

Scales, methods and technical analysis of China's residential environment evaluation

Li Sui^{1,2,3} Shi Tiemao² Zhou Le⁴

(¹Institute of Applied Ecology, Chinese Academy of Sciences, Shenyang 110016, China)

(²School of Architecture and Urban Planning, Shenyang Jian Zhu University, Shenyang 110168, China)

(³Graduate University, Chinese Academy of Sciences, Beijing 100049, China)

(⁴School of Architecture and Civil Engineering, Shenyang University, Shenyang 110044, China)

Abstract: To improve China's residential environment evaluation system and enhance its guiding role, current research results are analyzed and summarized from three aspects including research scales, evaluation methods and applied technology by means of comparison, induction and empirical application. The guiding role of the current macro-scale evaluation system of urban planning and construction is generally not obvious, whereas the guiding role of medium and micro-scale systems to the improvement of residential environments is improving. There are diversified methods for determining the threshold values and the weights of indices in China's evaluation system. For instance, the analytic hierarchy process (AHP) method is adopted to determine the weights of indices. The advantages and disadvantages of the method are analyzed on the basis of empirical calculation. In the course of comprehensive analyses, a nonlinear model can reflect interactions among indices more than a linear model; the evaluation model under the ARCGIS platform prevails since it combines space and attribute, and it has intuitive results. So far, the methodological system of China's residential environment evaluation has not been established; its subject coverage and research category should be expanded, and its guiding role should be enhanced.

Key words: residential environment; evaluation system; scale; threshold value; weight; evaluation model; geographic information system (GIS)

Being one of the most important human activities, place of residence constitutes the most widely distributed man-made environment in the world^[1]. With increasingly severe global crises in ecology and the environment, people start reviewing their own residential environments. China's research on residential environment evaluation began in the 1990s, and Wu^[2] first laid the theoretical foundation of the sciences of human settlements, and carried out empirical studies. Related researches in China mainly focus on such fields as ecology, geography, urban planning and architecture. In recent years, cross-disciplinary research has become a new trend, and the technical methods of evaluation are more diversified and richer. The development situation of China's residential environment evaluation system is analyzed from three aspects including research scales, evaluation

methods and applied technology, and its development direction is put forward based on the discussion of its advantages and disadvantages.

1 Different Research Scales of Evaluation System

1.1 Macro-scale

In terms of its research scale, residential environment evaluation is divided into macro, medium and micro levels. Besides, there are differences in the evaluation contents concerned^[3]. The space extension of macro-scale research mainly regards regions and cities as units, and its evaluation content includes not only various natural and man-made material elements, but also non-material elements related to society, economy and culture. These non-material elements become important indices influencing the residential environment. Accordingly, an overall evaluation of comprehensive macro residential environment can be achieved only when an objective evaluation is combined with a subjective evaluation, and some econometric analyses are made. Taking Zhang's^[4] Hangzhou-based empirical work, for example, he and his companion carried out an objective element evaluation based of the GIS grid data and a subjective element evaluation of the urban data and conducted a questionnaire survey, and then obtained comprehensive results through a combination of the two evaluations. On the whole, China's macro-scale evaluation system plays a weak role in guiding urban planning practice, lacking specific countermeasures to implement its evaluation results on the factors of space level. Recently, some urban planning scholars have begun to pay attention to analysis methods for the macro evaluation of residential environments, providing a new ideal for urban planning. In 2008, Yu and Zhou^[5] broke down the restrictions of administrative divisions and proposed a concept of minor watershed "human residential ecological units" and evaluation methods based on the geomorphology of the Loess Plateau. They solved the problems related to urban planning by landscape ecology and geography.

1.2 Medium-scale and micro-scale

Medium-scale research takes communities and quarters as a category on which to build its evaluation framework^[6-7], and the internal environment of dwelling spaces is micro-scale. The book, *Technical appraisal handbook for ecological residences in China*, published in 2001, is the first evaluation book in mainland China, which includes medium and micro evaluations of the building environment in residential communities. In almost ten years since then, many books related to evaluation systems have been published. Compared

Received 2008-11-03.

Biographies: Li Sui (1977—), male, graduate, lecturer; Shi Tiemao (corresponding author), male, professor, tiemaos@sjzu.edu.cn.

Foundation items: The National Key Technology R&D Program during the 11th Five-Year Plan (No. 2006BAJ11B04-2), the Soft Science Project of the Ministry of Construction of China (No. 2008-R2-25).

