Construction of Urban Spatial Pattern in Underdeveloped Mountainous Counties

Taking Shanyang County as an Example*

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Abstract—**Qinba Mountain Area belongs to one of the 14 contiguous poverty-stricken areas in China. Taking Shanyang County as an example, this paper combs the evolution mechanism of the spatial structure of urban settlements in the county and finds that it is moving from single-center structure to point-axis space structure. Furthermore, the dominant factors of this evolution are analyzed, including traffic conditions, government policies, and resource and environmental carrying capacity. Finally, the future spatial development trend of Shanyang County is predicted to be a new dual-core structure, and corresponding policy recommendations are proposed.**

Keywords—urban system spatial structure; regional dual-core structure; resource and environmental carrying capacity evaluation; southern Shaanxi immigrants

I. INTRODUCTION

Qinba mountainous area is one of 14 contiguous poverty-stricken areas in China, including 76 counties (districts). There are no super-large central cities in the region. The mountainous terrain is mainly mountains (generally over 80%). The population density is small, and the level of county economic development has been very low for a long time. In recent years, influenced by the policy of the southern Shaanxi migration, the urbanization rate of the county has increased rapidly, and the population has been rapidly concentrated in the small towns. Meanwhile, the implementation of the strategy of China Western Development and "the Belt and Road Initiative" has greatly improved the traffic links of the region with the outside world. The implementation of various industrial development plans has also accelerated the pace of economic growth, and the spatial structure of the urban settlements in the county is also is also being reconstructed.

Urban system of the county is the end of the whole urban system. It not only has the characteristics of the initial stage of urbanization, but also shows a leap-forward change because of the influence of large and medium-sized cities in

the region. Especially, the urbanization rate may grow slowly because of the transgressive migration. The more accessible the region is, the more obvious this phenomenon will be [1]. However, on the other hand, the improvement of traffic conditions has provided convenient conditions for industrial development. With the industrial gradient transfer in China, county economy in underdeveloped mountainous areas has begun to rely on its own resource advantages and preferential industrial development policies. This process is also synchronously reflected in the spatial reconstruction of urban system. In view of the spatial reconstruction of urban settlements, domestic scholars have also done a lot of relevant research. Xie Shouhong (2003) believed that expressway affected urban spatial layout, and suggested that the point-axis model be adopted to promote the development of urban space in mountainous areas. Zhang Guohua and Li Xun (2009) analyzed the relationship between comprehensive transportation planning and urban spatial structure. They believed that the formation and evolution of urban spatial structure was promoted by comprehensive transportation facilities. Yang Rongnan (1997) and Fang Chuanglin (2006) believed that physical geographical environment, economic development and traffic construction affected the formation and development of urban system. Lin Tao (2011) believed that the connection and function intensity of urban regional spatial structure depended to a great extent on the traffic accessibility of the region, i.e. the traffic network [2]. This paper draws on some research methods of the above scholars. Based on the classical central place theory and point-axis development theory of geography, this paper studies the process and influencing factors of spatial reconstruction of urban settlements in typical poverty-stricken mountainous counties by combining qualitative and quantitative methods.

II. METHOD EXPLORATION

A. General Thought

The spatial structure of urban settlements in a region refers to the comprehensive and coordinated relationship of cities and towns at different levels within a specific range.

Reasonable spatial pattern is conducive to the sustainable development of regional economy, society and space. The basic theory of studying the spatial structure of urban settlements is the central place theory. According to the central place theory, the higher level the central place is, the more types of functions the central place provides, and the greater the scope of service the central place provides. Therefore, to study the evolution mechanism of spatial structure of urban settlements in the county is to study the spatial evolution process of the functions of the central places in the county.

The functions of the central places are mainly to provide services and goods for the surrounding residents, including social and cultural activities. Generally speaking, the lower level the economic development is, the lower the urbanization (10%–30%) and the simpler the spatial structure of urban system of the county will be, that is to say, only two levels of central places — counties and other towns. This is mainly due to the threshold theory revealed by the central place theory, that is, various public services and commercial facilities have the lowest scale requirements. When the population size is small and the level of consumption is low, the functional units that can support are very few. With the gradual advancement of urbanization process, the main way of migration of rural population to large and medium-sized cities has changed in the early stage. With the deployment of new urbanization and rural rehabilitation strategies, the population of small towns in county has increased rapidly, and the functions of the central places have also changed. More and more ordinary towns have approached the county seat and assumed some functions of public service facilities originally provided by the only central place.

