EVALUATION OF THE SUITABILITY OF HUMAN SETTLEMENTS IN QINGPU DISTRICT, SHANGHAI

by

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In recent decades, people's attention to human settlements has been increasing. However, the research on the evaluation method of the suitability of human settlements is still in the exploratory stage, and there is no universally accepted evaluation method worldwide. Considering the uncertainty in the evaluation index system, this paper combines the set pair analysis theory and the Logistic model to construct a new evaluation model of the suitability of human settlements and applies the model to the dynamic evaluation of the suitability of human settlements in Qingpu district from 2007 to 2016. The evaluation results show that the overall suitability of human settlements in Qingpu district is on the rise. Based on the analysis of the evaluation results, this paper puts forward some opinions on the development plan of Qingpu District and verifies the validity of the constructed model.

Key words: *suitability of human settlements, set pair analysis, logistic model, Qingpu district*

Introduction

Sustainable development has become a global consensus on human development, and the construction of a human settlement environment is an indispensable part of sustainable development. China has changed from the stage of rapid economic development to the stage of high-quality development. Accordingly, the construction of the human settlement environment in China is also facing new requirements and challenges [1, 2]. On the one hand, the evaluation of a region's habitat suitability can test the effect of previous regional development, and on the other hand, it can provide a reference for future planning. At present, China's urbanization process is constantly advancing, and a large number of metropolitan circles, urban agglomerations and the urban belts have been formed. This new development situation requires the establishment of a more comprehensive evaluation system for the suitability of human settlements.

The study of the human settlement environment was first carried out by urban planning scholars. The industrial revolution accelerated urbanization in the Western world, resulting in the deterioration of urban sanitation and high population density. The concept of the garden city, put forward by Ebenezer Howard in 1898, changed the view of people to solve problems of urban planning [3, 4]. The urban reconstruction after the Second World War promoted the development of the study of human settlement environment. In 1954, the Greek

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scholar Doxiadis put forward the concept of human settlement science, making the concept of human settlement environment officially known by the public, see in [4]. In the process of the development of human settlement environment research, interdisciplinary scholars rich the theoretical system of human settlement environment with their discipline theory constantly, such as Richard *et al.* [5] from the university of Berkeley put forward the concept of an ecological city, thinking the city should be seen as a system of life. The World Health Organization put forward the basic concepts of safety, health, convenience, and amenity, which have become an essential basis for the evaluation of livable cities [6]. However, the practice of qualitative and quantitative evaluation of the suitability of human settlement environments is still in the exploration stage globally. Few existing studies consider the uncertainty [7, 8] and missing data [9] in the evaluation system of the suitability on the human settlement environment.

The objective of this study was to construct an evaluation system that includes three systems: society, economy, and ecology and establish an evaluation model combined with the theory of set pair analysis (SPA) and the logistic curve model, then use the established evaluation system and model to evaluate the construction of human settlement environment in Qingpu district, Shanghai from 2007 to 2016, and at the same time, to provide a reference for the establishment of the evaluation system of the suitability of human settlement environment.

Methods

Set pair analysis

So-called set pair means that two sets that are related form a pair [10]. For example, according to question W, the characteristics of set pair H are analyzed, and n characteristics are obtained, among which s characteristics are common to two sets A and B in set pair H, and p characteristics are opposite to each other in the two sets. The other f characteristics ($f = n - s - p$) are neither opposite nor different. The following formula can be used to express the total relation status of the two sets:

$$\mu(w) = a + bI + cJ \tag{1}$$

where $\mu(w)$ is called the correlation degree, which is generally the formula on the right-hand side, but in special cases is a number which called the correlation number, $a = s/n$ called the consistency degree of set A and set B in question W, $b = f/n$ called the difference degree of set A and set B in question W, $c = p/n$ called the opposition degree of set A and set B in question W, and I is the coefficient of the difference degree. It can be taken as the value in the interval of [–1, 1] or it can only play a marking role. J is the coefficient of the opposition degree, and its constant value is -1 or it can only play a marking role [11, 12].

