Measuring morphology and internal compactness in Harbin, China

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Abstract

The idea of compact city has been considered a development direction of future cities that could promote the healthy and sustainable development of cities. This paper put forward a measurement model of the overall compactness of a city from two perspectives, namely the morphological compactness and the internal compactness; and conducted practical research with the variation of compactness in Harbin from 2007-2017 as an example. Firstly, the morphological compactness of Harbin was measured by built-up area and perimeter; after that, the internal compactness was measured from the perspective of population, economy, transport and land use with entropy method, and the influencing factors of internal compactness analyzed. The results demonstrated that, the overall urban compactness of Harbin showed a fluctuant increasing trend over the past ten years, yet the value of compactness remained at a low level; among others, transport and land use were key influencing factors of internal compactness. In the end, strategies for higher compactness of Harbin was proposed from the perspective of optimization of land use.

1 Introduction

Driven by the explosive expansion of cities, urbanization has been constantly improved since China's opening up and reform. Whereas, the positive role of urbanization has been weakened by accompanying problems such as inefficient land use, the declining city center, and wealth gap, etc. In that case, the concept of "compact city" that advocates a urban morphology featuring high density, mixed-functions, and public transport domination can contribute to addressing certain problems in city development, ensuring people's human settlement and living quality, which will surely provide a meaningful reference in the process of achieving China's urbanization.

Urban morphology compactness measurement and internal compactness measurement are two major international measurements concerning city compactness. Researchers build an index to measure the compactness of urban morphology, and select cities for case sty through comparing urban morphology with a variety of geometric shapes(Angel, Parent, & Civco, 2010, Kotharkar, Bahadure, & Sarda, 2014). Wang et al. systematically discuss the urban development morphology and its land use after conducting surveys in Zhengzhou and Changsha, China. And researches on urban internal compactness emphasize the social, economic, and environmental benefits as well as operating efficiency of the city(Wang, Zhang, & Chai, 2018). Chen et al. establish an urban compactness index as well as analyze costs and benefits of urban development based on a plurality of cities in China from the perspective of infrastructure, public transportation and resource consumption(Chen, Jia, & Lau, 2008). And Burton et al. summarize a number of compactness indexes from high density, versatility, and diversity, and verify those indexes through investigating multiple cities and towns in Britain(Burton, 2002). Focusing on Taiwan cities, Chang analyzes and discusses variations in economic and social environment and various industries in a decade on the basis of classifying the compact city in line with urban development

characteristics(Chang & Chen, 2016).

Cities might be formed and developed in different patterns due to influences and restrictions of natural conditions such as landform, rivers, and resources, etc. Thereby, it's really difficult to accurately determine the comprehensive urban compactness via the morphology compactness. Similarly, internal urban compactness is to measure the quality and efficiency of internal operation in a city. It should be noted that external urban morphology not taking into account is also an important index for measuring the comprehensive compactness. Hence, an evaluation system is built with the combination of urban space morphology compactness and internal compactness to practically study the urban compactness measurement in Harbin, China. Moreover, a strategy to improve the urban compactness is proposed with respect to land use.

2 Construction of urban compactness measurement system

2.1 Urban form compactness measurement method

In this paper, RICHARDSON's compactness calculation formula is used to measure urban form compactness(Riehardson,1973). The measurement method takes the circular area as the standard unit of measurement and sets the compactness value to 1. Its measurement formula is as follows:

$$K = 2\sqrt{\pi A} \Big/ P \tag{1}$$

Where, K is the compactness of the city, A is the city area, and P is the perimeter of the city contour.

2.2 Measure method of compactness in city: entropy method

2.2.1 Constructing mathematical model

(1) Construction of original index data matrix

Assuming there are m programs to be evaluated and n evaluation indexes, the initial data matrix of the evaluation system can be formed:

$$X = \begin{pmatrix} x_{11} \cdots x_{1n} \\ \vdots \ \ddots \ \vdots \\ x_{m1} \cdots x_{mn} \end{pmatrix} \tag{2}$$

Where x_{ij} represents the value of item j of the ith sample.

