

Evaluating Green Degrees of China's Endowment Communities

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Abstract

With the aging population problem becoming more and more serious, how to effectively promote green development of endowment community has become a research hotspot in academia. Based on literature research, this paper establishes the index system from the whole process of site selection, design planning, construction, operation and maintenance, and the evaluation model combining with AHP-ANP-entropy method-distribution maximization method. The constructed system and model are applied to measuring greening degrees of China's four typical endowment communities in 2017. The findings showed that the greenness score of Shanghai Shenyuan is significantly higher than other three communities, and the average score of the construction criterion layer for four communities is larger than other three criteria layers. Based on comparative analysis, the greenness scores of design planning, construction, and operation and maintenance of Shanghai Shenyuan were much higher than that of other three communities. Except for site selection, the greening degrees of other three criteria layers in Dalian Lechunxuan were significantly lower than other three communities. Additionally, the green development of endowment community is affected by regional economic basis and ecological environment.

Keywords

Endowment Community, Green Degree, Measurement and Evaluation

1. Introduction

Under the background of globalization, the aging of population has become a worldwide topic. Since 1999, China has entered the aging society, and the demographic dividend gradually disappeared. With the gradual deepening of the aging population, the pension problem will become a huge challenge affecting

China's economic development and social stability. Both theory and practice have proved that compared with the traditional way of providing for the aged, community providing for the aged is an effective way of solving the problem (Wu et al., 2019). With the gradual improvement of economic development level, per capita welfare level and social security system, the market demand of endowment community is increasing day by day (Seah et al., 2019).

At present, the research on the green level of endowment community is still in the initial stage, and the quantitative evaluation research is even less, mainly focused on the evaluation of the aging and green community. For example, Subica et al. (2016) have built a community system for the aged from three aspects: service function, service environment and service support. Based on life care, medical care and social contact, Rapaport et al. (2018) constructed the evaluation index system of community pension service. Dickens et al. (2011) put forward the evaluation index system of comprehensive elderly care community from the perspective of medical care, elderly living, life service, leisure and entertainment, cultural exchange, giving full play to the needs of the elderly. Heatwole Shank and Cutchin (2016) used AHP, correlation statistics and other methods to build a relatively rational evaluation index system with sufficient data support from the aspects of supporting facilities, pension services, environmental design, etc. Buffel (2018) set out from comfort, convenience, economy, traffic and other important factors that affect the living environment of the elderly, and established the evaluation index system of the environmental suitability for the elderly in endowment community by using the analytic hierarchy process. The existing literature mainly evaluates the green degree of endowment community from the aspects of service function, infrastructure, residential environment, etc., and lacks the evaluation research from the perspective of the whole process and the whole life cycle, resulting in the lack of accuracy of the evaluation results (Tran and Nguyen, 2017). From the perspective of the research object, the existing research focuses on the measurement and evaluation of a single elderly care community (Abdelwahab et al., 2018). Although scholars try to measure the green level of multiple communities, they are limited to the static analysis of cross-section data, resulting in the measurement results only have horizontal comparability and lack of vertical comparability (Chen et al., 2016). Therefore, the comparative analysis and dynamic analysis of typical endowment communities need further study.

Therefore, based on the scientific definition of the concept of greening endowment community, this paper systematically constructs the evaluation index system of greening endowment community from the perspective of site selection, design planning, construction, operation and maintenance. Combined with four methods of AHP-ANP-entropy-maximum deviation, this paper constructs the evaluation model, and selects four typical pension communities in China for an empirical research. The purpose of this study is to find out the key problems in the green development process of endowment community by measuring

greening degree of endowment community in China, so as to provide a reference for better promoting the healthy development of endowment industry.

2. Evaluation Index System

Green development of endowment community pursues efficient resource utilization and minimum environmental impact in the whole process and life cycle. Therefore, green level evaluation should consider all stages from site selection to maintenance (Sui et al., 2018). The evaluation index system of endowment community's green level in this study is mainly constructed from four criteria levels: site selection, design planning, construction, operation and maintenance. As shown in Table 1.

Among them, site selection is the first stage, the quality of which has a great impact on the choice of consumers (Kasahara and Saito, 2019); design planning has an important impact on the early investment, progress and quality of the endowment community (Yuen and Vogtle, 2016), and is a decisive link in community quality (Rao et al., 2018); the construction stage is the implementation of the results of design and planning (Yusof et al., 2017); the operation and

Table 1. Evaluation index system of greening degree on endowment community.

