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Space-time Relationship Between Urban Municipal District Adjustment and Built-up Area Expansion in China

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Abstract: Municipal district adjustment and built-up area expansion are two main forms of urban spatial expansion. Using geometric methods, this study constructed a space-time path method to characterize the space-time relationship between municipal district adjustment and built-up area expansion, and drew the space-time path sets of major prefecture level cities from 2000 to 2010 by constructing a coordinate system of the standardized built-up areas and municipal district areas. This divided them into four quadrants, namely, H-H, L-H, L-L, and H-L, based on the relative mean value to evaluate overall and individual stability by three indexes of the trajectory vectors, namely, direction, length, and slope. Results provide the following conclusions. 1) Municipal district adjustment is an effective spatial expansion way for city-scale promotion in China. Since 2000, municipal district adjustments have been mainly distributed in the eastern coastal regions and mid-western capital cities along with their surrounding cities. 2) Municipal district adjustment affects the scale and status of a city in China. Many cities that have expanded municipal districts behave stably and cross quadrants. 3) Great majority second-tier cities have effectively promoted their scale and status through municipal district adjustment. The municipal district adjustment of medium and small cities in the mid-west area is relatively advanced compared with city development. 4) Municipal district adjustment with minimal magnitude is severely restricted from upgrading the scale and status of a city. The transformation from entirely incorporated counties or cities to municipal districts should be the mainstream in future municipal district adjustment.

Keywords: municipal district adjustment; built-up area; space-time path; administration division

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1 Introduction

China is undergoing rapid urbanization. From 2000 to 2010, the population urbanization rate of China increased from 36.22% to 49.68%, with an average annual growth rate of 1.35%. Simultaneously, Chinese cities entered a period of rapid spatial expansion. For one thing, urban built-up areas have sprawled rapidly, and new towns have been built in various places. According to data from the China City Statistical Yearbook, the average area of built-up areas in the municipal districts of prefecture and higher level cities increased from 61.68 km² to 110.68 km² within 10 years, with an average annual growth rate of up to 6%. For the other thing, municipal districts have expanded actively, and administrative division adjustment has spread by establishing districts with revoking counties as the typical way. The average area of administrative regions in the municipal districts of prefecture and higher level cities increased from 1677.66 km² to 2190.15 km² within 10 years, with an average annual growth rate of nearly 3%. Under the current strict land policy in China, these drastic urban spatial expansion phenomena, along with their corresponding rationality and regional effect, have become

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the focus of academic circles and government departments (Zhou, 2006; Dai *et al*., 2010). Current studies have asserted that urbanization in China has lost control of sprawl development and spatial expansion, which is called 'rash advance' urbanization (Lu and Yao, 2007). At the theoretical level, Liu *et al*. (2008) categorized the spatial patterns of land use change in cities into historical form pattern, regional economic pattern, decision-making behavior pattern, and political economy pattern. Meanwhile, various forms of urban spatial expansion can be divided into three growth types: simple, distributed, and structured. Fractal theory and the cellular automaton model (Batty *et al*., 1997; Batty, 1998), as well as the rank-size rule (An *et al*., 2012), were also introduced to the research on built-up area expansion. Scholars explored administrative division and its derivative effect (Zhen *et al*., 2010; Guo *et al*., 2014), and consequently, administrative division adjustment and urbanization effect were proposed. Administrative division adjustment patterns can include revoking a county and establishing a municipal district, establishing a new municipal district, merging several municipal districts, and expanding an existing municipal district, among others (Qu, 2012). Adopted research methods have mainly been summaries (Wang and Chen, 2011). Built-up areas (physical areas) and municipal districts (administrative areas) are important carriers of the new type of urbanization. Zhou and Shi (1995) conducted extensive research on establishing a physical urban area in China. In summary, most current studies have mainly focused on built-up area expansion and administrative region expansion (Hu and Luo, 2015); however, comprehensive studies on both types of expansion remain rare, particularly research on spatial relationship. Municipal districts expansion provides land for built-up area expansion and urban development, and built-up area expansion has become a requirement and the driving force of municipal districts expansion. Determining whether a municipal districts and a built-up area, along with their alteration, are identical or reasonable at the national level is beneficial to understand the current situation and problems of urban spatial expansion in China.

As an administrative means, administrative division adjustment can change the scale of urban space to satisfy the demands of city-scale expansion. With the expansion of a municipal district, built-up area expansion can be categorized into three types: a new built-up area in the original municipal district, the original built-up area in a new municipal district, and a new built-up area in a new municipal district. Thus, both municipal district area and built-up area increased. However, it does not mean the rank of the city size could be upgraded absolutely because that the municipal district area and built-up area of others cities also increased at the same time. Sometimes the rank of city size could be upgraded. But sometimes it even degraded. And municipal district area in some cities may be stable but the actual built-up area increases, which also upgraded the rank of city size. Therefore, selecting an appropriate method to analyze the relationship between municipal district adjustment and built-up area expansion is necessary.