On the basis of eq. (1), this study extends the ternary correlation number to the multivariate correlation number:

$$u_{i,j} = v_{i,5} + v_{i,4}I_1 + v_{i,3}I_2 + v_{i,2}I_3 + v_{i,1}J \tag{2}$$

where $u_{i,j}$ represents the correlation number of index J of sample I, and $v_{i,5}$,$v_{i,4}$,$v_{i,3}$,$v_{i,2}$ and $v_{i,1}$ represent five correlation number components of sample I [11, 12]. Different from the a, b, and c in eq. (1), the five correlation number components have an order of merit. In other words, $v_{i,5}$, $v_{i,4}$, $v_{i,3}$, $v_{i,2}$ and $v_{i,1}$ represent V, IV, III, II, and I, five levels of evaluation. The indicator situation represented by $v_{i,5}$ is better than that of $v_{i,4}$ and so on. The I_1, I_2, and I_3 represent three coefficients of the difference degree. The interval of [–1, 1] is divided into three subintervals according to the equal division, method, namely $I_1 \in (0.333, 1]$, $I_2 \in (-0.333, 0.333)$, and $I_3 \in [-1, -0.333)$ [13]. The J represents the coefficient of the opposition degree.

Logistic model

Even if the values of the same index in different samples are in the same level, the evaluation results will be different due to the difference in the values of the index [14]. This difference can be reflected by the coefficients of the difference degree. However, the value of coefficients of the difference degree can only be determined between [–1, 1] other than a specific value, which means the evaluation result is not intuitive enough to meet the expectation. Therefore, this study uses logistic affiliation model to calculate the value of $v_{i,2}$, $v_{i,3}$ and $v_{i,4}$. At the same time, I_1, I_2, I_3, and J only play marking roles. This not only considers the uncertainty but also guarantees the intuitiveness of the result. The logistic curve is a common S--shaped curve named by Pierre Francois Veruler when he was studying the relationship between population size and population growth. The generalized Logistic curve can simulate the S-shaped curve of population growth, P, in some cases. At first, it is roughly an exponential growth, and then the increase slows down as it starts to saturate. Finally, the increase stops when maturity is reached, fig. 1.

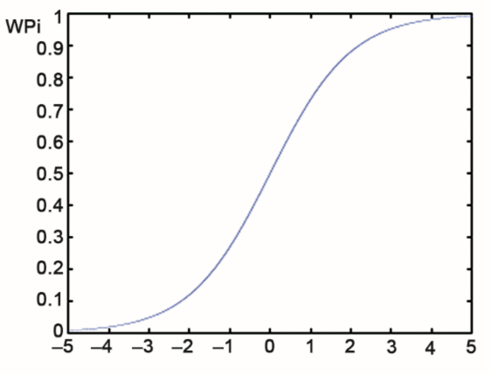

Figure 1. Logistic curve

The relationship between the suitability of the human settlement environment and social development is similar to the relationship between population size and population growth. Therefore, this study selects the logistic curve model to calculate the membership degree:

$$v_k = \frac{\sqrt{3}}{1 + \mathrm{e}^{\frac{1.317(s_k + s_{k-1} - 2x)}{s_k + s_{k-1}}}} + \frac{1}{2} - \frac{\sqrt{3}}{2} \tag{3}$$

$$v_{k-1} = 1 - v_k \tag{4}$$

where s_k and $s_{k\text{-}1}$ are the upper and lower thresholds of this grade, respectively and x – the actual value of the index [15].

Case study

Study area, fig. 2

As a first-tier city in China, Shanghai ranks top in the development of finance and trade, scientific and technological innovation, ecological construction, and cultural construction, *etc.* Improving livability is also one of its essential goals in building a global city [16]. Qingpu district is located in the southwest of Shanghai, the lower reaches of Taihu Lake and the upper reaches of Huangpu River. Qingpu District covers a total area of 676 km^2. The terrain is flat with an average elevation of 2.8 m to 3.5 m above sea level. Qingpu is an important water channel for Jiangsu, Zhejiang and Shanghai. With rivers crisscrossing the territory and lakes dotted all over the district, inland waterway shipping has unique advantages. The water area accounts for 22.1% of the total area of the district and Dianshan Lake, which is located in the northwest of Qingpu district, is the largest freshwater lake in Shanghai.