Target layer	Criteria layer	Number	Index layer	References	
Greening degree on endowment community	Site selection (X1)	Income level	X11	Per capita disposable income	Arteaga et al., 2015; Buffel, 2018; Worrell et al., 2013; Yuen and Vogtle, 2016
		Market demand	X12	Proportion of the elderly	
		Local ecological and natural environment	X13	Days above level 2	
			X14	Per capita public green area	
	Design planning (X2)	Completeness of basic supporting facilities	X21	Proportion of intelligent aging facilities	Rapaport et al., 2018; Chen et al., 2016; Jerome et al., 2017; Abdelwahab et al., 2018
			X22	Proportion of green infrastructure	
		Green design of building materials	X23	Proportion of 3R materials use	
		Clean energy use design	X24	Utilization rate of green energy	
	Construction (X3)	Degree of energy saving and consumption reduction	X31	Construction energy saving	Laun et al., 2019; Aw et al., 2017; Heatwole Shank and Cutchin, 2016; Abdelwahab et al., 2018
		Degree of pollution reduction and efficiency enhancement	X32	Construction waste recycling rate	
			Use of green construction equipment	X33	
		Green management of construction organization	X34	Perfection of green management in construction organization	
		Operation and maintenance (X4)	Green operation management	X41	
	X42			Number of service personnel per household	
Green elderly service management	X43		Medical investments per capita		

maintenance stage is the longest phase in the life cycle of endowment community (Aw et al., 2017), whose task is to monitor and evaluate green management, energy, material resources, water resources and environmental quality.

In the stage of site selection, there are four indicators, namely, per capita disposable income, proportion of the elderly, days above the level 2 and per capita public green area; the design planning stage is mainly investigated from proportion of intelligent aging facilities, proportion of green infrastructure, 3R materials proportion and utilization rate of green energy; the construction stage is the implementation of the design and planning results, including four indicators of construction energy saving, construction waste recycling rate, utilization rate of energy-saving appliances and the perfection of the green management in construction organization are selected for the greening of this aspect; the operation and maintenance stage is mainly measured by three indicators of standard rate of domestic waste treatment, proportion of number of service personnel to the elderly residents, and per capita medical investment.

3. Evaluation Model

Evaluation model of endowment community's green level is constructed by combining with four weighting methods of AHP, ANP, entropy and maximum deviation (Li and Zhao, 2016). This model can effectively avoid the shortcomings of single weighting method in subjective and objective evaluation methods, and ensure the scientificity and rationality of evaluation results.

3.1. Normalization of Original Data

Setting x'_{ij} as the normalized value of x_{ij} ; x_{ij} is index j of endowment community i ; m represents the number of endowment communities. The indicators selected are all positive indicators, which can be standardized according to the positive scoring Formula (Wu et al., 2017):

$$x'_{ij} = \frac{x_{ij} - \min_{1 \leq i \leq m} (x_{ij})}{\max_{1 \leq i \leq m} (x_{ij}) - \min_{1 \leq i \leq m} (x_{ij})}. \quad (3.1)$$

3.2. Calculation of Combination Weights

1) Weight calculation by AHP

Analytic hierarchy process (AHP) is a method system suitable for the analysis of multi factor system with complex structure (Chiang, 2013). In this paper, 1 - 9 scale method is used to compare and judge the relative importance of each index in each level (Wu et al., 2017).

According to the expert opinion, the judgment matrix is constructed, and the weight a^s ($s = 1, 2, 3, 4, 5$) of the criterion layer s relative to the target layer is obtained, so is the weight b_j ($j = 1, 2, \dots, n$) of the index j to the criterion layer s . Then the weight of index j to the target layer is:

$$c_j = a^s \times b_j \quad (3.2)$$

where, the index weight vector is $c = \{c_1, c_2, \dots, c_n\}$.

After the judgment matrix is obtained, it needs to be tested for consistency. If the test passes, the weight distribution is reasonable. Otherwise, the judgment matrix will be reconstructed to calculate the weight. As AHP is widely used in the literature, the specific calculation process will not be described in detail.

2) Weight calculation by ANP

Analytic Network Process (ANP) is a kind of decision-making method, which is put forward in the 1990s (Theiben and Spinler, 2014). Its network structure is more complex than AHP. It has not only hierarchical structure, but also internal dependence and feedback structure. The specific steps are as follows:

a) Construction of comparative judgment matrix

Each scheme $U_i (i = 1, 2, \dots, n)$ gets the normalized matrix A according to ps criterion and the definition of judgment scale:

$$A = \begin{bmatrix} \frac{w_1}{w_1} & \frac{w_1}{w_2} & \dots & \frac{w_1}{w_m} \\ \frac{w_2}{w_1} & \frac{w_2}{w_2} & \dots & \frac{w_2}{w_m} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{w_m}{w_1} & \frac{w_m}{w_2} & \dots & \frac{w_m}{w_m} \end{bmatrix} = A(a_{ij})$$

where a_{ij} in the matrix represents the importance of U_i and U_j . And $a_{ji} = 1/a_{ij}$, the matrix of $n \times n$ needs to be judged $\frac{n(n-1)}{2}$ times in total, and the importance judgment of different factors needs to refer to the scale table of hierarchical comparison.

