The Success of Smart Growth of a City

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ABSTRACT

With the development of urbanization and the increase of urban population, smart growth has become an important criterion for urban construction. We propose an evaluation model to measure the success of smart growth of a city. Then, the growth plans are developed for both cities: Jersey City, NJ and Miami, FL.

KEYWORDS
Urbanization, Smart growth, Evaluation Model.

INTRODUCTION

Many cities have gradually put smart growth plan [1] into practice. Smart growth is a kind of city planning theory. It is committed to curb the continued spread of the city and the loss of farmland. It includes three E goals (economic prosperity, social equity, and environmental sustainability) and ten principles. Its core is to build sustainable cities.

The importance of smart growth has become increasingly significant. With the globalization of economic and the world's urbanization process continues to advance, the city gradually played a leading role. Urban population showed a rising trend. By 2050, the urban population is expected to reach 66% of the world's total population. The government should construct the harmonious city, and enhance the quality of working and living environment. In order to seize the development opportunity and realize the sustainable prosperity of the city, urban construction needs to be based on the principle of smart growth.

Our goals are to define an index to measure the success of smart growth plans. And make future growth plans for the city based on the city's geographic location, expected growth rates and economic opportunities.

In this article, we set up an index called Smart Growth Status Metric to measure the success of urban smart growth and help the two cities design growth plans. In our SGSM model, we definite five supporting indexes, including economic, social, resource, environmental and geographical conditions. The value of the SGSM is used to evaluate the success of the growth plan.
SMART GROWTH STATUS METRIC MODEL

In this section, we construct a metric that contains demographics, growth requirements, and geographical conditions, named Smart Growth Status Metric (SGSM). Larger SGSM means that a city’s growth plan is more satisfying.

First, we constructed an evaluation system that included five supporting indexes and the seventeen sub-indexes included. The weight of each sub-index is determined by analytic hierarchy process (AHP), then the indexes are integrated into the smart growth status metric by using T-S fuzzy neural network algorithm, so as to determine the success degree of the growth.

The Construction of Evaluation

Smart Growth’s goal is to help the local community solve a series of thorny problems. Such as reducing traffic congestion, combating crime, promoting economic growth, controlling the impact of climate change and improving the level of urban services. After reading the related literature [2], we combined five E-goals and ten principles, namely, the Economic Supporting Metric, the Social Supporting Metric, the Existence Supporting Metric, the Environmental Supporting Metric and the Geographic Supporting Metric. And the five indexes are divided into 17 sub-indexes. The evaluation system is shown in Figure 1.

Figure 1. Smart Growth State Evaluation System.
The Construction of Index

Economic Supporting Metric (ECSM) measures a city's economic development. Economic prosperity is a prerequisite for urban development, although high urban economic growth does not necessarily lead to high welfare, but no certain economic conditions certainly do not have a good urban life.

Social Supporting Metric (SSM) measures the level of social equality in a city. Social equity means that managers not only consider the total economy of the city, but also concerned about the distribution of individual income and wealth, the enjoyment of resources, employment, health, medical and education, etc.

The change in the Existence Supporting Metric (EXSM) shows a change in demand of the city. Natural resources is an important material foundation for the development and progress of human society, which plays an extremely important role in the primitive accumulation of the national wealth of a country. The development of a city and the population growth will both inevitably increase demand for resources.

The city's economic growth should be low-cost and environmentally friendly. On the contrary, if the city's development at the cost of environmental pollution and inability, then the quality of life of urban residents will reduce. Environmental sustainability is indispensable to the development of urban intelligence. The smaller Environmental Supporting Metric (ENSM) represents the less urban pollution.

Geographical conditions are divided into natural geographical conditions and economic geographical conditions. Geographical conditions determine the climate and terrain water, having impact in traffic development, tourism, and human economic development. Geographic Supporting Metric (GSM) affects the formation and development of cities by affecting the living environment of the population and the spatial distribution of the population.

