

Study of Urban Expansion and Driving Forces Based on RS and GIS

----A Case Study of Tangshan City

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Abstract—In the period of rapid urbanization, timely and comprehensively understanding the spatial and temporal characteristics of urban expansion has substantial meaning for the city scientific planning and rational use of land. This paper, using the multispectral image data of “TM” and “Beijing-1” small satellite and based on geographic information system (ArcGIS) data analysis platform, carries out the statistical analysis of built-up area expansion and space variation in Tangshan City, Hebei Province in the recent 20 years from 1988 to 2009; interprets the occupied land-use types during the process of urban expansion; analyzes the impact of urban expansion on land use; extracts the urban road network and analyzes the relationship between urban expansion and road network through the establishment of buffering area and overlay analysis. On this basis, the driving forces of urban expansion are analyzed by integrating the natural condition, economic development, population growth and transportation construction plan in the Tangshan City, revealing the evolution law of Tangshan City spatial pattern and trends which shall direct the corresponding measurement for the rational distribution of urban development in the future.

Keywords—urban expansion, remote sensing, driving forces, Tangshan City

I. INTRODUCTION

Nowadays, China is under the stage of rapid urbanization. To keep abreast of the historical footprint of urban expansion and its trends in future are particularly important. By understanding the coverage, conversion speed, orientation of extended urban built-up area, the relationship of land type conversion during the spatial and temporal change progress, the law of urbanization^[1] can be revealed which could provide the foundation for scientific planning and rational distribution of modern cities' development as well as for rational land use and farmland protection.

In recent years, due to the development of remote sensing observation technology, many researches are on the dynamic change of urban expansion from different aspect. The main directions are urban expansion morphology and expansion mode^[2-3], expansion mechanism and driving forces^[4-5], urban

expansion and land use^[6-7], expansion forecast models^[8-10] and so on.

Based on the “TM” and “Beijing-1” small satellite multispectral image data, this paper implements the built-up area monitoring of Tangshan City nearly two decades in four aspects: monitoring the urban built-up area boundary of Tangshan City in 1988, 1998, 2008, 2009; analyzing the spatial-temporal change progress of built-up area expansion; interpreting the types of occupied land and its number and proportion in three period during the urban expansion process and analyzing the impact of urban expansion on land use; extracting urban traffic network in four levels (freeway, railway, national and provincial road) and analyzing the relationship between urban expansion and traffic network. Based on aforesaid four research aspects, the driving forces of urban expansion are analyzed in-depth to provide a foundation for city scientific planning and rational land use structure adjustment.

II. STUDY AREA AND DATA SOURCE

Tangshan is one of the important cities in Hebei Province, located in the northeastern part of Hebei Province at 117°31'-119°19' S, 38°55'-40°28' N, about 130 km wide in west-east and 150 km wide in north-south. It is neighboring Bohai Sea in the south and Yanshan Mountain in the north, adjacent to Beijing and Tianjin in the west, which is an important part of the Beijing-Tianjin-Tangshan metropolitan area. The Tangshan city has six districts and six counties, and until the year of 2012 its population is about 7,417,800 and covering 13472 square kilometers. It's a century-old coastal city of heavy industry which is located in the fortress as Beijing-Shenyang, Beijing-Qinhuangdao and Datong-Qinhuangdao three railways across the whole territory, linking the north and the northeast regions of China.

This paper uses 30m resolution “TM” data in 1988, 1998 and “Beijing-1” small satellite 32m resolution multi-spectral remote sensing image in 2008 and 2009 to dynamically monitor the urban expansion of Tangshan. Four periods' remote

sensing images have very good quality with cloud-free coverage. Other assistant data includes the DEM images, topographic maps, atlas and the national administrative boundary map of province, city and county.

III. REMOTE SENSING MONITORING AND ANALYSIS ON URBAN BUILT-UP AREA EXPANSION

A. Related Concepts

1) Built-up Area

Urban built-up area generally refers to the actual development and construction areas centralizing the basically municipal utilities and public infrastructure. In this paper, airport is covered in the range of built-up area.

2) Type of Occupied Land in the Process of Urban Expansion

As the center of built-up areas have been expanding constantly, urban expansion's impact on the surrounding land is mainly occupying the other types of land. By using "National Land Classification (Trial)" as reference, the actual occupied land types during the urban expansion is divided into three categories, including arable land (referring to the land for cultivation of crops), construction land (referring to the urban land, rural residential land, independent mining and transport land) and other land (referring to water, woodland, grass and unused land).

