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Evaluating Shanghai new towns' maturity of urban form: an exploration index based on new urban data

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Abstract

The natural evolution of urban forms over time is a key issue in urban morphology. With the rapid development of quantitative analytical tools and new urban data, new research potential has emerged. This study attempts to develop an analytical framework for evaluating the urban maturation process. Using street blocks as the analytical unit, this study integrates the spatial design network analysis (*sDNA*)*, Spacematrix, Points-of-Interests (POIs), and Open Street Map (OSM) in the geographical information system (GIS) to calculate the urban maturation index in the context of big data. Shanghai, a metropolitan city with a long urbanisation history and a series of new towns, was selected as the case study. The validation of this new index was first achieved by comparing this maturation index between several districts located in the city centre and suburban new towns. Insights in this direction would help generate new urban design guidance for creating vibrant urban places. This study also aimed to introduce new quantitative thinking into the previously qualitative and intuition-based fields of urban morphology and urban design.*

Keyword: *quantitative urban morphology, maturity of urban form, new town, new urban data, Shanghai*

Introduction

In this study, the urban form refers to the tangible characteristics of the cities' physical space, mainly focusing on urban space and activities. Next, this research defines maturity as the degree to which a city has gone from an initial boring construction state to a mature state with high quality and vitality. Additionally, "maturity of urban form" refers to the state of urban spatial elements that continuously create high-quality areas and generate lively urban activities. The natural evolution of urban forms is a key issue in urban morphology. This study attempted to develop an analytical framework to evaluate the urban morphological maturation process.

Background

China has vigorously advocated for new town construction since the early 1990s. Some of those towns have developed into prosperous urban areas comparable to the old towns, but most of them have not become vibrant urban spaces (Keeton, 2011). After decades of development, thousands of new towns still lack vitality and attractiveness, as well as independence (Reijndorp, 2006). Under these circumstances, the Chinese government pointed out that introducing digital technologies into traditional architecture and urban areas and solving the urgent demand for quality of high-density areas has become a national strategy. As a result, the use of digital analysis to promote high degrees of urbanity has become an irreversible trend.

Urban form, one of the determining factors of urban quality and vitality (Montgomery, 1998), is one of the most effective breakthroughs for evaluating urban maturity through digital analysis into practice (Marcus, 2007). However, classic urban morphology is mostly driven by a qualitative perspective and subjective experience, and there is a lack of a systematic and objective understanding of the urban forms (Ye and Van Nes, 2014). How can the urban form be quantitatively analysed and visualised using new urban data? How can we establish an index that can scientifically and effectively quantify the maturity of urban forms of cities and districts? These are two important topics of the new towns' planning and renewal.

New research potentials in urban morphology

Owning to a prompt increase in quantitative analytical tools and new urban data, new research potential in urban morphology has emerged. For instance, Form Syntax, an analytical tool that combines three urban morphological components, can be used to classify the degree of urbanity (Ye *et al.*, 2017). However, the tool can be significantly improved. First, the researcher did not use new urban data for more in-depth investigation due to technological limitations. Second, the hypothesis was mainly verified in Dutch cities (Ye and Van Nes, 2013). Thus, the morphology indicators are all based on European standards, resulting in low practicality of the domestic evaluation of Chinese new towns' maturity. Nevertheless, this research adjusted and revised the previous tool, bringing a new measurement index to classify the degree of maturity and, thus, offering special strategies to enhance the vibrant urban design.

Methodology

Research area

The cases include the Panyu area and the core centres of five new towns in Shanghai: Songjiang, Jiading, Fengxian, Qingpu, and Nanhui, published in "Shanghai Master Plan 2017-2035" by local governments. All of the new towns have been developed in the past two decades, whereas the Panyu block has been developed for nearly a hundred years in the same province. Taking these six urban areas as examples (Figure 1), this study analysed and compared the current morphological maturity of the old and new cities.

