-village construction in China, this paper presents an evaluation index system of eco-village construction. It includes the six secondary indices, such as economic development, environmental hygiene, pollution control, resource protection and utilization, sustainable development and public participation, and 15 tertiary indices, and a method of eco-village construction utilizing multi-attribute decision models (MADM) of the Catastrophe Progression Method (CPM) and Analytical Hierarchy Process AHP method were constructed based on Capacity Index (CI) for comprehensive performance assessment. The comprehensive assessment result shows that the evaluation index system for eco-village construction can successfully assess and ensure village-level sustainability is attained in China, and can provide a beneficial reference framework for eco-villages elsewhere.

Keywords: eco-village construction, evaluation index system, performance assessment, multi-attribute decision models, sustainable rural development

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1 Introduction

The eco-village movement is a worldwide phenomenon that has arisen in response to the effects of the modern lifestyle on both our social and ecological environments. This movement is of particular interest and potential relevance in the United States, the country with by far the highest per capita consumption of resources (Kirby, 2003). Planning for the eco-village at Ithaca (EVI) began in 1991 as a group of individuals and families began meeting to plan a demonstration community that would challenge the existing social mode and offer a new model for sustainable development. The goal of the constructed eco-village at Ithaca is to create a "socially harmonious, economically viable and ecologically sustainable settlement that will demonstrate that human beings can live cooperatively with each other and with the natural environment" (Kirby, 2003).

The "eco-village" is a critical concept for the international establishment of sustainable human settlements (Dichristian, 1996), addressing it from an integrated perspective in trying to find sustainable solutions that can be managed locally, where farmers can take active part in research and in finding options to improve their livelihoods. The eco-village concept lies close to the UN Millennium Project (Sanchez et al., 2007) and aims at making a contribution to this program. Eco-construction refers to the application of ecological principles to the development of human ecosystems in order to achieve sustainability. It consists of three components: ecological engineering, ecological institutional reestablishment and ecological cultural remolding.

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In the 1990s', developed countries began to establish and study eco-villages due to the issues arising from over-expanded populations in cities, the exhaustion of non-renewable resources and deteriorating eco-environment. The eco-villages of European and North American countries are mainly designed for urban residents who are willing to live in the suburbs, containing advanced "green" houses and eco-technologies. In Japan, the eco-villages also present a solution for reviving rural areas (Liu et al., 2005). Since 1980, a vigorous campaign for demonstrating eco-construction has appeared in China and many eco-polis, eco-counties, eco-villages as well as eco-families have sprung up all over the country (Hu and Wang, 1998).

In fact, the eco-village is a form of ecological system composed of society, economy and nature. It is important to develop a framework of evaluation at the ecological level for eco-village construction in order to promote the sustainable development of rural areas. At a national level, an ecological level evaluation should establish an eco-environmental evaluation index system, and assess the ecological condition of certain regions from the perspective of ecological improvement and environmental protection, in order to bring about unified eco-environment programming and legal management. At the same time, the ecological level evaluation has been the main content of the management regulation of national environmental examining. Currently, there are imminent demands for ecological evaluations of ecological demonstration zones, ecological city and eco-village construction in China. An eco-village is an idealized model to achieve the sustainable rural development. To assess the performance of rural ecological planning, construction and management, the index and method of eco-village evaluation becomes the primary source of evidence. However, research of eco-village construction both in China and overseas are now at an exploratory stage given that there is no perfect evaluation system and method of eco-village construction.

Therefore, this paper promotes an evaluation index system of eco-village construction, based on the concept definition, characteristic analysis of an eco-village and the national criterion for the eco-village construction issued by Ministry of Environmental Protection of China (MEPC). Synchronously, the aim of the present study was to develop multi-attribute decision models (MADM) that assessed the sustainable developmental performance of eco-village construction utilizing the Analytical Hierarchy Process (AHP) and Catastrophe Progression Method (CPM) based on Capacity Index (CI). The remainder of this paper is organized as follows: Section 2 sets out the concept of eco-villages and the survey of eco-village construction. Section 3 puts forward and explains an evaluation index system and evaluation method of eco-village construction utilizing the AHP and CPM based on CI. Section 4 describes the application of the evaluation method of eco-village construction, and presents the results of the case analysis. In Section 5 the conclusions are provided.