3) Transport Infrastructure

Transport infrastructure contains a large number of contents. This paper focuses on extraction and monitoring of four types of infrastructure, including the freeway, railway, national road, provincial road.

B. Urban Expansion Area and Spatial Variation Analysis

From 1988 to 2008, the built-up area of Tangshan City had expanded from 83.37km² to 151.55km², and total extension area reached 68.18km² with expansion ratio of 81.78%. In 2009, the built-up area increased to 264.38km² which was three times of that in 1988 and the expansion area reached 181.01km² with expansion ratio as high as 217.12%. It can be seen from the expansion rate that the built-up area is greatly accelerated in recent years along with the rapid development of the urban economy. According to the Tangshan City planning, in 2020, Tangshan central city area will reach more than 300km², which can be foreseen that the future expansion will be even faster.

The progress of built-up area expansion spatial distribution in the city center of Tangshan in past 20 years is shown in Figure 1-a. From the analysis of Figure 1-a, we can see from the late 1980s to the late 1990s, the Tangshan city center built-up area expansion has obvious direction and major expansion is to the northwest, while the pace of expansion is slow in other directions. From the late 1990s to 2008, the built-up area expansion direction of Tangshan city center changes from northwest to the surrounding direction. From 2008 to 2009, the built-up area expansion is very fast, mainly towards the southwest, supplemented by the direction of the north and northeast, and accompanied with the phenomenon of the city internal blank area is filled.

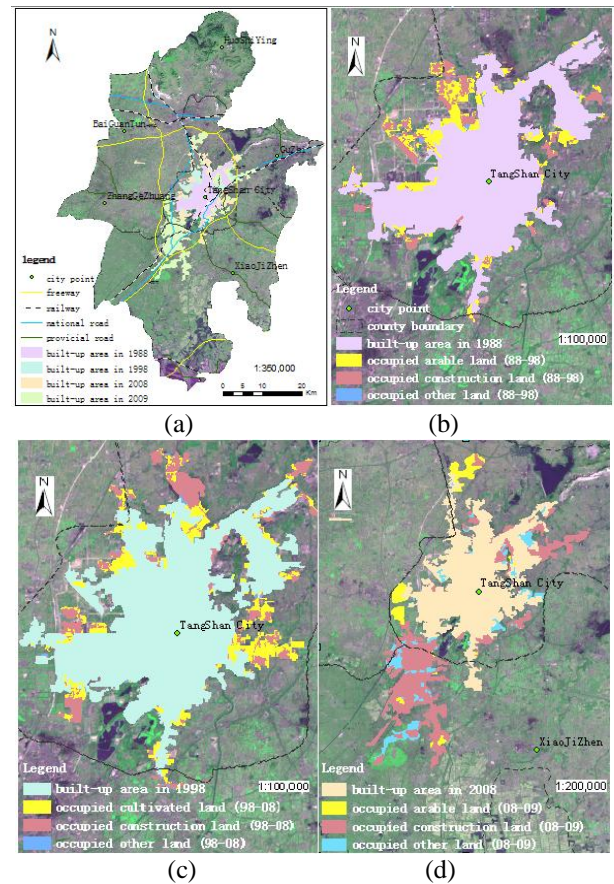


Fig. 1. Tangshan City built-up area expansion and occupied land type.

C. The Volume of Occupied Land Type and Orientation Analysis during the Process of Urban Expansion

From 1988 to 1998, the total area of occupied land, including arable land, construction land and other land, is 20.71km² during the urban expansion process. About half of the occupied land comes from the arable land and 40% from the construction land, only about 2% from the other type of land. In this decade, Tangshan urban expansion shows significant directivity which is towards to the northwest where the most occupied arable land and construction land located (as shown in Figure 1-b).

During the period from 1998 to 2008, the area of arable, construction and other land occupied by urban expansion of Tangshan City is 47.47km². The occupied proportion law of the three land types is consistent with the previous period. The proportion of arable, construction and other land is about 52%, 46%, 2%. The basic type of occupied land is arable land which is close to the original built-up areas during the expansion. The basic occupied land during outer expansion is construction land, and the features of merging with original construction land can be found (as shown in Figure 1-c).