In order to more objectively and accurately measure the relative position between the county and other towns and optimize the spatial structure of the urban system, it is necessary to establish an index system to calculate the characteristic index of each central place in different periods. The index increase represents the functional type, service scope and scale of the central place, etc., which has the potential to transform to a higher-level of central place. Meanwhile, the spatial distribution of the index can reflect the spatial structure characteristics of urban settlements in the whole region.

B. Algorithms and Steps

The author considers the indicators available in terms of public service facilities, transportation conditions, employment opportunities and business services. As far as the traditional functions of central places are concerned, they mainly include the following types: first, the provision of public service facilities, such as education, medical treatment, sports and culture; second, the provision of administrative functions, such as people's governments at all levels, administrative departments; third, the provision of transportation facilities, such as airports, railways, highways and other facilities, and transport capacity; fourth, the provision of commodity services, such as department stores, supermarkets, wholesale markets, etc.; fifth, providing employment opportunities, such as the planning and construction of industrial parks, the level of industrial cluster development, etc. In addition, the urbanization rate, population size and the distance from the regional geometric center should be taken into account.

Through screening out the key indicators at all levels, the characteristic index D of the central place is constructed.

$$D = \sum_{i=1}^{m} W_i Z_i \qquad Z_i = \frac{X_i}{\sqrt{\sum_1^n X_i^2}} \tag{1}$$

That is to say, the dimension of the index is removed by normalization, and the value Z_i of the M index of the nth town is calculated. Using expert scoring method to determine the weight of each index W_i, and the author finally calculates the characteristic index D of central place of each town.

C. Evaluation of the Spatial Structure of Urban System of County

The spatial structure of urban system in Qinba mountainous area has undergone tremendous changes in the past ten years. On the one hand, the functional types of the original regional-level central places have increased, while other secondary central places have also developed rapidly, the gap between them has gradually narrowed, and the single-center pattern of the urban system of the county has also changed. By using the calculated characteristic index of central place in each town, its position and function in the urban system can be visually reflected, and the change and spatial distribution of the index reflect the evolution process of the system. By comparing the characteristics of urban structure in different periods, the author can predict the future development trend and put forward policy recommendations.

III. CASE STUDY OF SHANYANG COUNTY

A. Overview of the Region and Selection of Elements

Shanyang County is located at the southern foothill of Qinling Mountains, which is the geographical dividing line between the north and the south of China. In the region, mountains and ravines criss-cross. The three mountain ranges are in the east-west direction, forming a "three mountains with two rivers" pattern. The vertical and horizontal Juanling Mountain links the northern Liuling Mountain with the central Guling Mountain to form a complex terrain with high central, northern and low east-west-south sides. The total area of the county is 3535 square kilometers. It is a relatively large county with a population density of 118 people per square kilometer. Among them, 2898 square kilometers (82.6%) are mountainous area, 296 square kilometers (3.3%) are water area, and 320 square kilometers (9.1%) are arable land, so it is called "eight mountains, one water area and one field". Since ancient times, Shanyang County has a mild climate, abundant precipitation and natural resources, especially forests and minerals. Before the Qing Dynasty, because of its vulnerable

geographical location to war, the population was relatively scarce. In the middle of the Qing Dynasty, the refugees along Yangtze River and Huai River went to Shanyang County to reclaim wasteland, and the population surged by more than 100,000 people. From then on, man-made forest destruction began. Since then, immigrants have flourished, mainly from Shanxi to the north of the Guling Mountains, and mainly from the Yangtze River and Huai River to the south of the Guling Mountains, thus forming a region with distinct cultural differences between the north and the south.