2 The background in the eco-village construction

2.1 The concept of eco-villages

2.1.1 The origin of eco-villages

Early in the 1990s, some developed countries had reflected on environmental degradation, excessive consumption of non-renewable resources, habitat pollution and destruction and unsustainable life styles. In June 1996, the U.N. convened the second Conference on Human Settlements (HABITAT II) to discuss that how people should maintain sustainable settlements on the earth, protect the environment and the future generations, thereby stimulating subsequent research and development of the eco-village concept, and giving rise to an burgeoning world-wide eco-village movement sprang in both developed and developing countries .

The work of Robert C. Gilman was important in giving definition to the eco-village movement and shaping the direction of the Global Eco-village Network. In 1991, the Gilman co-authored Eco-Villages and Sustainable Communities, a seminal study of eco-villages for Gaia Trust. Also in 1991, Gilman, who was publisher of the magazine In Context, wrote an article entitled "The Eco-village Challenge" that set out a definition of an eco-village as a: "human-scale, full-featured settlement, in which human activities are harmlessly integrated into the natural world, in a way that is supportive of healthy human development and can be successfully continued into the indefinite future". This was to become the standard definition on which the eco-village movement was founded and is still considered by many to be the most authoritative (Gilman, 1991). Through his investigation on the Ithaca eco-villages, Kirby (2003) found that "human beings can live cooperatively with each other and with the natural environment". Hence the eco-villages model encompasses complex sets of relations, including those between human beings and the natural landscape, artificial landscape, within the community itself, contact between individuals and contact between generations.

The research also showed that the eco-villages were not simply about advocating the maintenance of a natural landscape without any changes in the actions of human beings, but emphasized in eco-village construction the need for material recycling, economic development and ecological balance promoting social progress, natural harmony and stability. Economic development is main driver of the whole ecological system, and social progress implies improvement of settlement environment, enhancement of management level and population quality.

From the late 1970s, the national scholars had advocated the concepts of ecological balance and ecosystem to guide agricultural research, and gradually perfected the basic ideas and practical implementation of Chinese Ecological Agriculture. The concept of the eco-village in China emerged in the context of ecological agriculture in rural areas. At present, eco-village is generally considered as part of an agricultural ecosystem in China, which makes full use of natural resource and accelerates material recycling and energy conversation in natural or administrative villages in order to achieve ecological balance, economic development and social benefit together in the agricultural ecological system. In the practice there have been numerous eco-village modes such as "planting-breeding-processing", "four-in-one", "biogas utilization" and so on, which indicated that the development of ecological agriculture was integrally part of the construction and operation of the eco-villages. Furthermore, a rural area is not only an agricultural ecosystem but also a compound system combining both the agricultural and human ecosystems. In American and European eco-villages , the ethos was more inclined to the religious spiritualization, attaching importance to the landscape of the of rural area, aesthetic values and life-styles, to the heterogeneity of appearance and utilization of natural resources of the buildings to conserve energy and water, environmental greening and re-cyclable material (Yang, 2000). Hence there are a great of differences in the value orientations between the concept eco-villages in China and elsewhere in western countries, which shows that the content of 21st century. Eco-villages should contain not only ecological agriculture but also ecological dwelling houses, a pleasant rural landscape, and good social relationships (Su et al., 2004).

Sustainable development, especially from the viewpoint of harmonizing and planning the city zone and rural area as a whole, is now at the core of 21st century developmental thinking in China. In spite of the process of integration of town and country accelerating and rural infrastructure changing fundamentally, the construction of the eco-village still remains the primary developmental orientation of 21st century villages, which can not only accelerate the process of integration of town and country but also show clearly the developmental direction to better integrate them. Whereas, the eco-village is a historical and developmental concept arising out of different requirements in different periods, the content of the eco-village is more and more extensive (Su et al., 2004).

2.1.2 The definition of eco-village

There is, at this time, no generally agreed definition of an eco-village. This paper argues that the eco-village is an ideal model for the rural areas to accomplish sustainable development, which is an ecosystem making full use of natural resource in a natural village or an administrative area, enhancing material recycling and energy transformation to achieve the synchronous and synergistic development of ecological, economic and social benefits. Eco-village development utilizes ecological economic theory and system engineering methods to change production and consumption behaviour and approaches to decision making and administration to draw on all useful potential resources in rural areas within the carrying capacity of the rural ecosystem (Li et al., 2007).