(2) Data standardization processing

The forward indicator means that the larger the data is, the more compact the city is; the reverse indicator means that the larger the data is, the less compact the city is. The maximum value of the jth index is denoted as $x_{j\max}$, and the minimum value is denoted as $x_{j\min}$. Then, for the positive index, its standardized calculation formula is:

$$x'_{ij} = \frac{x_j - x_{\min}}{x_{\max} - x_{\min}} \tag{3}$$

For the inverse index, its standardized formula is:

$$x'_{ij} = \frac{x_{\max} - x_j}{x_{\max} - x_{\min}} \tag{4}$$

(3) Calculate the proportion y_{ij} of the index value of the ith year of the jth index

$$y_{ij} = \frac{x'_{ij}}{\sum_{i=1}^{m} x'_{ij}} \tag{5}$$

The specific gravity matrix of the data can be established $Y = \{y_{ij}\}_{m*n}$.

(4) Calculate the entropy value of the jth index. The calculation formula is:

$$e_j = -K \sum_{i=1}^{m} y_{ij} \ln y_{ij} \tag{6}$$

Where, $K = 1 \big/ \ln m$

(5) Calculate the difference coefficient of evaluation index

The value of the information utility of an indicator depends on the difference between the entropy e_j and 1 of the indicator. Its value directly affects the size of the proportion. The larger the value of the information utility, the greater the proportion.

$$d_j = 1 - e_j \tag{7}$$

(6) Calculate the proportion of evaluation indicators

The essence is to use the value coefficient of the index information to calculate. The higher the value coefficient, the greater the importance to the evaluation. The proportion of the jth indicator is:

$$w_j = \frac{d_j}{\sum_{i=1}^{m} d_j} \quad (8)$$

(7) Calculate the evaluation value of the sample
The sum formula is used to calculate:

$$U = \sum_{i=1}^{n} y_{ij} \cdot w_{ij} \cdot 100 \quad (9)$$

Where U is the comprehensive evaluation value, n is the number of indicators, and w_j is the proportion of the jth indicator. Obviously, the larger U is, the closer the index value of the sample is to the target value of the index, the greater the internal compactness of the sample. Finally, all U values are compared to reach a conclusion.

2.2.2 Index selection

This paper starts with the connotation of compact cities and selects the factors that affect the degree of compactness within cities. The high density of cities is mainly determined by the degree of population concentration, and the mixed use of functions involves the use of land. The high efficiency can be reflected by the economic level and the development of public transportation. To sum up, The internal compactness of a city was evaluated from four perspectives, including compactness of population, compactness of transportation, compactness of economy, and compactness of land use. The factors that affect the four perspectives the most were selected and further divided into the secondary indicators. All of them, except the information entropy of urban construction land, are positive indicators (Table 1).

3. The calculation and analysis of the compactness of Harbin city

3.1 Overview of the study area and data sources

In the process of urbanization, the area of the built-up area in Harbin has been expanding, and the urban population has also been increasing. While rapid urbanization has brought huge benefits, the accompanying social, economic and environmental issues cannot be underestimated.

The area and perimeter needed to study the compactness of urban morphology in this paper is mainly obtained from Google Earth imagery. The research data used to calculate the internal compactness mainly come from the Harbin government website, "China City Statistical Yearbook 2008-2018", "China City Construction Statistical Yearbook 2008-2018", "Harbin Statistical Yearbook 2008-2018"and Harbin 2007-2017 Statistical Communique on National Economic and Social Development. Relevant data such as density and specific gravity are calculated based on the original data.

