

## Quantitative Evaluation of the Environmental Quality of New Rural Communities-a Case Study of Henan Province, China

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**Abstract:** The construction of new rural communities is an important measure to promote the integration of urban and rural areas. The environmental quality of new rural communities represents the residential suitability of the communities. The evaluation of the environmental quality can help promote the healthy development of new rural communities. The present study combines AHP (Analytic Hierarchy Process) and TOPSIS (Technique for Order Preference by Similarity to an Ideal Solution) for the evaluation and ordering of the environmental quality of 28 new rural communities in Henan Province, China. The AHP model containing four hierarchies is constructed: objective hierarchy, principle hierarchy, index hierarchy and factor hierarchy. The principle hierarchy is composed of 3 factors: social environment, material environment and ecological environment; the index hierarchy consists of 7 factors: service environment, civilized environment, planning environment, architectural environment, facility environment, greening environment, sanitation environment; the factor hierarchy consists of 14 factors: life service, health service, education degree, neighborhood relationship, spatial layout, functional layout, architectural style, architectural functions, infrastructure, public facilities, percentage of green open space, leisure and entertainment facilities, garbage treatment rate and wastewater treatment rate. By AHP model, the weight of the factors in every hierarchy is obtained and TOPSIS is employed for the ordering of the environmental quality of the 28 new rural communities. The results show: in the environmental evaluation, spatial layout, functional layout, architectural functions, infrastructure and neighborhood relationship have a relatively higher weight and more importance should be attached to these respects. The ordering of environmental quality of new rural communities has a high discrimination. The five communities with the highest environmental quality (representing 17.8% of the total communities) are R<sub>13</sub>, R<sub>6</sub>, R<sub>24</sub>, R<sub>23</sub> and R<sub>28</sub>. The result can effectively reflect the environmental quality of new rural communities. On the one hand, this result can provide the basis for the transform and restructuring of the existing communities; on the other hand, it can be used as the reference for the quality control of newly-built communities, so that the objectives of new rural community construction will be met.

**Keywords:** AHP, environmental quality, evaluation, new rural communities, TOPSIS

### INTRODUCTION

The planned economic system that was once implemented in China for a long period resulted in a dual structure of urban development: urban and rural areas have been confined to be a closed unit. The rural areas are retarded in the economic, social, infrastructure and cultural aspects compared to the cities. During the transform from planned economic system to market economy, the dual structure seriously impedes the development of urban and rural areas. The integration of urban and rural areas to promote the development of rural areas is an important measure in the context of coordinated development of urban and rural areas in China in new period (Zhen-Long, 2012). In 2005, the Chinese government launched the new rural area development strategy: completely transforming the underdeveloped rural areas through the construction of new rural areas, as part of the efforts to facilitate the

modernization of agriculture. The construction of new rural communities is crucial to the elevation of rural residents' living quality and the residential suitability of rural areas. It is directly related to the health and the welfare of the rural residents. Therefore, how to scientifically evaluate the environmental quality of rural communities becomes a research subject of practical significance, especially to the standardization of the construction of new rural communities.

At present, the research on the quality of community environment in China is mostly focused on the urban communities. Yuan Lingling conducted research on the comprehensive evaluation of the living environmental quality of communities based on AHP method (Ling-Ling *et al.*, 2004). Sha constructed the environmental evaluation index system for the ecological community construction strategy, but they did not give the applicable and concrete evaluation methods (Jing-Jing and Xue-Hua, 2007). Zhuang

established the cognitive evaluation index system for health environmental quality of communities (Zhuang *et al.*, 2001). Sun established the environmental evaluation model for urban communities from the perspective of physical environment (Sun *et al.*, 2008). The research on the environmental quality of new rural communities is rare. Zhu Bing utilized entropy method for the evaluation of the rural living environmental quality of Jiangsu Province from the four aspects: living environmental system, infrastructure system, public service system and ecological environmental system (Bin and Xiao-Dong, 2011). Hao Ying-qun studied the evaluation methods of rural environmental quality from the perspectives of air environment, water environment, soil environment and ecological environment (Ying-Qun *et al.*, 2011).