The basic conditions to be satisfied in the eco-village construction are: a) planning according to the general demands of regional environmental planning with a scientific program, rational layout, tidy rural surroundings, green areas surrounding the houses and roadside, sanitary water and atmosphere; b) villagers are able to follow the rules and regulations of environmental protection consciously aware of the its need and of avoiding possibilities of environment pollution; c)local economic development accords with national industrial policy and environmental protection policy; d) display and signage of rural regulations and environmental publicity to advocate the ecological civilization.

2.2 The survey of eco-village construction

Eco-construction as a scientific concept was explicitly put forward in 1987. It originated from the Chinese cultural tradition of agriculture in the very early ancient period and has been spontaneously applied all over the country for several thousands of years in China (Dumreicher, 2008). It refers to the application of ecological principles to develop human settlement in harmony with its environment. Eco-construction consists of three components: eco-engineering construction, eco-institutional construction and eco-cultural construction. Eco-construction presents a conceptual framework for China to achieve strugglingly local or regional sustainable development (Wang, 1990). As China started to redirect its steps towards the profound transition from planned to market economy in the early 1980s, a vigorous campaign for Ecological Demonstrative Rebuilding for Sustainable Settlements (EDRS) took place and many projects of ecopolis, eco-counties, eco-villages, as well as eco-families, were initiated and carried out across the country, these EDRS projects were aimed at applying the principles of ecology to the practice of local development and to explore further the specific operational approaches to achieve local sustainability (Wang and Hu, 1994; Zhang et al., 2007).

The first application of the concept of eco-village is in the report "eco-village and sustainable society" wrote by Robert Gilman from Danish. In 1991, an eco-village organization, the Gaia investment trust fund, was set up in Denmark. From then eco-villages began to spread gradually across the globe, where experts in agriculture, ecology and architecture collaborated spontaneously in rural areas, and gave attention to protecting problems of the economic, ecological and cultural heritage in order to advocate establishing a sustainable developmental society. Across the world, there are many well-known eco-villages, such as Bramfeld in Germany, the Eco-Tribe village in Netherlands, Tuggelite eco-village in Sweden, Earthaven eco-village in USA and Gaia eco-village in Argentina (Yang, 2000).

Chinese eco-villages developed initially in the late 1970s and early 1980s. As the rural areas relied mainly on agricultural production in China, the eco-village developed gradually following by the construction of ecological agriculture. "The eco-village is an agricultural ecosystem, which make full use of natural resource in a natural village or an administrative area, and accelerate material recycling and energy transformation to achieve synchronous development of ecology, economy and social benefit", is a viewpoint that Chinese scholars approve generally. For example, Liu Minying village in the Daxing district of Beijing city was voted one of the "500 best global environmental protection" by the United Nations Environment Programme in 1986, and awarded the title of "the first village of ecological agriculture in China" (Zhang and Ouyang, 2007). The early construction of eco-villages in China paid more attention to the practical model and methods of production, such as the organic agricultural methods, planting and breeding projects, material and energy re-cylcing projects and the diagnosis of the agricultural ecosystem. Hence Chinese eco-village planning, in contrast to many foreign urban and suburban eco-villages, just focused on the establishment of organic agriculture, merely referring incidentally to the program of village spatial arrangement, land resource protection and settlement design. At present, the concept of eco-village in China is narrowly limited not only to the rural areas in the scope but also to the agricultural economic system in the eco-village construction (Yang 2000).

3 The evaluation methodology for eco-village construction

MADM evaluate alternatives to determine the best or better rated one according to decision-making goals. MADM are based on a hierarchical decomposition of the problem, where the target goal is decomposed into sub-concepts (represented by aggregate attributes) and finally to a finite set of (measurable) basic attributes. Basic-level descriptions of alternatives are gradually aggregated into the values of higher level attributes, until a final evaluation of each alternative is eventually obtained at the target (root) attribute (Bohanec et al., 2008). Many methodologies exist for MADM (Aguarón and Moreno-Jiménez, 2003; Korhonen and Voutilainen, 2006). In ecological modeling problems, these are often used to represent and combine indicators, evaluate alternatives and provide decision support in general. In some recent applications, MADM methods were used for decision support in land-use planning (Ananda et al., 2008), sustainable agriculture, eco-industrial development (Fang, Côté, Qin, 2007), and economic and ecological assessment of genetically modified crops (Bohanec et al., 2008).