Analytic Hierarchy Process to Determine Weights

EXSM and ENSM can be obtained by literature [3]. So we use the analytic hierarchy process (AHP) [4] to determine the subjective weights of the other three supporting indexes. The hierarchical structure of index is established. The judgment matrix and weight of criterion layer are as follows:

| TABLE 1. JUDGMENT MATRIX AND WEIGHT OF ECSM AND GSM. |
|-----------------|-----------------|----------------|-----------------|
| ECSM | II | LSI | FIG | Weight |
| ISM | 1 | 2 | 5 | 0.6483 |
| LSI | 1/2 | 1 | 3 | 0.2297 |
| FIG | 1/5 | 1/3 | 1 | 0.1220 |
| GSM | VC | CCI | TDD | Weight |
| VC | 1 | 3 | 1/2 | 0.3000 |
| CCI | 1/3 | 1 | 1/6 | 0.1000 |
| TDD | 2 | 6 | 1 | 0.6000 |

| TABLE 2. JUDGMENT MATRIX AND WEIGHT OF SSM. |
|-----------------|-----------------|----------------|-----------------|
| SSM | EI | LEI | SR | GO | Weight |
| EI | 1 | 3 | 5 | 1 | 0.3936 |
| LEI | 1/3 | 1 | 2 | 1/3 | 0.1375 |
| SR | 1/5 | 1/2 | 1 | 1/5 | 0.0753 |
| GO | 1 | 3 | 5 | 1 | 0.3936 |
The maximum eigenvalue $\lambda$ of the judgment matrix $C$ is calculated by MATLAB software, which is equal to 3.0037. Then the consistency index $CI$ is calculated to be 0.0018, and the correction coefficient $RI$ is calculated to be 0.58 by the look-up table. Thereby calculating the consistency ratio $CR$ equal to 0.0212, which is less than 0.10, satisfying consistency test. The other two indexes as well.

The judgment matrix and the weight distribution of the second-order index are obtained, and the calculation matrixes are not more than 0.1, so the judgment matrices meet the consistency requirements. The specific weights of the indexes are as follows:

$$V_{ECSM} = (0.6483, 0.2297, 0.1220)$$
$$V_{SSM} = (0.3936, 0.1375, 0.0753, 0.3936)$$
$$V_{GSM} = (0.3000, 0.1000, 0.6000)$$

**T-S Fuzzy Neural Network**

Here we use the Takagi-Sugeno fuzzy neural network algorithm [5] to modeling. Enter the five indexes and output the Smart Growth Status Metric. The Takagi-Sugeno fuzzy neural network has the advantages of strong self-adaptability, automatic updating, and constant modification of membership functions of fuzzy subsets.

**NORMALIZATION OF EVALUATION INDEX DATA**

In order to integrate the evaluation indexes of different dimensions, we need to normalize each evaluation index. Using the membership function approach, we construct the following non-dimensional normalization function

$$y_{ij} = \left( \frac{x_{ij} - x_{\min j}}{x_{\max j} - x_{\min j}} \right)^a$$  \hspace{1cm} (1)

Where $x_{ij}$ and $y_{ij}$ are the original value and evaluation value of the $i$-th city $j$-th index. While $x_{\max j}$ and $x_{\min j}$ are the maximum and minimum evaluation values of the $j$-th index respectively, and $a$ is the index property parameter being taken as 1 in this paper.

**CONSTRUCTION OF T-S FUZZY NEURAL NETWORK**

T-S fuzzy neural network is divided into four layers: input layer, fuzzy layer, fuzzy rule calculation layer and output layer. The input layer is connected to the input vector $x_i$, and the number of nodes is the same as the input vector. The fuzzification layer adopts the membership function

$$\mu A^j_k = \exp \left( -\left( x_j - c^j_i \right)^2 / b^j_i \right), \quad j = 1, 2, \ldots, n$$
Fuzzy membership degree $\mu$ is obtained by fuzzing the input layer. Where $c_j^i$ and $b_j^i$ are the center and width of the membership function, $k$ is the input parameter, and $n$ is the number of fuzzy subsets.