On the basis of the aforementioned situations, this study constructs a space-time path that can reflect changes in municipal districts and built-up areas to estimate and analyze the space-time relationship of the municipal district adjustment and built-up area expansion of Chinese cities using a geometric method (Wang *et al*., 2005; Li and Sun, 2007; Qi and Wang, 2010; Shen *et al*., 2010; William, 2011; Yi, 2011). Prefecture and higher level cities are selected as research objects because the spatial expansions of these cities are the most remarkable since 2000. By analyzing the recent spatial distribution pattern of the municipal district adjustment and built-up expansion of China, this study classifies the types of urban expansion based on their relationship and discusses existing problems and factors to provide a reference for the research and practice of urban space regulation and administrative division adjustment.

2 Data and Methods

2.1 Data sources and data processing

The research objects are prefecture cities and national municipalities between 2000 and 2010. With the viewpoint of expansion types of municipal districts, this research focuses on 262 cities, and Suizhou has taken out for its decreasing municipal districts. The geographic information data were obtained from the Data Sharing Infrastructure of Earth System Science of the Chinese Academy of Sciences at a scale of 1 : 1 000 000 between 2000 and 2009, which was the Albers equal-area secant conic projection-based county administrative map. The data were checked by referring to the Admin-

istrative Division of the People's Republic of China. We modified the 2009 administrative map into that for 2010 and adopted it as the research base map. The built-up area data were based on the 1 km × 1 km land use grid data between 2000 and 2010, which were provided by the Data Center for Resources and Environmental Sciences of the Chinese Academy of Sciences. The spatial database construction and operations were processed using the software package ArcGIS. Data mainly included the distribution and area, as well as the built-up area and its distribution, within the scope of the municipal district of each city between 2000 and 2010.

2.2 Space-time path method

To characterize the space-time dynamic process of regional economic development, Rey and other scholars introduced several measurement ways to evaluate space-time path and space-time stability when building the space-time evolution path of LISA using spatial autocorrelation characteristics (Anselin and Rey, 1991; Rey, 2004; Rey and Janikas, 2006). The present study constructs a space-time path using both its overall and individual stability to characterize the space-time stability of the municipal district adjustment and built-up area expansion of cities. A method, which is similar to Rey's T-LISA method, is put forwarded to identify the space-time process of city-size rank and scale in China. The specific methods are described as follows.

Firstly, both municipal district area data and built-up area data should be normalized using the Z-score standardization method. The equation is as follows:

$$x^* = \frac{x - \mu}{\delta} \tag{1}$$

where x^* represented the standardized value, x is the original value, μ is the mean value of all data and δ is the standard deviation of all data. The normalized value described the relative grade of municipal district area or built-up area in different cities. If the normalize value is above 0, it means municipal district area or built-up area of a city is bigger than national average value. While if the normalize value is below 0, it means municipal district area or built-up area of a city is smaller than national average value. And cities could be divided into four static types.

(1) H-H Type: the municipal district area and the built-up area are both higher than the national average.

(2) L-H Type: the municipal district area is lower than the national average, but the built-up area is higher than the national average.

(3) L-L Type: the municipal district area and the built-up area are both lower than the national average.

(4) H-L Type: the municipal district area is higher than the national average, but the built-up area is lower than the national average.

Secondly, a Cartesian coordinates should be given. The x-coordinate is stand for the normalized value of municipal district area and the y-coordinate is stand for the normalized value of built-up area. Thus, each city has a point in this coordinates in a year. Four static types are corresponding to four quadrants in this coordinates. And for n years, each city has n points in this coordinates.

(1) Overall stable H-H type: a city that keeps H-H type in different years.

(2) Overall stable L-H type: a city that keeps L-H type in different years.

(3) Overall stable L-L type: a city that keeps L-L type in different years.

(4) Overall stable H-L type: a city that keeps H-L type in different years.

(5) Overall unstable type: a city whose static type changed during a period.

Thirdly, the trajectory vectors could be drawn for each city in the Cartesian coordinates. As shown in Fig.1a, each city has different points in different years in the Cartesian coordinates. The points could be connected chronologically, which forms a temporal line for a city. Different cities have different temporal lines. Those lines could be regarded as trajectory vector. For a period (t, t+1), each city will have a section of temporal line or trajectory vector. As shown in Fig. 1b, putting the starting point of each trajectory vector during the period (t, t+1) at the coordinate origin, the relative Cartesian coordinates will be formed. slope $|k'|$ means the main factor that causes point change is municipal district area change or built-up area change. If $|k'| < 1$, it indicates municipal district area change is the main factor; If $|k'| \geq 1$, it indicates built-up area change is the main factor. According the direction and slope $|k'|$ of the temporal line during the period (t, t+1), the cities could be divided into four local dynamic types.