Any environmental or ecological evaluation methodology should be objective, comprehensive and feasible. The central aim of evaluation of eco-villages is to improve their overall sustainable development. Therefore, this paper takes overall sustainable development as the main objective in evaluating the eco-village. The comprehensive capacity of sustainable development of an eco-village is influenced by many factors, and hence the evaluation system is multivariate, requiring a range of indices with appropriate weights in their construction. Therefore, this paper proposes an evaluation index system and evaluation method of eco-village construction utilizing the AHP and CPM method.

3.1 The evaluation index system of eco-village construction

In general, the improvement of ecological environmental evaluation index indicates that the research on sustainable development has evolved gradually from the exploration of individual, single attribute or single subject to the investigation of multi-dimensional, multi-level, multi-subjects system of society, economy and ecological environment, while the evaluation methods have changed from the traditional statistical analysis of the society and economy and environmental monitoring to the comprehensive evaluation of the multiple methods, multi-scale integration. As every system with the ecological environmental function is a complex composed of the multiple variables, there could be therefore a large and complicated index system on the description and evaluation of sustainability constitute, which could possess the function of description, evaluation, explanation, early warning and decision-making. It should reflect the developing speed and trends of every eco-environmental function and system in the time dimension, the integral distribution functions in the space dimension, the function strength and dimension in quantity, the function structure in layers. Of course, the evaluation system for an eco-village mainly embodies the condition of its rural economy, environment, ecology and society in the context of the degree of sustainability of its development (Li et al., 2007).

Based on the national criterion for the eco-village construction issued by MEPC, this paper presents the evaluation index system for the eco-village construction, which includes the 6 types (secondary indices) of the economic development, environmental hygiene, pollution control, resource protection and utilization, sustainable development and public participation, and 15 tertiary indices (Table 1).

Table 1 The evaluation index system for the eco-village construction

Primary index	Secondary index	Tertiary index
Comprehensive capacity of sustainable development for an eco-village	Economic development	Per capita annual net income of rural residenter
	Environmental hygiene	Rate of health living drinking water
		Coverage rate of household sanitary toilets
	Pollution control	Pointing clean-up & deposit rates of living wastes (or Sound treatment rate for living wastes)
		Cleansing rate for living sewage
		Eligibility rate for the discharge of industrial pollutants
	Resource protection and utilization	Penetration rate of clean energy
		Recovery rate of plastic film
		Comprehensive utilization rate of crop straw
		Comprehensive utilization rate of wastes from large-scale integrated livestock and poultry
	Sustainable development	Coverage rate of vegetation
		Percentage of non-pollution, green, organic agricultural products base
		Average amount of fertilizer and pesticides application
		Content of farmland soil organic matter
	Public participation	Satisfaction degree of the villagers to environmental protection

Notes: The "village" referred in the national criterion for the eco-village construction issued by MEPC means the administrative village established according to the state institutions concerned.

3.2 Performance assessment model based on CPM

Catastrophe progression method is used to decompose the general objective of evaluation into a multi-level structure, and calculate from bottom to top by normalization formula to obtain the membership function (the evaluation result). The evaluation objective is divided into multiple levels, arranged in a hierarchy tree, and the original data only requires knowing the bottom index data. Relatively important indicators from the same layer are put in front, avoiding the weight determination and reducing the subjectivity.

3.2.1 Common catastrophe types

After constructing the index system of hierarchy structure, it is necessary to change the hierarchical structure model into mutation progression model according to the theory of catastrophe progression. The type of mutation model is determined according to the control variables and the number of dimensions (Table 2). The control variables of the general catastrophe system are not more than four, and four common catastrophe types are fold, cusp, swallowtail, and butterfly.

