Research on the spatio-temporal evolution pattern of traffic dominance in Shaanxi Province

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ABSTRACT

To measure and analyze the transportation situation within the counties of Shaanxi province over a certain period of time, and to promote the province's future transportation planning and development, this paper proposes a reasonable layout plan and compares model rationality. The study uses entropy weight method to measure the transportation advantages of 107 counties in Shaanxi province from three dimensions: road network density, trunk line influence and location advantage in 2013 and 2021 and applies spatial autocorrelation analysis method to analyze the spatial layout and development trend of county-level transportation and conducts OLS regression on transportation impact factors and other influencing factors. The paper also compares the regression fitting degree of the GWR model and the OLS model. The results show that spatially, the transportation advantages of Shaanxi province generally show a decreasing trend from the Weihe Plain to the surrounding areas, and mainly exhibit high-high clustering phenomenon. Temporally, transportation advantages show an overall upward trend, and the phenomenon of spatial imbalance gradually decreases. People's travel demands have changed to some extent, and the demand for rapid transportation has increased overall. The GWR model regression fitting degree of transportation advantages is 0.74, which is higher than the OLS regression model's fitting degree of 0.64. Based on the evolution of transportation advantages, it is predicted that this trend will continue for a period in the future. To improve the transportation advantages of Shaanxi province, increasing the layout of rapid transportation can effectively enhance the transportation advantages of Shaanxi province.

Keywords: Traffic dominance model, spatial autocorrelation analysis, temporal and spatial evolution

1. INTRODUCTION

In the process of continuous national development, transportation planning and layout have always been placed in an important position. Quantitative analysis of transportation advantage and spatial analysis can effectively evaluate the status and development of transportation infrastructure construction in a region, thereby reflecting the transportation advantages and future transportation layout of the region. Meanwhile, analyzing the spatial and temporal evolution pattern of transportation advantage can effectively evaluate the quality of regional infrastructure, the distribution of transportation facilities, and the specific characteristics of spatial transportation advantage, reflecting the spatial development trend of the region.

In 1959, Hansen first proposed the concept of transportation accessibility, using this concept to evaluate the quality of regional transportation conditions [1]. Subsequently, many scholars conducted in-depth research on the European road network using comprehensive indicators and proposed measures to promote the level of accessibility in peripheral areas [2,3]. Transportation advantage will greatly affect the economic development level of a region, especially in tourism, industry, and other aspects [4-7], therefore, research on transportation advantage has always been a concern of researchers. The research objects have also expanded from transportation advantage within urban rail transportation to aviation networks, and the proposed recommendations for operation and management also vary with different research regions or systems, resulting in different management and layout schemes [8-10]. Transportation advantage in a region is also considered to have a certain degree of correlation with social equity, so the reasonable layout of transportation will deeply affect the social environment of the region [11,12]. At the same time, with the rapid development of Geographic Information Systems (GIS) in recent years, researchers have new research methods and more intuitive ways of displaying the analysis of transportation advantage in different regions [13–16]. Overall, fully utilizing regional transportation advantages and avoiding transportation disadvantages can play an important role in the formulation of regional economic development strategies, industry selection, and spatial structure optimization [17–19].

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2. RESEARCH DATA AND METHODS

2.1 Research Data Sources

This paper takes 107 county-level units as the research object and conducts statistical analysis on the spatial scope of county-level units in 2013 and 2021. The research data includes road network and administrative area data, population data, etc. in this area. All road network data are from the official website of OpenStreetMap; the administrative division vector map files of Shaanxi Province are from the Shaanxi Provincial Geographic Information Public Service Platform, the population data and economic data of each district and county come from the official website of the statistics bureau of the prefecture-level city; the land use type data of Shaanxi Province comes from the resource and environment science data of the Chinese Academy of Sciences The central website; the elevation data of Shaanxi Province come from the geospatial data cloud website.