b) Calculation of weight vector

According to Formula (3.3), the set average value of judgment matrix is calculated, and $\bar{w} = (\bar{w}_1, \bar{w}_2, \dots, \bar{w}_n)^T$ is obtained, and normalizes it with Formula (3.4). Then, according to Formula (3.5), the maximum eigenvalue λ_{\max} of the judgment matrix is calculated, and finally, the consistency is checked according to Formula (3.6).

$$\bar{w}_i = \sqrt[n]{\prod_{j=1}^n a_{ij}}, i = 1, 2, \dots, n \quad (3.3)$$

$$w_i = \frac{\bar{w}_i}{\sum_{i=1}^n \bar{w}_i}, i = 1, 2, \dots, n \quad (3.4)$$

$$\lambda_{\max} = \sum_{i=1}^n \frac{A w_i}{n w_i} \quad (3.5)$$

$$C.I = \frac{\lambda_{\max} - n}{n - 1} \quad (3.6)$$

Generally, when $C.I \leq 0.1$, the judgment matrix is acceptable. The order and

consistency of the judgment matrix have the opposite trend, so the consistency index $C.I$ should be modified, and the average random consistency index $R.I$ should be used to adjust $C.I$. If $C.R \leq 0.1$, then the judgment matrix is unacceptable, it is necessary to calculate again, and finally get the consistency test results. Among them,

$$C.R = \frac{C.I}{R.I} \quad (3.7)$$

3) Weight calculation by entropy

Entropy method is a widely used objective weight calculation method (Huang et al., 2018). The smaller the value is, the greater the influence of the index on the decision-making results and the greater the weight distribution; the greater the information entropy is, the smaller the difference between the indexes is, and the smaller the weight is. According to the magnitude of entropy, namely the variation degree of each index, the weight of each index can be calculated. The main steps are as follows:

a) Index proportion:

$$f_{ij} = \frac{x_{ij}}{\sum_{i=1}^m x_{ij}} \quad (3.8)$$

x_{ij} is the initial value of index j of community i , $i = 1, 2, \dots, m$; $j = 1, 2, \dots, n$.

b) Index entropy:

$$e_j = -\frac{1}{\ln m} \sum_{i=1}^m f_{ij} \ln(f_{ij}) \quad (3.9)$$

e_j is entropy of index j and when $f_{ij} = 0$, $f_{ij} \ln f_{ij} = 0$.

c) Index weight:

$$\omega_j = \frac{1 - e_j}{\sum_{j=1}^n (1 - e_j)} \quad (3.10)$$

where ω_j is the weight of index j .

4) Weight calculation by maximum deviation method

The maximum deviation method is also an objective evaluation method. By calculating the proportion of the deviation of the index j in the total deviation of all indexes, the importance of the index is reflected (Li et al., 2018). The larger the proportion is, the more important the index is.

a) Set s_{pj} be the normalized value of index j of the object p , and w_j be the weight of index j . For indicator j , $H_{pj}(w)$ is used to represent the deviation between object P and other object indicator values, then:

$$H_{pj}(w) = \sum_{j=1}^m |s_{pj}w_j - s_{pk}w_j| \quad (3.11)$$

b) In terms of calculation index j , the total deviation between all objects and other objects:

$$H_j(w) = \sum_{p=1}^n \sum_{k=1}^n |s_{pj} - s_{pk}| w_j \tag{3.12}$$

c) According to the principle of maximum deviation, the optimization model is constructed:

$$\begin{aligned} \max H(w) &= \sum_{j=1}^m \sum_{p=1}^n \sum_{k=1}^n |s_{pj} - s_{pk}| w_j \\ \text{s.t.} \quad &\begin{cases} w_j \geq 0 \\ \sum_{j=1}^m w_j^2 = 1 \end{cases} \end{aligned} \tag{3.13}$$

d) The weight of the maximum deviation method is obtained by calculating the above model and normalizing it.

$$w_j = \frac{\sum_{p=1}^n \sum_{k=1}^n |s_{pj} - s_{pk}|}{\sum_{j=1}^m \sum_{p=1}^n \sum_{k=1}^n |s_{pj} - s_{pk}|} \tag{3.14}$$