Table 2 Four common catastrophe types

Catastrophe type	Dimensions of control variation	Potential function	Bifurcation set	Normalization formula
Fold catastrophe	1	$f(x)=x^3+ux$	$u=-3x^2$	$x_u=\sqrt{u}$
Cusp catastrophe	2	$f(x)=x^4+ux^2+vx$	$u=-6x^2,\ v=8x^3$	$x_u=\sqrt{u},\ x_v=\sqrt[3]{v}$
Swallowtail catastrophe	3	$f(x)=\frac{1}{5}x^5+\frac{1}{3}ux^3+\frac{1}{2}vx^2+wx$	$u=-6x^2,\ v=8x^3,\ w=-3x^4$	$x_u=\sqrt{u},\ x_v=\sqrt[3]{v},\ x_w=\sqrt[4]{w}$
Butterfly catastrophe	4	$f(x)=\frac{1}{6}x^6+\frac{1}{4}ux^4+\frac{1}{3}vx^3+\frac{1}{2}wx^2+tx$	$u=-10x^2,\ v=20x^3,\ w=-15x^4,\ t=4x^5$	$x_u=\sqrt{u},\ x_v=\sqrt[3]{v},\ x_w=\sqrt[4]{w},\ x_t=\sqrt[5]{w}$

3.2.2 Establishment of the catastrophe progression model

First of all, the hierarchical structure model is established by using the weight value of the analytic hierarchy process to adjust the order of the original index. Because the number of control variables per layer is not more than four, the 6 secondary indexes could be divided into 3 groups according to index category. The index system changed from the 3 to 4 level index. The catastrophe progression model for evaluation value of the comprehensive capacity of sustainable development for eco-village is shown in Figure 1.

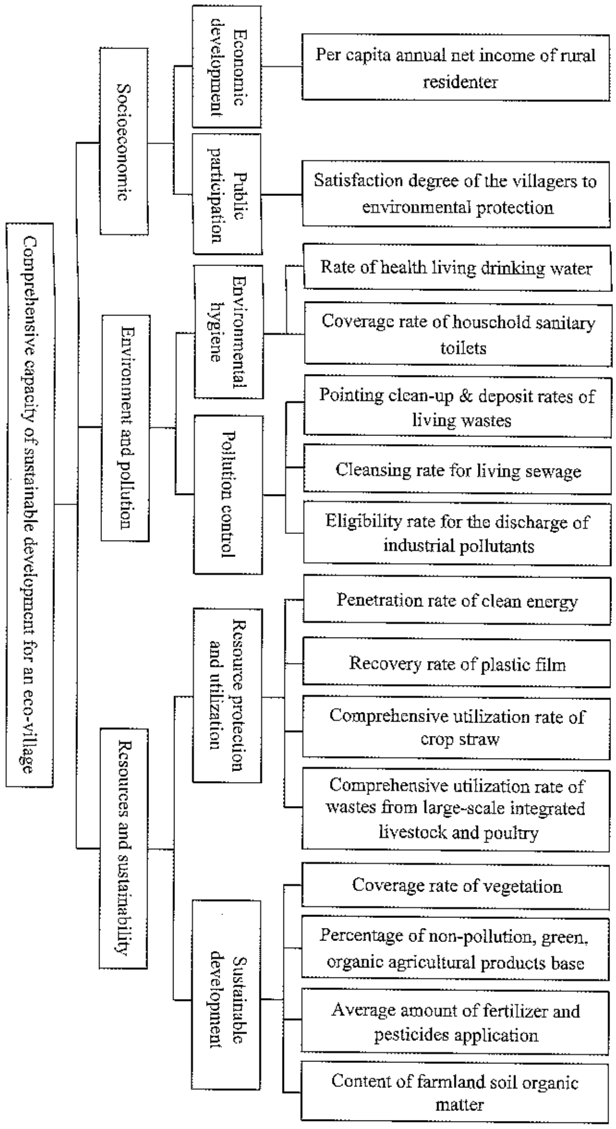

Figure 1 Catastrophe progression model

3.2.3 Normalization formula evaluation and standard index

Because the range of the original data and the measurement units are different, they cannot be directly compared. According to the requirements of catastrophe theory, before using the normalization formula, it is necessary to convert the original data of the control variables into the larger dimensionless values in the range of [0, 1]. The subordination degree concept of fuzzy had been used to dimensionless for data. The positive-type index is standardized using Equation (1), which indicates that performance assessment value is the greater with the increase of index value, such as rate of health living drinking water, coverage rate of vegetation. The negative-type index is normalized by using Equation (2), which indicates that performance assessment value is the lower with the increase of index value, such as Average amount of fertilizer and pesticides application.

