Evaluation model of smart growth

Qiqi He
[1]School of North China Electric Power University, Baoding 071003, China
289198812@qq.com

Keywords: evaluating index system, AHP, Fuzzy Synthetic Evaluation.

Abstract: In order to measure the success of smart growth, we establish a scientific comprehensive evaluation model and take Miami as example. Firstly, We build the evaluating index system. The first layer includes eight indexes such as people density, urban floor area ratio, land productivity and so on. The second layer is composed of five aspects in public infrastructure, industrial structure, traffic, environment and economic. Secondly, Analytic Hierarchy Process (AHP) is adopted to ascertain the weight of the indexes in the two levels. Then the score of the success of smart growth can be calculated with the Fuzzy Synthetic Evaluation Model. Finally, the score of current plan in Miami is 75.82, which called good.

1. Background analysis

Smart growth, focuses on building cities that embrace the E's of sustainability —Economically prosperous, socially Equitable, and Environmentally Sustainable. Taking three E's of sustainability of smart growth into deep consideration, we are required to define the measure gauges of the success of the smart growth using a model and analyze the selected gauges quantitatively and qualitatively.

2. Model hypothesis

(1) The area of city land is constant. The land may become the river because of large amount of precipitation, and the river may dry up into land. The variation is small so we neglect it to simplify calculation.

(2) We ignore the inflation and use GDP as an evaluation index of economic benefits.

(3) The three E's can perfectly reflect the success of smart growth.

3. Symbol Description

symbol	Description
W_F	The weight set vector
W_E	The remark set vector
R	The fraction set vector

4. The Establishment and Solution of Model

4.1 Establishing the AHP Model

To establish the AHP model, we build two layers of evaluating indexes.

- **The first layer**

With deep consideration about the three E's of sustainability of smart growth economically, socially and environmentally, we construct an index system with eight indexes to judge the success of smart growth. And the data should be calculated in dimensionless treatment..

With the increasing of population density, the urban area will suffer the greater pressure, which is obviously negative about smart growth;

The floor area ratio can measure the intensity of urban growth. Higher values represent more intensity;

Copyright © 2017, the Authors. Published by Atlantis Press.
This is an open access article under the CC BY-NC license (http://creativecommons.org/licenses/by-nc/4.0/).

Land productivity can measure the production benefits of the urban. They are positively correlated;

Cultivation index is the relative change ratio of the cultivated land;

Per capita road possession is the index to evaluate traffic network accessibility. The transportation is more convenient, the economy and trading links more closely and citizen satisfaction is higher.

Employment rate will also do an effect on the population-urbanized ratio;

Green space ratio is larger and the society satisfaction is higher;

Urban expansion coefficient reflects the intensive level of urban land use. There is a negative correlation between them.

Table 1 The definition and quantification of the criteria

criteria	formula	definition
People density	$\rho = \frac{N}{S}$	N is city population, S is city area
Urban floor area ratio	$\alpha = \frac{S_1}{S_2}$	S_1 is total floorage, S_2 is land area of construction
Land productivity	$\beta = \frac{G}{S}$	G is the city GDP, S is city area
Cultivation index	$\delta = \frac{S_3}{S}$	S3 is The area of land reclaimed, S is city area
Per capita road possession	$\lambda = \frac{C}{N}$	C is total highway mileage of city, N is city population
Employment rate	$\eta = \frac{n}{N}$	n is employment population, N is city population
Green space ratio	$\theta = \frac{S_4}{S}$	S4 is urban green area, S is city area
Urban expansion coefficient	$K = \frac{\Delta A / A}{\Delta N / N}$	A is urban built-up area, N is city population

- **The second layer**

To evaluate the smart growth plan better, we select five alternatives (In the following model application, we will change them into corresponding initiatives) with a close relationship to the first layer. These alternatives are municipal infrastructure, industrial structure adjustment, highway traffic construction, environment comprehensive treatment and urban economic growth benefit. As we can see in Figure1, by establishing comparison matrix, we can confirm weight of indexes.