5) Combination weight

Based on the above formula, the weight w_c ($c = 1, 2, 3, 4$) of each index is calculated in four ways, and then the combined weight is calculated (Zhao et al., 2018).

$$\omega_j = \sum_{c=1}^s \alpha_c w_c \tag{3.15}$$

where α_c is the combination weight coefficient, and $\sum_{c=1}^s \alpha_c = 1, c = 1, 2, 3, 4$.

w^T in Equation (3.16) is the transpose of combination weights. The evaluation score of greening degree of each community (Z) can be obtained by multiplying w^T and the normalization results of x_{ij} . Q_i ($i = 1, 2, 3, \dots, n$) is each community's evaluation score.

$$Z = W^T \times X = (Q_1, Q_2, Q_3, \dots, Q_n) \tag{3.16}$$

The following two factors need to be considered in determining the combined weight coefficient:

a) Ensure the minimum generalized distance between the weighted score of each evaluation object and the ideal point.

$$\min \sum_{i=1}^m d_i = \sum_{i=1}^m \sum_{j=1}^n \sum_{c=1}^s \alpha_c \omega_j^c (1 - Y_{ij}) \tag{3.17}$$

where, d_i is the generalized distance between the weighted score and the ideal point of each evaluation object; ω_j^c is the weight of index j under method c ; Y_{ij} is the standardized value of index j of community i .

b) Jaynes maximum entropy principle is introduced to reflect the consistency of the weight distribution results of each index, and the objective function is established based on the idea of minimizing the difference of weight distribution

results.

$$\max \beta = -\sum_{c=1}^z \alpha_c \ln \alpha_c \quad (3.18)$$

Objective function:

$$\begin{aligned} \min & \theta \sum_{i=1}^m \sum_{j=1}^n \sum_{c=1}^z \alpha_c \omega_j^c (1 - x_{ij}) + (1 - \theta) \sum_{c=1}^z \alpha_c \ln \alpha_c \\ \text{s.t.} & \sum_{c=1}^z \alpha_c = 1, \alpha_c \geq 0 \end{aligned} \quad (3.19)$$

Parameter θ ($0 \leq \theta \leq 1$) is the balance coefficient between two targets, generally $\theta = 0.5$.

c) The Lagrange function is constructed to solve the combined weight coefficient.

$$\alpha_c = \frac{\exp \left\{ - \left[1 + \theta \sum_{i=1}^m \sum_{j=1}^n \omega_j^c (1 - x_{ij}) / (1 - \theta) \right] \right\}}{\sum_{c=1}^z \exp \left\{ - \left[1 + \theta \sum_{i=1}^m \sum_{j=1}^n \omega_j^c (1 - x_{ij}) / (1 - \theta) \right] \right\}}. \quad (3.20)$$

4. Evaluating Greening Levels of China's Typical Endowment Communities

4.1. Selection of Evaluation Objects

With the rapid development of endowment industry, endowment community is rising rapidly in various cities in China (Sui et al., 2019), especially in coastal cities with good environment, pleasant climate and developed economy. According to the principles of typicality, difference, objectivity and availability, we choose Dalian Lechunxuan, Vanke Yiyuan, Ttaikangshen garden and Sanya Yishan County as the research objects to measure and evaluate the green degree of endowment community.

There are three reasons: First, the four communities have been put into operation, have made some achievements, and have a good influence in the local area; Second, the four communities are located in the coastal areas, respectively in the northern coastal area, the central coastal area and the southern coastal area, which are relatively comparable in the region; Third, the most important thing is that the relevant data of the four communities can be obtained by means of network query, document sorting and field research, which is also crucial to carry out this study.

4.2. Measurement Results

Taking 2017 as the research time, the original data of indicators in site selection criteria layer come from China Urban Statistical Yearbook (2018), and others are from field interviews. Equation (3.1) is used to normalize original data.

For indicators difficult to obtain data directly, such as the perfection of green

management in construction organization, green life care, green health care and other indicators, it is necessary to multiple experts' opinions. These indicators are evaluated by experts with seven different states, that is, "very low", "low", "relatively low", "medium", "relatively high", "high" and "very high", and then they are processed by triangular fuzzy function, shown in **Table 2**.