$$x = \frac{x_i - x_{\min}}{x_{\max} - x_{\min}} \tag{1}$$

$$x = \frac{x_{\max} - x_i}{x_{\max} - x_{\min}} \tag{2}$$

After normalization, the catastrophe progression of control variables of the last level will be obtained and used as the control variable for the next level index depending on the principle of 'complementary' or 'non-complementary', until reaching the top of the catastrophe progression (namely evaluation results G). If there is a strong interaction between the control variables of the same index, the control variables of the object are called 'complementary type', or 'non-complementary type'. For complementary indicators, the value is obtained according to the principle of the average value (Equation (3)). The minimax principle (also called the minimum value principle) had been used for non-complementary indicators (Equation (4)).

$$x_b = average(x_{c1}, x_{c2}, \ldots x_{cn}) \tag{3}$$

$$x_b = \min(x_{c1}, x_{c2}, \ldots x_{cn}) \tag{4}$$

Finally, the average interval method was used to classify the level of evaluation of the comprehensive capacity of sustainable development for eco-village, and the results were divided into 4 grades (Table 3).

Table 3 The classification standard of results for CPM

Level	Index value	Performance situation
I	0.76-1	Very good comprehensive capacity of sustainable development
II	0.51-0.75	Better comprehensive capacity of sustainable development
III	0.26-0.50	General comprehensive capacity of sustainable development
IV	≤0.25	Poor comprehensive capacity of sustainable development

3.3 Performance assessment model based on AHP

3.3.1 Constructing the hierarchical structural model

From the primary strategic goal layer to the lowest level indicator layer, there exists a distinct three-level hierarchical structure in the evaluation system for eco-village construction. The top level is the general strategic goal of the hierarchical structure, namely the overall objective layer (A) with only one key element of the comprehensive capacity of sustainable development for eco-village. The intermediate level is the criterion layer (C) with six intermediate elements, such as economic development, environmental hygiene, pollution control, resource protection and utilization, sustainable development and public participation, by which the key elements of the index layer influenced on the general goal of the comprehensive capacity of sustainable development for eco-village. The lowest level, namely the evaluation index layer of eco-village construction, is composed of fifteen key elements. There exists a specific logic in the relationships between neighboring levels; each pair of the elements in three layers are compared to establish the fraction relationship and determine the synthesized priorities for the key elements of index layer with respect to the general goal, using hierarchical or network structure methods.

3.3.2 The classification standard of results for AHP

In ecological evaluation for eco-village construction based on sustainable rural development, we adopt the evaluation standard of the comprehensive capacity of sustainable development. By taking various statistical yearbooks, bulletins and other relative data and national and international corresponding index standards into account, we designed a four-stage classification standard with the critical value and values of upper and lower limit of the index of comprehensive capacity of sustainable development for eco-village (Li et al., 2007) (Table 4).

Table 4 The classification standard of results for AHP

Level	Index value	Performance situation
I	76-100	Very good comprehensive capacity of sustainable development
II	51-75	Better comprehensive capacity of sustainable development
III	26-50	General comprehensive capacity of sustainable development
IV	≤25	Poor comprehensive capacity of sustainable development

Data resource: Li et al., 2007.

3.3.3 Weight calculation and consistency test

Based on the analytical methodology above, questionnaires were designed in light of the hierarchical structural model for evaluating the sustainability of eco-village construction in China. Data were collected through a questionnaire that had been sent to 180 persons invited to take part in the consultation, including the field experts, farmer representatives and government managers from the environmental sectors in China, of which 131 completed questionnaires were received, providing a 72.8% response. These questionnaires represent the attitudes of three social positions or ranks with regard to the eco-village construction in China. Each questionnaire consisted of three parts: 1) information related to the definition and categorization of the eco-village construction in China, and technique concerning the completion of the questionnaires; 2) effective scoring information by using the scale; and 3) paired comparison matrices information. In part 2, the key elements of evaluation index layer that affect comprehensive capacity of sustainable development for eco-village were assessed using on a scale from 1 to 9. In part 3, the reviewer was required to compare each criterion element (the key elements of evaluation index layer) against the others to constitute paired comparison matrices for the A-C layer and C-P layers. From to the collected questionnaires, we could systematically calculate the action forces and weight of different key elements of the evaluation index layer effects on the general objective of comprehensive capacity of sustainable development for eco-village.