2.2 Calculation of traffic dominance

Based on the three basic theories accepted by many scholars—point-axis theory, traffic location theory, distance attenuation theory, and the research of Chinese scholar Jin Fengjun, the situation of a local traffic facility ("degree" and "quantity"), traffic volume Geographical location ("potential") to measure the transportation convenience or planning layout of a region [20-23]. Therefore, it is proposed to use the comprehensive evaluation of the three indicators of traffic facility network density, traffic arterial influence degree and location advantage degree to reflect the traffic convenience of a certain area. Standardize the traffic network density, traffic arterial influence degree, and location advantage degree according to a certain method, and then carry out comprehensive integration to obtain the traffic advantage degree index of each district and county, which can be expressed as:

$$F_i = \sum (\omega_i \times TD_i + \omega_2 \times TA_i + \omega_3 \times TL_i) \tag{1}$$

Where F is the traffic advantage degree of the county unit, and the larger the value, the better the traffic advantage of the region; TD indicates the various road network densities of the county unit, TA indicates the arterial influence degree of the county unit, and TL indicates the location advantage degree of the county unit; ω_1, ω_2, ω_3 represent the weight of network density, traffic arterial influence degree, and location advantage degree.

1)1road network density

The density of the traffic road network is the most direct response to the traffic development of a region. This index is widely used in various traffic evaluations. It reflects the supporting capacity of regional development to a certain extent, and it is also the embodiment of traffic supply capacity. The greater the road network density, the better the traffic development in the area. Its expression is:

$$TD_i = \sum L_i / S_i \tag{2}$$

Where L is the length of various roads in the county unit; S is the administrative area of the county unit.

2)Location advantage

The degree of location advantage refers to the degree of accessibility between each county unit in the study area and the key node (city center) in the city, so this indicator represents the superiority of the geographical location of each county unit. The average shortest travel time between the administrative centers of districts and counties and the centers of prefecture-level cities is used to express. The shorter the time, the higher the degree of location advantage.

Its expression is:

$$t_{iq} = D_{iq} / V_q , \quad TL_i = \sum_j^n t_{ij} \Big/ N \tag{3}$$

Where D_{iq} is the road network length of the research area unit i road type q, V_q is the average driving speed of the road type q, t_{iq} is the average time cost of the research area unit i road type q, and N is the number of road types.

3)Influence degree of traffic arterial line

The degree of influence of traffic arteries is the embodiment of the region's ability to connect with the outside world, and to a certain extent, it can reflect the ability of transportation infrastructure to support and guarantee regional development. The greater the degree of influence of a traffic artery, the stronger its ability to support regional development. Judging from the existing research, the current research will include consideration of ordinary railways, expressways, national highways, high-speed railways, airports, and water ports. Since Shaanxi is in the interior of Northwest China, the water transportation volume is very small, so the impact of water transportation is not considered here, and the classification assignment method is used to evaluate the influence degree of the traffic arteries of each county unit according to relevant research. Calculated as follows:

$$E_{im} = \sum_{q=1}^{n} Q_{iqm} \times N_{iqm} \text{ },TA_i = \sum_{m=1}^{m} B_m \times E_{im} \tag{4}$$

Where Q_{iqm} indicates the weight assignment of the m traffic facility type q, N_{iqm} is the number of the subtype m of traffic arterial facilities q in unit i; B_m is the weight of the type m traffic arterial facilities; E_{im} is the score of the m traffic arterial facility in the research area unit i.

2.3 Influencing factors of traffic dominance

1)traffic elements

There are many traffic elements that affect traffic dominance. In the process of correlation regression analysis, that is, to study the contribution of traffic elements to traffic dominance, it should be ensured that there is no linear relationship between variables, so as to ensure that there is no linear relationship between the variables in the regression analysis. Residual variables do not appear during the analysis. Select the following indicators based on relevant studies of the data: Distance from train station, Distance from the airport, County Road density, other road densities, railway density.

2)other elements

In addition to being directly affected by transportation facilities, the degree of regional transportation advantage is also indirectly or directly affected by multiple factors such as regional GDP, urbanization level (proportion of built-up area), industrial structure, population density, and elevation. In order to analyze which factors, contribute the most to the traffic dominance and improve the regional traffic dominance on this basis, relevant regression analysis is carried out. The premise of regression analysis must ensure that there is a causal relationship between the two in theory. The five indicators are obtained according to the availability and theoretical relationship.