Quantitative evaluation methods have a large application perspective in environmental quality evaluation. Multiple regression analysis (Li-Fang *et al.*, 2009), fuzzy clustering, Fuzzy-Topsis (Anjali *et al.*, 2011), principle component analysis and hierarchical analysis (Kung-Jen and Li-Ting, 2008) are the main research methods used abroad. Hierarchical analysis is a decision-making technique combining quantitative evaluation and qualitative evaluation (Jian-Guo *et al.*, 2007). It is widely applied in economic management (Ming-Chyuan *et al.*, 2008), city planning, scientific research evaluation, project selection (Morteza, 2010), etc. TOPSIS is short for technique for order preference by similarity to ideal solution (Irfan and Nilsen, 2009). It is a technique for the ordering of a limited number of evaluation objects by their similarity with the ideal solution. Its main principle is the ordering of evaluation objects based their distance to the ideal solution and the worst solution. If an object is the nearest to the ideal solution and the farthest from the worst solution, this object is the optimal; otherwise, it is the worst. The combined application of hierarchical analysis (Melissa

*et al.*, 2012) and TOPSIS has a great potential in the environmental quality evaluation of new rural communities. The present study establishes an environmental evaluation model of new rural communities based on AHP-TOPSIS.

## RESEARCH AREA AND RESEARCH METHODS

**Research area sampling:** Henan Province is situated in the center of China. As one of the main crop production regions in China, it has a total area of 160000 km<sup>2</sup> and a population of 100 million. For a long time, the urban-rural dual system of Henan Province has impeded the development of rural areas. The urbanization level is low and the economy is undeveloped. In order to promote the development of new rural areas, Henan Province implemented the Planning Outline of New Rural Areas 2006-2020, which marked the beginning of the accelerating construction of new rural communities. The samples of new rural communities selected are located in 17 cities in Henan (Fig. 1). The samples include: Suzhuang village community of Anyang (R<sub>1</sub>); Xixinzhuang village community of Puyang (R<sub>2</sub>); Gangpo village community (R<sub>3</sub>) and Hekou village community (R<sub>4</sub>) of Hebi; Liuzhuang community (R<sub>5</sub>), Guguzhai new village community (R<sub>6</sub>) and Gengzhuang community (R<sub>7</sub>) of Xinxiang; Hantai village community of Jiaozuo (R<sub>8</sub>); Liaowu new living community (R<sub>9</sub>), Nanshan Garden community (R<sub>10</sub>) and Lianshui Garden community (R<sub>11</sub>) of Jiyuan; Yingtaogou community (R<sub>12</sub>), Madu community (R<sub>13</sub>) and Nanyangzhai village community (R<sub>14</sub>) of Zhengzhou; Qiliwan village community of Kaifeng (R<sub>15</sub>), Baima Temple village community of Luoyang (R<sub>16</sub>); Yaojia village community (R<sub>17</sub>), Changzhai village community (R<sub>18</sub>), Dongmingyi village community (R<sub>19</sub>) and Luma village community (R<sub>20</sub>) of Xuchang; Nanjie village



Fig. 1: Position of Henan Province, China and the cities under the administration of Henan Province

Table 1: The meaning of relative importance

Scale	Significance
1	The two factors have the same importance in comparison.
3	The latter is a little more important than the former in comparison.
5	The latter is significantly more important than the former in comparison.
7	The latter is highly significantly more important than the former in comparison.
9	The latter is extremely more important than the former in comparison.
2, 4, 6, 8	The intermediate points of every two adjacent judgments above.
Reciprocal	If the importance rate of i and j is $\alpha_{ij}$ , then the importance rate of j and i is $\alpha_{ji} = 1/\alpha_{ij}$ .

Table 2: Average Random Index (R. I.)

Matrix order	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
R. I.	0	0	0.52	0.89	1.12	1.26	1.36	1.41	1.46	1.49	1.52	1.54	1.56	1.58	1.59

community (R<sub>21</sub>) and Xipoli community (R<sub>22</sub>) of Luohe; Qianwangzhuang community (R<sub>23</sub>) of Pingdingshan; Yadi village community of Sanmenxia (R<sub>24</sub>); Xionglou village community of Shangqiu (R<sub>25</sub>); Liyangnan community of Nanyang (R<sub>26</sub>); Sanlihe Liuzhuang village community (R<sub>27</sub>); Jiangwan village community (R<sub>28</sub>) of Xinyang.

