

The Establishment of a Smart Growth Evaluation System

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Abstract: The world is rapidly urbanizing, and urban planning is becoming more important. Smart growth is a planning theory that can realize the sustainable development of the city effectively. In this paper, we study the principles of smart growth and set up a complete index system.

1. Introduction

“Smart growth is about helping every town and city become a more economically prosperous, socially equitable, and environmentally sustainable place to live.”[1] It is projected that by 2050, 66 percent of the world’s population will be urban. This is to say the world is rapidly urbanizing. Consequently, urban planning has become increasingly important and necessary to ensure that people have access to equitable and sustainable homes, resources and jobs. Smart growth focuses on building cities that embrace the E’s of sustainability—Economically prosperous, socially Equitable and Environmentally Sustainable. Such we set up a complete index system to measure the degree of smart growth.

2 Our Index System

Based on AHP, we define a multi - index extension comprehensive evaluation method [2], which is based on the matter - element theory of extension and extension mathematics.

2.1 Basic method

2.1.1 Model preparation

We mainly consider according to the level of economic development, social equity and environmental sustainability. We select the key factors that affect the sustainable development of the city as the evaluation factor. We define material element as

$$\mathbf{R} = (L, M, X) = \begin{pmatrix} L & M_1 & X_1 \\ & M_2 & X_2 \\ & \vdots & \vdots \\ & M_n & X_n \end{pmatrix}$$

2.1.2 Calculate the correlation

According to the correlation function, the correlation of \mathbf{R}_0 for L_j is

$$\lambda_j(L_0) = \sum_{i=1}^n \omega_i K_j(x_i) \quad (1)$$

We determine ω_i based on AHP.

$$K_j(x_i) = \begin{cases} \frac{-\rho(x_i, X_{0ij})}{|X_{0ij}|}, & x_i \in X_{0ij} \\ \frac{\rho(x_i, X_{0ij})}{\rho(x_i, X_{ij}) - \rho(x_i, X_{0ij})}, & x_i \notin X_{0ij} \end{cases} \quad (2)$$

$$\rho(x_i, X_{0ij}) = \left| x_i - \frac{(a_{0ij} + b_{0ij})}{2} \right| - \frac{(b_{0ij} - a_{0ij})}{2} \quad (3)$$

$$\rho(x_i, X_{ij}) = \left| x_i - \frac{(a_{ij} + b_{ij})}{2} \right| - \frac{(b_{ij} - a_{ij})}{2} \quad (4)$$

2.1.3 Comprehensive analysis

We substitute the actual data into (1) and we get $\lambda_j(L_0)$.

- If $\lambda_j = \max \{ \lambda_j(L_0), j = 1, 2, \dots, n \} > 0$, the level of sustainable development of the city is L_j .
- If $\lambda_j(L_0) \leq 0$ for all j , it indicates that the level of sustainable development of the city is out of range, we should adjust the parameters and weight factors, and then conduct a reasonable assessment.

2.2 Extension comprehensive evaluation of urban smart growth

2.2.1 Evaluation factors and classification options

Our assessment is based on the ten principles of "smart growth" proposed in 1990. From the connotation of different elements, mixed with the use of land and maximize the use of compact building design is the level of urban land structure design indicators, reflecting the level of economic prosperity. The remaining principles relate to improvements in social equity and environmental sustainability. To this end, this paper, based on the international smart growth evaluation index system, increases GDP, per capita road area and many other indicators to evaluate the smart growth of different cities.

We define three sub-targets, which are economic development capacity Y_1 , social equality Y_2 and environmental sustainability Y_3 . We record their weight as $\omega_i (i = 1, 2, 3)$. And we establish more detailed indicators $Y_{ij} (i = 1, 2, 3; j = 1, 2, \dots, 6)$ as $M_i (i = 1, 2, \dots, 15)$.

we get a city of any of the 15 measured data corresponding to four levels of development, and then we get four assessed material elements, which are

$$\mathbf{R}_0 = \begin{pmatrix} L_i & M_1 & x_1 \\ & M_2 & x_2 \\ & \vdots & \vdots \\ & M_{15} & x_{15} \end{pmatrix}, i = 1, 2, 3, 4$$

2.2.2 Determine the weight of the evaluation factor

We take the weights of the corresponding four evaluation factors of ω_3 as an example and get their weights.

Relative to the overall goal, the relative importance of the three sub-targets is shown in Table 1

Table 1 Sub-target judgment matrix

Y_i	Y_1	Y_2	Y_3
Y_1	1	2	3
Y_2	1/2	1	2
Y_3	1/3	1/2	1

The eigenvectors corresponding to the largest eigenvalues of the judgment matrix

$\mathbf{A} = \begin{pmatrix} 1 & 2 & 3 \\ 1/2 & 1 & 2 \\ 1/3 & 1/2 & 1 \end{pmatrix}$, then we normalize it and get $(0.5396, 0.2970, 0.1634)$. As above, we can

get the weights of $Y_{1,2,3}$, which are $\omega = (\omega_1, \omega_2, \omega_3) \neq (0.5396, 0.2970, 0.1634)$.

For the third sub-goal, the relative importance of the four evaluation factors is shown in Table 2.

Table 2 Evaluation factor judgment matrix

Y_{ij}	Y_{31}	Y_{32}	Y_{33}	Y_{34}
Y_{31}	1	1/3	2	3
Y_{32}	3	1	2	1
Y_{33}	1/2	1/2	1	3
Y_{34}	1/3	1/3	1/3	1

Similarly, we calculate the relative weights between the four evaluation factors, which are

$$\omega_3 = (\omega_{31}, \omega_{32}, \omega_{33}, \omega_{34}) = (0.279, 0.336, 0.228, 0.157)$$

The specific weights of the four evaluation factors of the third sub-goal are

$$M_{12,13,14,15} = (0.046, 0.055, 0.037, 0.026)$$

As above, we obtain the specific weights of the other 10 evaluation factors. As shown in Table 3.

Table 3 The weights

factor	M_1	M_2	M_3	M_4	M_5	M_6	M_7	M_8
weight	0.178	0.065	0.151	0.059	0.086	0.068	0.056	0.053
factor	M_9	M_{10}	M_{11}	M_{12}	M_{13}	M_{14}	M_{15}	
weight	0.042	0.036	0.042	0.046	0.055	0.037	0.026	

3. Conclusions

In our paper, we study the ten principles of smart growth and the connotation of three “E”. Considering the subjective defects of AHP, we use the matter-element theory of extension mathematics to establish a complete index system. And we translate qualitative principles into 15 quantitative indicators. We set four levels for the city's smart growth success, which are “best, better, general and poor”.

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