(1) Type I: H-H direction and $|k'| \geq 1$. Both the

rank of municipal district area and built-up area upgrade. But comparing to municipal district area, the built-up area upgrade more or similarly. This type shows that the municipal adjustment enhanced the city size grade in the country. And the adjustment efficiency is powerful.

(2) Type II: H-H direction and $|k'| < 1$. Both the rank of municipal district area and built-up area upgrade. But comparing to built-up area, the municipal district area upgrade more. This type also shows that the municipal adjustment enhanced the city size grade in the country. But the adjustment efficiency is lower than Type I.

(3) Type III: H-L direction. The rank of municipal district area upgrades while the rank of built-up area degrades. It means the municipal district adjustment is relatively ineffective.

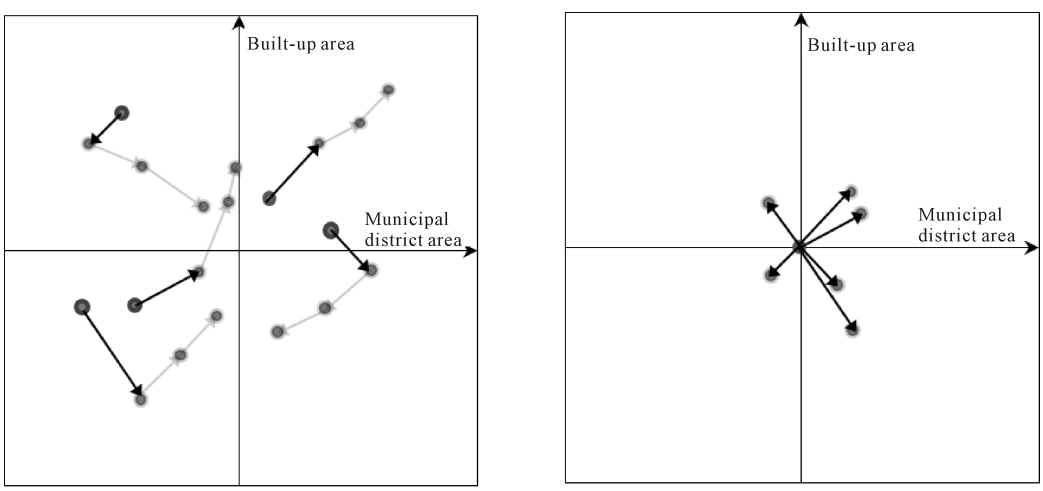
(4) Type IV: L-H and L-L directions. The municipal district adjustment does not play a positive role for built-up area expansion.

Those cities that do not have any municipal district administrative adjustment could also be any type above. Our research focuses on those cities that have municipal district administrative adjustment to explore the efficiency of administrative adjustment for city-size rank.

3 Results and Analysis

3.1 Basic patterns of municipal district changes in China for the past 10 years

As shown in Fig. 2, the changes of municipal district and national municipalities from 2000 to 2010 mainly include three types. 1) The municipal district area is expanded. For example, Nanjing revoked Pukou District and Jiangpu County to establish Pukou District and revoked Dachang District and Liuhe County to establish Liuhe District. 2) The municipal district area is reduced. For example, several townships of Zengdu District were set aside to establish Sui County. 3) New prefecture-level cities are established and new municipal districts are set up. For example, Zhangye Prefecture and Zhangye County were revoked to establish Zhangye City and Ganzhou District. The first and third types were the two main types. For spatial distribution, prefecture-level cities that newly established and municipal districts that newly set up were mainly distributed in the northwest and the southwest, and municipal district adjustments were mainly distributed in the coastal regions and in the middle or western central cities. Evidently, the administrative division adjustment continued to prefecture-level administration from 2000 to 2010 in China. Prefecture-level city was gradually replacing administrative district which was established to manage cities and counties in its jurisdiction by provincial government in the western region, which was slightly lagging behind compared with the eastern and central regions. In these later regions, particularly the Yangtze River Delta, the Pearl River Delta, the Beijing-Tianjin-Hebei Region, and provincial capital cities, municipal district adjustment had become an important way for city spatial expansion to meet the demands of the urban social and economic development.



a. Absolute standardized coordinate system b. Relative standardized coordinate system

Fig. 1 Sketch map of space-time trajectory method

There are about a quarter of the 262 cities which have conducted municipal district adjustment. Expansions mainly occurred in nearby areas. The main forms included establishing districts by revoking counties (e.g., Daxing County was revoked to become a municipal district of Beijing) or acquiring parts of areas from nearby counties (e.g., Lianyungang). However, the extents of expansion significantly differ among cities. A new municipal district area with 10 cities is now 10 times larger than its original area, and Foshan is the largest among these cities. A new municipal district area with 44 cities (approximately 70% of all the cities) is now twice its original area. Most of the municipal districts of these cities clearly expanded at a large scale and amplitude.