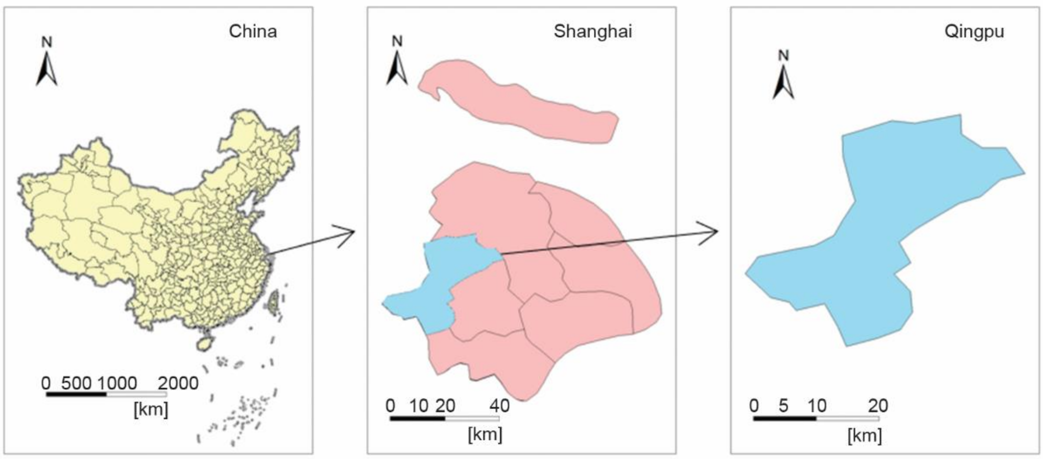

Figure 2. Study area

Data

Drawing on the thematic indicators proposed by the World Bank [17] and the theory of socio-economic - natural complex ecosystem, this study selected five indicators for each system. All the data used in the evaluation process come from the Qingpu Yearbook (2008-2017).

Due to the different dimensions of the selected data, standardization should be carried out first to facilitate the subsequent analysis. This study chooses the range-standardization method to process the data:

$$x_{aj} = \frac{f_j(a) - f_{j^*}}{f_j^* - f_{j^*}} \tag{5}$$

$$x_{ak} = \frac{f_k^* - f_k(a)}{f_k^* - f_{k^*}} \tag{6}$$

where $f_i(a)$ and $f_k(a)$ are the value of the selected indicators, f_j^* and f_k^* are the maximum value of the selected indicators, and f_{j^*} and f_{k^*} are the minimum values of the selected indicators.

In this study, the combination weighting method is selected to determine the weight. The subjective weighting method mostly consults experts in related fields who make judgments on problems based on their own knowledge and experience. Compared with other objective weighting methods, the CRITIC method considers the stability between the same index value and considers the conflict between different indicators [18]. Firstly, the standard deviation between each index value is calculated. The larger the standard deviation is, the greater the variation of the index value is, and the more critical this index is in the evaluation [19]. Secondly, the linear correlation coefficient r between each index is calculated. Obviously, the more incongruent the index j and the index k are in the change process, the smaller the r_{jk} value is:

$$\sum_{k=1}^{m}(1-r_{ik}) \tag{7}$$

where m is the total number of indicators.

Here, the Spearman correlation coefficient method, which is widely used, is used to calculate r_{jk}:

$$r_{jk}=\frac{\Sigma_i(x_{ij}-\overline{x_j})(x_{ik}-\overline{x_k})}{\sqrt{\Sigma_i(x_{ij}-\overline{x_j})^2\Sigma_i(x_{ik}-\overline{x_k})^2}} \tag{8}$$

The amount of information in the multi-objective decision analysis problem is related to the stability and conflict of the index [20]. Therefore, the amount of information C_j is calculated by combining standard deviation and correlation coefficient:

$$C_j=\sigma_i\sum_{k=1}^{m}(1-r_{ik}) \tag{9}$$

According to the previous analysis, the greater the C_j value is, the greater the information conveyed by indicator J will be, and the greater its influence on the evaluation result will be. The objective weight of the indicator can be calculated by [21]:

$$w_j=\frac{C_j}{\sum\limits_{k=1}^{m}C_k} \tag{10}$$

After obtaining the subjective weight of each indicator $W_1 = (W_{1,1}, W_{2,1}, ..., W_{m,1})$ and objective weight $W_2 = (W_{1,2}, W_{2.2}, ..., W_{m,2})$, the combined weight of the index can be obtained according to [22], tab. 1:

$$W_j=\frac{W_{j,1}W_{j,2}}{\sum\limits_{n=1}^{m}W_{n,1}W_{n,2}},\quad j=1,2,...,m \tag{11}$$

