ATLANTIS PRESS
Advances in Computer Science Research (ACSR), volume 76
7th International Conference on Education, Management, Information and Mechanical Engineering (EMIM 2017)

Study on Comprehensive Evaluation of Smart Growth Cities

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Keywords: Smart growth cities; Fuzzy comprehensive evaluation; Sustainable development.

Abstract. This paper studied the problem of comprehensive evaluation of smart growth cities from three dimensions of sustainable development. Concretely, an evaluation system for smart growth cities from the dimensions of sustainable development - economic, environmental and social, is constructed, then a fuzzy comprehensive evaluation method is presented to evaluate the development level of smart growth cities, and an application example is given to highlight the implementation, availability, and feasibility of the proposed comprehensive evaluation method.

Introduction

Many communities are implementing smart growth initiatives in an effort to consider long range, sustainable planning goals. “Smart growth is about helping every town and city become a more economically prosperous, socially equitable, and environmentally sustainable place to live. Smart growth focuses on building cities that embrace the E’s of sustainability—Economically prosperous, socially Equitable, and Environmentally Sustainable. This task is more important than ever because the world is rapidly urbanizing. It is projected that by 2050, 66 percent of the world’s population will be urban—this will result in a projected 2.5 billion people being added to the urban population. 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 is an urban planning theory that originated in 1990’s, after decades of practice, people summarize 10 basic principles for smart growth that deeply rooted in the 3E’s of sustainability — Economically prosperous, socially Equitable, and Environmentally Sustainable [1]. The continuing urbanization and overall growth of the world’s population is projected to add 2.5 billion people to the urban population by 2050, meanwhile about 66 percent of the world’s population will be living in cities [2]. These circumstances call for cities to function smarter to provide dignity for the increasing urban dwellers.

The Evaluation Index System

In this section, an evaluation system for evaluate the development level of smart growth cities was established. Drawing from the existing related research [3-8], we take into account three dimensions of sustainable development - economic, environmental and social to construct an evaluation system as shown in Table 1.

Each attribute in Table 1 is briefly described as follows.

A_1 GDP growth rate, which reflects a country or region’s economy vitality. In general, the GDP growth rate of developing countries are greater than developed countries.

A_2 GDP per capita, is a more persuasive criteria than the region’s total GDP. A metropolis with huge GDP volume does not necessarily belong to the smart cities club.

A_3 Service industry proportion. Smart cities generally have robust service industry, thus they can focus on preserving open space, farmland, natural beauty, and critical environmental areas.

A_4 Imports-Exports. A city that keeps a close relation with the outer economy tends to work smarter.

A_5 AQI, which is based on the five "criteria" pollutants: ground-level ozone, particulate matter, carbon monoxide, sulfur dioxide, and nitrogen dioxide.

A_6 Forest coverage, which reflects how "green" a city is, including natural parks, community gardens and historical sites area.

A_7 PM2.5. Considering that the AQI index may be too general, we also choose PM2.5 index to reflect the air quality.

A_8 Crimes rate, which reflects the social security level.

A_9 Health care rate. Extensive public health care can give citizens sense of security, fairness and dignity.

A_{10} Unemployment rate. Low unemployment rate contribute to public anxiety reduction and public intelligence emergence.

Table 1. Evaluation index system for evaluate the development level of smart growth cities

First level attribute	Second level attribute
Economic criterion	A_1 GDP growth rate A_2 GDP per capita A_3 Service industry proportion A_4 Imports-Exports
Environmental criterion	A_5 AQI A_6 Forest coverage A_7 PM2.5
Social criterion	A_8 Crimes rate A_9 Health care rate A_{10} Unemployment rate

Fuzzy Comprehensive Evaluation Method

Fuzzy set theory [9-17] has been developed and extensively applied since 1965 (Zadeh, 1965). It was designed to supplement the interpretation of linguistic or measured uncertainties for real-world random phenomena. We use the data of Zhuhai City to show the whole process.

Step1: Establish the factor set.

We have already articulate our metrics for ranking. Totally, there are 10 second level attributes are given to They constitute the factor set U:

$U = [A_1, A_2, \ldots, A_{10}]$

Step2: Establish the evaluation set.