The fuzzy layer is calculated by fuzzy multiplicative formula

$$\omega^i = \mu A_1^i(x_1) \times \mu A_2^i(x_2) \times \cdots \times \mu A_n^i(x_n), i = 1, 2, \ldots, n$$

By calculation we get $\omega$. And according to the fuzzy calculation result, the output value of the fuzzy model is as follows:

$$y_{ij} = \sum_{i=1}^{k} \omega^i (p_0^i + p_1^i x_i + \cdots + p_k^i x_k) / \sum_{i=1}^{k} \omega^i$$

(2)

Error calculation

$$e = \frac{1}{2} (y_d - y_c)^2$$

(3)

Where $y_d$ is the desired output of the network, $y_c$ is the actual output of the network, and $e$ is the expected output and the actual output error.

Coefficient correction

$$p_j^i(k) = p_j^i(k-1) - \alpha \frac{\partial e}{\partial p^i_j}$$

$$\frac{\partial e}{\partial p^i_j} = (y_d - y_c) \omega^i / \sum_{j=1}^{m} \omega^i \cdot x_j$$

Parameter correction

$$c_j^i(k) = c_j^i(k-1) - \beta \frac{\partial e}{\partial c_j^i}$$

$$b_j^i(k) = b_j^i(k-1) - \beta \frac{\partial e}{\partial b_j^i}$$

Where $c_j^i$ and $b_j^i$ are the center and width of the membership function, respectively.
TRAINING AND TESTING

We use data from 35 cities in China as training objects for neural networks, where the population is expressed as the resident population of the city. From the National Bureau of Statistics of China collected 35 cities to reflect the intelligent growth of the five evaluation indexes of the data used as a learning sample in order to train neuron connection weights, and learning accuracy $\varepsilon = 10^{-3}$, using MATLAB neural network toolbox on neural network Training, after 100000 learning, the results shown in Figure 2.

Next, the model is tested, and the five evaluation indexes of the other five cities are input into the trained neural network to get the results shown in the Figure 3, and the error is marked with green line.

![Figure 2. Results of model training.](image)

![Figure 3. Results of model testing.](image)
TABLE 3. MEASURE OF SUCCESS.

<table>
<thead>
<tr>
<th>Output</th>
<th>Degree of Success</th>
<th>Satisfactory success</th>
<th>General success</th>
<th>Unsatisfactory success</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.42 or more</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Between 0.38</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>and 0.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.38 or less</td>
<td></td>
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</tbody>
</table>

Obviously, at this time the error is very small, indicating that the model has been a good training network, the actual growth of the city can be intelligent success rate of evaluation. And the higher the output value represents the higher the success rate of the intelligent growth plan. Based on the results, we list the model results hierarchy as shown in the Table 3.

CONCLUSION

In this paper, we evaluate the growth plans of the two cities and develop plans for their growth over the next few decades.

The smart growth status indexes are divided into economic, social, survival, environment and geography five supporting indexes. Under the five indexes it contains 17 sub-indexes. The five supporting indexes are merged into SGSM through AHP and T-S fuzzy neural network algorithm, and the corresponding success grade is obtained. We use the data of 35 cities to carry on 100,000 training to the model, test the model with the data of 5 cities, the result shows the model precision is extremely high.

Strength

- Our SGSM contains five supporting indexes that strictly adhere to the three E objectives, covering almost the ten principles of intelligent growth.
- In the construction of SGSM model, we use T-S fuzzy neural network algorithm, which has strong adaptability and can automatically update the membership function of fuzzy subset. And the model test results show that the model has a small error, which means that our model is objective and persuasive.
- Our time series AR model used in the forecast has a small error, which means that our predictive performance is good.

Weaknesses

- Our training and verification samples may not include a sufficient number of cities.

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