First-level indicators	Secondary indicators	Indicator description
Population compactness	Net population density	Non-agricultural population/urban built-up area
	Spatial expansion and population growth	Urban population change rate/built-up area change rate
Traffic compactness	Density of road network in built-up area	Urban road network length / urban area
	Urban public vehicle share	Public transport vehicles per 10,000 people
	Bus operation line network density	Total length of bus operation lines in built area / area of built area
Economic compactness	Economic density	Output value of secondary and tertiary industries / built-up area
	Space Expansion and Economic Growth	Growth rate of secondary and tertiary output values / change rate of built-up area
Land use Compactness	Construction land information entropy	$H = -\sum_{i=1}^{N} P_i \log P_i$
	Heterogeneity	Indicates the degree of mixed land use

Table 1.Intracity compactness measurement index system

3.2 Calculation of urban morphology compactness in Harbin

Harbin has made remarkable changes every three years, since the city always complies with the government's requirements for urban development, including the master plan and detailed regulatory plan. Therefore, the compactness of urban morphology was measured by selecting three years as the interval and the built-up areas of Harbin as the survey region. In 2014, Harbin classified Shuangcheng District into its municipal districts. Given that the change may have some impacts on the compactness of urban morphology, the years 2007, 2010, 2014 and 2017 were finally selected as the milestones. The acreage and perimeter of the built-up areas in the four years were measured. Based on the compactness formula, a line chart was drawn to reflect the change in compactness of urban morphology(fig1 2).

The evolution of compactness in the outline and morphology of built-up areas can demonstrate the periodicity of urban expansion in space. The compactness of built-up areas in Harbin has been presenting a rising trend with fluctuations. It suggests that although the construction of new urban areas, science parks and development zones brings Harbin to the stage of rapid expansion, the planning of newly developed areas has begun to focus on the regularity and compactness of urban morphology. In addition, the development pattern of the main urban area is also shifting from outward expansion to inward filling and transformation.

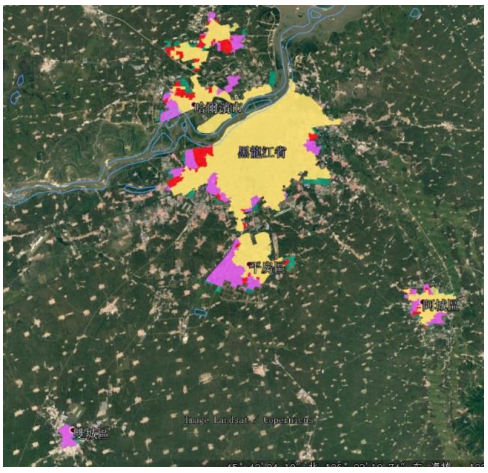

Figure 1. expansion diagram of Harbin built-up area from 2007 to 2017

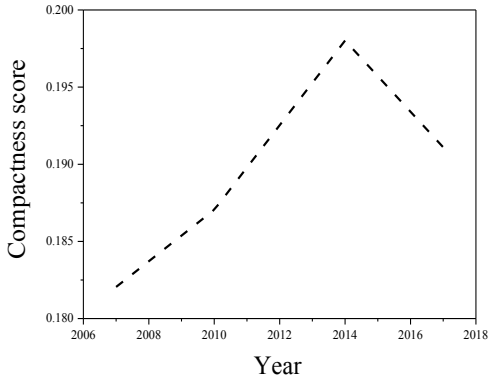

Figure 2. change curve of shape compactness

3.3 Calculation of Urban interior Compactness in Harbin

The entropy method was used to measure the internal compactness of Harbin city for 11 consecutive years from 2007 to 2017(fig3 4).

It can be seen from the fig.4 that the internal compactness of Harbin showed a rising trend