The main steps are as follows (Dutton, 1993):

If the number of experts is m , the probability of the index x_i in state j given by expert n can be transformed into triangular fuzzy number

$\tilde{Q}_{ij}^n = (A_{ij}^n, B_{ij}^n, C_{ij}^n), (n = 1, 2, 3, \dots, m)$. The arithmetic average method is adopted to integrate evaluation results of m experts, that is,

$\tilde{Q}_{ij}^* = \frac{Q_{ij}^1 \oplus Q_{ij}^2 \oplus \dots \oplus Q_{ij}^m}{m} = (A_{ij}^*, B_{ij}^*, C_{ij}^*)$. Then, the average area method is used

to solve the fuzzy problem, and the score of the index x_i in state j is:

$\tilde{Q}'_{ij} = \frac{A'_{ij} + 2B'_{ij} + C'_{ij}}{4}$. Finally, the accurate score obtained by normalization is

$$Q_{ij} = \frac{Q'_{ij}}{\sum Q'_{ij}}.$$

This study invited five experts from the fields of green development, environmental management, community management research and practice to assess the evaluation indicators of greening degree. Take Lechunxuan in Dalian evaluated by 5 experts as an example. The first expert rates the indicator "proportion of intelligent aging facilities" as "low", and the triangular fuzzy number is (0, 0.1, 0.3) according to **Table 2**; other four experts all assess this indicator as "medium", and its triangular fuzzy number is (0.3, 0.5, 0.7). Based on the above processing method, the triangular fuzzy number on this indicator of the five experts can be converted into an accurate value of 0.425. As shown in **Table 3**, the exact values of the subjective data indexes of four endowment communities can be obtained by this method.

The specific calculation process and results are as follows.

1) Weights calculation by AHP

Table 2. Semantic value of the event state probability and the corresponding triangle fuzzy number.

Probability range	Triangle fuzzy number	Presentation statement
<1%	(0.0, 0.0, 0.1)	very low
1% - 10%	(0.0, 0.1, 0.3)	low
10% - 33%	(0.1, 0.3, 0.5)	relatively low
33% - 66%	(0.3, 0.5, 0.7)	medium
66% - 90%	(0.5, 0.7, 0.9)	relatively high
90% - 99%	(0.7, 0.9, 1.0)	high
>99%	(0.9, 1.0, 1.0)	very high

Table 3. Conversion results of triangular fuzzy number for subjective data indicators.

Indicator	Community			
	Dalian	Qingdao	Shanghai	Sanya
Proportion of intelligent aging facilities	0.425	0.82	0.535	0.77
Proportion of green infrastructure	0.65	0.84	0.7	0.88
Proportion of 3R materials use	0.42	0.645	0.455	0.3
Utilization rate of green energy	0.12	0.425	0.54	0.265
Construction energy saving	0.65	0.685	0.715	0.425
Construction waste recycling rate	0.54	0.69	0.59	0.33
Utilization rate of energy-saving appliances	0.33	0.75	0.71	0.5
Perfection of green management in construction organization	0.3	0.43	0.33	0.29
Compliance rate of municipal solid waste treatment	0.3	0.5	0.54	0.43
Number of service personnel per household	0.67	0.8	0.75	0.84
Medical investments per capita	0.65	0.82	0.75	0.77

a) Five experts from the fields of environmental management, green development, pension industry and community management were invited to evaluate the relative importance of four criteria levels and 15 indicators, and the judgment matrix was obtained.

b) The weight of criterion layer relative to target layer is obtained. The consistency ratio of the judgment matrix is 0.0515, less than 0.1, which indicates that the weight distribution of the criterion layer has passed the consistency test. The consistency ratios of four criteria levels including site selection, design planning, construction and operation maintenance are 0.0439, 0.0596, 0.0967 and 0.0825, respectively, less than 0.1, indicating that the weight distribution of four criteria levels has passed the consistency test.

c) Bring the weights a^s and b_j into the Formula (3.2), and get the AHP weight c_j of the index, as shown in **Table 4**.

2) Weights calculation by ANP

a) According to experts' scores, a comparative judgment matrix is constructed.

b) The index weights are got by bringing the standardized data into Equation (3.4), as shown in **Table 4**.

3) Weights calculation by the entropy method

a) The index weights are obtained by taking the normalized data into Equation (3.8).

b) Carry the index weight into Formula (3.9) and Formula (3.10) to get the index weight of each index layer, as shown in **Table 4**.

4) Weights calculation by the maximum deviation method

Bring the standardized data into Equation (3.14) to get the weight of each index in the index layer, as shown in **Table 4**.

Table 4. Weights of evaluation indicators based on four weighting methods.