During the period from 2008 to 2009, the area of arable, construction and other land occupied by urban expansion is 112.83km². Construction land is in an absolute dominant position whose ratio reaches 70.85%, while arable land and other land are about 10% separately. It shows a significant

feature of merging with original construction land (as shown in Figure 1-d).

In summary, urban expansion also has a certain direction by occupying land in various types. Arable land is basically from the north and west. Most of the construction land locates in both directions from the northeast and southwest. There are two main sources of other land -- the internal blank area of the original built-up area and the merged construction land of villages and towns.

D. The Link between Urban Expansion and Major Roads

The road infrastructure is a media between towns, and plays a very important role in urban development. The analysis of the relationship between the urban built-up area expansion direction and the main roads has significant meaning for understanding the urban built-up area development pattern.

The main roads' spatial distribution in Tangshan City is acquired through monitoring. From the statistical data, total length of four major types of roads including freeway, railway, national and provincial road is 2325km. The distribution of roads is dispersing, and mainly of it is the provincial road, while freeway, railway and national road have the similar length. Spatial distribution is shown in Figure 1-a.

Road infrastructure has a certain range of radiation effects. This paper is based on the establishment of buffer zones along the main roads, to analyze the relationship between polygons of urban built-up area expanded and road radiation zones. By specifically setting the buffer size as the range of 300 meters, 500 meters and 1,000 meters, the urban expansion polygons distribution data is overlaid for analysis, carrying out the statistics of proportion relationship between different roads buffer zones and expansion polygons in Tangshan.

Through the statistical data analysis, it shows that the expansion polygons within the buffering area are increased with the expansion of radius of such buffering area in different period. From 1988 to 1998, the corresponding proportion of expansion polygons in the 300m, 500m, 1,000m road buffering area were 19%, 28%, 45%. In the 21st century, with the rapid economic development, such proportion increased greatly by about 10%. In two periods from 1998 to 2008 and from 2008 to 2009, the main roads buffer area within 1,000m possessed more than 60% of new urban expansion polygons. Urban expansion shows significant characteristics in road direction along the main road, and the road infrastructure is of great importance in the pattern of urban built-up area expansion.

IV. DRIVING FORCES ANALYSIS OF URBAN SPATIAL EXPANSION

The driving forces of urban expansion are analyzed from four aspects: population growth, economic development, transportation construction, natural and geographical conditions. Population growth will lead to land use incensement in spatial scale which shall inevitably promote the urban area expansion gradually. Economic development is the fundamental driving force for urban expansion, as the economy is the basic factor to determine the direction of the development. The traffic is the lifeline for urban development. Urban expansion will inevitably be towardsto the superior traffic conditions and transportation

has great impact on the direction of urban built-up area expansion. In recent years, the impact of natural and geographical conditions on urban expansion is increasing day by day. There are two factors: one is the mountain of city itself formed as a natural barrier of urban expansion which blocks urban expansion; the other one is that the nature reserves, basic farmland protection area, ecological conservation and some other elements constrain urban expansion.

A. Analysis of Population Growth Driving Force

The space requirement of the growing urban population is the source for urban expansion. A direct manifestation of the population growth is demand for housings, transportation, hospitals, schools, restaurants and other basic infrastructure, which would inevitably lead to the expansion of urban space. This paper, based on population and built-up area statistics of Tangshan City in the period from 1992 to 2007, obtains a very high linear correlation with the correlation coefficient of 0.8 through correlation analysis (as shown in Figure 2). Thus, urban population growth is one of the key driving forces of urban built-up area expansion.

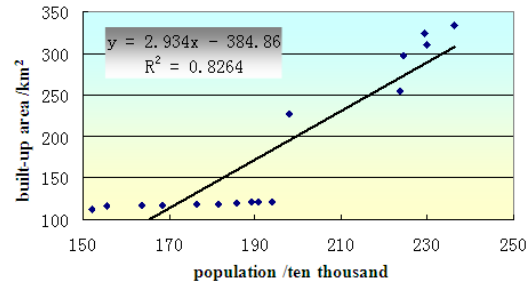


Fig. 2. Tangshan City, population and built-up area correlation.

