



Application of a hybrid Entropy–McKinsey Matrix method in evaluating sustainable urbanization: A China case study



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ABSTRACT

Although urbanization can promote social and economic development, it can also cause various problems. As the key decision makers of urbanization, local governments should be able to evaluate urbanization performance, summarize experiences, and find problems caused by urbanization. This paper introduces a hybrid Entropy–McKinsey Matrix method for evaluating sustainable urbanization. The McKinsey Matrix is commonly referred to as the GE Matrix. The values of a development index (DI) and coordination index (CI) are calculated by employing the Entropy method and are used as a basis for constructing a GE Matrix. The matrix can assist in assessing sustainable urbanization performance by locating the urbanization state point. A case study of the city of Jinan in China demonstrates the process of using the evaluation method. The case study reveals that the method is an effective tool in helping policy makers understand the performance of urban sustainability and therefore formulate suitable strategies for guiding urbanization toward better sustainability.

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Introduction

The urbanization process involves rural people migrating to urban areas. According to a recent report by the United Nations (UN), more than half (52.1%) of the world population were living in urban areas by the end of 2011 (UN, 2012). Developing countries such as China have been experiencing large-scale urbanization in recent years, and this phenomenon is expected to continue into the foreseeable future, with the ratio of China's urban population being predicted to reach 65% by 2025 and 77% by 2050 (DESA-UN, 2011). As addressed in the 2012 China Central Economic Work Conference, the Chinese government defines urbanization as the main driving force for boosting future domestic economic and social development (Liu, 2012).

The strategic roles and effects of urbanization to social and economic development have been well recognized in previous studies. For example, Dyson (2011) opined that urbanization can provide new opportunities to improve social services and promote economic development. Others studies have recognized that the

urbanization process helps upgrade industrial structure and increase per capita income (Spence, Annez, & Buckley, 2009).

However, recent studies have also indicated that rapid urbanization has also caused a variety of problems such as the loss of farming land, increase of CO₂ emissions, shortage of water resources, traffic congestion, and rising crime rates (Huang & Chen, 2001; Wang et al., 2013). Excessive urbanization in many countries has raised a major concern about the detrimental effects of urbanization on the environment (Jaeger, Bertiller, Schwick, & Kienast, 2010). During the urbanization process in China, approximately 2.5–3.0 million farmers per year lost their farm lands in recent years because of land expropriation, which adds to the problem of social instability because the majority of these farmers could not find new jobs in cities (Tao & Cao, 2008).

The recognition of the problems caused by urbanization has led to the promotion of sustainable urbanization. Principles and methods for implementing sustainable urbanization have been introduced in various studies. Mobaraki, Mohammadi, and Zarabi (2012) pointed out that the urban sprawl growth model is one of the reasons of urban unsustainability and suggested that “Smart growth” is the best form of sustainable development for the city of Urmia in Iran. Amado, Santos, Moura, and Silva (2010) stressed the importance of building a public and community participation mechanism for making policies in implementing sustainable urban

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development. Other studies have also presented various indicators for guiding and measuring sustainable urbanization performance, which relates to social, economic, environmental, and governance dimensions (Bossel, 1999; Ronchi, Federico, & Musmeci, 2002; Shen, Ochoa, Shah, & Zhang, 2011; Shen, Peng, Zhang, & Wu, 2012). Moreover, governments throughout the world have been devoting a considerable amount of resources and efforts in implementing various sustainable urbanization schemes. For example, the Mexico City government launched the Mexico City Green Plan in 2007 to promote the long-term sustainable development of the city. Melbourne government adopted Melbourne's City Plan 2010, which contains strategies, policies and actions to help achieve the vision of becoming a thriving and sustainable city (Shen et al., 2011). The Chinese government has recently decided to implement sustainable development principles in the urbanization process by building intelligent, green, ecological, and low-carbon cities (Xinhua Website, 2012; Wu, Peng, Zhang, Skitmore, & Song, 2012).

In line with these developments, studies have introduced various models and mechanisms to assess the sustainability performance of urbanization. For example, Hunter and Shaw (2007) introduced the ecological footprint (EF) method to evaluate sustainable tourism in the United Kingdom (UK). The EF method is a quantitative tool that helps assess the resource consumption and waste assimilation requirements of a defined economy in terms of a corresponding productive land area (Wackernagel, 1996). However, this method oversimplifies the real situation and is not effective for cities with large population density and small geographical area (Lenzen & Murray, 2001). Another method, data envelopment analysis (DEA), has been adopted by many researchers to evaluate the sustainable development capacity of a specific city based on the input and output of every decision-making unit (DMU) (Qiu, Li, & Tong, 2009; Wu & He, 2006; Zeng, Gu, & Zhang, 2000). However, the result obtained via the DEA method only presents the relevant efficiency of individual indicators (Li & Li, 2009). Other methods evaluate urbanization performance based on a single aspect such as speed or quality. The assessment results of using mono-parameter-based methods nevertheless present difficulty for city decision-makers to select a suitable development strategy.