Indicator	AHP	ANP	Entropy method	Deviation maximization method	Combination weight
X11	0.0362	0.0887	0.0697	0.0622	0.0638
X12	0.0514	0.0119	0.0577	0.0641	0.0464
X13	0.0428	0.2502	0.0861	0.0647	0.1098
X14	0.0303	0.0119	0.0804	0.0665	0.0470
X21	0.0313	0.0510	0.0673	0.0734	0.0555
X22	0.0491	0.0785	0.0728	0.0737	0.0683
X23	0.0795	0.0510	0.0666	0.0633	0.0653
X24	0.0978	0.0510	0.0621	0.0690	0.0704
X31	0.0461	0.1191	0.0493	0.0637	0.0694
X32	0.0542	0.1118	0.0527	0.0641	0.0706
X33	0.0645	0.0426	0.0592	0.0715	0.0596
X34	0.1015	0.0314	0.1142	0.0656	0.0780
X41	0.0347	0.0380	0.0535	0.0672	0.0483
X42	0.1137	0.0314	0.0558	0.0673	0.0678
X43	0.1668	0.0314	0.0527	0.0637	0.0798

5) Combination weight

The weights of AHP, ANP, entropy method and deviation maximization method are brought into Formula (3.20) to obtain the combined weight coefficient. The combination weight of each index can be obtained by taking the combination weight coefficient into Formula (3.15), as shown in **Table 4**. The combination weights of criterion layers are listed in **Table 5**.

4.3. Evaluation and Discussion

The evaluation score of each community and each criterion layer can be obtained by taking the standardized data and combination weight coefficients of each index into Formula (3.16).

4.3.1. Endowment Communities' Greening Degrees

Figure 1 is the score result chart of four typical endowment communities in 2017. It can be seen that there was a significant difference in four greening degree scores. Among them, the greening degree score of Shanghai Shenyuan was 0.7809, the largest one, followed by Qingdao Yiyuan, Sanya Yishanjun and Dalian Lechunxuan. The score of endowment community in Dalian was only 0.2281, the smallest one.

From the overall level of four communities, the green development of endowment community in China is in the initial stage, and is actively exploring the paths. However, due to obvious regional characteristics of pension industry,

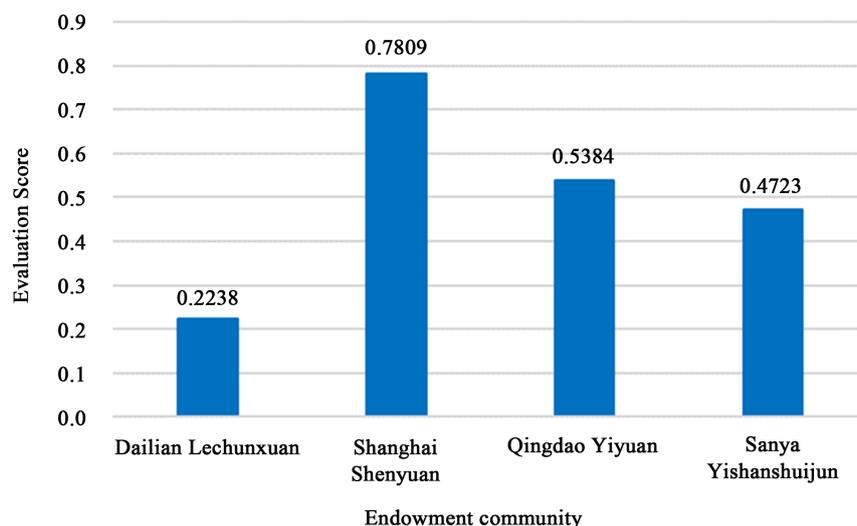


Figure 1. Score results of greening degrees of four endowment communities.

Table 5. Combination weights of criterion layers.

Criterion layer	Weight	Secondary criterion layer	Weight
Site selection (X1)	0.2670	Income level	0.0638
		Market demand	0.0464
Design planning (X2)	0.2595	Local ecological and natural environment	0.1568
		Completeness of basic supporting facilities	0.1238
		Green design of building materials	0.0653
		Clean energy use design	0.0704
Construction (X3)	0.2776	Degree of energy saving and consumption reduction	0.0694
		Degree of pollution reduction and efficiency enhancement	0.0706
		Use of green construction equipment	0.0596
Operation and maintenance (X4)	0.1959	Green management of construction organization	0.078
		Green operation management	0.0483
		Green elderly service management	0.1476

it is impossible to copy the successful experience directly. So the green development of endowment community should take into account economic, social and environmental characteristics of each region. For example, due to strong economic strength, high education level, complete infrastructure, and perfect corresponding standard system, endowment communities in Shanghai and other developed coastal cities have a rapid pace of greening development, which can serve as a demonstration for other regions. In 2017, per capita GDP of Shanghai was 124,600 yuan, about twice the national per capita GDP, which was significantly higher than that of Qingdao, Sanya and Dalian.