3. SPATIO-TEMPORAL CHARACTERISTICS ANALYSIS

According to the three-dimensional index of traffic advantage degree: traffic road network density, traffic arterial influence degree, traffic location advantage degree and entropy weight method Calculate the traffic dominance level of the counties in Shaanxi Province. After standardization, the entropy weight method calculates the relevant weight according to the information entropy. The steps are as follows:

(1) Calculate the information entropy e (uncertainty) of each indicator

$$e_j = -\frac{1}{\ln n} \sum_{i=1}^{n} p_{ij} \ln(p_{ij}) \tag{5}$$

(2) Calculate the weight:

$$d_j = 1 - e_{j,} (j = 1,2,3.....,m), \quad w_j = d_j \Big/ \sum_{j=1}^{m} d_j, \quad (\mathrm{j} = 1,2, \ldots..,\ ) \tag{6}$$

Where is the utility value of information, and is the weight of each indicator. The information entropy and weight of each index calculated according to the entropy value method are shown in Table 1. Among them, due to the greatest difference in road network density in each county, the higher the information contained in this indicator, the higher the weight of this indicator, accounting for 53.1%, exceeding the sum of the other two indicators.

Table 1 The weight of each index of transportation advantage degree

Index	Information entropy	Information utility	weight
road network density	0.75	0.25	53.1%
Location advantage	0.98	0.042	26.7%
traffic arterial influence degree	0.969	0.031	20.2%

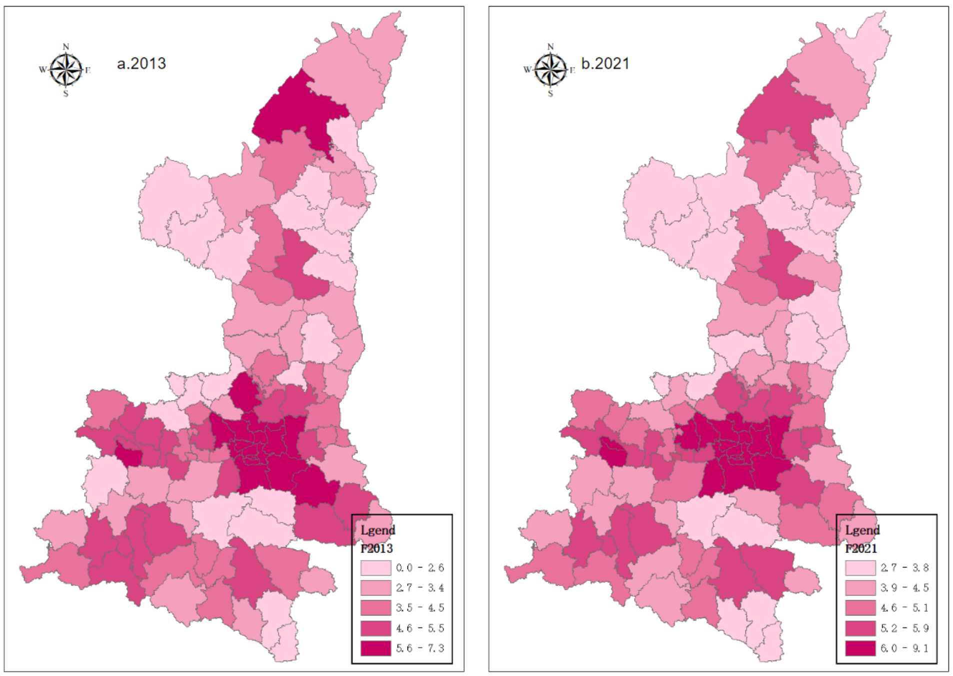

Figure 1 Overall traffic advantages in 2013 and 2021

According to the weights and standardized figures in Table 1, the transportation advantage degrees of 107 districts and counties in Shaanxi Province in 2013 and 2021 were finally calculated|(Figure1), and the traffic advantage degrees were divided into five grades according to the quantile method. It can be seen from the figure that the areas with high traffic advantages are mainly distributed in the Weihe Plain and the Hanjiang River Basin, and the prominent places form a "+" character. During the eight years, affected by the construction of main roads, airports in northern Shaanxi, and high-speed railways, the overall traffic advantage of Shaanxi Province has been rapidly improved. In 2013, the overall average traffic advantage index of 107 districts and counties in Shaanxi Province was 4.0, and in 2021, the average traffic advantage index was 5.0, with an average growth rate of 25%. The areas with higher growth rates are the northern Shaanxi area and the southern Shaanxi area.