Citation: Li Sui, Shi Tiemao, Zhou Le. Scales, methods and technical analysis of China's residential environment evaluation [J]. Journal of Southeast University (English Edition), 2009, 25(2): 274 – 277.

with macro-scale research, medium and micro-scale evaluation systems play an increasingly strong guiding role in improving residential environments. The main reasons are listed as follows. First, stimulated by economic growth, the housing industry is developing rapidly, which facilitates the research of residential environment evaluations. Secondly, it is easy to quantitatively control the evaluation index as the evaluation content within smaller space extension is specific, and the national industry code is available to provide ref-

erence standards for evaluation. Three representative evaluation systems, including *Technical appraisal handbook for ecological residences in China* (2007 edition)^[8], *Evaluation standard for green building*^[9], and *Comprehensive appraisal method to green residence and its design criteria*^[10], are chosen for comparison in terms of evaluation content and index structure. Please refer to Tab. 1 for results.

Tab.1 Comparison of three evaluation systems in respect of content and structure

Item	Evaluation standard for green building ^[9]		Comprehensive appraisal method to green residence and its design criteria ^[10]		Technical appraisal handbook for ecological residences in China ^[8]		
	Index	Proportion/%	Index	Proportion	Index	Proportion/%	
Assessment content	Common index	Land saving	20	Land development and utilization	Calculated by analytic hierarchy process	Location and residential environment	20
		Energy saving	20	Energy utilization		Energy and environment	20
		Water saving	15			Water environment in residential area	20
		Material saving	15	Material using		Material and resource	20
		Indoor environment	16	Indoor environment		Indoor environment quality	20
	Unique index	Management utilization	14	Outdoor environment Pollution prevention Economy and region	Calculated by analytic hierarchy process	Essential examination and verification	
	Index number	49	34			168(design stage) 146(inspection stage)	
	Appraisal system structure	2-level index total		3-level index total		2-level index total	

By comparison, the medium-scale evaluation content gives priority to field environment, energy utilization, materials and resources, as well as water environment, while the micro-scale evaluation focuses on such indoor physical environment factors as sound, light, heat and air. Both of them are not different in evaluation content, but they differ only with reference to some special items. Different evaluation mechanisms and methods of the three systems reflect the diversified evaluation methods in China.

2 Main Evaluation Methods and Applied Technology

2.1 Setting up of index system and establishment of threshold value

Residential environment is a complex system in relation to society, economy and nature. Its evaluation system is not only an index set based on some principles, but also an organic whole. After the establishment of system content, it is necessary to quantify indices, including threshold values and weights.

The complexity of an index system content makes it difficult to determine the threshold of an index by use of a unified standard. The following methods are usually adopted in China’s evaluation system:

- 1) Threshold is determined based on the existing standards for an index having national or local standards;
- 2) Threshold is determined by comparisons and taking a local, demonstrated project as the standards for a content without industry standards;
- 3) These qualitative indices are changed into quantified values mathematically(e. g. the nine-grade

scoring method, the fuzzy evaluation method) based on such ways as questionnaire surveys and scores given by experts.

2.2 Determination of index weights

The weight of an index not only has a great effect on the accuracy of evaluation results, but also plays a role in highlighting key indices and representing the guiding direction of an evaluation system. It can be determined in many ways, such as Delphi, the APH, fuzzy model analysis, and so on. In the development of China’s evaluation system, the APH has been adopted by more and more systems because it features qualitative and quantitative combinations. We take the comprehensive appraisal method to the green residence and its design criteria as an example. Five experts are consulted from different fields to give scores, and the APH is used to calculate the individual index weights (D₅ to D₁₁) of two sub-items C₃ and C₄ in the level 2 index item(B₂). The process is as follows:

- 1) First, set up a matrix and compare the relative importance of individual indices through a 9/9 to 9/1 scaling method, and then work out relative weights in C₃ “energy utilization”(C₄ process omitted). Please refer to Tab. 2.

Tab.2 Judgment matrix and weight value

Partial index of C ₃	D ₅	D ₆	D ₇	D ₈	Weight
D ₅	1	8/9	9/7	9/5	0.288
D ₆	9/8	1	9/7	9/4	0.323
D ₇	7/9	7/9	1	9/6	0.235
D ₈	5/9	4/9	6/9	1	0.153

2) Put the data into the following formula to check the consistency of the matrix,

$$C_R = \frac{C_1}{R_1} \tag{1}$$

If $C_R < 0.1$, then the judgment matrix is consistent.

$$C_1 = \frac{\lambda_{\max} - n}{n - 1} \tag{2}$$

$$\lambda_{\max} = \sum_{i=1}^n \frac{(AW)_i}{nW_i} \tag{3}$$

where λ_{\max} is the largest root of the judgment matrix; n is the row number of the judgment matrix; A is the judgment matrix; W is a vector of the judgment matrix; $(AW)_i$ is AW 's i -th element. R_1 is the index of average and random consistency, and the decision of the value range is made by referring to the exponent number(see Tab. 3), $n = 4$, $R_1 = 0.90$ in item C_3 . Through checking, $C_R = 0.0433 < 0.1$, which means that the matrix is consistent.