**Research methods:** The environmental quality evaluation of new rural communities follows the following steps:

- Screen the key factors that have an influence on the environmental quality of new rural communities.
- Establish AHP model to determine the weight of every influential factors.
- Establish the set of comments and collect the data on influential factors of the environmental quality of the communities.
- Order the new rural communities by environmental quality using TOPSIS.

The details of each step are as follows:

**Step 1:** Construct standardized data matrix

Suppose there are N objects to be evaluated and for every object there are M indexes. Which form the characteristic matrix of evaluation index:

$$A = (a_{ij})_{n \times m} \tag{1}$$

**Step 2:** Determine the composite weight of every factor:

- **Calculate the weight:**
  - Establish the hierarchical structure model.
  - Compare the importance of every two factors in the same hierarchy in relation to a certain principle of immediately upper hierarchy and construct the judgment matrix (1-9 scale) (Table 1).
  - Calculate the relative weight of the factors in comparison with respect to the principle based on the judgment matrix.
  - Calculate the composite weight of the factors in every hierarchy with respect to the system objective and order the factors:

$$\omega_j = \frac{\sum_{j=1}^n a_{ij}}{n \sum_{k=1}^n \sum_{j=1}^n a_{kj}} \quad j = 1, 2, \dots, m \tag{2}$$

- **Calculate the consistency proportion:**
  - Calculate the maximum characteristic root  $\lambda_{\max}$ :

$$\lambda_{\max} = \sum_{i=1}^n \frac{(AW)_i}{n\omega_i} = \frac{1}{n} \sum_{i=1}^n \frac{\sum_{j=1}^n a_{ij}\omega_j}{\omega_i} \tag{3}$$

- Calculate the consistency index C. I.:

$$C.I. = \frac{\lambda_{\max} - n}{n - 1} \tag{4}$$

- Search for the corresponding average random index R. I. (Table 2)
- Calculate the consistency ratio C. R.:

$$C.R. = \frac{C.I.}{R.I.} \tag{5}$$

When C.R.<0.1, it is believed that the consistency of the judgment matrix is acceptable; when C.R.≥0.1, necessary correction should be made to the judgment matrix.

**Step 3:** Construct the weighted matrix

From A, the standardized matrix Z' and the weighted matrix Z can be constructed, their factors being respective. Z'<sub>ij</sub> and Z<sub>ij</sub>:

$$Z_{ij} = \omega_j Z'_{ij} \quad (i = 1, 2, \dots, n; \quad j = 1, 2, \dots, m) \tag{6}$$

**Step 4:** Determine the ideal solution and negative ideal solution of the objects

Suppose that J represents the object set which is better if larger; J' represents the object set which is better if smaller, then:

$$\begin{aligned} Z^* &= (\max Z_{ij} | j \in J, \min Z_{ij} | j \in J') = (Z_1^*, Z_2^*, \dots, Z_m^*) \\ Z^- &= (\min Z_{ij} | j \in J, \max Z_{ij} | j \in J') = (Z_1^-, Z_2^-, \dots, Z_m^-) \end{aligned} \tag{7}$$

Table 3: The AHP model for the environmental quality evaluation of new rural communities

Objective hierarchy (A)	Principle hierarchy (B)	Index hierarchy (C)	Factor hierarchy (D)	Explanation
Community Environment (CE)	Social Environment (SOE)	Service Environment (SEE)	Live Service (LS)	The perfection degree of daily life service
			Public Security Service (PSS)	The perfection degree of public security in the community
		Civilized Environment (CE)	Education Degree (ED)	Education degree of community residents
			Neighborhood Relationship (NR)	Degree of harmony between neighbors
	Material Environment (ME)	Planning Environment (PE)	Spatial Layout (SL)	Reasonability of the spatial layout of community
			Functional Layout (FL)	Reasonability of the functional layout of the community
		Architecture Environment (AE)	Architectural Style (AS)	The unity of the architectural style in the community
			Architectural Functions (AF)	The applicability of the architecture in the community
		Facility Environment (FE)	Infrastructure (IN)	The perfection degree of the infrastructure in the community
			Public Facilities (PF)	The perfection degree of school, healthcare service and body-building facilities in the community
	Ecological Environment (EE)	Greening Environment (GE)	Percentage of Green Open space (PGOA)	Percentage of green open space in the community
			Leisure and Entertainment Facilities (LEF)	The quality of leisure and entertainment facilities
		Sanitation Environment (SE)	Garbage Treatment Rate (GTR)	Garbage treatment rate in the community
			Wastewater Treatment Rate (WTR)	Centralized wastewater treatment rate in the community