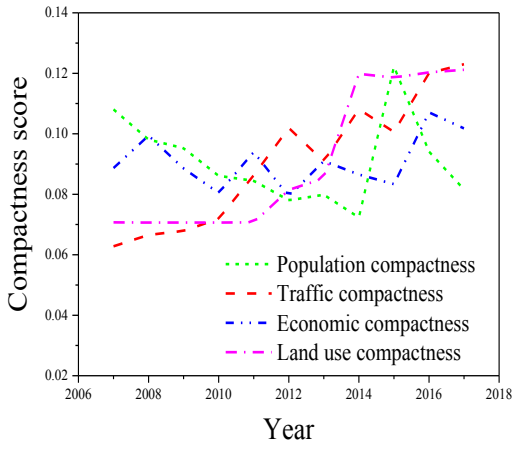

Figure 3. change curve of compactness of each index

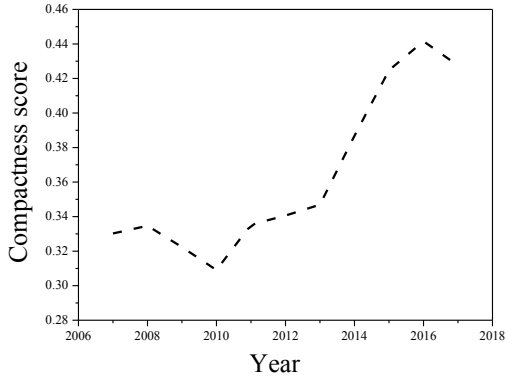

Figure 4. comprehensive compactness change curve

with fluctuations, the internal compactness underwent the three stages from decline, slow growth to rapid rise.

In the first stage: the stage of fluctuations(In2007-2010).The status of urban development was correlated with net residential density (a factor in the compactness of population) and economic structure.

In the second stage: the stage of slow growth(In2010-2013).At the Seventh Plenary Session of the Twelfth Harbin Municipal Party Committee in 2009, it was proposed to apply an urban development strategy called "Expand to South and North". The strategy aimed to build a new industrialized town in Jiangbei District and the Southern Area. Since then, the use ratio of urban land and economic compactness started to increase slowly. Upon the completion of the "Two Bridges and Two Roads" project and "Two Bridges and One Road" project in 2010, the density of urban road networks and the public transportation system were further improved. As the compactness of transportation continued to increase, the overall compactness of the city began to show a rising trend.

In the third stage: the stage of rapid rise(In2013-2017).Since 2013, the economic growth in Northeast China continued to decline. In 2014, the central government of China issued the Opinions of the State Council on Several Major Policies and Initiatives for Revitalizing Northeast China in the near Future, so as to rely on innovation to drive development, focus on developing competitive and featured industries, and finally consolidate and expand the achievements of revitalization and development in Northeast China. The Opinions helped the city realize its healthy development in both economy and society. The economic growth at this stage increased the internal compactness of the city.

3.4 Strategies for improving compactness in Harbin based on land optimization

To sum up, it could be learned the compactness of Harbin in both external morphology and internal functions was rising, yet the value of compactness remained low. Enhancement of compactness was still one of the important ways to improve urban functioning efficiency of Harbin. Reasonable and optimized land distribution helped inhibit the disordered urban expansion, ease traffic and social problems, and promote the growth of national economy. This paper put forward strategies for improvement of compactness of Harbin from the perspective of optimization of land use:

(1) Change the pattern of urban expansion, advocate mixed land use
Change land expansion to the filled-dominated pattern, delimit boundaries of expansion of urban land. Promote the compact use and diverse growth of urban land, reduce the pendulum-like commuting traffic.

(2) Optimize the urban transport system with public transport as leading force
Traffic problems, in the final analysis, are land use problems. Stick to the coordinated development of land use and urban public transport, improve metro engineering, and accelerate the green development of urban public transport; and ensure the balanced development of urban public transport among different regions by controlling the construction scale and intensity in central city and effectively dispersing central city functions.

4. Conclusion

Compact city is not only a theory of intensive, low-carbon and humanized urban development, but also a theory to guide the scientific, reasonable, fair and efficient use of land in cities. The comprehensive measurement model of urban compactness from the perspective of urban form compactness and internal compactness can reflect the development status of compact cities comprehensively. Through the comprehensive measurement of the compactness degree of Harbin from 2007 to 2017, this paper finds that although the compactness degree of Harbin has been on the rise, its comprehensive compactness degree is still relatively low, among which traffic and land use are the two factors that have the greatest influence on the compactness degree of Harbin. These research results will be conducive to the government decision-making, and also have certain reference significance for the development of other similar types of city compact degree.

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Endnotes

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