According to the specific situation of Shanyang County, the following functions are selected as indicators to measure the index of central place, and the weights are determined according to the expert scoring method (see "Table I"):

TABLE I.   INDEX SELECTION AND WEIGHT

First-level indicators	secondary index	Weight
Transportation junction	high speed	0.1
	provincial highway	0.1
	county highway	0.1
	Distance index from the center of the county	0.05
Public service function	Hospital	0.05
	Clinic	0.05
	senior high school	0.05
	junior high school	0.05
	Gerocomium	0.05
	Administrative services	0.05
	scenic area	0.1
Commercial trade function	commodity market	0.05
	Industrial Park	0.1

B. Spatial Distribution of Characteristic Index of Central Place

This paper uses the visualization of GIS to display the central place index of each town. By using the natural breakpoint method, people can see that the larger the central place index is, the more attractive it is to the population, and the population is more likely to gather nearby. Before 2007, the urban system structure showed a remarkable single-center model. The index of county is obviously higher than that of other towns, and the primacy ratio of population is 14.2, while the gap among that of other towns is small. By 2016, tremendous changes have taken place. The county still has outstanding advantages, but the second echelon has emerged, and the geographical locations are close, that is, Manchuanguan and Faguan Town. The distance between two built-up areas of counties is 5 to 10 minutes of driving. The built-up areas of Chengguan Street and Shilipu Street, which are centered on the county, are almost connected objectively. There are two groups located at the north and south ends of the central axis of the county.
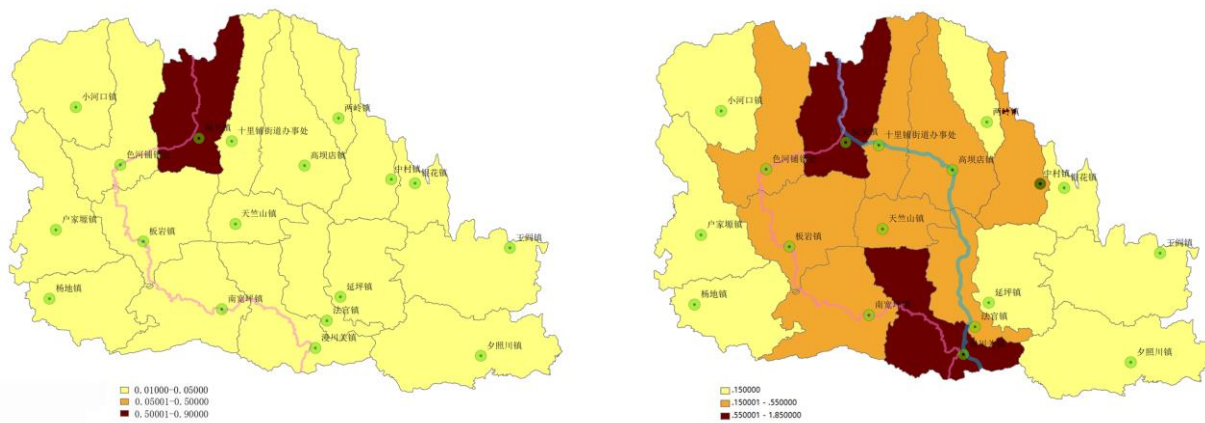

Fig. 1. Central Place Index of Shanyang County in 2007 and 2016.

1) Spatial structure of Urban Settlement before 2007: Manchuanguan Town, the core of the second echelon, is an ancient border town with a long history in Shanyang County. From the Ming and Qing Dynasties to the early years of the Republic of China, Manchuan became an important trade

town in the Hanjiang River due to the development of water transport. Especially after the Opium War, the Westernization Movement rose, and the water transport of the Hanjiang River flourished. Manchuanguan became the key point of the water and land transportation of "North to

Qin and Jin States, South to Wu and Chu States" [5]. Chengguan Town (changed to Chengguan Street Office in 2015) has been the county seat since the Ming and Qing Dynasties, and is the political center of the county. With the increase of trade volume, the population gathers and the border core gradually forms, which belong to typical endogenous spatial polarization pattern. At the end of the Qing Dynasty and the beginning of the Republic of China, Shanyang County experienced frequent wars and depressed people's livelihood, and gradually resumed production and economic development after the founding of the People's Republic of China. However, as the channel connecting Shaanxi and south China was changed to pass through Shangnan County, the commercial function of Manchuanguan shrank and gradually declined. The whole county takes Chengguan Town as a single core, which is not only the administrative center, but also the county center where industry and commerce gather and provide public services.