Table 4: The scoring results of the factors in the factor hierarchy

	LS	PSS	ED	NR	SL	FL	AS	AF	IN	PF	PGOA	LEF	GTR	WTR
R <sub>1</sub>	8.5	8.9	4.8	8.8	7.6	8.5	8.4	9.4	8.8	7.8	0.13	4.7	0.90	0.90
R <sub>2</sub>	7.3	7.4	5.7	9.2	8.2	8.0	7.9	7.0	7.9	9.6	0.24	8.4	0.85	0.96
R <sub>3</sub>	9.7	6.8	4.0	7.6	9.5	9.2	9.4	8.5	9.5	7.2	0.19	5.6	0.87	0.87
R <sub>4</sub>	8.2	9.3	3.9	7.8	7.8	8.8	9.2	7.6	9.1	6.9	0.17	6.7	0.92	0.91
R <sub>5</sub>	5.9	8.7	6.2	7.2	9.4	9.1	7.6	9.4	8.4	9.4	0.23	9.0	0.84	0.89
R <sub>6</sub>	6.7	9.0	5.6	9.7	8.5	8.4	8.1	8.8	8.9	8.6	0.31	7.6	0.86	0.85
R <sub>7</sub>	8.4	6.1	4.7	8.6	7.1	9.0	6.9	7.6	9.3	7.0	0.26	4.3	0.90	0.94
R <sub>8</sub>	7.0	7.2	6.8	7.5	8.6	8.2	7.7	9.1	7.5	9.4	0.18	5.6	0.84	0.98
R <sub>9</sub>	6.8	8.8	3.8	8.2	9.5	8.9	9.4	7.5	9.8	8.1	0.20	9.1	0.76	0.86
R <sub>10</sub>	9.2	7.4	4.2	6.9	8.4	7.5	9.8	9.0	9.1	7.9	0.30	8.5	0.88	0.97
R <sub>11</sub>	7.8	7.9	5.1	7.6	7.6	8.3	8.4	8.6	8.6	6.8	0.34	7.4	0.92	0.99
R <sub>12</sub>	6.4	9.9	5.3	8.4	6.9	7.3	9.6	7.4	9.2	9.5	0.14	7.9	0.87	1.00
R <sub>13</sub>	7.2	9.4	6.0	9.8	9.8	8.4	7.9	9.2	8.0	7.6	0.26	6.4	0.89	0.94
R <sub>14</sub>	8.8	8.7	5.4	7.0	9.5	8.7	6.4	8.9	9.6	8.4	0.18	2.8	0.96	0.87
R <sub>15</sub>	6.9	9.0	4.9	8.5	8.7	9.0	8.9	7.0	7.1	9.4	0.24	7.9	0.85	0.93
R <sub>16</sub>	7.3	8.4	4.5	9.4	8.6	7.8	7.5	8.1	8.6	7.6	0.16	6.7	0.78	0.92
R <sub>17</sub>	8.4	7.5	4.8	7.1	9.0	8.5	8.9	9.6	9.4	9.0	0.25	4.5	0.93	0.84
R <sub>18</sub>	9.5	6.2	6.1	6.4	7.2	8.7	9.8	7.2	9.0	6.4	0.32	9.3	0.82	0.93
R <sub>19</sub>	9.6	7.6	5.4	7.6	6.7	7.9	8.1	8.9	8.6	7.9	0.17	8.8	0.90	0.98
R <sub>20</sub>	8.1	7.9	4.9	9.4	6.9	8.4	7.6	9.1	8.9	9.3	0.25	7.4	0.96	0.85
R <sub>21</sub>	7.9	9.4	5.0	8.9	9.3	7.6	7.1	8.0	9.2	7.3	0.19	6.2	1.00	0.94
R <sub>22</sub>	7.8	8.6	8.4	7.4	8.2	8.5	9.4	7.5	7.8	8.1	0.27	4.9	0.94	0.90
R <sub>23</sub>	7.7	9.4	5.8	7.9	9.1	8.6	7.8	9.1	9.4	9.1	0.19	6.4	0.98	0.88
R <sub>24</sub>	9.6	7.3	4.5	9.4	8.8	9.4	9.2	8.8	8.6	8.0	0.26	7.3	0.86	0.92
R <sub>25</sub>	8.7	9.0	5.1	9.2	7.6	8.7	7.5	8.4	8.9	7.2	0.24	8.1	0.90	0.93
R <sub>26</sub>	5.9	7.8	4.7	8.7	7.0	6.8	8.0	9.5	9.6	6.9	0.19	4.9	0.79	0.98
R <sub>27</sub>	8.2	8.6	3.9	7.9	8.9	9.0	9.2	7.6	8.2	8.4	0.23	6.8	0.87	0.91
R <sub>28</sub>	7.0	9.0	6.2	9.8	9.4	8.2	7.3	8.1	9.0	7.6	0.18	7.0	0.90	0.88

