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RESIDENTIAL ENVIRONMENT EVALUATION SYSTEM CONSIDERING ENVIRONMENTAL QUALITY AND ENVIRONMENTAL LOAD FOR SUSTAINABLE DEVELOPMENT OF RESIDENTIAL DISTRICT

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ABSTRACT: Residential environment is one of the most important elements for quality of life, as well as the main support for the activities of economy, culture and society. On the other hand, the improvement of residential environment quality also has been increasing the consumption of energy and emission of pollution. In this paper, we established a systematic methodology for the evaluation of sustainable residential environment, considering both residential environmental quality (*Q*) and residential environmental load (*L*). The part of *Q* is constructed by safety, healthy, amenity, convenience and community of residential environment. The part of *L* is about the environmental impact of the lifecycle of the housing and community. We hope the results of our study can contribute to the sustainable development and improvement of urban residential environment for rapidly developing China.

Keywords: Residential environment, evaluation system, residential environment quality, residential environment load

INTRODUCTION

Residential environment quality is one of the basic elements for quality of life, as well as the main support for the activities of economy, culture and society (Higasa, 1997). The improvement of residential environment quality has become one of the main targets of city policy and urban planning. On the other hand, the improvement of residential environment quality also has been increasing the consumption of energy and emission of pollution. It is with great significance to establish the sustainable model for the development and improvement of residential environment with high environmental Quality and low environmental Load. In this paper, we attempted to establish a systematic methodology for the evaluation of sustainable residential environment, considering both residential environmental quality and residential environmental load.

The evaluation system of green building had been broadly studied and applied around the world, such as BREEAM (England), LEED (U.S.), CASBEE (Japan), NABERS (Australia), GBCAS (China). These systems consider both environmental quality of buildings and the opposite influence to resources and pollution, focusing mainly on buildings. In the broader scale of residential environment, not only housing itself, but also the community and urban level should be taken into consideration. However, this kind of research is not adequate till now. In Japan, CASBEE has been applied to the spatial scale of block, district and region from 2006. In China, the assessment methods and design criteria of green residence has been published in 2006. It focuses both on buildings and the community, however, the system does not consider the quality and load respectively.

In this research, we want to establish a systematic methodology for the evaluation of sustainable residential environment, considering both residential environmental quality (*Q*) and residential environmental load (*L*). The characteristics of the system is that: (1) It focuses on the level of community and urban, not only the buildings; (2) The evaluation system is divided into two parts: *Q* (positive) and *L* (opposite); (3) Both the residents and experts can be appraisals. Environmental quality is evaluated by the users, and environmental load evaluated by experts. (4) In this study the weight of environmental load which is non-fixed is calculated by AHP. So in different region we can have different weight Suitable for the local environment. (5) We combined qualitative and quantitative evaluation methods together. In the evaluation of environmental quality, we used the qualitative assessment; in the evaluation of environmental load, we used the quantitative evaluation methods such as software simulation, data measurement and verification of the drawings. (6) The residential

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environment which consumes the minimum *L* but obtains the biggest *Q* is the best.

METHODOLOGY

Evaluation System

In our research, we present the evaluation system for the sustainable residential environment, shown in Fig.1.

In the first step, we focused on the first part of the evaluation system, which is the environmental quality (*Q*). This is a hierarchical multi-attribute index system shown in Fig.2. The first four sections were developed from the four concepts of residential environment satisfying the basic living requirements of human beings presented by the World Heath Organization in 1961. And each factors in level 2 has 2 to 4 sub-factors in level 3, and each sub-factors has several items in level 4(Japan Asso. for sustainable architecture, 2005). And the second part L has a similar index system to the first part. Figure 3 shows hierarchical evaluation system for residential environmental load.

Evaluation Weight

In the environmental assessment system, as the impact of each evaluation attribute is different, different attributes has different weight. It reflects the relative importance of each one.

