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A novel approach for urbanization level evaluation based on information entropy principle: A case of Beijing

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HIGHLIGHTS

- Novel urbanization level evaluation model is proposed based on information entropy.
- Beijing's urbanization level has ever kept increasing during 2005–2012.
- Contributions of economic and urban–rural development to Beijing changed most.
- Poor coordination of urban–rural development is largely existed in Beijing.
- We further discuss the objectivity and flexibility in choosing indicator network.

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ABSTRACT

Urbanization level evaluation (ULE) is an important scientific basis for guiding urban managers to make decisions. By introducing information entropy to describe the interactions between all indicators, a holistic structural parameter ξ, its dynamic equation and self-organizing feature map simulation technique are derived to describe the structural evolution of the indicator network. In this way, a novel ULE model is universally proposed. Then, we use the model to assess the evolutionary urbanization level of Beijing during 2005–2012. We calculate structural parameter ξ values of the indicator network with 35 microscopic indicators as nodes. The results show Beijing's urbanization level has ever kept increasing. Large increase of ξ values in 2008 and 2012 represented significant improvements of urbanization level in these two years, while a rapid adjustment of urbanization development occurred in 2010. Five meso-scopic subsystems as urban construction, economic development, social development, ecological environment and urban–rural development affected Beijing's urbanization level in different ways. The radar chart of the model shows the contributions of economic development and urban–rural development to Beijing's urbanization changed most, while poor coordination of urban–rural development largely existed. By showing Beijing's ULE based on two analytical ways, we further discuss the objectivity and flexibility in choosing indicator network. Finally, beyond the application case, we discuss the universality and superiority of the new model.

1. Introduction

In recent years, the development of world urbanization has ever been rapid. In China, from 2002 to 2012, proportion of urban population has increased with an average 1.35% annually, and reached 52.75% in 2012. Urbanization strategy has ever been an important aspect of world economic and social development. Doubtless, accurate urbanization level

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evaluation (ULE) has played important guiding roles in better urbanization strategic development. The importance of ULE has encouraged numerous researches on the methods of ULE during past decades. At present, the methods used in ULE are mainly divided into two categories [1]. One is single indicator method such as population ratio method and proportional method of urban land-use. Another is comprehensive indicator method such as AHP [2], fuzzy comprehensive evaluation method [3], projection pursuit comprehensive evaluation and data envelopment analysis [4], principal component analysis and cluster analysis [5], gray relational analysis [6], and so on [7]. Since urbanization systems are complex dynamic systems influenced by many indicators or factors, single indicator method has some shortcomings in reflecting urbanization level objectively and comprehensively. In contrast, comprehensive indicator method, which can take the effects of many indicators or factors into account, has many advantages over single indicator method. Nevertheless, we still notice most existing comprehensive indicator methods have many theoretical shortcomings and applicable restrictions. Two most serious problems exist for most available comprehensive indicator methods. One is that they cannot mathematically–physically treat the interactions between indicators. They are usually subjective in setting interaction weights between indicators. The other is that they have not given a mechanistic definition of urbanization level from comprehensive indicators. Being incapable of mechanistically treating the interactions between indicators and yielding a definition of urbanization level from comprehensive indicators, these methods often encounter many problems in ULE.

Actually, relating to many aspects as economy, society and ecology, urbanization processes with urban-scale expansion and urban population increase are open, non-equilibrium and nonlinear dynamical systems [8,9]. The ULE must then be reflected by the synergetic features under the interactions between huge numbers of indicators related to urbanization processes. Thus, to find a necessary road for us to go out of troubles faced by current methods of ULE, first, we need to put forward a mathematical–physical method to reflect the interactions between numerous indicators. Next, a definition of urbanization level from comprehensive indicators and an associated mechanistic model should be proposed.

In modern physics, thermodynamic entropy gives a useful description on the interactions between atoms or molecules in chemical–physical systems. Information entropy, as an extension of thermodynamic entropy, is a good parameter that can well handle the interactions between indicators in complex systems that are not restricted in chemical–physical scopes [10]. Information entropy principle is an effective method to characterize complex systems, and has been currently used to assess, forecast and regulate complex systems in wide ranges [11–16]. It is a logical deduction that information entropy principle may provide a mathematical–physical description on the interactions between lots of indicators of urbanization, from which a mechanistic definition of urbanization level from comprehensive indicators and an associated model should be elaborated.

Focusing on the synergetic indicator network during urbanization process, this article would like to give a new mechanistic definition of urbanization level. By introducing information entropy to characterize the interactions between indicators, structural parameter ξ of the indicator network, its evolutionary dynamic equation and self-organizing feature map simulation technique are deduced according to maximum information entropy principle (MIEP). By considering the structural feature of the indicator network as the urbanization level, we actually build a new mechanistic ULE model from the interactions between indicators. Then urbanization level of Beijing is studied from multiple angles to verify the feasibility of the new model. Last, beyond the given application case, we will discuss the universality and advantages of the new ULE model.

2. A new model of ULE based on information entropy principle

2.1. A new mechanistic definition of urbanization level from the connotation of healthiness

Since humankind needs a healthy urbanization, urbanization level must be defined from the connotation of healthiness. In qualitative phenomenal perspectives, a healthy urbanization level should be considered from "speed" and "quality" of urbanization processes. We need to synthesize "speed" and "quality" of the processes to evaluate the urbanization level. Beyond the phenomenal description, in a quantitative view, "speed" and "quality" of urbanization processes have to be represented by related indicators that can be numerically calculated. Conceptually, "speed" and "quality" of the urbanization processes may include the performance of urban-scale expansion and population increase, urban quality promotion, infrastructure capabilities improvement, coordination performance of urban–rural relations, etc., which can be represented by all kinds of indicators [17].

How will the indicators related to "speed" and "quality" of urbanization processes give a definition of healthy urbanization level? It is noted that, urbanization refers to the process of population aggregation to urban areas, bringing expanding urban coverage and associated economic and social developments. With the changes of economic, social and spatial structures, urbanization must be an evolutionary process induced by the dynamic interactions between many indicators in the system. In this connection, healthy urbanization level should be defined as the synergetic development between all indicators related to "speed" and "quality" of urbanization processes. This is a new mechanistic definition of urbanization level including the connotation of healthiness.

The new definition, which is given by the synergetic development between all indicators related to "speed" and "quality" of urbanization processes, improves our understanding of healthy urbanization processes. Of course, in some ways, our viewpoint does not seem completely new. In many available researches on urbanization system, it is generally accepted that one single indicator cannot represent urbanization level at all. Healthy urbanization level is actually embodied as a holistic body by concrete organic relations between the indicators. Unfortunately, despite these light-shedding thoughts, a much