Evaluation model

According to the previous contents, the evaluation model can be obtained:

$$u_{i,j}=\begin{cases} 5*1+0I_1+0I_2+0I_3+0J, & x>0.8 \\ 5*(1-v_2)+4*v_2I1+0I2+0I3+0J, & 0.6<x<0.8 \\ 0+4*(1-v_3)I1+4*v_3I2+0I3+0J, & 0.4<x<0.6 \\ 0+0I1+3*(1-v_4)I2+2*v_4I3+0J, & 0.2<x<0.4 \\ 0+0I1+0I2+0I3+1*1J, & x<0.2 \end{cases} \tag{12}$$

$$u_i = \sum_{j=1}^{j=15} u_{i,j} W_j \tag{13}$$

Table 1. Evaluation index system for the suitability of human settlement environment

System	Indicator	Dimension	Weight
Economic system (0.2853)	GDP per capita	Yuan	0.0564
	Disposable income per capita	Yuan	0.0597
	Balance of deposits at financial institutions at year end	Billion Yuan	0.0419
	Comparable growth in the tertiary industry	[%]	0.0727
	Electricity consumption per 10,000 Yuan of GDP *	KW	0.0545
Social system (0.3933)	Number of offences per 10,000 people *	A case	0.1252
	Average number of health technicians per 1000 people	A person	0.0733
	Student-faculty ratio (number of full-time students / number of full-time teachers) *	/	0.0577
	Housing-price-to-income ratio (commercial housing sales unit price / disposable income per capita) *	/	0.0847
	Average life expectancy	Year	0.0524
Ecological system (0.3214)	Good air quality rate	[%]	0.0763
	Urban sewage treatment rate	[%]	0.0617
	Industrial solid waste production *	10,000 tons	0.057
	Public green area per capita	[m^2]	0.0628
	Investment in environmental protection as a percentage of GDP	[%]	0.0636

The indicators with * in the table are restrictive indicators, while the others are developmental indicators.

Each constant coefficient of the correlation number component is their evaluation score, namely V level corresponding to 5 points, IV level corresponding to 4 points, III level corresponding to 3 points, II corresponding to 2 points, I level corresponding to 1:

- u_i represents the evaluation result of the suitability of sample *I*,
- $u_{i,j}$ represents the correlation number of index *j* of sample *I*, and
- w_j represents the weight of index *j*.

Results

As shown in fig. 3, the score of suitability evaluation in Qingpu district was on the rise from 2007 to 2016 and the score in 2016 was twice as much as that in 2007, which indicates that Qingpu district had achieved the remarkable effect in the construction of human settlement environment from 2007 to 2016. However, the score dropped off a cliff in 2010 and jumped in 2011. Compared to the index data of 2009-2011, it can be found that comparable growth in the tertiary industry, electricity consumption per 10000 yuan of GDP, average life expectancy, good air quality rate and industrial solid waste production had significant fluctuations. It is worth noting that this period of time is the official start of the construction of two wings of a city of Qingpu district and the integration of industry and city in the construction plan emphasizes that residence and industry promote each other. Based on the original planning scope, the 56 square kilometers Qingpu Industrial Park will be integrated into the whole. Therefore, this study speculates that the industry of Qingpu district developed by leaps and bounds in 2010 due to the new strategy of industry. Corresponding problems arose, such as the increase in industrial solid waste, the decline in air quality, the increase in electricity consumption per 10000 yuan of GDP, the hindering development of the tertiary industry and the reduction in life expectancy. After that, Qingpu district adjusted in time and achieved results in 2011.

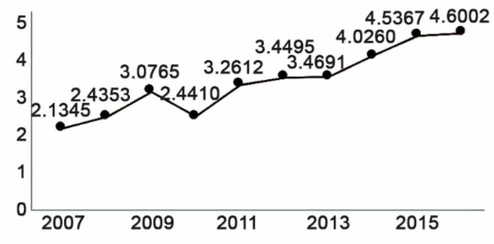

Figure 3. The evaluation results of suitability of human settlement environment in Qingpu district

Conclusions

Different from the existing evaluation methods for the suitability of human settlement environment, this study combines SPA theory and Logistic model to build Logistic SPA model. In the evaluation process, the uncertainty in the evaluation system can be taken into account and the suitability of the human settlement environment can be evaluated in a more detailed way. Using this model to evaluate the suitability of the human settlement environment in Qingpu district, Shanghai, it can be found that Qingpu district has achieved a remarkable effect in the construction of human settlement environment from 2007 to 2016. The development trend of the human settlement environment reflected by the evaluation result is basically consistent with the reality, which suggests that the Logistic SPA model built in this study is effective. In addition, this study standardizes the data in order to reflect the change of the suitability of the human settlement environment of Qingpu district from 2007 to 2016 directly.

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