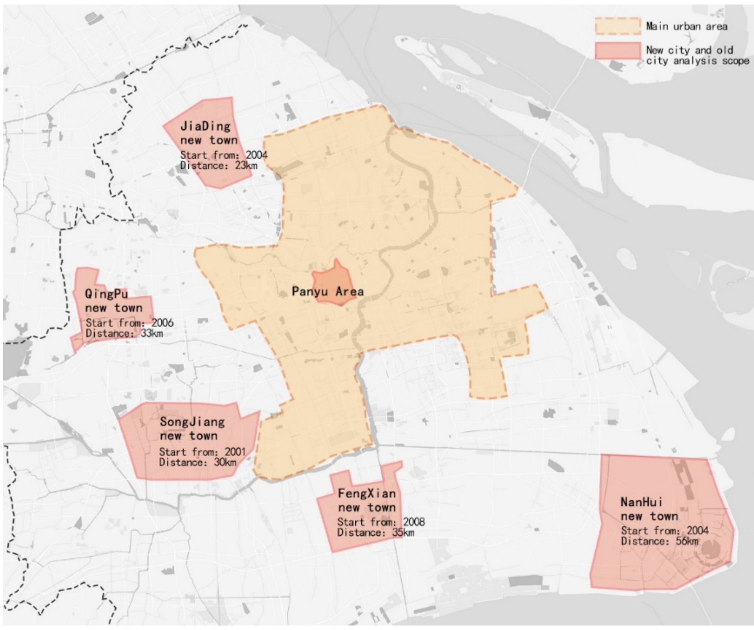

Figure 1. Locations of research areas.

Research framework

Separate extracted street blocks, an important unit for understanding the urban form, can be used to evaluate the development state of the areas more precisely than the Conzenian three traditional morphological elements (Conzen, 1960). Therefore, this research takes the street block as a research unit, combining the street, building system, and land pattern to facilitate an equal comparison of maturity.

The maturity of the urban form is composed of three key indicators: street-network accessibility, the three-dimensional form of the block, and functional mixture. Street-network accessibility consists of both pedestrians' and vehicles' accessibility. The three-dimensional form of the block is analysed from two aspects: the building density and type of the block and the degree of enclosure of the surrounding streets outside the block. The functional mixture is represented by the diversity of the POI types. Finally, three indicators were combined with equal weights to obtain the evaluation index of urban morphological maturity and generate the corresponding fine-scale urban design guidance and optimisation suggestions (Figure 2).

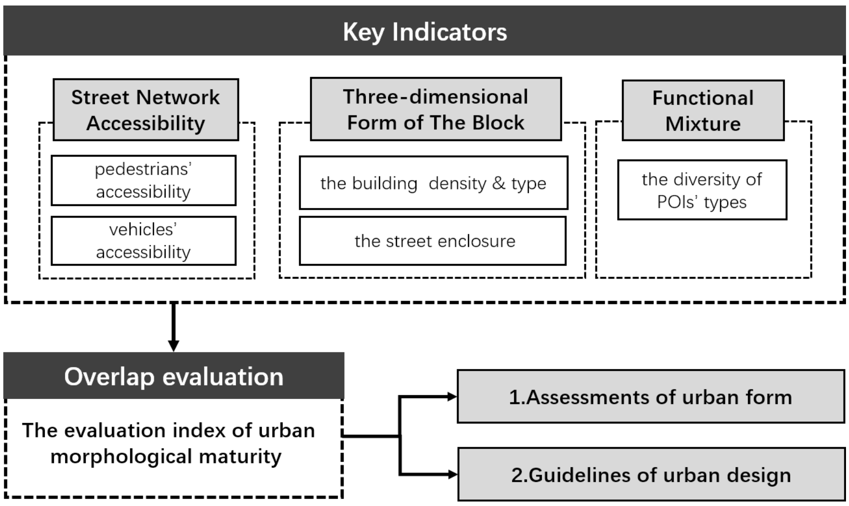

Figure 2. Research framework.