During this period, the economic development was slow, the per capita GDP was low, and the urbanization rate was less than 10%. Until 2007, the urban population of Chengguan Town was just over 20,000 people. Other towns usually did not exceed 1,000 people, and the population of Manchuanguan and Shilipu was less than 2,000 people (as shown in "Fig. 1"). Assuming that the whole Shanyang County is an economic region, Chengguan Town is the only first-level central place, and other towns can be regarded as the second-level central place. However, due to the great fluctuation and heterogeneity of the terrain, the first-level central place is not a regional geometric center, and the transportation connection with the second-level central place is inconvenient. The traffic conditions in the county are relatively poor, and only one provincial road runs through the north and south. Most villages do not have roads, or public transport. People travel mainly by walking to nearby towns, and then from the township government to the county government. On the other hand, it takes two or three hours to commute frequently, and the external traffic can only depend on the long-distance passenger station of the county, which leads to the low compactness of the whole region and the marginalization of the higher-level region, so the development is very slow.

2) Changes since 2007: In the late 1990s, with the rapid development of the national economy, the economic development of Shanyang County, a poor county in the west, began to accelerate. The main driving force came from the production and processing of mineral resources and the cultivation and extraction of ginger based on saponin production. With the start of the South-to-North Water Transfer Project in 2004, more and more chemical enterprises were shut down because of the ecological protection requirements for the water source area of Danjiangkou Reservoir, making the environment of the water source area in southern Shaanxi better, but the economic development has always lagged behind that of the whole province, and the people's lives have become poorer.

The government and people of southern Shaanxi Province have made great sacrifices to protect water resources and bear huge environmental protection costs. Therefore, the inexorable trend of water source safety in the middle route project of "South-to-North Water Transfer" is to promote local economic development and increase economic income through ecological compensation in southern Shaanxi Province [6]. As a result, a series of ecological compensation mechanisms cause some effects. The ecological migration project and the natural geographical conditions of southern Shaanxi Province have brought into play the advantages of Chinese medicine townships, focusing on the development of traditional Chinese medicine industry, green circular aquaculture industry and rural tourism industry, and achieved considerable economic development (as shown in "Fig. 2"). The spatial structure of urban system has also been reconstructed. The spatial structure of urban system has also been reconstructed.
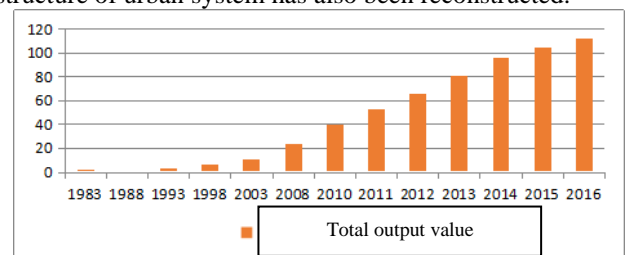

Fig. 2. Gross National Product of Shanyang County in Major Years.

First of all, the original transit provincial highway is restricted by the terrain. Along the valley, it is built along the western route, and the car speed on narrow and curved roads is relatively slow. There is no significant development axis. By 2009, the Shang-Man Expressway in Shaanxi Province section of the Fuyin Expressway was completed and opened to traffic. The situation has been greatly improved. The design speed of expressway is 80 km/h, and the construction of bridges across mountains shortens the distance, which makes it only one hour of driving distance from Chengguan Town to Manchuanguan Town. At the same time, it excavates and utilizes the history and culture of Manchuanguan Town to build the cultural and tourism characteristic town of Shanyang County, which leads to the gradual eastward shift of the focus of economy and population. In May 2010, the Shaanxi Provincial People's Government launched a 10-year project with over 100 billion yuan investment and 2.4 million people in the three cities of southern Shaanxi Province, twice the size of the migrants of Three Gorges Reservoir Region, known as the "most relocated" in the history of new China. Population is rapidly concentrated in cities and towns. In 2007, the urban population of the whole county was only 37.6 million. By 2016, nearly 130,000 people had moved to the cities and towns because of the joint effect of ecological migration, disaster migration and poor migration. By 2016, the urbanization rate with resident population as the statistical caliber had reached 45%.