In most existing evaluation systems, the weights of the attributes are fixed (Zhou, 2006). While China is a vast country and different places have different situations. So in this research, the weight of the attributes of environmental load which is calculated by AHP is non-fixed. In different region we can have different weight Suitable for the local environment. Equation 1 shows the weight of each attribute.

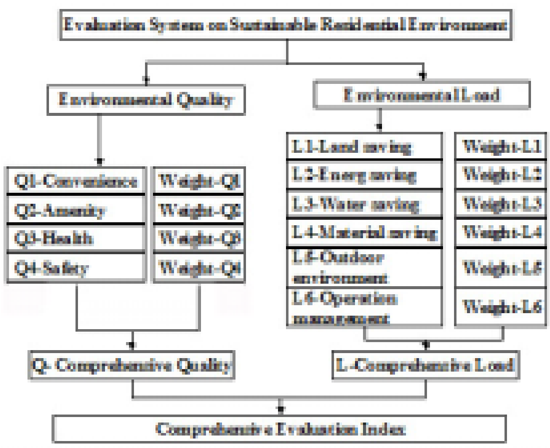

Fig.1 Hierarchical and multifactorial evaluation system for sustainbale residential environment

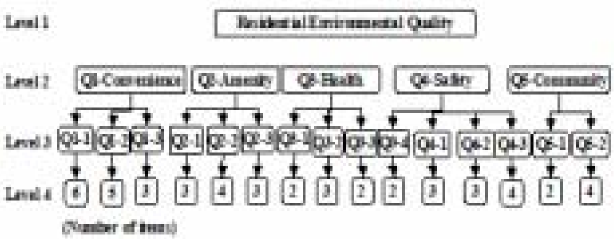

Fig.2 Hierarchical evaluation system for residential environmental qualtiy

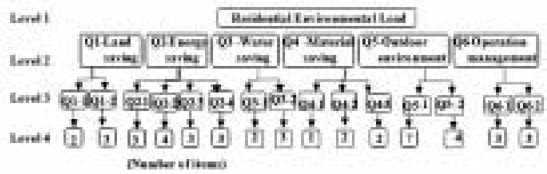

Fig.3 Hierarchical evaluation system for residential environmental laod

$$L = 0.154\,L1 + 0.253\,L2 + 0.210\,L3 + 0.138\,L4 + 0.121\,L5 + 0.124\,L6 \quad (1)$$

Scores and The Results Assessment

In the first part of environment quality, we asked the residents to evaluate their satisfaction on present residential environment quality according to a 5-grade-scale (1- dissatisfied thoroughly; 2- dissatisfied; 3- neutral; 4- satisfied; 5- satisfied thoroughly).

In the second part of environment load, we calculate the number of the attributes didn't meet the standards, and found its percentage in each indicator. We evaluate each indicator also according to a 5-grade-scale (above 90%-5, above 70%-4, above 50%-3, above 30%-2, below 30%-1). Then we took the score of each indicator into Eq.(1), and got the final scores of environment load.

Finally, we calculate the ratio of the environment quality and the environment load to get the results of the sustainable residential environment evaluation. We have 5 levels, REE<0.5 is very poor (E), 0.5-1 is poor (D), 1-1.5 is just so so (C), 1.5-3 is good (B), >3 is perfect (A) (Fig.4).

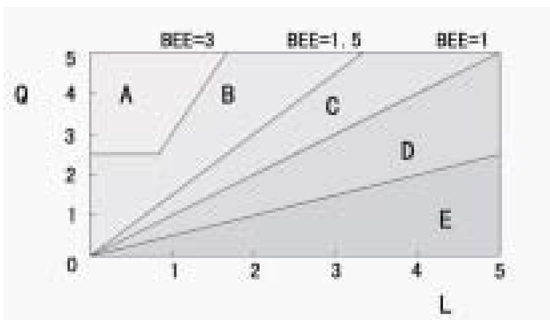

Fig.4 Evaluation levels

CASE STUDY

Study Areas

In this paper, we selected Huzhou as our research area. It is a small city which has a history of 2300 years. Huzhou is located in the middle of Changjiang Delta Region of China. And the development of the housing industry there started quite early. So far a considerable number of residential areas have received awards at home and abroad.