3.2 Overall stability of municipal district adjustment and built-up area expansion in China from 2000 to 2010

By adopting the *Z*-score standardization method, we processed the data of the municipal district area and the built-up area of the 262 cities between 2000 and 2010 and drew the space-time trajectory sets over this period. The number and change of each type were counted (Table 1). Overall, the number and share of the four types slightly changed from 2000 to 2010. The H-H and L-H types were minimal, and their numbers were reduced twice or thrice. By contrast, the number of the H-L type increased five times by 2010. The number of the L-L type was 138 (the maximum) (Table 1) its share was over 50%. Therefore, many cities had adjusted the scope of their municipal district, but the number of large-scale cities remained considerably less than that of small ones. The urban grade scale system remained stable. The share of the H-L type was higher than that of the L-H type, which indicated that the increasing number of the municipal district areas of cities was larger than that of the built-up areas. The share of this type of cities increased obviously in the past 10 years.

By counting the numbers of cities with municipal district adjustment in the four types, we found that the number of each type changed dramatically. The numbers of the H-H type and the H-L type increased significantly, but the numbers of the L-L type and L-H type decreased, particularly the L-L type, which decreased from 43 to 23. These data imply that municipal district adjustment affects the national scale and position of a city.

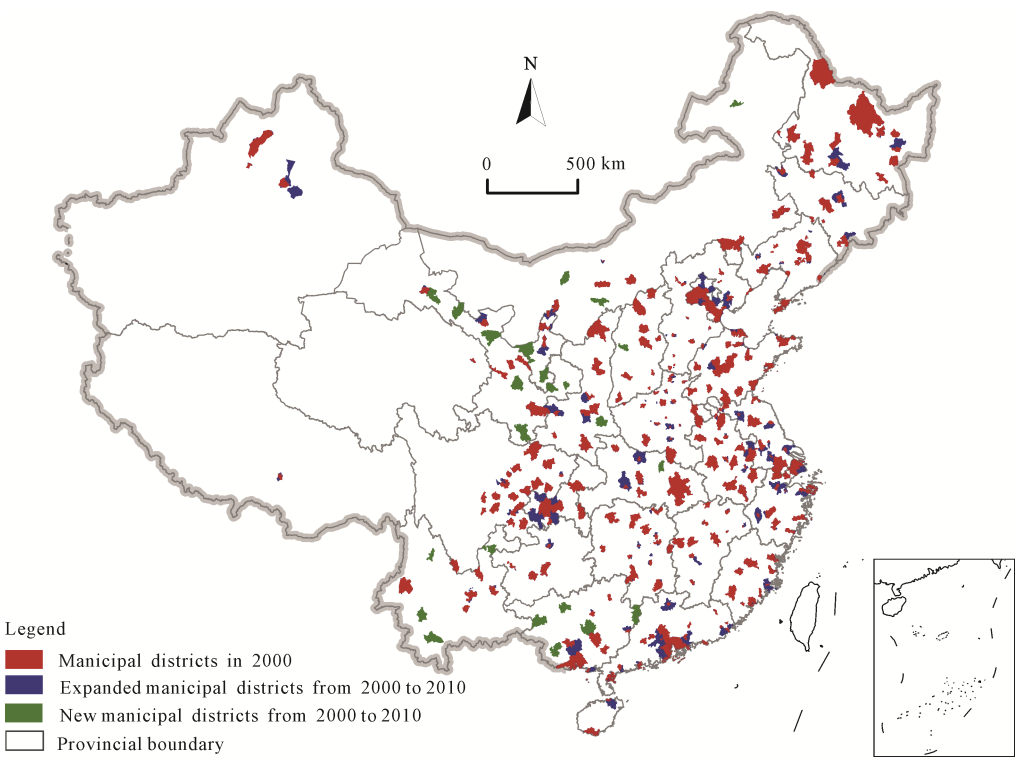


Fig. 2 Map of adjustment scope for municipal district from 2000 to 2010 in China

Table 1 Number and classification of cities based on statistics of overall stability