B. Driving Force of Economic Development

Since the reform and opening, China has maintained a GDP growth rate of up to 10% per year, and the speed of economic development draws the world's attention. The economy is the basic factor to determine the direction of development, and is the fundamental driving force of urban expansion. GDP reflects region's economic development as a comprehensive indicator. The paper, based on GDP and the built-up area statistics of Tangshan City during 1997-2007, obtains a very high linear correlation with a correlation coefficient of 0.8 by correlation analysis (as shown in Figure 3). Thus, economic development is one of the important driving forces of urban built-up area expansion.

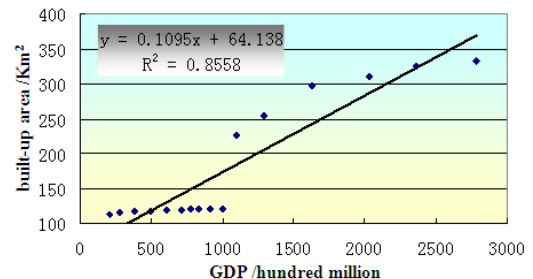


Fig. 3. Tangshan City, GDP and built-up area correlation.

C. Analysis of Road Traffic Driving Force

Tangshan City is a critical transportation center in China, as a hub from north to the northeast of China. The roads together with railway and freeway connect into a network and the traffic is highly developed. Beijing-Shenyang, Beijing-Qinhuangdao and Datong-Qinhuangdao three major railways are across its territory. Four freeways in Tangshan city are with the total length of 288km and the density of 2.12km/100 km², reaching the level of developed countries in the world.

Developed road traffic has significant impact on urban expansion direction in Tangshan City. It can be seen from figure 1-a the urban expansion is toward to areas with better traffic conditions and higher road network density. It has the characteristics of radioactive growth along the road network and filling up the gap between the inter-axis of road network. It shows the road traffic has a crucial influence on the direction of urban expansion.

D. Natural and Geographical Conditions Constraining Factor Analysis

The north of Tangshan City is a mountain and the south is the gulf. So the northward expansion will slow down by natural hinder of northern mountain. Due to its rich marine resources and with the construction of the Harbor Development Zone, Tangshan City will greatly accelerate the speed of built-up area expansion in the south.

V. CONCLUSION

The paper, using "TM" image data in 1988 and 1998, "Beijing-1" small satellite image data in 2008 and 2009 and topographic map, through ArcGIS data processing platform, extracts the Tangshan city built-up area boundary, interprets new increased polygons within the original land use types in built-up area, extracts freeway, railway, national and provincial road, analyzes the law of urban expansion from different aspects, and finally analyzes driving forces from four aspects including population growth, economic development, transportation construction, natural and geographical conditions in Tangshan City.

By using the overlay analysis of three periods' built-up area boundary in the last two decades of the Tangshan City, it can be concluded that the regional expansion area of 181.01km² in all with the expansion ratio of 217.12%, which shows that the expansion process is very fast.

By interpreting the land-use types of new polygons on built-up area from the original image during 1988-2008, it shows that the mainly occupied land use type is arable land whose proportion is about 50% and a very low unused land proportion of 2%, while the other 40% is the construction land. During 2008-2009, the urban expansion occupied land is mainly focusing on the construction land, and its ratio reaches 70.83%. Meanwhile, the proportion of the arable land and other land area is about 10% separately. The main form of urban expansion changes to the merging of city surrounding township.

By establishing 300m, 500m, 1,000m road buffering area, based on extracting of four levels road network, the relationship between transportation and urban expansion is analyzed by

overlaying with new polygons. The result shows that the expansion polygons proportion increases while the buffering radius is enlarging. During 1988-1998, it was 19%, 28%, 45% and after entering the 21st century, with the rapid economic development, the proportion is significantly promoted about 10%. During two periods of 1998-2008 and 2008-2009, more than 60% of urban expansion new polygons are fully located in 1,000m buffering area within the scope of the major roads. Urban expansion clearly shows the road directivity and the characteristic of its distribution is along the main roads. Obviously, the road infrastructure expansion has a critical impact on the expansion pattern of urban built-up area.

Finally, through the analysis of four driving forces of urban expansion, the population growth is identified as the source power, economic development is the fundamental driving force, the road traffic and the natural and geographical factors have a significant impact on the expansion direction.

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