In view of the limitations of the existing methodologies, this study proposes the application of a hybrid Entropy–GE Matrix method for assessing the sustainable urbanization performance. The researchers consider that the hybrid method can not only comprehensively assess the performance of urbanization from the perspectives of both speed and quality, but also provide a method to select development strategies for improving sustainable urbanization. The remainder of the paper is therefore organized as follows: Section 'Principles of Entropy and GE Matrix for assessing sustainable urbanization performance' introduces the principles of Entropy and GE matrix. Section 'The hybrid model integrating Entropy theory and GE Matrix for assessing sustainable urbanization' presents the hybrid Entropy–GE Matrix model and its suitability for assessing sustainable urbanization performance. Section 'The application of Entropy–GE Matrix: A case study' presents the application of the method in a case study. Finally, the results are analyzed and discussed, followed by a conclusion.

Principles of Entropy and GE Matrix for assessing sustainable urbanization performance

The Entropy method

The Entropy method was first applied in thermodynamics and was introduced into the information management discipline by Shannon in 1948 for the expression of information or uncertainty.

The method is based on the principle that greater uncertainty about outcomes, results in a more uniform probability assigned to them (Jha & Singh, 2008). At present, this method has been widely used in engineering, economy, finance, and other disciplines (Zou, Yun, & Sun, 2006). The application of this method has also been extended to urban ecosystems such as water management, energy utilization, landscape analysis, and the quality of economic growth (Antrop, 1998; Balocco & Grazzini, 2000; Herrmann-Pillath, Kirchert, & Pan, 2002; Larsen & Gujer, 1997). Previous studies and current practice have also recognized that this method can be used effectively for performance evaluation based on a group of indicators by determining properly the weightings of evaluation indicators (Shemshadi, Shirazi, Toreihi, & Tarokh, 2011).

The Entropy principle can assess the performance of both development index and coordination index between a set of indicators. In the context of urbanization, these two indexes can be used to reflect the speed and quality of urbanization. The process of using the Entropy theory is as follows (Lei, Wu, & Ye, 2012; Qiu, 2002):

n indicators are assumed, as are m sample cases that apply the indicators. Considering that different indicators have different dimensions or magnitudes, and/or different effects (positive or negative) on performance evaluation, a normalization process is necessary. For positive indicators, a larger value indicates a better result. The ideal value of indicator i is assumed x_i^* , and $x_i^* = \max_j(x_{ij})$. r_{ij} is defined as the proximity of x_{ij} to x_i^* . Then Eq. (1) can be obtained:

$$r_{ij} = \frac{x_{ij}}{\max_j(x_{ij})} \quad (1)$$

On the contrary, for negative indicators, a smaller value indicates a better result. Therefore, $x_i^* = \min_j(x_{ij})$. Then Eq. (2) can be obtained:

$$r_{ij} = \frac{\min_j(x_{ij})}{x_{ij}} \quad (2)$$

f_{ij} is considered the standardized value of indicator i for sample j after normalization, which can be written as:

$$f_{ij} = \frac{r_{ij}}{\sum_{j=1}^m r_{ij}} \quad (3)$$

In Eqs. (1)–(3), x_{ij} is the original value of the indicator i for the sample case j . ($i = 1, 2, 3, \dots, n$; $j = 1, 2, 3, \dots, m$). $\max_j(x_{ij})$ and $\min_j(x_{ij})$ denote the largest and smallest value among all m samples for the indicator i respectively.

In applying Entropy theory, the weighting for each indicator needs to be established. Hence, the Entropy value for indicator i , H_i must be obtained first. When n indicators and m present samples, the Entropy of indicator i is defined as

$$H_i = -k \sum_{j=1}^m f_{ij} \cdot \ln f_{ij} \quad i = 1, 2, 3, \dots, n \quad (4)$$

where $k = \frac{1}{\ln m}$.

The weight of indicator i is defined as

$$w_i = \frac{1 - H_i}{\sum_{i=1}^n (1 - H_i)} \quad (5)$$

Following the Entropy theory, the performance of development index (speed of urbanization) for the sample case j can be obtained by the following formula:

$$F_j = \sum_{i=1}^n w_i \cdot f_{ij} \quad (6)$$

In the context of urbanization sustainability evaluation, evaluation indicators are classified into three dimensions, namely economic, social, and environmental dimensions. The development index for each dimension can therefore be defined as

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