4. SPATIO-TEMPORAL CHARACTERISTICS ANALYSIS OF TRAFFIC DOMINANCE AND THE INFLUENCE ANALYSIS OF VARIOUS FACTORS

4.1 Characteristic Analysis of Spatial Distribution

1)Spatial Balance Difference of Traffic Dominance

To evaluate the balance and fairness of a certain index in a region, the index of variation coefficient is widely used in research at home and abroad. However, the traffic dominance index in Shaanxi Province has obvious spatial imbalance and difference. To measure this unevenness, the index of variation coefficient is introduced. Its expression is:

$$CV = \partial^{p} \Big/ \sum M_i A_i \Big/ \sum M_i \tag{7}$$

To explore the spatial balance of traffic dominance in each county in Shaanxi Province, the above formulas were used to calculate the coefficient of variation of the three first-level indicators and the total traffic dominance in two years, and then calculate the change rate. The results are shown in Figure 2. Among them, TA, TL, TD, and F represent Influence degree of traffic arterial line, Location advantage, road network density, and traffic dominance respectively. The larger the coefficient of variation, the more obvious or unbalanced the spatial difference of the index is, otherwise, the smaller the difference is, the more balanced the spatial distribution is. Among the three first-level indicators of traffic dominance, the coefficient of variation of traffic road network density in each county in Shaanxi Province was the highest in both periods, 1.00 and 1.57 in 2013 and 2021, respectively. The balance of road network distribution is the lowest in terms of county traffic dominance. According to the calculation, the coefficient of variation of the overall traffic dominance degree in Shaanxi Province is from 0.319 in 2013 to 0.257 in 2021, with a growth rate of -19.4%, indicating that during this period, the spatial difference in traffic dominance in Shaanxi Province gradually decreased. At the same time, the variation coefficients of arterial influence degree, location advantage degree, and road network density in Shaanxi Province have declined to varying degrees, and the growth rates of the variation coefficients are -36%, -46.5%, and -36.3%, respectively. This is due to the impact of Shaanxi Province's strengthening of transportation infrastructure in other places.

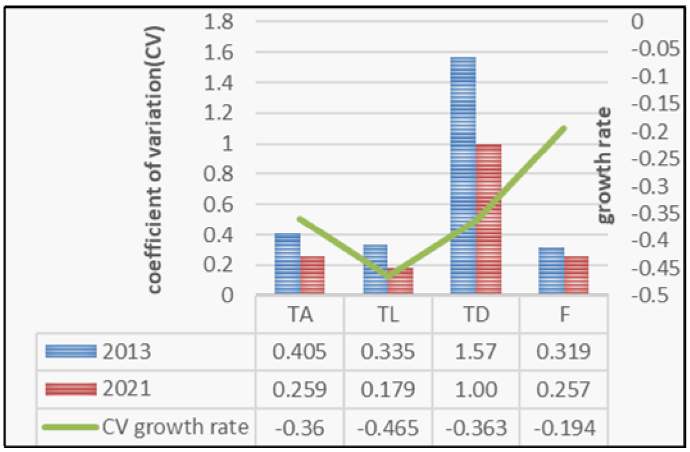

Figure 2 The coefficient of variation of each index and its growth rate

2)Distribution pattern of cold and hot spots of traffic dominance

It can be seen from the above that the variation coefficients of traffic dominance in Shaanxi Province in the two periods are greater than 0.25, that is, the traffic dominance has obvious spatial imbalance. To explore and understand the situation of spatial imbalance, spatial anomaly and cluster analysis, Hot and cold analysis. Firstly, Moran I was used to conduct global autocorrelation analysis on the overall traffic dominance in 2013 and 2021 respectively. The Moran I indices were all positive. Usually, the standardized statistic Z value is used for significance test, and the calculation formula is:

$$Z(\text{Moran'I}) = (Moran'I - E(Moran'I)) \Big/ \sqrt{Var(Moran'I)} \tag{8}$$

where $E(Moran'I)$ and $Var(Moran'I)$ are the theoretical mathematical expectation and variance of Moran I. Calculate the Getis-Ord Gi* index of traffic dominance in Shaanxi Province in 2013 and 2021 respectively, divide it into 7 levels according to the confidence level, and finally get the distribution of cold and hot spots of traffic dominance in Shaanxi Province in the two periods shown in Figure 3. Overall, the hot spots in Shaanxi Province are concentrated in the west of the Weihe Plain, that is, the An-Xianyang area. Most of the cold spot areas are distributed in the east-west boundary of northern Shaanxi, and the other parts are indistinct gathering areas. From the perspective of topography and landforms, most of northern Shaanxi is a loess plateau, and the east-west border does not pass through the main traffic road, which leads to cold spots.