**Step 5:** Calculate respectively the Euclid distance from the object to ideal solution  $S_i^*$  and to negative ideal solution  $S_i^-$ :

$$S_i^* = \sqrt{\sum_{j=1}^m (Z_{ij} - Z_j^*)^2} \quad S_i^- = \sqrt{\sum_{j=1}^m (Z_{ij} - Z_j^-)^2} \quad (8)$$

**Step 6:** Calculate the relative similarity of every project to the ideal solution:

$$C_i^* = \frac{S_i^-}{S_i^* + S_i^-} \quad 0 \leq C_i^* \leq 1 (i=1,2,\dots,n) \quad (9)$$

Table 5: Weights of the influential factors in every hierarchy in relation to the immediately upper hierarchy and the weights of the factors with respect to the objective hierarchy

Projective hierarchy (A)	Principle hierarchy (B)	Weight of the hierarchy	Index hierarchy (C)	Weight of the hierarchy	Factor hierarchy (D)	Weight of the hierarchy	Composite weight
CE	SOE	0.3229	SEE	0.5167	LS	0.4167	0.0496
			CIE	0.4834	PSS	0.5833	0.0784
	ME	0.5402	PE	0.5217	EL	0.2250	0.0298
			AE	0.2180	NR	0.7750	0.1031
			FE	0.2603	SL	0.5834	0.1842
			GE	0.4584	FL	0.4167	0.1302
			SE	0.5417	AS	0.1715	0.0225
			EE	0.1370	BUF	0.8286	0.1100
	EE	0.1370	GE	0.4584	BAF	0.7917	0.1237
					CF	0.2084	0.0319
GAR					0.7750	0.0485	
RA					0.2250	0.0140	
EE	0.1370	SE	0.5417	GTR	0.3750	0.0271	
				STR	0.6250	0.0470	

**Step 7:** Order the evaluation objects by the relative similarity.

### THE ENVIRONMENTAL QUALITY EVALUATION MODEL FOR NEW RURAL COMMUNITIES

**Establish the evaluation model and judgment criteria:** The focus of the construction of new rural areas is five "new": new houses, new facilities, new environment, new peasants and new customs (Zhang, 2011). The choice of the factors in the environmental quality evaluation of new rural communities should conform to the essential requirements of the development of new rural communities. The factors are ordered based on their occurrence frequency in literature. The concerns of community residents are surveyed. The factors are finally selected by experts according to the criteria that the influential factors can reflect the essential requirements of the environmental quality of new rural communities. The AHP model containing four hierarchies, objective hierarchy, principle hierarchy, index hierarchy and factor hierarchy, is established (Table 3).

