Sprawling Urban Form and Expanding Living Space: A Study on the Relationship of Residential Space Development and Urban Built-up Area Expansion in Nanjing, China

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Abstract
Within the context of high-speed urbanization and significant housing commercialization development in China, this research investigated the expansion of urban spatial form and the formation process of residential space, with a focus on the relationship between these concepts over the past 60 years. Nanjing, an important Chinese city in the Yangtze River Delta, is taken as the object of study. In this research, Arc GIS data analysis technology was used to construct and analyze a database. Moreover, the kernel density estimation method was introduced in the research on urban form. Through quantitative and superposed contrast analyses, this research aimed to determine the facts and objective laws behind the data and to prove the interaction between the urban area expansion and residential space formation through a precise example.

Keywords: urban built-up area; residential space; suburbanization; kernel density estimate

1. Introduction
The urbanization rate of China has changed significantly over the 30 years of reform and opening-up. Especially after 2000, the yearly average increase rate for urbanization was 1.1%, while in 2010, the rate rose to 47.5%. Such change has been accompanied by rapid economic development. Chinese cities are undergoing unprecedented and tremendous change. The sprawling of urban built-up areas has always been the focus of urban form studies in China.

Over the past 10 years, with the establishment of residential commercialization, the significant development of urban residential space also has drawn considerable attention from Chinese architecture and urban planning scholars. It is wildly accepted that the construction of residential areas has become one of the major reasons for the expansion of the urban built-up area and has accelerated the progress of urbanization to some extent. However, few studies examine the relationship between these two phenomena, and a quantitative research with a case study is yet to be conducted. Therefore, our study focuses on the relationship between the formation progress of the residential space and the expansion of the urban built-up area. Taking the city of Nanjing for example, the study aims to verify the widely accepted impressions and to clarify objective facts regarding urban development.

2. Background of Nanjing
Nanjing is one of the most important cities in the Yangtze River Delta urban agglomeration (the largest urban agglomeration in China), and its urbanization progress is similar to that of other megalopolises. The total urban population of Nanjing increased from 3.38 million in 1978 to 5.5 million in 2008. Such a huge population inevitably resulted in increased urban construction. The total amount of housing construction in Nanjing has increased yearly since 1978. In 2003, the urban construction in Nanjing underwent rapid development in preparation for the 10th National Games (2005) (Fig.1.).

The increase in urban construction is reflected in the additions to the completed building floor area, as well as in the inevitably sprawling urban form. The urban built-up area of Nanjing City has expanded enormously over the past 60 years. According to the definition in China Basic Terminology of Urban Planning (GB / T 50280–98), an urban built-up area is a developed track of land within the city administrative division equipped with municipal infrastructures and public facilities.
Based on the research requirement and the availability of related materials, the maps for 1940, 1978, 1995, 2003, and 2008 were selected and transformed into a vector diagram using ARCMAP software (Fig.2.) to observe clearly the expanding progress of urbanization in the built-up area step by step.

Moreover, residential commercialization in China has developed since the 1980s after a long period of housing shortage during the planned economy era. The government issued an official notification to cancel the Housing Distribution System on July 3, 1998 and to establish a market driven housing system.

As residential commercialization developed, people’s material lifestyles have continuously improved since the 1990s, and the pursuit of better living conditions has become increasingly popular. In Nanjing, as shown in Fig.3., development trends became increasingly similar between the total amount of urban residential construction and the total amount of urban building construction.

In sum, rapid urbanization and residential commercialization resulted in urban built-up area expansion and residential space development in Nanjing City during the 30 years of reform and opening-up in China.

3. Scope and Methods

3.1 Period of the Study

This research covers a very long duration from 1940 (before the People's Republic of China was founded) to 2008. The development of built-up area and residential space during this time was not uniform. Such development has always been affected by new public policies or important events.

Thus, the whole duration could be divided into several periods to facilitate the study. The authors chose three important time nodes: 1978, 1995, and 2003 (Table 1.). Far-reaching events occurred and important public policies were issued in each time node. Each had a significant effect on construction in Nanjing City. In this way, the study time was divided into four periods: from 1940 to 1978, from 1979 to 1995, from 1996 to 2003, and from 2004 to 2008. They represent different stages of urban development in Nanjing City.

3.2 Spatial Range of the Study

The built-up area expansion from 1995 to 2008 (Fig.2.) expanded rapidly. The area expanded in two distinct ways: Occupation and Integration. Occupation involves land that was originally vacant land, agricultural land, or forestland. These pieces of...
land became built-up areas after urban construction. In contrast, integration is a kind of qualitative change. Thus, some lands are gradually integrated into the core urban built-up area after administrative divisions are adjusted. These divisions were formerly the suburbs or nearby satellite cities. Essentially, this type of expansion would interfere with research because a comparison could not be made with the formation of the residential space in the same period.