Research method and data

First, the multi-source urban data were collected. Next, the fine-scale street network and building plot data of six research areas were downloaded from the OpenStreetMap (OSM) platform. In addition, 115,766 street-view photos of 118,457 sampling points at 50-meters intervals, and the POI data in the six research areas were captured from Baidu and Gaode maps. Subsequently, the spatial design network analysis (sDNA), Spacematrix, Tensorflow, and SPSS combined with the geographic information system (GIS) were used to calculate the street-network accessibility, three-dimensional form of the block, and functional mixture.

sDNA is a three-dimensional spatial network analysis tool applicable to ArcGIS and QGIS. It can be used to calculate the accessibility of street networks and the potential for walking, bicycles, motor vehicles, and other public transportation (Cooper and Chiaradia, 2020). This study used the "Betweenness" to characterise and normalise the accessibility of vehicles and pedestrians within 50 m around the block to obtain a final score of the accessibility value (Ye, Li and Liu, 2018; Cooper *et al.*, 2021).

Spacematrix can quantitatively describe building types and display the building height, base area, and building density (Pont and Haupt, 2010), here defined as a ground space index (GSI), floor space index (FSI), and average layers (L_{AVG}). In Figure 3, the Y-axis represents the FSI and the X-axis represents the GSI. The slope of the linear function is L_{AVG}. A previous study used this method to define nine building types in Rotterdam (Ye and van Nes, 2014). However, these dividing standards cannot reflect the actual Chinese construction status for the high-density and high-rise buildings in Shanghai accurately. Therefore, a pre-study was carried out to reclassify 12 categories of building types (Figure 3) by randomly choosing 1977 plots in Shanghai and three surrounding cities and calculating their GSI.

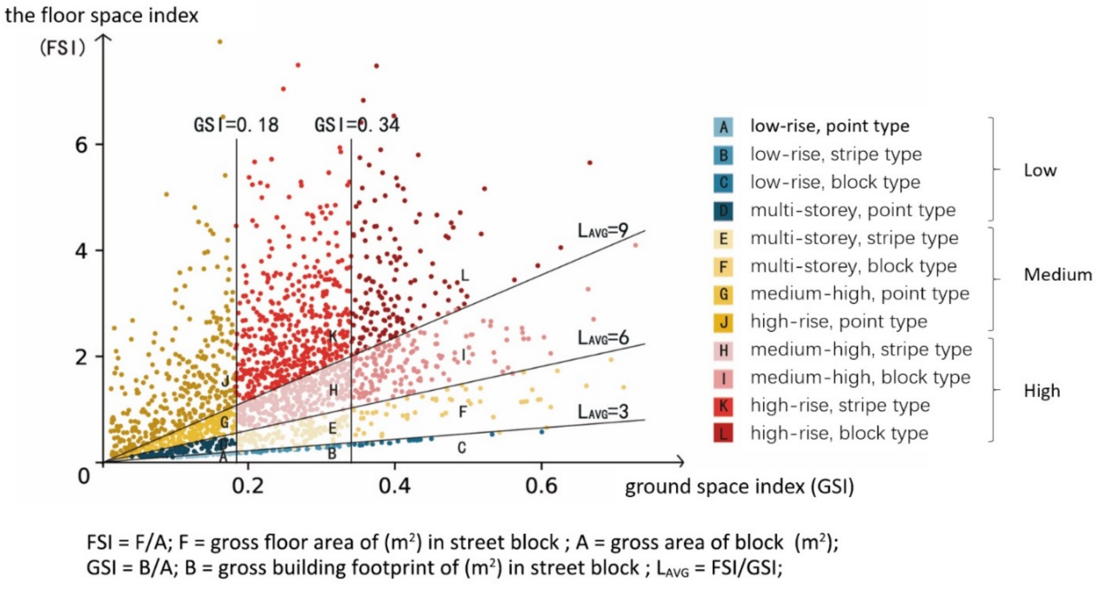

Figure 3. *Division of building density and type.*

Millions of street view data can simulate the actual vision of a pedestrian, and these data, combined with machine learning algorithms, can objectively quantify micro-factors such as greenery, enclosure degree, sky views, and pedestrian space (Ye *et al.*, 2019). The enclosure in this paper does not only represent buildings but also includes the enclosure formed by plants; thus, the enclosure is calculated by removing the proportion of sky pixels from the street view.

Shannon entropy was used to quantify the functional mixture in previous built-environment studies (van Eggermond and Erath, 2016). POIs reflect the functional attributes to a certain extent, representing the convenience of residents' daily lives. This study used Shannon entropy of nine categories of POIs of the Gaode map to calculate the function mixture.