**Establish the set of comments of evaluation factors:** Establish the set of comments. The evaluation of the factors in the factor hierarchy obeys the criteria as follows: the measured percentage of green open space, garbage and wastewater treatment rates (percentage). Life service, public security service, spatial layout, functional layout, architectural style, infrastructure, public facilities, leisure and entertainment facilities and neighborhood relationship are scored by experts based on set of comments (0<very poor≤2, 2<poor≤4, 4<ordinary≤6, 6<good≤8, 8<very good ≤10). The average is taken as the final result. The education degree is scored according to the survey (not educated = 2, primary school = 4, junior high school = 6, high school = 8, college and above = 10). The average is taken as the final result. These factors are factors that are better if higher, i.e., the higher the score, the better.

Experts from Henan Agricultural University, Henan Science and Technology University, Henan Institute of Science and Technology and Xinxiang Planning Bureau were invited for the scoring (Table 4). The calculation is done by the Yaahp and DPS software and the data are automatically normalized by the software.

**Weight calculation:** According to step 1-2, experts compare the importance of every two influential factors for every hierarchy. On the premise of passing the consistency test, the weight of the influential factors in every hierarchy in relation to the immediately upper hierarchy is obtained and the weight of factors with respect to the objective hierarchy (Table 5).

### RESULT ANALYSIS AND DISCUSSION

**Weight of influential factors:** From Table 5, by a decreasing weight we have the following arrangement: material environment>social environment>ecological environment. This indicates that the rural communities in China lack unified planning and urgently need high-quality material construction to improve the environmental quality of rural communities. In the overall ordering of the factors in factor hierarchy by weight, spatial layout, functional layout, infrastructure, architectural functions and neighborhood relationship have a higher weight, which should be put in an important place in the environmental construction of new rural communities. But this does not mean that the role of other factors can be played down. Only by comprehensive consideration with a priority can sustain the healthy development of new rural communities. In addition, with the development of the society and the changes in the cognition, the weight distribution of these factors will change as well. For example, the construction of leisure and entertainment facilities which is very important in urban communities does not draw enough attention in the construction of new rural communities (Ross *et al.*, 2005, 2009).

The choice of evaluation indexes can directly influence the weight distribution of the evaluation

Table 6: Ordering by Euclid distance, the closeness to ideal solution

SN	S*	S <sup>-</sup>	C <sub>i</sub>	Order	SN	S*	S <sup>-</sup>	C <sub>i</sub>	Order
R <sub>1</sub>	0.0141	0.0128	0.4762	20	R <sub>15</sub>	0.0130	0.0139	0.5174	15
R <sub>2</sub>	0.0135	0.0119	0.4682	21	R <sub>16</sub>	0.0127	0.0130	0.5050	16
R <sub>3</sub>	0.0115	0.0167	0.5921	11	R <sub>17</sub>	0.0106	0.0156	0.5939	9
R <sub>4</sub>	0.0142	0.0120	0.4588	23	R <sub>18</sub>	0.0167	0.0123	0.4240	25
R <sub>5</sub>	0.0103	0.0166	0.6161	6	R <sub>19</sub>	0.0173	0.0099	0.3631	28
R <sub>6</sub>	0.0088	0.0164	0.6514	2	R <sub>20</sub>	0.0144	0.0131	0.4762	19
R <sub>7</sub>	0.0156	0.0121	0.4353	24	R <sub>21</sub>	0.0107	0.0157	0.5936	10
R <sub>8</sub>	0.0136	0.0119	0.4662	22	R <sub>22</sub>	0.0127	0.0126	0.4992	17
R <sub>9</sub>	0.0110	0.0169	0.6062	7	R <sub>23</sub>	0.0095	0.0161	0.6302	4
R <sub>10</sub>	0.0127	0.0136	0.5175	14	R <sub>24</sub>	0.0092	0.0166	0.6443	3
R <sub>11</sub>	0.0131	0.0129	0.4962	18	R <sub>25</sub>	0.0119	0.0137	0.5350	13
R <sub>12</sub>	0.0177	0.0110	0.3817	27	R <sub>26</sub>	0.0171	0.0115	0.4010	26
R <sub>13</sub>	0.0080	0.0189	0.7039	1	R <sub>27</sub>	0.0114	0.0141	0.5513	12
R <sub>14</sub>	0.0109	0.0166	0.6033	8	R <sub>28</sub>	0.0099	0.0168	0.6284	5

indexes. In the future research, the indexes should be further screened, to reduce the index amount so that the model is simpler and easier for application. The academic knowledge and practical experience of experts have important impact on the results of weight distribution. Properly increasing the number of experts can help increase the reliability of the evaluation result.