Therefore, the authors chose the main boundary of the main city of Nanjing, a widely accepted boundary, as the scope of this research. In this scope (Fig.4.), the urban space is a relatively independent individual with a functional structure. The expansion style is unique and mostly Occupation. The research in this scope can eliminate the interference as much as possible as well as increase the accuracy and effectiveness of the result.

### 3.3 Methods of the Study

In this research, quantitative and overlay contrast analyses were conducted.

A GIS database of the residential space in Nanjing City from 1940 to 2008 was created to help the quantitative analysis. The authors selected 854 residential areas in total, which should meet the following criteria: located in the scope of Nanjing main city, built from 1940 to 2008, and have centralized construction and development. Each residential area was treated as an individual subject that carried data, such as identity number, name, spatial location, completion timeframe, and area (Fig.5.).

The authors classed all the residential areas into four categories according to their completion timeframe (Fig.6.).

Similar to the expansion of the urban built-up area, the formation of residential space was also an evolution of the city at the macro level. Comparing the location of each individual residential area with the expansion of urban built-up area is not sensible. However, the distribution of the construction of the urban residential area could reflect the focus and direction of residential space development at the macro level, and it would be comparable with the urban built-up area.
To visualize the distribution of residential space better, the kernel density estimate was also introduced to the research. This process is a fundamental data-smoothing problem, in which inferences on the population are made on the basis of a finite data sample. The kernel density estimate could calculate the density distribution of residential space in each period, and show it in a contour map (as shown in Fig.7.). During calculation, the area for each pattern subject was treated as the weighting factor.

Thus, the authors could obtain a clear contour map of residential space distribution for each period (Fig.8.). The colored part of the map is where construction density is higher in terms of numbers and area. Then, the authors went further with the overlay contrast analysis by overlapping the contour maps on the expansion of built-up area to obtain the relationship between them.

4. Overlay Analysis and Discussion

On the basis of the discussed preparation steps, the authors superposed the sprawling status of the urban built-up area with the density distribution of residential space in the same period. The authors then used comparative analysis to explore the interactive relationship between these factors.

4.1 From 1940 to 1978

For 38 years, the urban built-up area in Nanjing increased by 9,664.5 ha. Moreover, 98% of the newly completed residential space is located in the newly built-up area. However, developing the residential space was not the most important impetus for expanding the built-up area. In fact, industrialization was the theme of this period in China. Factories were constructed. Consequently, expansion of the urban built-up area was promoted, and changes in urban form were stimulated. At that time, residential spaces were commonly located near the industrial area as a type of industrial facility because companies usually allotted dwellings to their employees as part of the welfare system (Fig.9.).

Fig.10. shows that areas with higher residential construction density are located near the Ming City wall, which was also the boundary of the old city. In addition, the area with the highest density is approximately 11 km away from the urban center.
Many vacant lands were still available, a typical example of the increased urban development in this period. Actually, the dense urban built-up area has not yet spread very far. The appearance of this area can be attributed to the development of industrial lands (especially chemical industries with heavy pollution), which first brought the key elements for a built-up area. These elements include roads and municipal infrastructure. The surrounding vacant land was then gradually filled with subsequent constructions.

### 4.2 From 1979 to 1995

The tight urban expansion policy of the 1960s was executed with the Reform and Opening-up in China (1978). This policy did not stop urban sprawl but slowed it to some extent. Thus, from 1979 to 1995, 68% of the newly completed residential space turned out to be located inside the urban built-up area constructed in 1978. As a result, most constructions filled vacant or renewed land.

Although only a third of the newly completed residential space was in the expanding built-up area, it concentrated to form the highest construction density area in this period (as shown by Fig.12, Point A). This formation played a very important role in changing the morphology contour of the city.

In fact, this special case was related to the housing policy in a special period. In 1980, the population in Nanjing grew unexpectedly rapidly. Thus, the government started to renew the old residential area and shantytowns to relieve the pressure of housing shortage. Numerous residential areas called "XX village" emerged under this situation. Nanhu Village (Fig.11.), which is located in Point A, was the most concentrated and typical. Housing construction was a result of an emergent contingency policy and occurred in the very short term. They were cheap and crowded.

### 4.3 From 1996 to 2003

The eight years from 1996 to 2003 was generally a rapid growth period for urban expansion and residential construction. More than 280 ha of built up area and more than 34 residential areas were built up per year on average.