We chose 3 different typical residents in Huzhou to conduct our research, Majunxiang, Baiyutan and Yangguangcheng. The Majunxiang resident is in the downtown, and has a construction area of 76,300 square meters. Baiyutan and Yangguangcheng are in the suburb, and the construction areas are 170,500 square meters and 290,000 square meters respectively.

Environment Quality

As the first step of our research, we focused on the first part of the evaluation system, which is the evaluation system and model of residential environment quality (Q). We performed questionnaire surveys in three residences focusing on the residential environment quality. Then, we analyzed the residential environmental quality satisfaction of people, and conducted a multiple regression analysis on contributing factors.

Surveys

From July to August, 2007, we preformed questionnaire surveys among the residents of Majunxiang, Baiyutan and Yangguangcheng. Table 1 shows the general condition of the surveys. Table 2 shows the main contents of the questionnaire, which are divided into three parts with totally 78 questions.

Results on residential quality

Table 3 shows the average evaluation and standard deviation of items on Level 1 and Level 2. We can see that the satisfaction of residential quality in Yangguangcheng is the highest, while in Baiyutan is the

Table 1 General condition of questionnaire survey

City	Number of distribution	Number of effective collection	Effective collection rate (%)
Majunxiang	100	95	95.0
Baiyutan	150	144	96.0
Yangguangcheng	150	130	87.0
Total	400	367	92.0

Table 2 Contents of questionnaire survey

Number	Contents		Number of questions
I	Personal attributes		17
II	Residential conditions		5
III	Evaluation on residential satisfaction	Convenience	24
		Amenity	14
		Health	14
		Safety	13
		Comprehensive evaluation and attachment	1
Total			78

Results on residential quality

Table 3 shows the average evaluation and standard deviation of items on Level 1 and Level 2. We can see that the satisfaction of residential quality in Yangguangcheng is the highest, while in Baiyutan is the lowest. Further more, safety has a best evaluation of the 4 items in all three residents.

Multiple regression analysis

According to the hierarchical and multi-factorial evaluation system for residential environment, we conducted a multiple regression analysis on Level 1 and Level 2, in order to make clear the contributing factors of the lower level to the higher level. The analysis is conducted by the software SPSS 12.0. Take the Majunxiang residence as an example.

$$\text{Residential Environment Quality} = 0.220+0.257\times\text{Convenience} + 0.291\times\text{Amenity} + 0.167\times\text{Health} + 0.377\times\text{Safety} \quad (R^2=0.756)$$

$$\text{Convenience} = 0.095+0.294\ Q1\text{-}1+0.463\ Q1\text{-}2+0.292Q1\text{-}3 \quad (R2=0.577)$$

$$\text{Amenity}=0.474+0.277Q2\text{-}1+0.221Q2\text{-}2+0.345Q2\text{-}3 \quad (R^2=0.727)$$

$$\text{Health}=0.242+0.210Q3\text{-}1+0.284Q3\text{-}2+0.186Q3\text{-}3+0.261Q3\text{-}4 \quad (R^2=0.779)$$

$$\text{Safety}=0.329+0.403Q4\text{-}1+0.245Q4\text{-}2+0.282Q4\text{-}3 \quad (R^2=0.777) \qquad (2)$$

According to the analysis results of multiple regression analysis, we obtained the evaluation model (Eq.(2)). We can find that in Majunxiang, all of the factors in Level 2 contribute to the evaluation of Level 1, which means that the comprehensive residential environment satisfaction is influenced effectively by convenience, safety, amenity and health in the order of importance, especially the influence of safety and amenity.