3) Work out the combinational weight coefficient by referring to the weight distribution in level C. Please refer to Tab. 4.

Tab.3 The mean random consistency index

Exponent n	1	2	3	4	5	6	7	8	9	10
R_1	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Tab.4 Combinational weight of C_3 and C_4 individual index

Level C	Weight of level C	Level D	Weight of level D	Combinational weight of level D
C_3 Energy utilization	0.0838	D_5 Natural ventilation	0.288	0.0241
		D_6 Natural lighting and sun-shading...	0.323	0.0271
		D_7 Maintaining structure and material	0.235	0.0197
C_4 Land development	0.0364	D_8 Clean and renewable energy	0.153	0.0128
		D_9 Use of non-arable land	0.212	0.0077
		D_{10} Location	0.453	0.0165
		D_{11} Building size and form	0.335	0.0122

It is clear from the process of calculation that this method can reflect slight differences between index weights, but it has the following disadvantages:

1) The weight quantification is uncertain, and the process of assigning a value and giving a score is more subjective. In the above case, there is a large difference in weight value because five experts giving scores focus on different subjects.

2) For a system with many levels, the multi-level weight calculation will increase the complexity of evaluation and make the operation difficult.

Although the adoption of the weight-avoiding method in some systems, is favorable for easy operation, it fails to reflect the emphasis among evaluation items. There is so far no generally recognized achievement in weight throughout the world, and China has a long way to go to improve the setting of weights in residential environment evaluations.

3 Applied Technology of Comprehensive Evaluation

Based on the evaluation of subitem indices, comprehensive evaluation results can be achieved by classification, sequence and comparison of evaluation objects through specific evaluation models. The most general evaluation is a hierarchical index system model taking residential environments as vertices^[11]. The calculation method of the model is divided into linear and nonlinear models. The linear model, which was generally adopted by China's early evaluation systems is easy to understand and operate. The advantage of a nonlinear model is that it can reflect the relationships of interactions among indices. In 2001, Liu and Zhou first proposed a new calculation method of nonlinear evaluation which uses an improved TOPSIS to make a comparative

study for ecological residential schemes^[12]. Nowadays, there are many nonlinear mathematical models with different algorithms that have provided foundation for research, for example, TOPSIS, ANN and so on. Although the comprehensive evaluation by calculation of evaluation models is precise, it possesses a relatively complex process, difficult operation, and unclear results, and it needs an aided computer program.

The geographic information system(GIS) provides a new method for evaluation in terms of technology and application. Functioning as a collector and a manager of spatial information, the GIS can combine all the evaluation index data that constitute a residential environment with space, and it has been widely applied to the establishment of residential environment databases integrating space and attributes. Based on the GIS, some scholars have established an evaluation model under the GIS platform. The model makes full use of its own functional calculation capacity, and utilizes map algebra calculations for geometrical packing. It can be used to analyze the space divisions, structures and change of residential environments, and it can obtain quantitative data and intuitive pictures so as to provide a more convenient and effective decision-making basis for urban planning.

4 Conclusions

Residential environment evaluation is essential to the sound survival and development of humankind, which is being researched, probed and practiced in many countries in the world. The following is the developmental direction of China's residential environment evaluation.

1) Interdisciplinary theory and research approaches will be introduced under the platform of the science of human settlements. It is necessary to build an interdisciplinary and

comprehensive evaluation system by fully utilizing the individual technological advantages of such subjects as ecology, environmentology, architecture, and geoinformatics.

2) Overall consideration will be given to urban and rural areas as rural residence occupies a larger proportion in China's residential environment, and the improvement of rural dwellings will have an important impact on China's urbanization that has entered a rapid stage of development. Research on rural residential environment should be enhanced as most of the existing evaluation systems in China focus on urban residential environment.