The statistics result showed that the urbanization rate of Nanjing increased to approximately 63% in 2000. According to the urbanization S-curve theory proposed by American geographer Ray M. Northam in 1979 (Fig.13.), the urbanization of Nanjing City started to slow down and enter the transition phase from rapid development to stagnation. On one hand, housing remained lacking while the urban population increased. Moreover, residential commercialization had been fully
established, thus promoting residential construction significantly. On the other hand, the city center cannot accommodate such a large population. Thus, a large urban population began to migrate from downtown to the suburbs.

Unlike typical western "suburbanization," the city center did not fall into neglect when the residential construction in Nanjing concentrated in the suburbs. Following residential commercialization and the dramatic increase in land price in the city center, the business and commercial space began to concentrate in the downtown area. By contrast, the industrial and residential space had to move to the periphery urban area. Reasonably, residential space sprawled to the suburbs both under pressure from the high land price downtown and by the attractiveness of the comfortable environment in suburban areas (Fig.14.).

Public facilities, such as health care, education, and commerce, in the suburbs were superior to those downtown. However, the low price of housing and the relaxing living environment were very attractive in the suburbs. Under the combined action of "pushing" the downtown and "pulling" the suburbs, urban residential space developed significantly around the periphery of the built-up area in 1995 (Fig.15.).

The most direct results of suburbanization were prolonged commuting time and increased commuting costs. The problem worsened because of the limited public rail transit in Nanjing, which was still under construction in that period. To facilitate commuting, people living in the suburbs had an increasing demand for private cars. Pressures on urban traffic and environment protection emerged.

4.4 From 2004 to 2008

From 2004 to 2008, the urban built-up area increased by more than 4,455 ha., and 249 residential areas were completed in total. The residential construction density distribution presented a "double cycle" distribution in the spatial morphology (Fig.17.). Three-fifths of the newly completed residential areas were located inside the existing built-up area, mainly located in a circle away from the city center by approximately 4 to 5 kilometers. The remaining two-fifth sprawled beyond the city boundary in 2003, and concentrated into four areas with the highest residential construction density (as shown by Fig.17., Points A, B, C, and D). These points were all 7 km to 9 km from the city center.

Fig.17. shows that the south part of the inner circle "coincidentally" located on the edge of the urban built-up area built in 2003, and the outer circle located in the expansion area built in 2004 to 2008. Thus, the most active housing construction occurred around the edge of the urban built-up area.

In this period, the main city was still the most attractive place around the region. With the continual increasing urban population in the main city, the demand for dwellings was growing sharply. As an alternative to the high price in the city center, most commercial residential buildings, which targeted general citizens, had no choice but to move to suburban areas, which were far from the city center and had low land prices. The suburbanization of residences continued to intensify.

Compared with the dwellings built in the previous period, the newly built residential areas emphasized landscape construction and improvement of the supporting services (Fig.16.). Housing construction not only pulled the urban morphology that expands outward, but also attracted public facilities. Therefore,
residential construction notably influenced the urban form expansion in this period.

5. Conclusions and Discussion

The analyses show that from 1940 to 2008, the development of urban morphology reflected the actual urban economic development. As an important part of urban development, residential area construction is influenced by multiple factors, such as national policies, economic development level, and urban development strategy.

However, as the residential system was gradually commercialized, the construction of residences began to be dominated by the objective laws of the market economy and further advanced the development of urban morphology. Overall, the relationship of urban built-up area expansion and residential area formation in Nanjing became increasingly close, and the synergistic effect between each was gradually enhanced every year.

In addition, the city cannot continuously sprawl outward uncontrollably. Expansion without control imposes tremendous pressure, results in inefficient urban transportation, and decreases the quality of citizens’ daily life while preventing the city from being low-carbon, energy saving, and environmentally friendly.

Future urban development should emphasize the following two aspects to prevent the situation from worsening: First, given the recent and unavoidable suburbanization, the city should organize its functional structure and strengthen public services, such as commerce, medical, and education, in suburb areas. In this way, commuting time and length could be decreased for residents. Public transport should be encouraged, and relevant constructions or services should be provided to mitigate urban commuting pressure and improve the urban environment.

Second, from the core point of perspective, the population of the main city should be controlled within a reasonable range. It would help to limit the expansion fundamentally. But it should better be through natural population flow rather than mandatory administrative methods.

In 2010, the central government proposed "The New Urbanization" policy, which aims to foster small towns and develop the metropolis. The small towns near the main city of Nanjing underwent significant development in terms of physical space and society. An increasing number of young people choose to stay in their hometowns instead of rushing into the main city because their hometowns also present opportunities for personal development. This phenomenon helped slow the population growth in the main city (Fig.18.\(^1\)). More importantly, this phenomenon also contributes to limiting the uncontrolled sprawling of the urban built-up area and promotes the sustainable development of cities.

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Note

\(^1\) The data in the Fig.18. is from Statistic Yearbook of Nanjing (2010-2013).
References