Table 3 Results of residential quality

Items	Majunxiang		Baiyutan		Yangguangcheng	
	Average	Standard deviation	Average	Standard deviation	Average	Standard deviation
Q1-convenience	3.54	0.633	3.38	0.567	3.63	0.593
Q2-amenity	3.28	0.724	3.54	0.579	3.77	0.585
Q3-healthy	3.26	0.703	3.41	0.625	3.67	0.693
Q4-safety	3.60	0.659	3.5	0.580	3.83	0.719
Q-comprehensive	3.55	0.615	3.49	0.562	3.75	0.614

In the multiple regression analysis of Level 2, Traffical Service (*Q*1-2) has the biggest influence on the evaluation of convenience; Amenity of living space (*Q*2-3) has the biggest influence on the evaluation of amenity; sound environment (*Q*3-2) has the biggest influence on Health; Safety from disaster(*Q*4-3) has the biggest influence on Safety.

Evaluation on Residential Load

We used the quantitative evaluation methods such as software simulation, site survey and verification of the drawings to conduct the evaluation of residential load.

Software simulation

In the analysis, we simulated wind environment, sunshine duration, energy consumption and indoor lighting by different auxiliary software such as Pheonics3.5, Tianzheng2004, PKPM and Ecotect5.0. Fig. 5,6,7,8 show the results of the simulation to Majunxiang residence.

We found that the sunshine duration and the energy consumption in Majunxiang residence didn't fit the Chinese national standard, while the target of wind environment and indoor lighting conformed.

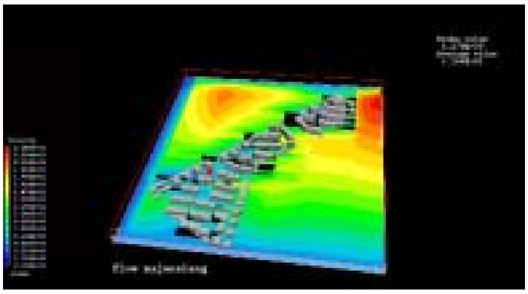

Fig.6 Wind environment of Majunxiang residence (Pheonics3.5)

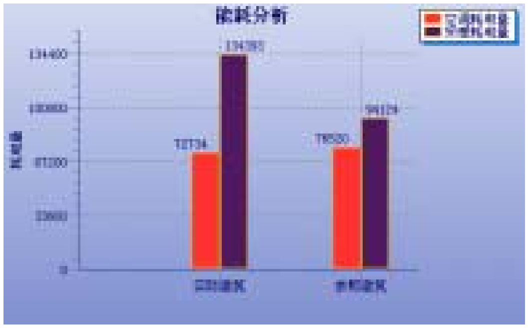

Fig.7 Energy consumption of the No1 building in Majunxiang residence (PKPM)

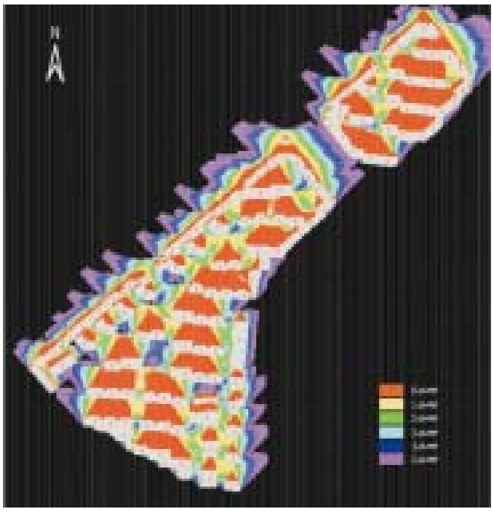

Fig.5 Sunshine duration of Majunxiang residence (Tianzheng2004)