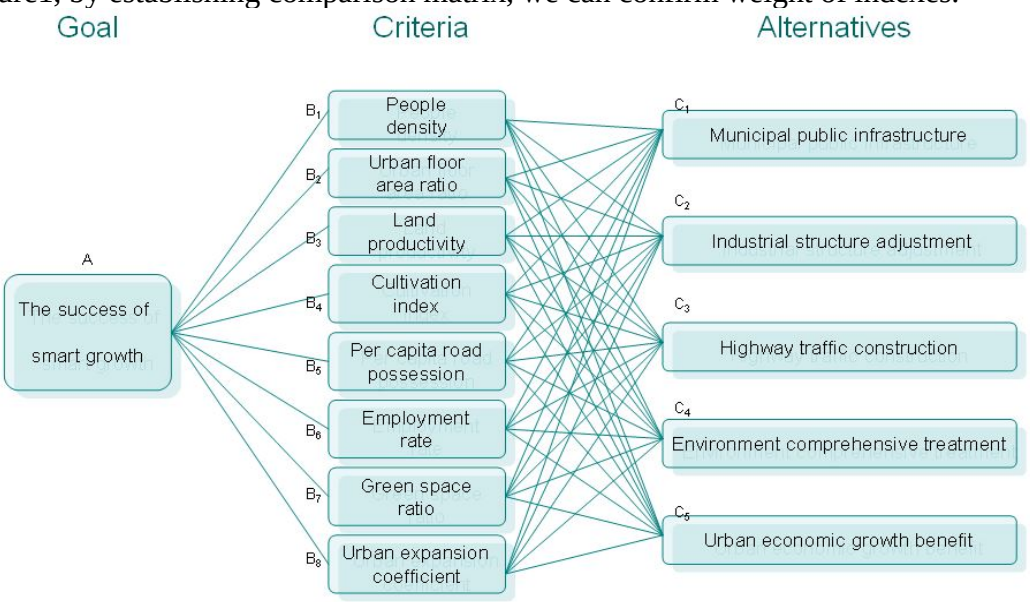

Fig. 1 AHP Hierarchy Figure

4.2 Establishing the Fuzzy Synthetic Evaluation Model

The model for fuzzy synthetic evaluation is composed of factor set, remark set based on the evaluation of experts or persons familiar with internal control, weight set and fraction set. [1] On the basis of AHP model, we get weight of indexes. And we use the second layer to evaluate the success of smart growth. So the five value of weight consists of weight set vector

$$W_F = \{ w_1, w_2, w_3, w_4, w_5 \} \tag{1}$$

We define the remark set W = { wonderful, better, good, general, below average } and the remark set vector

$$W_E = \{ 90, 80, 70, 60, 50 \} \tag{2}$$

Based on the evaluation of nine authority experts in the study of city development, we can get fraction set vector

$$R = \begin{bmatrix} r_{11} & r_{12} & r_{13} & r_{14} & r_{15} \\ r_{21} & r_{22} & r_{23} & r_{24} & r_{25} \\ r_{31} & r_{32} & r_{33} & r_{34} & r_{35} \\ r_{41} & r_{42} & r_{43} & r_{44} & r_{45} \\ r_{51} & r_{52} & r_{53} & r_{54} & r_{55} \end{bmatrix} \tag{3}$$

r_{ij} (i, j = 1,2…, 5): i is the number of index set; j is the number of remark set.

Finally, we obtain the score to evaluate the success of smart growth by computing the following formulate

$$G = W_F \bullet R \bullet W_E^T \tag{4}$$

5. Model Results

We collect a lot of statistical data of Miami based on needs of Table 1, such as city population[2], city GDP[3], city area[4] and so on, via Internet.

Based on the AHP model, we can get different weights of evaluation criterion shown in Table 1. As we can see in Figure 1, B_i (i = 1,2,…,8) represent eight indexes in criteria layer, C_i (i = 1,2,…,5) represent five indexes in alternative layer. While the specific representative of C_i depend on corresponding initiatives within the growth plan of Miami.

Table 2 Criterion's weights to overall objects in Miami

Criteria B		B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8	Weight of Alternative w_C
Weight of criteria w_B		0.13	0.1102	0.0712	0.1032	0.1437	0.1314	0.1536	0.1568	
Alternative C	C_1	0.0984	0.1741	0.1538	0.1805	0.2333	0.2111	0.141	0.1457	0.1673
	C_2	0.3935	0.2264	0.1597	0.2449	0.2069	0.1583	0.1717	0.2403	0.2273
	C_3	0.2444	0.3159	0.2327	0.3152	0.1645	0.1766	0.2353	0.2309	0.2349
	C_4	0.1406	0.1451	0.2479	0.1514	0.1359	0.3017	0.2903	0.1146	0.1893
	C_5	0.1232	0.1385	0.206	0.1079	0.2594	0.1523	0.1617	0.2684	0.1813

C_1: people-oriented construction C_2 : a relatively free economic system
C_3 : construction of urban rail system
C_4: strengthen ecological protection C_5: industrial diversification

With the weights of indexes, we can apply the fuzzy synthetic evaluation model to scoring the success of smart growth, and the scores of the final goal are gotten in Table 3. The average score of Miami is 74.58 and we describe Miami as good.

Table 3 Score of Miami from 2000 to 2015

Year	2000	2001	2002	2003	2004	2005	2006	2007
Score	60.08	66.98	59.93	64.48	63.78	65.61	73.73	74.37
Year	2008	2009	2010	2011	2012	2013	2014	2015
Score	72.13	72.37	71.62	69.05	70.44	67.23	69.21	68.47

References

[1] Information on http://xuewen.cnki.net/CJFD-CSJR200701009.html

[2] Information on https://en.wikipedia.org/wiki/List_of_U.S._metropolitan_areas_by_GDP

[3] Information on https://www.census.gov/dataviz/visualizations/026/508.php

[4] Information on http://ah.anhuinews.com/system/2016/10/08/007475914.shtml