Type	Number and share in 2000		Number and share in 2010	
	Total	Municipal district adjustment	Total	Municipal district adjustment
H-H Type	35 (13.36%)	9 (3.44%)	32 (12.21%)	17 (6.49%)
L-H Type	35 (13.36%)	12 (4.58%)	33 (12.60%)	11 (4.20%)
L-L Type	138 (52.76%)	43 (16.41%)	138 (52.67%)	23 (8.78%)
H-L Type	54 (20.61%)	0 (0.00%)	59 (22.52%)	13 (4.96%)

To measure the effect of municipal district adjustment extensively, we classified the cities as stable or unstable according to the change between quadrants. The overall stable type consists of four subclasses, and the results are presented in Fig. 3a. The first one is a stable H-H type. The municipal district area and the urban construction land area of these cities are always higher than average. The primacy ratios of most of these cities are extremely high. These cities mainly include municipalities, provincial and regional center cities, and a few resource-based cities (e.g., Daqing) or developed coastal cities (e.g., Dalian, Suzhou). Among these cities, Beijing, Shanghai, Guangzhou, Tianjin, and Nanjing, have adjusted their administrative division. These cities have high primacy ratio, and administrative division adjustment further strengthens their advantages. The second class is stable H-L type. Those cities have a relative low level of municipal district adjustment but a relatively high level of urbanization development, including the provincial capital city in the central region and a few sub-central cities in the eastern region. Some of these cities have also adjusted their municipal district area, but the spatial scale is relative small (e.g., Shijiazhuang). The majority of the cities of this type did not adjust their administrative divisions, and these cities should extend their administrative district appropriately to meet their land demand. The third class is stable L-L type. The cities of this type are mainly small and medium-sized cities with weak urban competitiveness. These cities occupy a secondary position in the urban agglomeration system. Although many cities have adjusted their administrative divisions, the effect of the expansion scales is highly limited to upgrade their national size and position. The fourth class is stable L-H type. The urban construction land areas of these cities are relatively low. Although they have a larger administrative area, most of these cities belong to second-tier cities in the Chinese regional development pattern and are mainly distributed in the central and western regions, although a few are found in coastal regions. This type of cities exhibits large-scale municipal district areas in 2000, and a few of them have adjusted their municipal districts. The existing administrative scope can fully meet the existing demand of urban construction expansion. The fifth class comprises the unstable cities, whose type has been replaced distinctly. Most of these cities have adjusted their municipal districts and exactly changed their relative size and position. Some of these cities have not adjusted their administrative; however, their types have changed and have been influenced by the municipal district adjustment or built-up area expansion of other cities. For example, Hohhot has reduced the level of its built-up area and its type has shifted from H-H to H-L. In general, stable cities account for 75% of all cities, with a few cities under H-H and L-H types. The number of cities classified under H-L is more than these two types, whereas the number of those under L-L is the highest. This classification is similar to that between 2000 and 2010. The status of most of these cities has not been affected by municipal district adjustment. By contrast, unstable cities account for 25%, with nearly half of them having adjusted their municipal districts. Manifesting as stable types, most cities maintain their original status by adjusting their municipal districts. However, some of the cities that have changed their status by adjusting their municipal districts are manifested as unstable. Others have not adjusted their municipal districts but their status has been changed because of the influence of other cities or the scale of their urban construction land; these cities are also manifested as unstable.

3.3 Local stability of municipal district adjustment and built-up area expansion in China from 2000 to 2010

By placing the trajectories of the municipal district adjustment and built-up area expansion of all the cities from 2000 to 2010 into the relative coordinates, we can