In February 2015, Chengguan Town and Shilipu Town were transformed into subdistrict offices. The pattern of banded groups gradually appeared in the central urban area of the county seat. In the future, Gaobadian Town in the east of the county seat will be abolished at an appropriate time and changed to subdistrict office. Thus, the three groups of Chengguan Town, Shilipu Town and Gaobadian Town will form banded groups along the main traffic axis (as shown in "Fig. 3"). Manchuanguan and Gaobadian along the Fuyin

Expressway are listed as key towns of the state, while Hujiayuan along the Shanzuo Expressway in the Tianzhushan Town is listed as key town at the municipal level (as shown in "Table II"). In this way, the spatial pattern of urban system in the county extends southward and connects with Manchuanguan Town, another core of the early dual-core structure, forming a point-axis spatial structure.
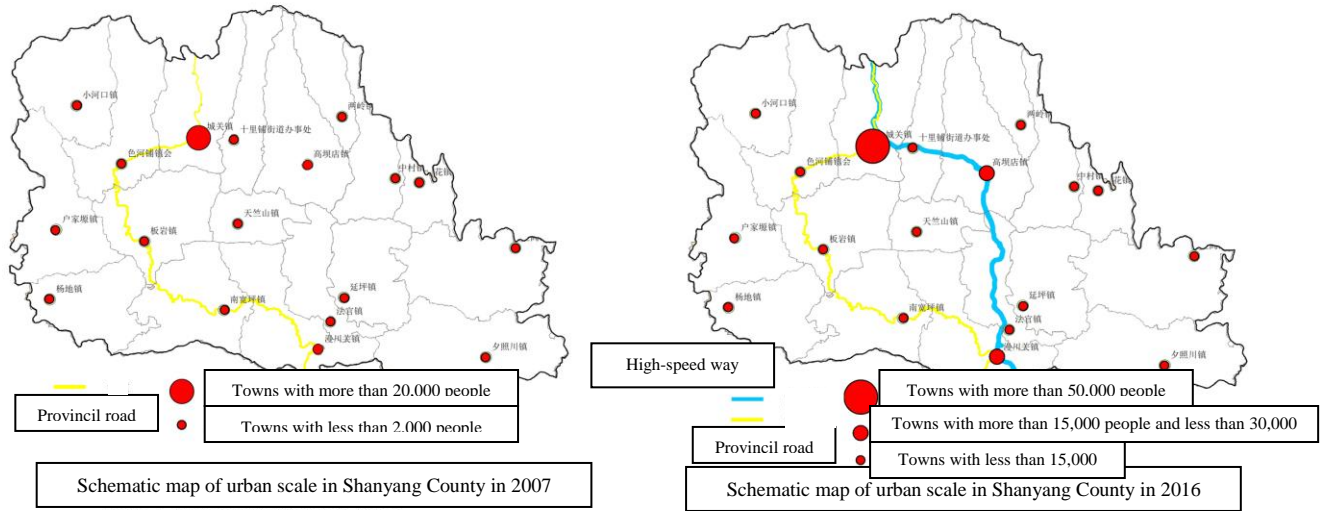

Fig. 3.   Schematic map of urban scale in Shanyang County.

a. (Source: drawn by the author.)

TABLE II.   FUNCTION DIVISION OF TOWNS ALONG SHANYANG COUNTY HIGHWAY (DRAWN BY THE AUTHOR)

Name	Nature	Industry	tourism resource	Key towns
Tianzhushan Town			AAAA Scenic Area	Municipal level
Chengguan subdistrict office	Political and Economic Center	comprehensive		
Manchuanguan Town	Small Towns with National Characteristics	Green cycle	AAAA Scenic Area	Provincial level
Hujiayuan Town		Plant		Municipal level
Shilipu subdistrict office		Traditional Chinese Medicine and Food Processing		Provincial level
Gaobadian Town		Breed		
Faguan Town		Green cycle	Qinlingyuan Town	

C. Evolution Trend and Suggestions of Spatial Pattern of Urban System in Shanyang County

1) Leading factors affecting the evolution of urban spatial pattern in Shanyang County: From the evolution of the spatial structure of Shanyang County, it can see that the physical and geographical conditions have laid the foundation. Transportation, especially external traffic and government policy are two dominant factors. Two important turning points in history have arisen as a result of changes in external traffic conditions. For the first time, highway transportation replaced water transportation. Manchuanguan Town declined rapidly, and the dual-core structure

disintegrated. For the second time, it is the construction of expressway, which brings Manchuanguan Town into the track of rapid development. Of course, the historical and cultural advantages of its ancient town of commerce and trade are the core competitiveness. The government's immigration policy has accelerated the process of urbanization artificially. Although the initial population has not yet achieved real urbanization and citizenization, this push can't be underestimated. In the future, these new immigrants will play an important role in the development of cities and towns. At the same time, the government has played an important role in the adjustment of industrial

structure and the establishment of industrial clusters. The government uses preferential tax, convenient land use and other incentive policies to attract the investment.