A comparison matrix for the A-C layer was constructed, by which we could reckon the weight of the criterion layer to the general objective in Table 5. The comparison matrix of A-C layer would be considered consistent (and accepted) with a CR lower than 0.1. Similarly, we could obtain the weight of the evaluation index layer P_1 to economic development C_1, the weight of the evaluation index layer P_2-P_3 to environmental hygiene C_2, the weight of the evaluation index layer P_4-P_6 to pollution control C_3, the weight of the evaluation index layer P_7-P_{10} to resource protection and utilization C_4, the weight of the evaluation index layer P_{11}-P_{14} to sustainable development C_5, the weight of the evaluation index layer P_{15} to public participation C_6 (wholly passed the consistency test, and accepted).

From Table 5, it can be seen that the weights of the criterion layer to the general objective are 0.3910, 0.1645, 0.2373, 0.0692, 0.0610 and 0.0769 for economic development, environmental hygiene, pollution control, resource protection and utilization, sustainable development and public participation respectively. The economic development has the maximum weight, pollution control the second, sustainable development the minimum.

Table 5 The weight calculated for the evaluation index system of eco-village construction in China

Evaluation index	Economic development	Environmental hygiene	Pollution control	Resource protection and utilization	Sustainable development	Public participation	Weight of total countable series of layers
	0.3910	0.1645	0.2373	0.0692	0.0610	0.0769	
Per capita annual net income of rural residenter	1.0000						0.3910
Rate of health living drinking water		0.6340					0.1043
Coverage rate of household sanitary toilets		0.3660					0.0602
Pointing clean-up & deposit rates of living wastes			0.3775				0.0896
Cleansing rate for living sewage			0.1526				0.0362
Eligibility rate for the discharge of industrial pollutants			0.4699				0.1115
Penetration rate of clean energy				0.0882			0.0061
Recovery rate of plastic film				0.1569			0.0109
Comprehensive utilization rate of crop straw				0.2717			0.0188
Comprehensive utilization rate of wastes from large-scale integrated livestock and poultry				0.4832			0.0334
Coverage rate of vegetation					0.5355		0.0371
Percentage of non-pollution, green, organic agricultural products base					0.1093		0.0076
Average amount of fertilizer and pesticides application					0.1300		0.0090
Content of farmland soil organic matter					0.2252		0.0156
Satisfaction degree of the villagers to environmental protection						1.0000	0.0769
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table 5 accordingly showed the weight of the 15 indices of the evaluation index layer to the general objective of comprehensive capacity of sustainable development, of which, the largest influence is per capita annual net income of rural residents (0.391), the eligibility rate for the discharge of industrial pollutants influences second important (0.1115) and the least influence is the penetration rate of clean energy (0.0061).

4 An empirical analysis

This paper made an environmental evaluation for eco-village construction based on sustainable rural development. The data used are collected from field survey conducted in China with the help of the rural eco-environmental protection report in 2007 of the MEPC legislative research project 'science popularization action on eco-environmental protection in vast rural areas'. Stratified random sampling was used to select the villages (Chen et al., 2014). First, we divided all provinces into three regions, including eastern, central and western, according to geographical position and resources, as well as the diverse economic development in these regions. Then, we randomly selected three provinces in each region and one village in each province for field surveys. As a result, the survey samples included 9 villages in different provinces (see Figure 2). The villages in China's eastern area were Qianwei village in Shanghai, Beizha village in Zhejiang and Mohe village in Heilongjiang. The central region villages were Dongzu village in Hebei, Baimiao village in Henan and Yongfeng village in Shanxi. Baimei village in Guizhou, Tawan village in Ningxia and Xinmin village in Yunnan were located in the western region villages.

The survey data were analyzed by using the CPM and AHP models constructed above. The results were showed in Figure 3 and Table 7. The results of CPM shows that Yongfeng village in Shanxi had a top evaluation value of the comprehensive capacity of sustainable development for eco-village, but Baimiao village in Henan had a minimum value despite the same region. From other point of view, the level of the comprehensive capacity of sustainable development in villages in a order from good to poor were good (Qianwei, Beizha and Yongfeng Tawan), better (Mohe, Dongzu and Baimei), general (Xinmin) and poor (Baimiao). As for the results of AHP, the evaluation data shows that Yongfeng village in eastern region had a top evaluation value of the comprehensive capacity of sustainable development for eco-village (consistenting with results of CPM), and Xinmin village in central region had a minimum value. According to the classification criteria of index value, 9 villages can be divided into 2 groups, such as good (Qianwei, Beizha, Yongfeng and Tawan) and general (Mohe, Dongzu, Baimiao, Baimeiand Xinmin).