Results

Street network accessibility

Based on the superimposed results of pedestrian accessibility and vehicle accessibility (Figure 4A), we can intuitively observe that the blocks in the Panyu Road block are all highly accessible, except for the Shanghai Jiao Tong campus, whereas the high-access blocks in the new city are gathered in the central area. The high accessibility blocks of Nanhui new town and Jiading new town are scattered, and their overall accessibility is lower. Regarding street accessibility, which was determined at the initial stage of planning, the gap between the new town and the old city is relatively large.

The three-dimensional form of the block

The evaluation of the three-dimensional form of the block included two parts. One part was the evaluation of the building density and type from a top-down perspective; the other part was the evaluation of the enclosure degree of the surrounding streets from a bottom-up perspective.

Concerning building density and type (Figure 4B), the Panyu area has a relatively high construction intensity. Regarding the new towns, blocks with good form in Jiading, Fengxian, and Qingpu new towns are located in the central area, and most of the other blocks have a poor three-dimensional form. As for the street enclosure (Figure 4C), almost all the blocks of the Panyu area have a high degree of street enclosure, whereas the five new towns have similar street enclosures. Except for the high-degree clusters of high-street enclosures near the centre of Qingpu, Fengxian, and Songjiang, the street enclosures of Nanhui and Jiading are evenly low. The building density and type overlapped with the street enclosure (Figure 4D). The study revealed that except for the historical area and the Nanhui new town, the other new towns have no differences in three-dimensional form, where the blocks with superior three-dimensional form are mostly clustered in the planned city centre.

Functional mixture of the block

The functional mixture of the Panyu area is much higher than that of the five new towns (Figure 4E). The difference in the functional mixture between Songjiang, Jiading, and Fengxian is relatively small compared to Nanhui and Qingpu. Some of the highly developed areas in the five new towns were planned for various types of commercial and public service land, with a highly functional mixture and relatively complete development. However, there is still a larger proportion of developed blocks with single functions, which require adjustments from both the government and enterprises.

Urban maturation index

After the three elements were normalised, the overlapped result was divided into five levels of visualisation using the natural discontinuity method (Figure 4F). The five new towns show a trend of declining morphological maturity from the central blocks to the outside blocks. The three-dimensional table (Figure 5) shows that the morphological maturity of the Panyu area in the old city is much higher than that of the five new towns, whereas Songjiang and Jiading have a higher morphological maturity than Qingpu and Fengxian, and the urban form of Nanhui ranks last.

The causes can be speculated. One factor could be the construction time. Songjiang and Jiading were developed earlier, followed by Fengxian and Qingpu. Therefore, Songjiang and Jiading were more well-developed. Another factor is the location. The distance between Nanhui new town and downtown Shanghai is twice the average distance of the other new towns, and the eastern surrounding areas are impossible to construct due to the sea. In addition, Nanhui's master planning does not contribute to the future formation of a mature urban form. Its core centre, Dishui Lake, is surrounded by business areas, and a wide green belt isolates the residential areas. This morphological design has considerably prevented the new town from growing into a vibrant urban space.