From the perspective of time development, the overall layout of cold and hot spots has not changed significantly, the overall hot spot area has not increased, and the cold spot area has partially decreased, which explains the decrease in the coefficient of variation to a certain extent.

4.2 4.2 Analysis of the Influence of Various Factors on the Evolution of Traffic Dominance

1)The Influence of Traffic Elements on the Evolution of Traffic Dominance

The development of traffic dominance depends on various traffic infrastructures. To explore the strength of the interaction between traffic dominance and various traffic elements in a region or the development relationship between traffic dominance and various traffic elements, the Shaanxi Province OLS regression analysis of relevant traffic elements is carried out on the traffic dominance degree from 2013 to 2021. The relevant indicators were standardized, and collinear variables were eliminated. The OLS regression fitting results from 2013 to 2021 are shown in Table 2.

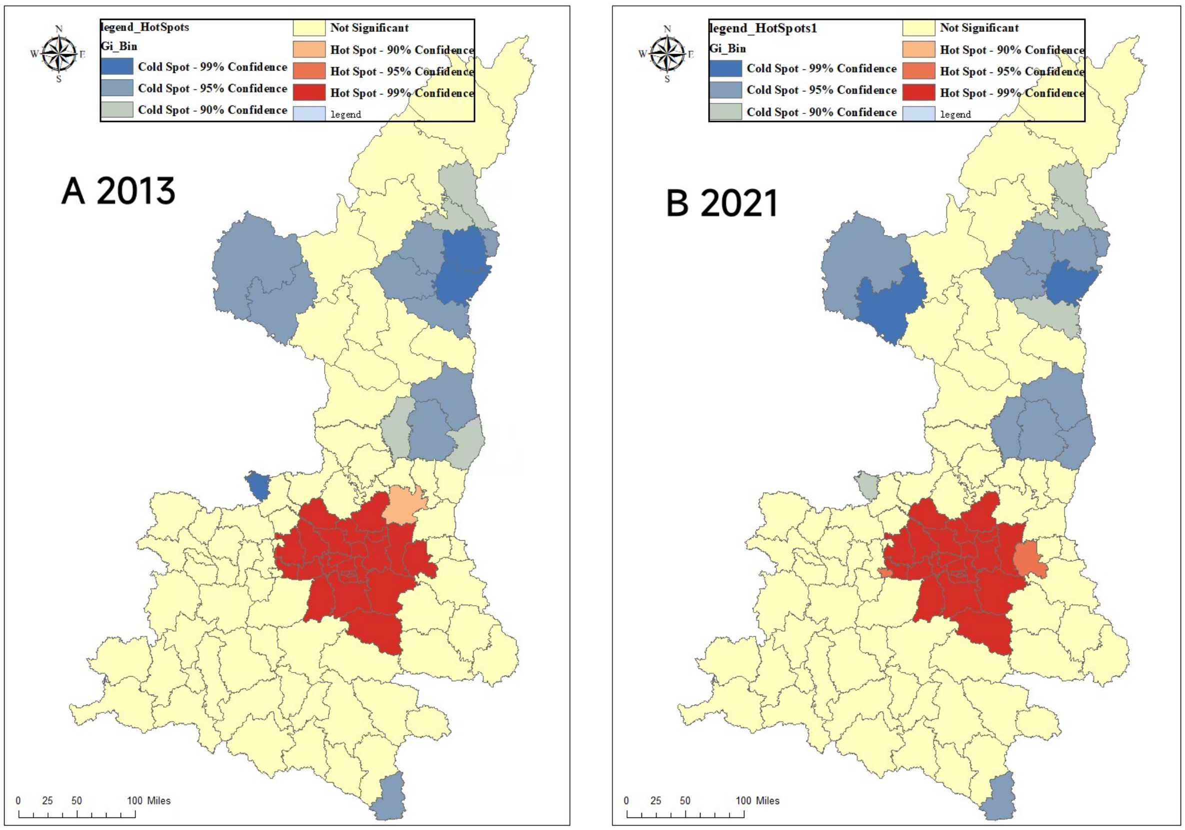

Figure 3 Analysis of cold and hot spots

Overall, the fitting effects of 2013 and 2021 are 0.57 and 0.62 respectively, and the fitting effects of the two periods are not much different. According to the regression results in 2013, the regression coefficient of county road density is 0.86, which is the variable with the highest regression coefficient among the variables studied in this period, The contribution of other transportation elements in this period from high to low is railway density, expressway national highway density, distance from railway station, and distance from airport. In the regression results for 2021, the density of counties and roads is still the variable with the highest regression coefficient of all research variables in China, and its regression coefficient is 1.20.