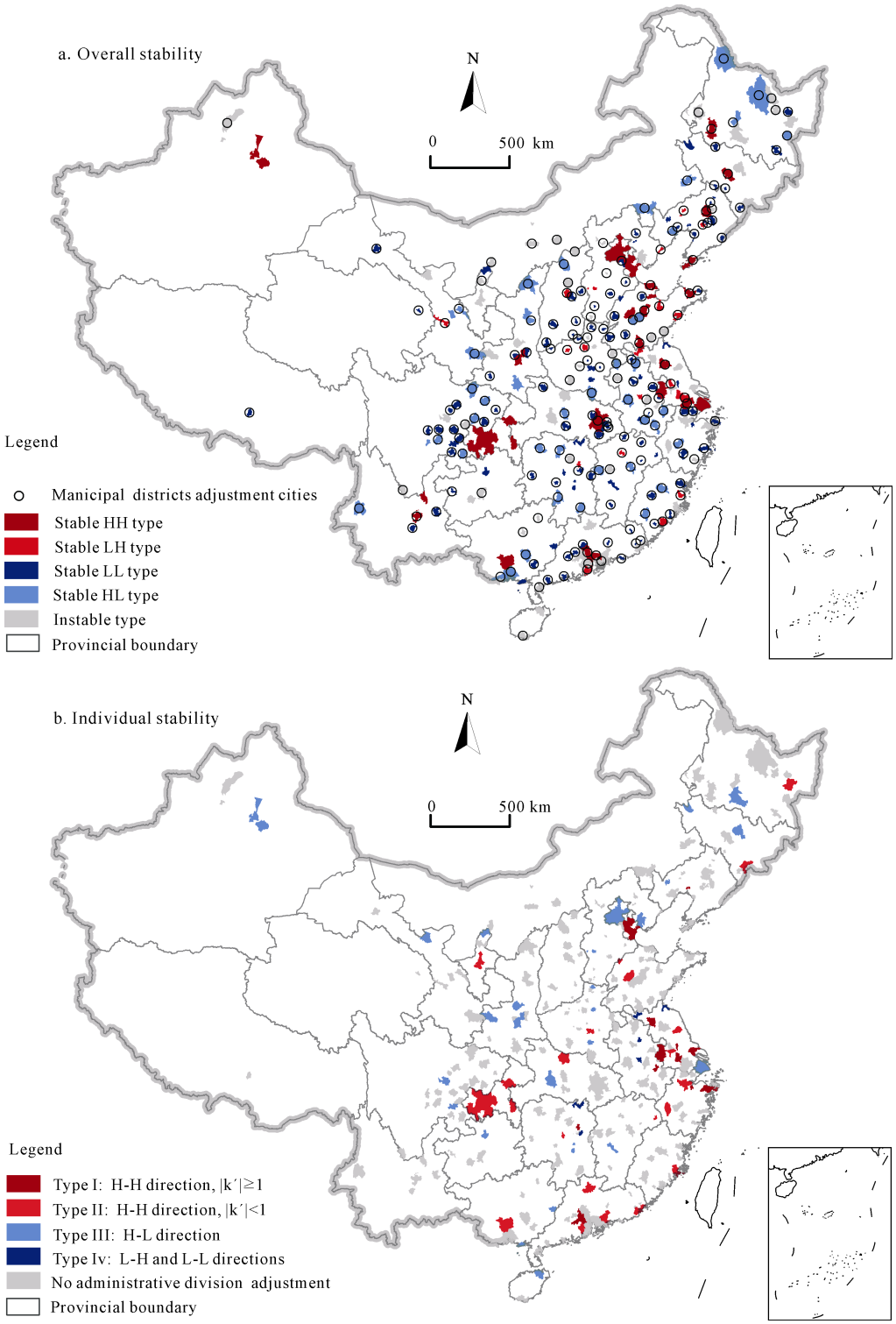


Fig. 3 Classification map of city based on overall stability and individual stability in China

observe a relative change in city scale influenced by municipal district adjustment during the aforementioned period. The statistics are provided in Table 2, and the changing trend is judged according to the vector direction. In general, cities with the L-L (131) and L-H (73) directions comprise the majority. However, a few of these cities have adjusted their municipal districts. Although not many cities have the H-H (32) or H-L (26)

directions, all of them have adjusted their municipal districts. Municipal district adjustment effectively promotes urban administrative region expansion and increases the position compared with the national average. Meanwhile, the length of the trajectory vector also reflects the intensity of the changes. The lengths of the trajectory vectors of the H-H and H-L directions are significantly longer than those of the L-H and L-L directions, which are evident from the statistical data of municipal district adjustment. Therefore, municipal district adjustment plays an important role in changing city scale and status. In addition, focusing on the change in the absolute value of slope K, regardless of the type of direction, the number of $|k'| < 1$ types is higher. Thus, the scale and status changes of most cities are influenced by their own municipal district adjustment or that of other cities.

Considering all three factors, we analyze the cities that adjusted their municipal district according to the classification standard of Types I, II, III, and IV, and the results are provided in Fig. 3b. Type I represents cities whose municipal district area and urban construction land statuses evolved into higher levels, and the latter one upgraded more. These cities need municipal district adjustment urgently, and built-up area expansion will remain a strong trend after administrative division adjustment. These cities mainly include Changzhou, Foshan, Nanjing, Nantong, Ningbo, Panjin, Shaoxing, Taizhou, Tianjin, Wuhu, Suqian, and Changsha. Considering their strategic locations, the social and economic developments of these cities are in the forefront of the entire nation or their respective region. These cities have experienced a rapid development period over the past 10 years. Type II represents cities whose statuses in both areas evolved to higher levels, and municipal district adjustment area upgraded more. These cities have effectively promoted their scale and status, and administrative division adjustment has provided modest development for urban construction land. These cities have the largest number, accounting for approximately 30% of all the cities. Type III represents cities whose municipal district area status evolved into a higher level, but whose urban construction land area status shifted to a lower level. Central cities such as Beijing and Shanghai belong to this type. Their municipal districts have expanded several times and are nearly saturated at present; hence, the new adjustment does not significantly affect urban land scale promotion. Other cities that belonged to Type III were small and medium-sized, and are mainly distributed in the central and western regions. The demand for urban construction land of these cities was weak over the past 10 years; hence, expansion speed was slow. The municipal district adjustment of this type of cities is slightly ahead of time. Type IV represent a minimal number of cities whose statuses in both areas evolved to lower levels; they include Bengbu, Hefei, Lianyungang, Xuzhou, Yueyang, Zhuzhou, and so on. These cities mainly separate a few villages and towns from nearby counties and relocate them into their municipal district scopes; thus, the promotion in scale and status of these cities is limited.

