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Intelligent Evaluation of City Development

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Abstract: This paper is building a metric with indexes aimed to quantify the qualitative smart growth of a city. I formulate the problem of metric as a comprehensive evaluation model in which the success of smart growth is a specific value *S*.

Primarily, based on the E’s of sustainability and principles of smart growth, I select several indexes measuring the success of smart growth, and establish a three-tier structure of the evaluation indexes system. Then, the analytic hierarchy process (AHP) is applied to evaluate the weights of each tier and get the specific value *S*.

The collected data of Liverpool, UK and Karamay, China, are used in my model. Meanwhile, I set a standard with several cities. The value in Liverpool is 1.1113, and 0.8415 in Karamay. I determine it’s successful in Liverpool and it’s unsuccessful in Karamay because of the standard. The biggest advantage of the model is to quantify the contribution of each index. The impact of the change of each index on the success of smart growth can be observed, which can help the government work out plans.

Introduction

The ten principles for smart growth that have gained widespread recognition are: [1,2]

- Create a range of housing opportunities and choices;
- Create walkable neighborhoods;
- Encourage community and stakeholder collaboration;
- Foster distinctive, attractive places with a strong sense of place;
- Make development decisions predictable, fair, and cost-effective;
- Mix land uses;
- Preserve open space, farmland, natural beauty, and critical environmental areas;
- Provide a variety of transportation choices;
- Strengthen and direct development towards existing communities;
- Take advantage of compact building design.

An optimal evaluation model is required for the communities to determine whether their growth plan conforms to smart growth.At first, I discuss and define the indexes of criterion layer to measure the success of smart growth of a city. After a long discussion, I determine the following indexes of sub-criterion layer: GDP, inward investment, unemployment rate, economic growth rate, the ratio of tertiary industry to GDP, housing density in central area, Gini coefficient, health technical per 10000 persons, college students per 10000 persons, crime rate, public transportation per 10000 persons, population, green coverage area, water resources per capita, solid pollutant emissions, number of air pollution days per year, and government annual investment in pollution control, as is shown in Fig.1.

As is shown in Fig.1, there is the hierarchical structure diagram of the evaluation model.

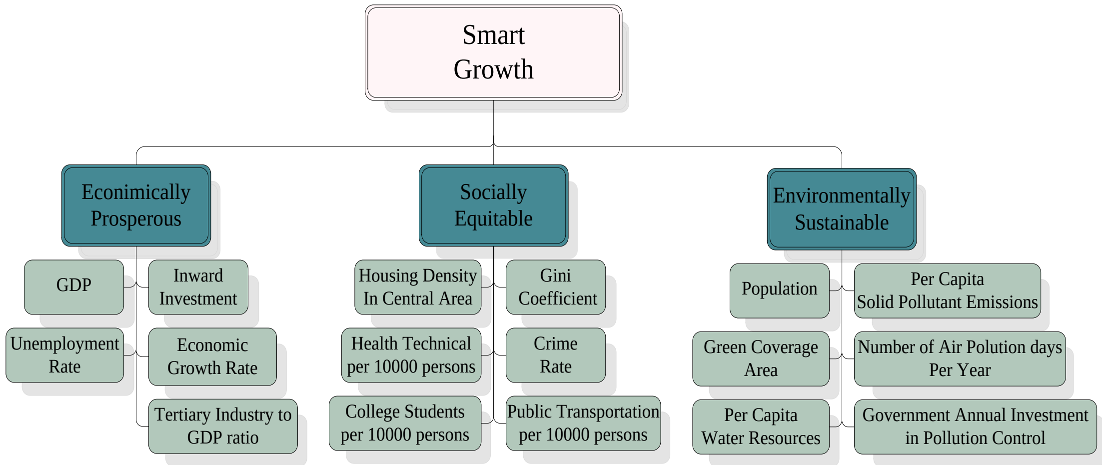

Fig.1: The hierarchical structure diagram of the indexes of my evaluation model.

Then I collect the related data of some typical cities and make standardization of these data, because I need to limit the range of data and remove the effect of unit.

Next, I determine the weight of these indexes by the Analytic hierarchy process.

Finally, I make the consistency check to make sure that the weight of these indexes is reasonable.

The Model

- Data Collection and Data Standardization

Consequently, I choose five typical cities as samples: Canberra, Karamay, Liverpool, Parreira, and Markham. The five cities with a population ranging from 100,000 to 500,000 are considerably representative in the industrial structure, urban morphology, geographical conditions and other aspects.

According to the influence of the indexes on the success rate of smart growth, I adopt two standardized formulas to make the data standardized. For positive indexes I use formula (1) to standardize them:

$$b_{Si} = \frac{b_i n}{\sum_{j=0}^{n} b_{ij}} \tag{1}$$

For passive indexes I use formula (2) to standardize them:

$$b_{Si} = \frac{\sum_{j=0}^{n} b_{ij}}{b_i n} \tag{2}$$

- Weight Analysis

✧ Determine the judging matrix: I determine the judging matrix by one-nine method [3].