The impact of traffic network changes on the reconstruction of settlement space in underdeveloped mountainous counties is sometimes decisive. By calculating the traffic accessibility of small towns in the county, and using the time-minimization method (as shown in "Fig. 4"), people can see that compared with 2007, the accessibility along the expressway is generally improved in 2016. The first five towns with the best accessibility are the two core groups mentioned above.
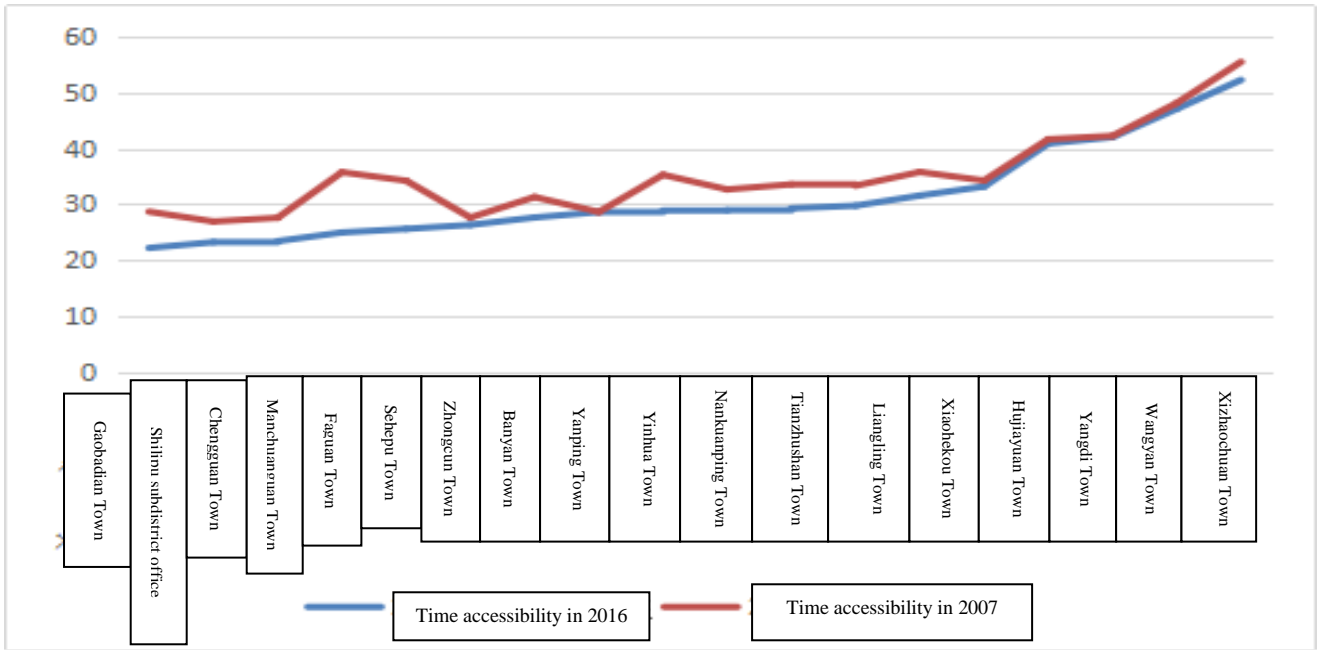

Fig. 4.   Accessibility of towns in Shanyang County.

2) Development trend: From the urban population scale distribution map in 2016, it can be clearly observed that the urban population mainly gathers toward two core areas. One is the northern core based on Chengguan Town, whose main functions are administrative center and industrial park. The other is the southern core based on Manchuanguan Town. Its main functions are to develop tourism, health care and ecological aquaculture. The urban population of these two groups has accounted for nearly 70% of the total urban population. According to the idea of industrial cluster development and the policy guidance of three centralizations, industrial enterprises are also concentrated in these two core industrial parks. In the future, the spatial structure of Shanyang County's urban system will probably develop into a new dual-core structure, Chengguan Group and Manchuanguan Group as the core. Although Manchuanguan Town is no longer a frontier town dominated by commerce and trade, it will become a business card for Shanyang County due to the construction of characteristic towns. Its popularity is far greater than that of the county seat (in terms of Baidu search ranking), and the functions of Chengguan Group are not duplicated. At the same time, there will also be two major changes in external traffic conditions of Shanyang County, namely, the construction of Shuiyang Expressway and Xiwu High-speed Railway.