Qingdao and Dalian are actively improving the pension system, and commu-

nity care and medical service level. Under the leadership of mature green endowment communities, those ones in medium developed coastal areas can accelerate systematic, intelligent and green endowment system construction, and realize the rapid promotion of green retirement community. However, due to the economic fluctuation in recent years, the pension industry in Dalian has been affected to some extent. On the one hand, the slowdown in economic development has limited the number of elderly residents and their consumption capacities; On the other hand, it has affected the investment and construction of endowment community. The local economic environment is one key factor considered by investors and builders of endowment community.

Because of climate and environmental advantages, the construction of elderly communities in the southern coastal areas, such as Sanya, started earlier. However, their green development has been limited for the reasons of economic foundation, residents' quality, and infrastructure. So, the greening level of Sanya elderly community has not yet reached a high level.

4.3.2. Criterion Layers' Greening Degrees

Figure 2 is the average greenness score of each criterion layer for four endowment communities. As shown in the chart, the average score of site selection, design planning, construction, operation and maintenance was 0.4533, 0.5209, 0.5838 and 0.4462 respectively.

The average green degrees of two criteria layers including design planning and construction are greater than 0.5, and play positive roles in improving the greenness of endowment community. The result is inseparable from relevant policies of environmental protection and resource conservation issued in recent years. For instance, according to "Regulations on Management of Urban Construction Waste", the enterprise couldn't discard construction waste at will except obtaining approval from the environmental sanitation supervision department. For another example, the "Revolution Strategy for Energy Production and

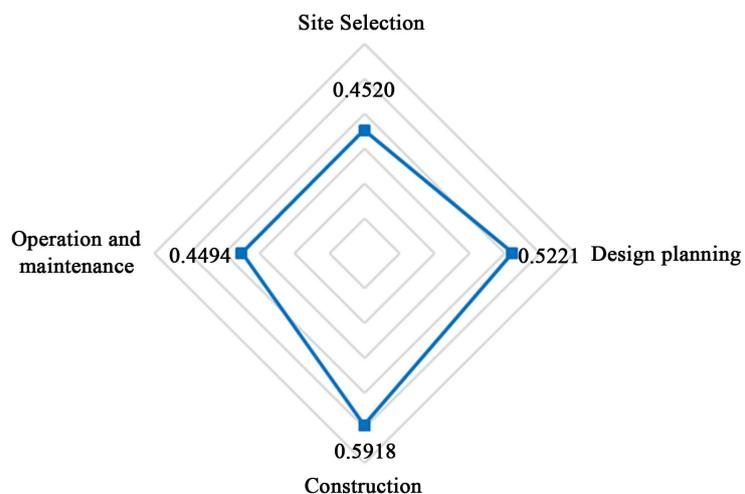


Figure 2. Overall development level of four criteria levels.

Consumption (2016-2030)” proposed that clean energy would become the main body of energy increase, energy structure adjustment makes significant progress, and non-fossil energy accounts for 15% by 2020. The introduction and implementation of related policies on energy conservation, waste recycling, and green infrastructure construction will help promote green development of China’s provinces, cities, and industries, as well as the greening level of elderly communities.

The average greening degrees of site selection and operation and maintenance are less than 0.5, which indicates that economic development, environmental governance and old-age service need to be further strengthened. Although the proportion of elderly population in China has gradually increased, the development of elderly community was slow, and difficult to meet the elderly need due to low economic investments and inadequate conditions of elderly communities. Facing the increasingly serious problems of resources and environment, Chinese government has continuously added investments in pollution control, resource efficiency, and green technology. In 2017, China’s total investment in environmental pollution treatment was 953.9 billion yuan, an increase of 7.2 times over 2001 and an average annual growth rate of 14.0%. It can be seen that China continues to make efforts to promote the coordinated development of social and economic development and the ecological environment, and lays a solid foundation for the future construction and development of elderly communities.

4.3.3. Comparative Analysis

According to measurement results of greenness degrees for four aging communities, a comparison chart is drawn as shown in **Figure 3**. As this chart shows, the greenness scores of design planning, construction, and operation and maintenance of Shanghai Shenyuan in 2017 were much higher than that of other three communities, and the score of site selection was lower; that of site selection