3) Local evaluation systems will be fully developed because China is a country with vast territory and a large geographic span. One evaluation system is difficult to meet the needs of the whole country. Accordingly, it is a good way to learn from the GB tool "operation transited from universality to local particularity"^[13]; the local evaluation systems should be developed into beneficial supplements to national standards on the basis of climatic characteristics, resources and human quality in the various regions.

4) The research of evaluation systems will be further improved as the methodological framework of evaluation is still not established. The technical support provided in terms of specific guiding measures and passive ecological design techniques is insufficient, and the guiding role should be enhanced.

With the increasing concern about ecology and the environment, the role of the residential environment evaluation system has been paid more and more attention to. Setting up an appraisal system suitable for China's national conditions will have an active effect on the sustainable development of the residential environment in China.

References

[1] Research Team on Green Olympic Buildings. *Assessment system for green building of Beijing Olympic* [M]. Beijing:

- China Architecture and Building Press, 2003: 7–9. (in Chinese)
- [2] Wu Liangyong. *Introduction to the science of human settlements* [M]. Beijing: China Architecture and Building Press, 2001. (in Chinese)
- [3] Yasushi Asam. *Appraisal methods on residential environment and its theory* [M]. Translated by Gao Xiaolu. Beijing: Tsinghua University Press, 2006: 25–27. (in Chinese)
- [4] Zhang Wenzhong. Index system and method of residential environmental evaluation in inner cities [J]. *Scientia Geographica Sinica*, 2007, **27**(1): 17–23. (in Chinese)
- [5] Yu Chunlong, Zhou Ruoqi. Research on the suitable appraisal method of the human residential environment in small basin based on grid data [J]. *Huazhong Architecture*, 2008, **26**(1): 4–7. (in Chinese)
- [6] Currie R, Thacker C. Quality of the urban environment as perceived by residents of slow and fast growth cities [J]. *Social Indicators Research*, 1986, **18**(1): 95–118.
- [7] Connerly C E, Marans R W. Comparing two global measures of perceived neighborhood quality [J]. *Social Indicators Research*, 1985, **7**(1): 29–47.
- [8] Nie Meisheng, Qin Youguo, Jiang Yi. *Technical appraisal handbook for ecological residences in China* [M]. Beijing: China Architecture and Building Press, 2007. (in Chinese)
- [9] Ministry of Construction of China. GB/T 50378—2006 Evaluation standard for green building [S]. Beijing: China Architecture and Building Press, 2003. (in Chinese)
- [10] Liu Qibo, Zhou Ruoqi. *Comprehensive appraisal method to green residence and its design criteria* [M]. Beijing: China Architecture and Building Press, 2006. (in Chinese)
- [11] Pacione M. The use of objective and subjective measures of life quality in human geography [J]. *Progress in Human Geography*, 1982, **6**: 495–514.
- [12] Liu Qibo, Zhou Ruoqi. Applying improvable topsis method in green building's synthetical assessment [J]. *Optimization of Capital Construction*, 2001, **22**(5): 30–32. (in Chinese)
- [13] GBT05. 2005 International initiative for a sustainable built environment(iiSBE) [S/OL]. (2005-01-27) [2007-09-20]. <http://www.iisbe.org/iisbe/gbc2k5/gbc2k5-start.html>.

我国居住环境评价的尺度、方法与技术分析

李 绥^{1,2,3} 石铁矛² 周 乐⁴

(¹ 中国科学院沈阳应用生态研究所, 沈阳 110016)

(² 沈阳建筑大学建筑与规划学院, 沈阳 110168)

(³ 中国科学院研究生院, 北京 100049)

(⁴ 沈阳大学建筑工程学院, 沈阳 110044)

摘要: 为了完善我国居住环境评价体系并加强其指导作用, 通过对比、归纳与实证应用等方法从研究尺度、评价方法 and 应用技术 3 个方面对现有研究成果进行分析与总结。现有宏观尺度评价体系普遍对城市规划建设的指导作用不明显, 而中观与微观尺度评价体系对改善住区环境的指导作用则逐渐加强。我国评价体系中确定指标阈值与权重的方法多元化, 以 AHP 法确定权重为例, 在实证计算的基础上, 分析了该方法的优势与不足。在综合评价过程中, 非线性模型比线性模型更能够体现各指标间相互影响的关系; ARCGIS 平台下的评价模型具有空间与属性一体化的优势, 而且结果直观。我国居住环境评价的方法体系仍未系统建立, 学科领域、研究范畴需要拓宽, 指导作用有待加强。

关键词: 居住环境; 评价体系; 尺度; 阈值; 权重; 评价模型; 地理信息系统

中图分类号: X821