**Comprehensive evaluation and ordering:** According to step 3-4, since the unit of every factor in the factor hierarchy is different, the data with a dimension must be non-dimensionalized for the calculation. After the normalization of the data on the factors in the factor hierarchy, the composite weight is calculated to obtain the ideal solution  $Z^*$  and negative ideal solution  $Z^-$ :

$$Z^* = (0.0114, 0.0176, 0.0089, 0.0229, 0.0406, 0.0274, 0.0050, 0.0237, 0.0260, 0.0071, 0.0135, 0.0035, 0.0058, 0.0097)$$

$$Z^- = (0.0070, 0.0109, 0.0040, 0.0150, 0.0278, 0.0199, 0.0032, 0.0173, 0.0188, 0.0047, 0.0052, 0.0011, 0.0044, 0.0081)$$

The ideal solution  $Z^*$  is the optimal environmental quality in these communities, with every factor reaching the optimum; the negative ideal solution  $Z^-$  is the worst environmental quality that can be conceived in the communities, with every factor reaching the worst.

According to step 5, the distance between the environmental quality to ideal solution and negative ideal solution is calculated, respectively. The distance to the ideal solution  $Z^*$  is  $S^*$ , while the distance to the negative ideal solution  $Z^-$  is  $S^-$  ( $S^*$  is the similarity of every object to the ideal solution. The smaller the value, the closer the distance to the ideal solution of the community environment is and the better the construction scheme is). According to step 6, the closeness degree  $C_i$  to the ideal solution is calculated. When  $C_i = 0$ ,  $Z_i = S^-$ . This shows that the environment of the community is the worst; when  $C_i = 1$ ,  $Z_i = S^*$ . Then the environment of the community is the best. In actual environmental evaluation of communities, the

occurrence possibility of the best or the worst environmental quality is extremely rare.

The principle of the ordering of the construction schemes is to compare the environmental quality with the ideal solution or the worst solution. The communities are ordered by environmental quality based on the  $C_i$  value. If the environmental quality of a community is the closest to the ideal solution and the farthest from the negative ideal solution, its environmental quality is the best in all communities.

From the  $C_i$  value of the environmental quality of the 28 communities and their ordering, it can be seen that great difference exists among the communities (Table 6). Ordering by Euclid Distance, the closeness to ideal solution). Based on this, a preliminary judgment can be made on the environmental quality distribution of new rural communities. The five communities with the highest closeness degree are  $R_{13}$ ,  $R_6$ ,  $R_{24}$ ,  $R_{23}$  and  $R_{28}$ , which represent 17.8% of the total samples. In particular,  $R_{13}$  has the highest score in environmental quality. The high scores of the factors with higher weights contributed to the No. 1 ranking of  $R_{13}$ . In addition, other factors also have balanced scores and the construction of  $R_{13}$  satisfies the long-term requirements of the community development. Therefore,  $R_{13}$  has a strong competitiveness. The construction scheme also has shortcomings.  $R_{13}$ 's scores on EL and RA are not high, which should be enhanced in the transform and restructuring. The community samples with high environmental quality can serve as a reference for the government to lay down the criteria for the construction of new rural areas.

## CONCLUSION

- The environmental evaluation system of new rural communities contains four hierarchies: the objective hierarchy has one factor, i.e., environmental quality; the principle hierarchy has three factors; the index hierarchy has 7 factors; the factor hierarchy has 14 factors.
- In the overall ordering by weight, spatial layout, functional layout, architectural function, infrastructure, architectural functions and neighborhood relationship have a higher weight,

with an important influence on the environmental quality of new rural communities.

- Through the construction of AHP model, the evaluation and ordering of the new rural communities by environmental quality is performed. The ordering results reflect the environmental quality of new rural communities. On the one hand, this result can provide the basis for the transform and restructuring of the existing communities; on the other hand, it can be used as the reference for the quality control of newly-built communities, to achieve the objectives of new rural community construction.

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