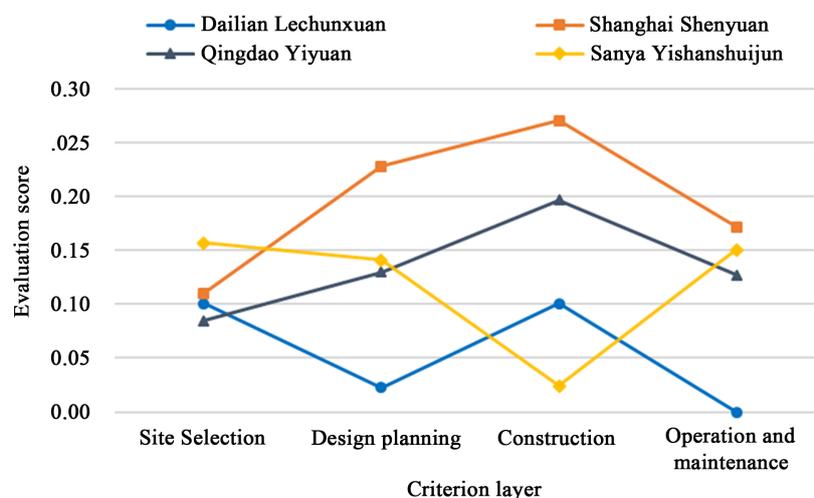


Figure 3. Comparative analysis of each criterion layer’s greening degree of each community.

in Qingdao Yiyuan was only 0.0846, lower than other three ones; that of site selection in Sanya Yishanshuijun was 0.1568, higher than other ones, while the score of construction was 0.0241, far from other three ones; that of Dalian Lechunxuan was relatively low, except for site selection, the scores of other three criteria layers were quite different from those of other communities.

Specifically, the green degree score of site selection for Sanya Yishanshuijun is higher than other three communities, and that of Qingdao Yiyuan is the lowest. This indicates that the environmental factors are the primary factor considered in the stage of site selection and project approval. Compared with Qingdao, Shanghai and Dalian, Sanya has regional advantages in climate and natural environment.

The green degree score of design planning in Shanghai Yiyuan has a significant advantage, and that of Dalian Lechunxuan is the smallest. The two communities of Qingdao Yiyuan and Sanya Yishanshuijun have comparable scores. This is closely related to economic basis and residents' quality. The higher local residents' education and quality level are, the higher their demands and awareness of environmentally friendly, cleaning and green products will be. Therefore, designers and planners need to focus on how to integrate green elements in pension communities.

At the criterion layer of construction, the greening degree of Shanghai Shenyuan is significantly higher than other three communities. The greenness score in the construction stage depends on the green integration of design planning phase on the one hand, and on the other hand, the capacity of energy conservation and emission reduction in the construction process.

The green degree of operation and maintenance in Shanghai Shenyuan is the highest, followed by Sanya Yishanjuan, Qingdao Yiyuan and Dalian Lechunxuan. The greening degree of this stage depends on qualities and skills of endowment community managers and servicers. The results show that endowment community in Dalian needs to strengthen environmental protection awareness and enhance service skills, so that the elderly truly felt the care and warmth of the family.

5. Conclusion

Combined with relevant index data, this paper applied the constructed evaluation index system and evaluation model to measure green degrees of four endowment communities in China. The empirical results are shown as follows:

- 1) From the overall level, the greening degree of Shanghai Shenyuan in 2017 was the highest, followed by Qingdao Yiyuan and Sanya Yishanshuijun and Dalian Lechunxuan. The average score of the construction criterion layer was the largest, followed by design planning, site selection, and operation and maintenance.

- 2) From the results of comparative analysis, the greenness scores of design planning, construction, and operation and maintenance of Shanghai Shenyuan

in 2017 were much higher than that of other three communities; that of site selection in Qingdao Yiyuan was lower than other three ones; that of site selection in Sanya Yishanshuijun was higher than other ones, while the score of construction was far from other three ones; except for site selection, that of other three criteria layers in Dalian Lechunxuan were significantly lower than other ones.

3) The green development of endowment community is affected by regional economic basis and ecological environment. Retirement communities in the southern coastal areas developed rapidly and had a high greening level. However, during the construction stage, waste management and energy consumption required effective governance and control. Because of favorable geographical locations, strong economic foundations and advanced technical level, the greening levels of retirement communities in eastern coastal areas have an absolute advantage. The greening degrees of elderly communities in the northern coastal areas are relatively low due to the limitation of economic level. At the same time, the backward medical service construction has an adverse effect on the development of the retirement community.

Although this paper has conducted a systematic research on greening degrees of endowment communities, there are some limitations. Firstly, the evaluation indicator system constructed in this paper is only applied in measuring greening levels of four communities in 2017, lacking a large amount of data to support. In future research, the time period will be expanded, and more data will be obtained to study the trend and characteristics of communities' greening degree. Secondly, the four endowment communities selected in this paper are all located in coastal areas, and the ones in inland and underdeveloped areas should be analyzed in future study. Due to the differences in economy, culture and custom and so forth, the green development of endowment communities will vary greatly. So, the next study should further add more communities in different regions to be evaluated.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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