✧ Determine the weight vector: the greatest eigenvalue of matrix A,B is λ_m, and the corresponding eigenvector is $\overline{W} = \left(\overline{w_1} \quad \overline{w_2} \quad \cdots \quad \overline{w_n}\right)^T$. Then I calculate the normalized eigenvector by the following formula:

$$w_i = \frac{\overline{w_i}}{\sum_{i=0}^{n} \overline{w_i}}, i = 1, 2, \cdots, n, \tag{3}$$

✧ The consistency check: I define an index of consistency check *CI* to make the consistency check:

$$CI = \frac{\lambda_m - n}{n-1} \tag{4}$$

Then I introduced a random consistency index RI to determine the allowable range of inconsistency of matrix A, B. And there are the values of RI in Table 1: [3]

Table 1: the values of *RI*

n	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49	1.51

Then I name the ratio of CI to RI as the consistency ratio CR:

$$CR = \frac{CI}{RI} \tag{5}$$

When $CR < 0.1$, the weight of these indexes is reasonable.
So the formula to evaluate the success of smart growth of a city is:

$$S_1 = AW \times \mathbf{a} \tag{6}$$

$$= aw_1 \times a_1 + aw_2 \times a_2 + aw_3 \times a_3$$

$$= aw_1 \times BW_1 \times \mathbf{b^1} + aw_2 \times BW_2 \times \mathbf{b^2} + aw_3 \times BW_3 \times \mathbf{b^3}$$

Where:

$$AW = \begin{bmatrix} aw_1 & aw_2 & aw_3 \end{bmatrix};$$

$$\mathbf{a} = \begin{bmatrix} a_1 & a_2 & a_3 \end{bmatrix}^T;$$

$$\mathbf{b}^1 = \begin{bmatrix} b_1 & b_2 & \cdots & b_5 \end{bmatrix}^T;$$

$$\mathbf{b}^2 = \begin{bmatrix} b_6 & b_7 & \cdots & b_{11} \end{bmatrix}^T;$$

$$\mathbf{b}^3 = \begin{bmatrix} b_{12} & b_{13} & \cdots & b_{17} \end{bmatrix}^T;$$

- Numerical Calculation and Consistency Check

Based on the conclusion in section 4.2.2, I reach the following results:

- The judging matrix of the criterion layer index to the goal layer:

$$A = \begin{bmatrix} 1 & 1/3 & 1/3 \\ 3 & 1 & 2 \\ 3 & 2 & 1 \end{bmatrix}$$

- Weight vector of it:

$$AW = \begin{bmatrix} 0.1396 & 0.5279 & 0.3325 \end{bmatrix}$$

For this level, $CR = 0.0462 < 0.1$.

- The judging matrix of the economic sub-criterion layer index to the criterion layer index(Economic prosperity):

$$B_1 = \begin{bmatrix} 1 & 1/2 & 1 & 1/2 & 1/3 \\ 2 & 1 & 2 & 1 & 1/2 \\ 1 & 1/2 & 1 & 1/2 & 1/3 \\ 2 & 1 & 2 & 1 & 1/2 \\ 3 & 2 & 3 & 2 & 1 \end{bmatrix}$$

- Weight vector of it:

$$BW_1 = [0.1093 \quad 0.1093 \quad 0.2063 \quad 0.2063 \quad 0.3689]$$

For this level, $CR = 0.0492 < 0.1$.

- The judging matrix of the socially sub-criterion layer index to the criterion layer index(Social equity):

$$B_2 = \begin{bmatrix} 1 & 3 & 3 & 1 & 3 & 1 \\ 1/3 & 1 & 1 & 1/3 & 1 & 1/3 \\ 1/3 & 1 & 1 & 1/3 & 1 & 1/3 \\ 1 & 3 & 3 & 1 & 3 & 1 \\ 1/3 & 1 & 1 & 1/3 & 1 & 1/3 \\ 1 & 3 & 3 & 1 & 3 & 1 \end{bmatrix}$$

- Weight vector of it:

$$BW_2 = [0.250 \quad 0.083 \quad 0.083 \quad 0.250 \quad 0.083 \quad 0.250]$$

For this level, $CR = 0.0462 < 0.1$.

- The judging matrix of the environmentally sub-criterion layer index to the criterion layer index(Environmental sustainability):

$$B_3 = \begin{bmatrix} 1 & 5 & 1 & 1 & 3 & 3 \\ 1/5 & 1 & 1/5 & 1/5 & 1/2 & 1/2 \\ 1 & 5 & 1 & 1 & 3 & 3 \\ 1 & 5 & 1 & 1 & 3 & 3 \\ 1/3 & 2 & 1/3 & 1/3 & 1 & 1 \\ 1/3 & 2 & 1/3 & 1/3 & 1 & 1 \end{bmatrix}$$

- Weight vector of it:

$$BW_3 = [0.1148 \quad 0.1148 \quad 0.3242 \quad 0.3242 \quad 0.0610 \quad 0.0610]$$

For this level, $CR = 0.0474 < 0.1$

Conclusions

Because of the above CR are all less than 0.1, so the weight of these indexes are credible. If a city development plan is evaluated by the model and the result is greater than 1, the plan is accord with smart growth. The impact of the change of each index on the success of smart growth can be observed, which can help the government work out plans.

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