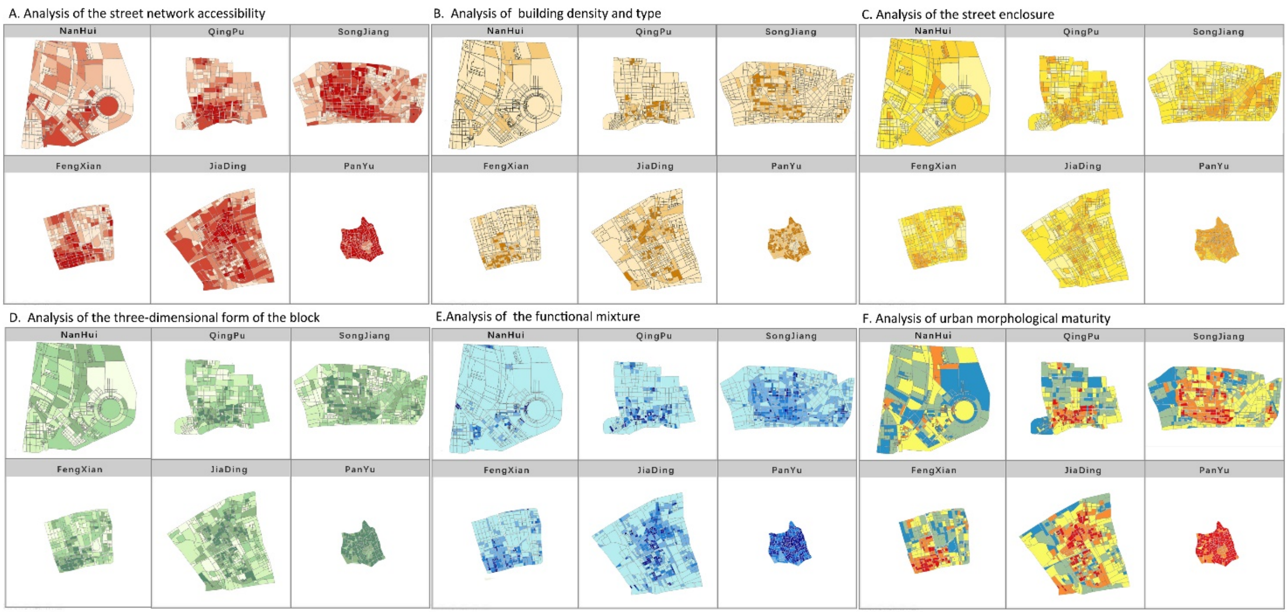

Figure 4. *Analysis of six morphological indicators.*

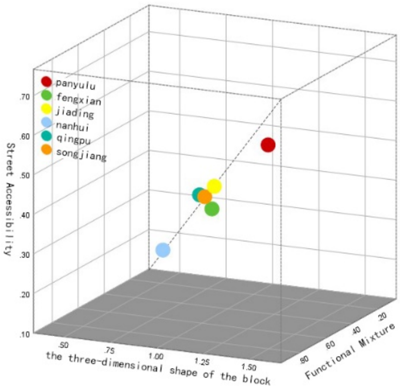

Figure 5. *Three-dimensional scatter plot of urban maturity.*

Discussions and Conclusions

An evaluation index of urban morphological maturity based on multi-source data

This study combined multi-source data and new analytical technology to build an evaluation index that can measure the maturity of the urban form. We improved the Spacematrix, proposing a standard that is more in line with the domestic construction context to recalculate the building density and type, and added street view photos to reflect the three-dimensional form of the residential block on a human scale.

Urban design guidance for promoting vibrant urban space

From the above analysis, we can acknowledge that the "Five New Towns" in Shanghai are much more immature than the historical downtown area in all terms of street accessibility, three-dimensional form, and functional mixture. In addition to time and location factors, there are three main problems in urban form. First, the branch roads are not dense enough to promote the walking experience. Second, the three-dimensional form of the block is mostly a point type, which is not beneficial for generating interactive communication. Third, the clustering of large-area single-function blocks leads to functional separation and inconveniences in daily life.

In response to these problems, we propose three mutually supporting effective strategies to optimise urban form in the design stage. First, the internal roads of larger industrial parks and residential quarters should be open to the public at specific times and connect their internal end roads with adjacent branch roads to form a loop. Second, more block and stripe types of buildings should be used, and sidewalks and street enclosures should be enlarged to bring residents closer and provide communicational spaces. Finally, for new towns dominated by industry and ecology, it is essential to introduce multifunctional, small-scale, and widely distributed commercial, residential, and public facilities. Only by converting the floating population into permanent residents, we can promote the urbanisation of the new town.

Integrating quantitative thinking with high-quality urban form

This study attempted to use abundant new urban data for urban morphology analysis and to quantitatively calculate and visualise elements that are difficult to describe, thus accurately determining the phased problems of new city construction. In this way, a scientific planning paradigm for new towns is promoted, with precisely targeted and highly implementable guidelines to optimise urban form at the initial stage.

Acknowledgements

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