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From design to digital model: A quantitative analysis approach to Garden Cities theory

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ABSTRACT

As a complement to the development of new theories, the reevaluation and knowledge mining of classical theories can be beneficial for urban development. In particular, quantitative analyses for cities can now take advantage of geographic information systems (GIS). Proposed more than one hundred years ago, Ebenezer Howard's Garden City is a generally acknowledged classical urban theory. On the basis of the original work, we model a digital Garden City in ArcGIS. The model is accurate to within 1% for both areal and length measures, and enables our further quantitative evaluation of the urban land-use structure and open green space accessibility. We then compare the classical theory with a modern-built area for the quantitative evaluation results. Zhujiajiao Town in Shanghai, winner of the International Award for Livable Communities in 2008, provides a reference. Although the central areas of Garden City and Zhujiajiao Town have different geographical and historical backgrounds, the measured land-use structures, including indicators of area proportion and area per capita, exhibits similarities on land-use types of residential, transportation, and ecological conservation, which offer a considerable reference for land-use structure of a livable urban area. Comparison of the accessibility to open green spaces in both cities shows that the average access time from a residential area to open green space in Garden City is just 186.77 s, which is much shorter than that in Zhujiajiao. Our research shows that the classical Garden City theory can be modeled into highly accurate digital forms, allowing richer information in quantitative terms to be obtained than from the original theory, and enabling comparisons with modern cities. Besides, the proposed digital modeling approach is widely applicable to classical theories and historical planning cases.

1. Introduction

In 1898, Ebenezer Howard proposed the Garden City in his book *To-morrow: A Peaceful Path to Real Reform*, which has been widely known through subsequent editions named *Garden Cities of To-morrow*. The Garden City is characterized as a living space that combines the advantages of urban and rural life, with a social city designed to overcome further increases in population after the limit of the Garden City is reached (Howard, 1898, 1902). The theory, its practical applications in Letchworth (Miller, 1989; Purdom, 1963) and Welwyn (Reiss, 1920), and the resulting worldwide Garden City movement (Jin, 2007; Ward, 1992) have all been extensively studied. For example, the theory has been recognized as the cornerstone of modern urban planning (Alexander, 1992; Buder, 1969). Further, the idea of the town–country magnet has caused general debate (Clark, 2003; Mumford, 1961), and the changes in residential living conditions have also been discussed (Edwards, 1913; Reade, 1913).

Bottlenecks in the progress of urbanization, such as traffic congestion, environmental pollution, and urban smog, have encouraged people to explore new solutions. The development of further studies on classical theories and historical urban planning cases for modern practice can be an effective means of finding new solutions. Therefore, it is sensible to study Garden City theory more in-depth. However, a survey of studies on Garden Cities over the past 100 years suggests that Howard's theory has only been considered qualitatively. That is, researchers have attempted to understand and discuss Howard's idea by analyzing the text and accompanying diagrams in the original work, while an accurate analysis of the theory's physical characteristics (layout, land-use structure, per capita indicators, etc.) has not been researched. In recent decades, geographic information system (GIS) technology has been widely used in urban planning. The advantages of spatial-data organization, management, and especially spatial

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analysis, make GIS particularly suitable for complicated calculations (Fotheringham and Rogerson, 1994; Matějíček et al., 2006). The application of GIS in urban planning generally falls into one of the two categories. The first assists with the visual presentation and quick editing of planning schemes (Beregovskih et al., 2010; Malczewski, 2004), and the second supports urban modeling, analysis, and prediction for real cities (Jiang and Yao, 2010). Both are implemented in modern cities in the real world. Even the leading studies of smart cities focus on the visual representation and simple analysis of real cities (Al-Hader and Rodzi, 2009). However, modeling classical and historical theories or cases is a challenge, because we have only incomplete data, inaccurate diagrams, and poorly organized descriptions. The archeological mining of these classical theories based on GIS, although rarely reported, can provide considerable benefits to modern urban planning.

Ongoing studies of urban spatial analysis are mainly focused on open-space accessibility (Geurs and van Wee, 2004; Tsou et al., 2005), landscape pattern measurement (Herold et al., 2002; Kong and Nakagoshi, 2006; Seto and Fragkias, 2005), complex transportation network analysis (Brockmann and Helbing, 2013; Crucitti et al., 2006), and energy metabolism and sustainability (Hall, 2011; Yang et al., 2014; Zhang et al., 2014). Since the 1950s, accessibility has been an important indicator for the urban green-space distribution (Van Herzele and Wiedemann, 2003). Accessibility can be measured by various methods, such as the buffer zone, minimum distance, travel impedance, and gravity index (Luo and Wang, 2003; Oh and Jeong, 2007; Talen and Anselin, 1998). Modern-built cities are generally the basis of these studies, and the analysis of classical and historical theories or cases is rare.