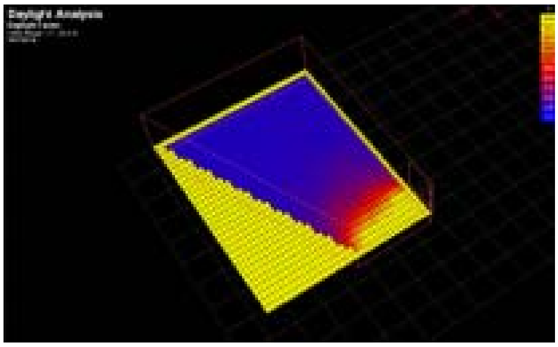

Fig.8 Indoor lighting of the living room of the No1 building in Majunxiang residence (Ecotect 5.0)

Site survey

From March to May, 2008, we measured the sound environment and the heat island effect of the three residences. Table 4,5 shows the measure results.

Table 4 Results of the sound environment measuremen

Residence	Outdoors		Indoors	
	Daytime db(A)	Night db(A)	Daytime db(A)	Night db(A)
Majunxiang	54.4	44.2	45.1	34.5
Baiyutan	49.2	40.2	38.1	30.4
Yangguangcheng	58	45.3	43.6	34.5
Standards	55	45	45	35

Table 5 Results of the heat island effect measurement

Items	Majun xiang	Baiyu tan	Yanggu angcheng	Sub- -urb
Outdoor environment (℃)	33.2	31.8	32.5	31.5
Margin of the temperature (℃)	1.7	0.3	1	0

From the results of sound measurement, we found that the sound of the Yangguangcheng residence outdoors is higher than the standards in both the daytime and the night. And the daytime sound of Majunxiang residence indoors is also higher that the standards.

From the results of the heat island effect measurement, we found the margin of the temperature between Majunxiang outdoor environment and suburb is 1.7℃, more than the standard (1.5℃).

Results on environment load

With the results of above simulation, measurement and the verification, we checked each item in the evaluation system of environment load. Table 6 shows the results.

Table 6 Scores of each facror

Items	Majun xiang	Baiyu tan	Yangguang cheng
The consumption of land (L1)	1	3	3
The consumption of energy (L2)	3	2	1
The consumption of water (L3)	4	3	3
The consumption of material (L3)	4	4	2
Indoor and Outdoor environment(L4)	3	1	1
Operation management (L5)	1	1	1

Put the scores of each factor into the formula that we calculated before by AHP , we got the result of the environment load evaluation. Table 7 shows the results. We can see that Majunxiang residence gets the largest load, Baiyutan next, and the load in Yanggangcheng is the minimum.

Sustainable Evaluation

Together with the environment quality and environment load, we calculated the ratio and got the final evaluation results. Table 8 shows the scores of the final results.

Yangguangcheng residence has a highest score of 2.01, and stands in level B which means a good sustainability, with a small consumption of resources and a good quality of the environment.

While the scores of Majunxiang and Baiyutan residence are a little lower, 1.27 and 1.46 apparently. And they are standing in level C, which means belonging to sustainable settlements, but with too much consumption of resources or slightly worse environment quality.

CONCLUSIONS

In this research, we developed the evaluation model for sustainability of residential environment focusing on the environment quality and environment load. Firstly, we established the evaluation index system and calculated the evaluation weight by AHP. Then we analyzed the environment quality and environment load by both qualitative and quantitative methods. Finally, we calculated the ratio of above two and got the final sustainable evaluation results.

Table 7 Result of the environment load evaluation

Residences	Majunxiang	Baiyutan	Yangguangcheng
environment load	2.792	2.395	1.866

Table 8 sustainable evaluation

Residences	Majunxiang	Baiyutan	Yangguangcheng
Environment quality	3.55	3.49	3.75
Environment load	2.792	2.395	1.866
Sustainable environment	1.27	1.46	2.01

In the future research, more case study will be done in other cities to have a further test of our evaluation system.

Moreover we will also compare this evaluation system to many existing systems at home and abroad through actual cases to find their differences. We hope the results of the research can contribute to the sustainable development and the improvement of Chinese residential environment.

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