Cities without administrative division adjustment were also affected indirectly, and they evolved toward the L-H and L-L directions. Apparently, the different intensities of their urban development also affected the relative expansion capability of their urban construction lands. Most cities with the L-L direction were small and medium-sized, and are mainly distributed in the mid-west and northeast regions. Their urban developments were not intense in the past 10 years. Cities with the L-H direction were mainly located in coastal regions, such as along the Yangtze River and in the Sichuan Basin. This study focused on cities whose municipal districts have experienced a relatively saturated expansion after 2000, such as Wuhan, Guangzhou, Shenzhen, and so on. These cities tended to change

Table 2 City classification and number (statistics based on individual stability)

Changing direction	All cities				Cities with municipal district adjustment			
	Total	$\|k'\|<1$	$\|k'\|\geq 1$	Average changing length	Total	$\|k'\|<1$	$\|k'\|\geq 1$	Average changing length
H-H direction	32	20	12	0.80	32	20	12	0.80
L-H direction	73	51	22	0.32	4	1	3	0.29
L-L direction	131	78	53	0.24	2	0	2	0.14
H-L direction	26	20	6	0.69	26	20	6	0.69

toward the L-L direction. The expansion speed of their urban construction land was lower than that of cities that have established new municipal districts. A similar conclusion could be given for cities such as Beijing and Shanghai, which behave as the H-L type, in terms of urban construction land expansion.

4 Policy Implications

4.1 Intensive land use

The results show that most of the cities that adjusted their municipal districts and evolved toward the H-H direction are second-tier cities in the past 10 years. Their municipal district adjustment has effectively satisfied the demands of urban development. First-tier cities, such as Beijing and Shanghai, exhibit the H-L direction. Meanwhile, the cities whose municipal districts are relatively saturated, such as Wuhan and Guangzhou, tend toward the L-L direction. Their municipal district adjustments are close to the saturation stage. The key to their future development involves expanding urban construction land in an orderly manner and using land frugally. For these cities, the elasticity provided by the new municipal district adjustment affects urban construction land expansion, which is also minimal.

4.2 Overall and local stability of city size in China

Analysis results show that approximately 25% of cities have adjusted their municipal districts and expanded city space from 2000 to 2010. For the entire country, however, the number of cities with different statuses and scales has slightly changed. Municipal district adjustment has mainly occurred in cities distributed in the eastern coastal region and the mid-west region, as well as in provincial central cities over the past 10 years. Newly established prefecture-level cities and their municipal districts are mainly distributed in the mid-west region. Municipal district adjustment does not occur everywhere in China, but they are achieved in various forms and promoted in an orderly manner. At the individual level, however, municipal district adjustment directly influences the scale and status of a city. Many cities that have adjusted their municipal districts are unstable. They have converted from one type to another, and the main evolution forms are L-H to H-L, L-L to H-H, L-L to L-H, and L-L to H-L. They have either improved the status of their municipal district area or that of their urban construction land. The lengths of the H-H and H-L directions are significantly longer than those of the other directions. Municipal district adjustment has a direct positive effect on promoting city scale and status. Municipal district adjustment is an effective way of spatial regulation to promote the city scale.

4.3 Relatively advanced municipal district adjustment in medium and western China.

For small and medium-sized cities whose grade scale is lower than that in the mid-west region, although they have adjusted their municipal districts, they tend toward the H-L direction. Cities, which have not adjusted their municipal districts, tend toward the L-L direction. The municipal district adjustment of these two types of cities slightly affects the expansion of their urban construction land. Urban construction land expansion is essentially built on the social and economic developments of a city, and municipal district adjustment can only strengthen spatial contact and provide urban reserved land. Therefore, municipal district adjustment includes a stage, which is a process of 'little demand-great demand-saturated demand'. However, considering the current urbanization in China, with the important function to absorb additional floating population and upgrade public services, municipal district adjustment should develop appropriately in advance to meet the demands of a region whose urbanization is in full swing. The municipal district adjustment of coastal eastern and western central cities will gradually move toward the 'saturated demand' stage in the future. Cities that will move toward the H-L direction should no longer have new expansions. However, cities that move toward the L-H direction can be the focal point of municipal district adjustment in the future.