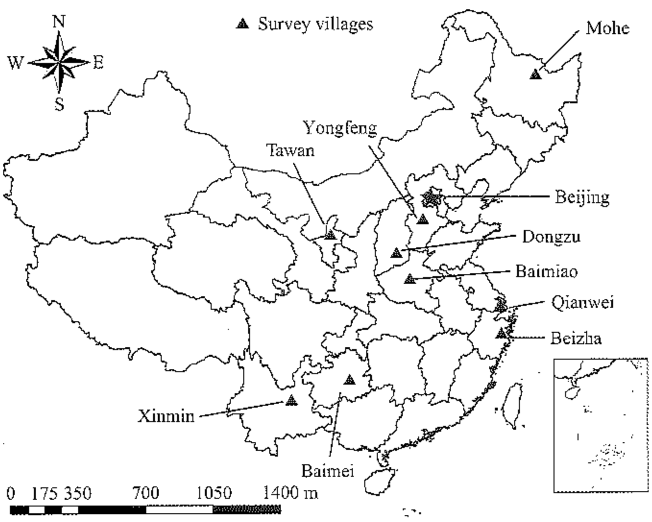

Figure 2 Location of villages in survey

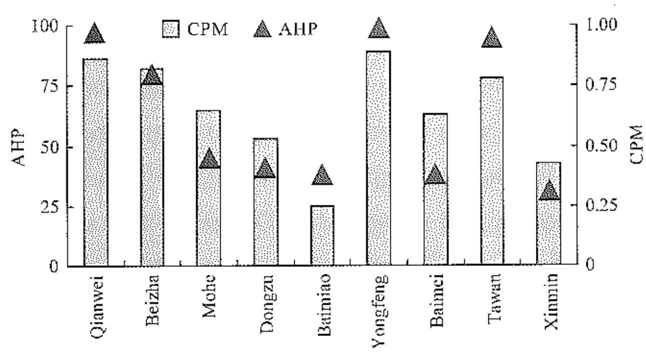

Figure 3 Results of CPM and AHP

Table 7 The evaluation results of the comprehensive capacity of sustainable development for eco-village

Regions	Villages	CPM		AHP	
		Value	Level	Value	Level
Eastern	Qianwei	0.86	I	97	I
	Beizha	0.82	I	80	I
	Mohe	0.65	II	45	III
	Mean	0.77	I	74.0	I
Central	Dongzu	0.53	II	41	III
	Baimiao	0.25	IV	38	III
	Yongfeng	0.89	I	99	I
	Mean	0.68	II	67.7	II
Western	Baimei	0.63	II	38	III
	Tawan	0.78	I	95	I
	Xinmin	0.43	III	31	III
	Mean	0.66	II	64.1	II

Furthermore, evaluation values of AHP have a greater different among villages than CPM. Six of the nine villages have the same level of the comprehensive capacity of sustainable development by AHP and CPM. The results (mean in three regions) of CPM and AHP together showed that the differences of the comprehensive capacity of sustainable development for eco-village of three regions are quite clear, and villages in the eastern region are greatest, in the central region come second and in the western region are lowest.

5 Conclusion

This paper makes the concept and characteristic analysis of an eco-village systematic, and puts forwards an evaluation index system of eco-village characteristics based on the national criterion for eco-village construction issued by MEPC. Besides, the CPM and AHP method were constructed based on CI to carry out a multivariate comprehensive assessment to be made of the overall sustainability of an eco-village. Finally, it is used to presented case study evaluations for 9 villages in China.

The results show that an eco-village evaluation index system can describe their likely relative levels of overall sustainability and provides a conceptual basis and methodological support for planning national eco-villages and solving rural eco-environmental problems in developing countries. These findings indicated that a multi-attribute decision model of CPM and AHP based on index system were effectively applied to evaluate performance of eco-village construction.

Through the performance assessment, the success of eco-village construction in China appears to be critically based on the following actions(Hu and Wang, 1998): 1) ecologically planning and designing village development; 2) implementing ecological engineering in environmental protection and the comprehensive utilization of local resources; 3) establishing social institutions to manage man-environment relations; 4) remaking local culture in its dimensions of behavior, psychology, intelligence and consciousness.

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