Therefore, our study considers the following three questions. First, is there a reliable modeling procedure for those classical urban theories presented in texts and diagrams but only available on papery material? If so, what are the differences between the modeling procedure for cities in classical theories and modern society? Second, is the urban land-use structure comparable in cities or towns with different geographical and historical backgrounds? Will the land-use structure designed by Howard be similar to that in modern cities? Third, as the pioneer of urban planning, Howard tried to solve the environmental problems of urbanization with a spatial allocation of open green spaces. Thus, what are the quantitative results of judging his planning scheme through an open green space accessibility analysis? In the remainder of this paper, we first reorganize the data and diagrams in Howard's original work, and model a highly accurate digital Garden City using the ArcGIS software. We then quantitatively analyze Howard's theory in terms of a land-use structure calculation and an open green space accessibility measurement on the basis of the digital model. Finally, taking Zhujiajiao Town as a reference, we apply the urban modeling procedure of modern cities, and analyze the results with the same land-use structure calculation and open green space accessibility measurement procedure used for the Garden City. We then contrast the modeling procedure for classical theories with that for modern cities, and compare the land-use structure and open green space accessibility of Howard's Garden City with that of modern Zhujiajiao Town.

2. Method

2.1. Modeling classical theory

The modeling procedure provides the foundation for further quantitative study. We have previously attempted to model a digital Garden City (Yuan et al., 2013a). Further improvements and repeated experiments have enabled us to identify the main modeling process for a digital Garden City, and this procedure is also suitable for other classical theories expressed by a literal description and schematic pictures. The modeling process consists of an analysis of the original theory, the selection of an appropriate mathematical foundation, data extraction and calculation, the systematic organization and design of an attribute structure, vectorization and digitization, verification of the model accuracy, and (if necessary) corrections to the model (see Fig. 1).

2.1.1. Original theory analysis

Analyzing the original theory ensures that the natural idea and characteristics are understood and accurately reflected in the model. The analysis is also important for the data calculations and framework design, which are strongly influenced by the information in the original work.

The modeling process of a digital Garden City offers a specific example. The analysis of Howard's original theory helps us understand what should and can be present and calculated in its digital form, and thus determine the extent and object of the model. The Garden City is part of a city group named the social city. Each social city includes several separate urban areas (one central city encircled by several Garden Cities), agricultural areas in the intervals between cities, and transportation systems of highways and railroads connecting each urban area. The most detailed part of the theory concerns the urban area of the Garden City, and this is the most important part of our study on urban planning. Thus, we consider the model's extent to be the entire social city, and focus on the central area of a single Garden City.

2.1.2. Mathematical foundation selection

Being ideal, the cities in classical theories are usually designed without spatial reference. Therefore, it is necessary to select a mathematical foundation that includes a suitable spatial coordinate system, a map projection that minimizes deformation, modern international units, and a scale that is appropriate to the size of the modeled city.

Because of the ideal and hypothetical characteristics of the social city, the mathematical foundation of a digital Garden City model need not consider the city's geographical location. Therefore, we build a new projection coordinate system called 'garden city'. To minimize the deformation of the model, we use the Aitoff projection because of the round shape of the social city and the Garden Cities. The false easting, false northing, and central meridian are all set to 0 because of the theory's idealistic construction. The model uses length units of meters. The geographic coordinate system of the garden city projection coordinates is GCS Beijing 1954 with Greenwich as the prime meridian, D Beijing 1954 as the datum, and Krasovsky 1940 as the spheroid.

2.1.3. Data preparation

The data in theories are usually scattered, incomplete, or hidden within text and diagrams. Data preparation aims to form a systematic, complete, and accurate data list through data extraction and calculation (see Fig. 2). Extracting the core points of a theory can make the data more systematic. The main references for this step are the data given in the text, urban layouts shown in diagrams, and geometric formulae. In some cases, data cannot be calculated because of deficiencies in the original work. Thus, it is necessary to add one or more assumptions to the author's design. These assumptions should be reasonable and reliable, and be related to the geometric features of modeling objects, such as the length and width of roads, area of parks, and so on. Both exact numbers and numerical relations can be assumed. Some assumptions may prove to be false, whereas others may be found to be poor when compared to other calculation results. Such assumptions should be abandoned or corrected. After comparing and adjusting, the final data list should be based on a single best assumption, or the group of