2)Effects of Other Factors on the Evolution of Traffic Dominance

After the spatial global autocorrelation and local autocorrelation analysis of Shaanxi province's traffic dominance, it is found that the traffic dominance of Shaanxi province's counties has obvious spatial aggregation and spatial heterogeneity, so simply using the general OLS regression model analysis often leads to making the fitting effect lower. However, the GWR model will have different fitting effects on the same variable due to different regions, which is caused by the different geographical and social environments in each region. This often makes the GWR model more advantageous on spatial data. The results of the regression analysis in 2013 show that the gross product value of districts and counties is the variable that has the greatest impact on the degree of traffic advantage among all the factors considered, followed by the proportion of built-up areas in districts and counties and the average elevation of districts and counties on the degree of traffic advantage. Larger, while the population density and per capita GDP of districts and counties have little impact on the degree of traffic advantage. It can be seen from this that the local economy and transportation development were closely related during this period. In the 2021 traffic dominance regression results, the proportion of built-up areas in districts and counties has the greatest impact on traffic dominance, with a regression coefficient of 0.37; followed by the district's and county's GDP, with a regression coefficient of 0.32; The average elevation, regression coefficient is 0.19; the least impact is the population density of districts and counties and per capita GDP of districts and counties.

From the perspective of time development, the largest influencing factors in the two periods are two different factors, but in their respective regressions, both are the top two influencing factors; at the same time, in terms of the smallest influencing factors, The influencing factors are the same in both periods. Overall, the regression coefficients of related variables in the two periods are similar, and there is no significant change. The biggest change factor is that the average elevation index of districts and counties has changed from 0.30 in 2013 to 0.19 in 2021; it shows that the traffic advantages of Shaanxi Province the degree is gradually less affected by the elevation.

Table 2 Regression analysis results of traffic elements

Year / Index	Regression coefficients		Adjust R^2	
	2013	2021	2013	2021
distance from train station	0.251	0.15		
Distance from the airport	0.10	0.24		
County road density	0.86	1.20		
other road densities	0.29	0.37	0.57	0.62
railway density	0.35	NULL		

Due to the influence of spatial heterogeneity of traffic dominance, OLS regression will not be able to optimize the regression results due to the characteristics of geographical elements; therefore, based on OLS regression analysis, GWR regression analysis is performed on other factors affecting traffic dominance in 2021. The regression results are shown the corrected coefficient of determination of the OLS in 2021 is 0.64, and the corrected coefficient of determination of the GWR in the same period is 0.74, and the degree of fitting has been improved to a certain extent. At the same time, the AICc index of OLS regression analysis was 746, while the AICc index of GWR in the same period was 728. The AICc index reflects the goodness of fit of the model and the complexity of the model. The lower the AICc index, the better the fit of the model. In the same regression analysis, the model with the smaller AICc index is generally preferred. These two indicators both indicate that the GWR model is more suitable for the regression analysis of traffic dominance in Shaanxi Province.

5. CONCLUSION

This article evaluates the transportation advantage of Shaanxi Province from the perspectives of time and space. By comparing and analyzing the geographical characteristics and the degree of influence of the factors affecting the transportation advantage in two periods, it reveals the spatiotemporal development trend of the transportation advantage and the degree of influence of each factor. The main conclusions are as follows:

(1) The transportation advantage of Shaanxi Province shows a gradual decline from the Weihe Plain center to the surrounding areas, with the south being higher than the north. The overall transportation advantage of the county-level units is on the rise, and the spatial unevenness is gradually decreasing, but there is still significant spatial heterogeneity and imbalance in 2013 and 2021.

(2) The main factors affecting the transportation advantage include fast transportation modes and Gross Domestic Product (GDP).

(3) Accelerating the layout of fast transportation in the future can effectively enhance the transportation advantage of Shaanxi Province. The gradual improvement of the road network and the enhancement of fast transportation modes will continue to promote the improvement of the transportation advantage.

Although this study comprehensively considers various aspects of transportation modes, there are still problems with factors affecting the transportation advantage that have not been included in the evaluation model. In the future, simulation software will be used to construct a more accurate road network model to calculate time parameters more accurately and provide more instructive recommendations for actual transportation planning.

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