We divide cities' performance in every norms into five levels, which denoted as $10, 8, 6, 4, 2$, and then rate the four levels for the convenience of quantitative analysis. We denote the evaluation set V as:

$V = [10, 8, 6, 4, 2]$

Step 3: Determine the degree matrix of membership.

We use Delphi method to determine the membership degree matrix. Delphi method, namely Expert Investigation Method, is a structured communication technique or method, originally developed as a systematic, interactive forecasting method which relies on a panel of experts.

The experts answer questionnaires in two or more rounds. The number of experts is n. We denote the membership degree of the factor u_{ij} as r_{ij} , in which i denotes the ith element in factor set, and j denotes the jth element in evaluation set.

From Table 1, we can get the degree matrix of membership as follows.

$$R_1 = \begin{pmatrix} 0.07 & 0.13 & 0.22 & 0.35 & 0.23 \\ 0.16 & 0.39 & 0.34 & 0.08 & 0.03 \\ 0.18 & 0.29 & 0.32 & 0.15 & 0.06 \\ 0.12 & 0.28 & 0.34 & 0.21 & 0.05 \end{pmatrix}$$

$$R_2 = \begin{pmatrix} 0.24 & 0.38 & 0.26 & 0.08 & 0.04 \\ 0.12 & 0.24 & 0.3 & 0.26 & 0.08 \\ 0.32 & 0.33 & 0.18 & 0.11 & 0.06 \end{pmatrix},$$

$$R_3 = \begin{pmatrix} 0.17 & 0.29 & 0.32 & 0.18 & 0.04 \\ 0.07 & 0.10 & 0.46 & 0.22 & 0.15 \\ 0.29 & 0.42 & 0.19 & 0.07 & 0.03 \end{pmatrix}.$$

Table 2. The evaluation results given by experts

First level attribute	Second level attribute	r_{ij}				
Economic criterion	A_1 GDP growth rate	0.07	0.13	0.22	0.35	0.23
	A_2 GDP per capita	0.16	0.39	0.34	0.08	0.03
	A_3 Service industry proportion	0.18	0.29	0.32	0.15	0.06
	A_4 Imports-Exports	0.12	0.28	0.34	0.21	0.05
Environmental criterion	A_5 AQI	0.24	0.38	0.26	0.08	0.04
	A_6 Forest coverage	0.12	0.24	0.3	0.26	0.08
	A_7 PM2.5	0.32	0.33	0.18	0.11	0.06
Social criterion	A_8 Crimes rate	0.17	0.29	0.32	0.18	0.04
	A_9 Health care rate	0.07	0.1	0.46	0.22	0.15
	A_{10} Unemployment rate	0.29	0.42	0.19	0.07	0.03

Step 4: Determine the weights matrix.
Applying Delphi method to the process, we obtain the following results.
First-layer norms weight: $P = (0.4, 0.3, 0.3)$.
Second-layer norms weight:
$P_1 = (0.2, 0.3, 0.3, 0.2)$, $P_2 = (0.4, 0.4, 0.2)$, $P_3 = (0.3, 0.3, 0.4)$.
Step 5: Results and analysis. We define the measure of fuzzy evaluation as B.
First-level fuzzy evaluation:
$B1 = P_1 \cdot R1 = [0.140, 0.286, 0.310, 0.181, 0.083]$,
$B2 = P_2 \cdot R2 = [0.208, 0.314, 0.260, 0.158, 0.060]$,
$B3 = P_3 \cdot R3 = [0.188, 0.285, 0.310, 0.148, 0.069]$.
Second-level fuzzy evaluation:
$B = A \cdot R = [0.1748, 0.2941, 0.2950, 0.1642, 0.0719, 0.0719]$.
Thus, the final score of Zhuhai City is $S = B\dot{V}^T = 6.6714$.

Conclusions

In this paper, the problem of comprehensive evaluation of smart growth cities from three dimensions of sustainable development is studied. First, an evaluation system for smart growth cities from the dimensions of sustainable development - economic, environmental and social, is constructed, then a fuzzy comprehensive evaluation method is presented to evaluate the development level of smart growth cities, and the data of Zhuhai City is used to show the whole process of this fuzzy comprehensive evaluation method, and we obtain a satisfied results.

Acknowledgments

This work is supported by the Natural Science Foundation of Hubei Province (No. 2015CFB420).

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