The Xiwu High-speed Railway, which will start construction in 2019, has decided to set up two stations in Shanyang, namely, Shanyang Station (located in Chengguan subdistrict office) and Manchuanguan Station (located in Manchuanguan Town). The establishment of a station in Manchuanguan Town can be said to affirm the good situation of social and economic development in Shanyang County in recent years. The opening of these two high-speed railway stations will further strengthen the trend of Manchuanguan Group developing toward the second core, and also increase the compactness of the county, which is conducive to the concentration of resources and the formation of a virtuous circle. When the high-speed railway is opened, the gap between the two groups and other urban nodes will be further widened, which has the potential to form a dual-core structure.

This is also in line with the development requirements of urbanization in mountainous counties. The mountainous counties generally have complex terrain, large geographical area, and small population density. The service scope of the central place under the single-center pattern is too large to meet the needs. For example, it takes more than three hours to drive from some towns to counties, while the multi-center pattern can better solve this problem, and relatively small circles of life can be used to cover the whole area. Of course, mountainous counties have small population and low-level economic development. The purchasing power is insufficient to support the development of regional centers to a higher level. The number of central places should be controlled. At

the same time, the carrying capacity of resources and environment, especially the carrying capacity of land resources, should be limited.

3) Policy recommendations: At present, China attaches great importance to the relationship between the development and utilization of land and the environment. Since the Wenchuan earthquake, the carrying capacity of resources and environment should be taken into account in areas with geological hazards. In the Key Points of Provincial Land Planning issued by the Ministry of Land and Resources in 2017, it is necessary to evaluate the carrying capacity of resources and environment, and has given detailed indicators. According to natural geographical conditions, life safety, ecological security, food security and other elements of resources and environment, this paper analyses the influence degree of elevation, slope, land difficult to use, mountain torrent disaster, landslide, debris flow, land subsidence, active faults, karst collapse, soil erosion, water resources, important ecological land, planning prohibited construction area, basic farmland and agricultural land grade on land development [8], and screens the factors according to the influence degree and data acquisition. In view of the situation of Shanyang County, the author chooses suitable factors to evaluate the carrying capacity of resources and environment, determines the suitable land area for construction, and then combines the provincial ecological protection requirements to determine the ecological red line scope. It is found that most of the two overlaps, leaving only 590 square kilometers of land for development and construction, and is relatively dispersed. The suitable construction land of the two core groups in the north and south is only 61 square kilometers and 66 square kilometers respectively, which is not rich. Therefore, there are already projects of mountain-cutting and land-building, indicating that the land-building cost is high. However, it is acceptable compared with the location advantage. Now, not only the population and land, but also the capital is rapidly centralizing toward the two cores. Township merger has changed greatly in recent years. Taking Shanyang County as the example, there were nearly 30 townships in 2007 and 18 townships in 2016, including two subdistrict offices, such as Chengguan Town.

When Liu Yuting studied the regional differences of population size in small towns, it found that when the population size of central towns was 10,000, 20,000 and 30,000 people, the benefits brought by population agglomeration were obviously different. The economic benefits of central towns with more than 30,000 people would be significantly enhanced, and the satisfaction of residents was generally higher than that of small towns with less than 30,000 people [9]. Small towns in mountainous areas are generally smaller than those in plain areas. For towns within 30 minutes of driving away, group development, joint advantage resources and regional development can be considered. The counties in Qinba Mountainous area should actively cultivate potential central

towns, consider joint development and improve the level of development of the whole county. It can cover the whole county more effectively.

IV. CONCLUSION

By synthetically considering the function types and service scopes of the central place, the larger the index Z is, the more functions the town provides. Then, the spatial structure characteristics of the urban system of the county can be visually reflected by cluster analysis. In Qinba Mountainous Areas, with the change of traffic conditions and other dominant factors, the living standards of urban and rural residents are constantly improving, and the functions of central place of the counties are more and more. The original single-center spatial model is gradually adjusting and reconstructing, evolving towards multi-node urban network along the main traffic axis, and even some counties may develop into dual-core structure when conditions are ripe. For mountainous counties with complex terrain, it can serve the whole region better. If the cluster development between the central towns with similar distances breaks through the economic boundaries of agglomeration, it will be more conducive to bring the economic benefits of the central towns in the process of urbanization.

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