4.4 Model of administrative division adjustment for a county or a county level city

The result shows that the cities that separate a few villages and towns from nearby counties and place them into their municipal district area mainly tended toward the L-L direction. Although they have adjusted their municipal districts, the actual effect on promoting city scale and status is limited. However, for cities that integrate a whole county or county-level city into a new municipal district totally, the promotion effect is significant. Thus, the form that a county or a county-level

city totally changed into a municipal district should be the main way for the municipal district adjustment. It is beneficial for promoting the balanced development and public services of urban and rural areas in the original county or county-level city. It could also promote sub-urbanization. If only changed several villages and towns with good locations and economic conditions into municipal district, the urban and rural gap could be enhanced.

5 Discussion and Conclusions

On the basis of two important variables, namely, municipal district area and urban construction area, this study proposes a space-time path visual model that describes the changes and stable characteristics of these two variables to study the driving effect of municipal district adjustment on the scale and status of a city. The main conclusions of the study are as follows.

(1) China has entered an active period of rapid urban development from 2000 to 2010. During this period, many cities extended their municipal district areas through administrative division adjustments to obtain sufficient land supply. These cities were mainly located in the Yangtze River Delta, the Pearl River Delta, the southeast area of Fujian, and the Beijing-Tianjin-Hebei Area, as well as the western central city and nearby areas. The newly established prefecture-level cities and municipal districts were mainly distributed in the mid-west region. From the perspective of administrative division adjustment, China remains in a transition period of development; substantial space remains available for municipal district adjustment in 2010.

(2) By standardizing urban construction land area and municipal district area using the *Z*-score method, building a coordinate system with two standardized variables, and then drawing a space-time trajectory map of city spatial expansion, the processing method can satisfy the comparability of a city with other cities in China chronologically. The result shows that the numbers of cities in the four different quadrants changed slightly nationwide, which reflects the stability of the city-grade scale system at the national level. Most cities can be classified as stable and has remained stable compared with the national average between 2000 and 2010. However, changes are evident in cities with municipal district adjustment. In general, the numbers of this type of cities in four different quadrants changed significantly. Meanwhile, more cities can be regarded as unstable but have evolved to a higher status through municipal district adjustment.

(3) Using the relative coordinates and the direction, length, and slope of the trajectory vector as auxiliaries, this study divided cities with municipal district adjustment into four types. Cities belonging to Types I and II were moving toward the H-H direction. These cities continued to promote their scale and status effectively through municipal district adjustment; they were mostly second-tier cities with sufficient power for development in the past decade. Urban construction land expansion played a more important role in promoting cities belonging to Type I, which exhibited considerable demands to adjust the municipal districts. By contrast, municipal district expansion played a more powerful role in promoting cities belonging to Type II. Municipal district adjustment provided sufficient reserved land to their city development. Cities belonging to Type III were moving toward the H-L direction. Their municipal district adjustment was relatively advanced compared with city development. These cities were mostly small and medium-sized, and located in the mid-west region. Cities belonging to Type IV were moving toward the L-L direction. The magnitude of their municipal district adjustment was minimal, and upgrading the capacity to increase the scale and status of these cities was highly limited.

(4) According to the analysis, overall, the current variation of municipal districts in China is stable. Municipal district adjustment is an effective spatial management method to promote the scale of a city in China. Corresponding to city development stages, municipal district expansion should have stage characteristics that behave from ‘little demand-great demand-saturated demand’. The largest cities, such as Beijing and Shanghai, are in the ‘saturated demand’ stage at present. For other second-tier cities with rapid social and economic developments, their municipal district adjustment should be advanced moderately to meet the demands of economic development. Changing from entirely incorporated counties or cities to municipal districts should become the mainstream form of future municipal district adjustment. This adjustment can effectively stimulate the scale of a city and enhance its status; it is conducive to the long-term coordination of city development.

Considering the geometric perspective and with the aid of geometric research methods, this study investigated the space-time relationship between urban construction land expansion and municipal district area adjustment. This study is a novel attempt and exploration. It demonstrates the macro-effect features of municipal district adjustment in China and provides a reference for administration division adjustment and city construction. However, city spatial expansion is a complex and systematic progress. Many driving factors are behind municipal district adjustment and built-up area expansion. Carefully studying these factors through individual cases can be the focus of future studies.

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