Analysis of regional traffic dominance based on different indicators – taking Shandong Province as an example

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Abstract. Taking Shandong Province as an example, select prefecture-level cities and county towns as research nodes, and use traffic network density (road network), proximity, and accessibility indicators to construct a comprehensive evaluation model of regional traffic dominance, using GIS network analysis and IDW. Spatial interpolation technique quantitatively analysed the spatial characteristics of the transportation network in Shandong Province. Through the spatial distribution characteristics of Shandong Province's traffic dominance, the results show that the traffic dominance is closely related to the level of economic development, forming a spatial structure centred on Jinan and Qingdao. The single indicator to indicate the traffic dominance has certain limitations. And there is high spatial coupling between traffic dominance and economic development. The density of the traffic network is limited by the topography and geomorphology. The accessibility is closely related to the choice of the central city and the location of the county. Qingdao and Jinan, the spatial coupling between traffic network density and economic development level in Shandong Province is not high and some county and city in the central region have higher accessibility level but their economic development ranking is not advanced.

1. Introduction
The development of the traffic area has the role of guiding, supporting and guaranteeing, and is an important indicator reflecting the advantages and disadvantages of regional development conditions [1]. The degree of development of the transportation network has different degrees of influence on the interaction of regional space, and ultimately affects the level of economic and social development of the region. How to evaluate the level of traffic development in a region is a concern of many economists and geographers. Traffic dominance is often used to measure the level of traffic development in a region. Traffic advantage refers to the level and status of economic and social activities supported by the regional system, including the comparison area and the target area, or the ideal target as the reference system. The traffic dominance is an integrated indicator for evaluating the regional transportation advantages. The size of the regional transportation facilities network (support capacity), the technical level of the main line (contact and agglomeration capacity) and the area in the macro overall transportation infrastructure network. The accessibility status (location advantage) is integrated in three aspects [1].

At present, there are many studies on traffic dominance, and from various angles. Sun Wei et al. (2010) used 107 county-level administrative units in Shanxi Province as an example to study the
traffic within the province from a single index and comprehensive indicators. The spatial distribution characteristics of dominance and the reasons for its formation [2]. Wang Chengxin et al. (2010) took Shandong Province as an example to construct an evaluation model of regional traffic dominance, and selected traffic network density (road network), traffic trunk level and location dominance as evaluation factors, and the participation evaluation system will be established in Shandong. The province's 139 counties (cities) are divided into five levels, which provide the basis for the formulation of relevant plans [3]. Huang Xiaoyan et al. (2011) analyzed the indicators of transportation network density, proximity, accessibility, etc., and established a model to evaluate the traffic superiority of Hainan. And analyzed and summarized the characteristics of traffic superiority and economic development level in various counties and cities in Hainan Province [4]. Guan Wei et al. (2018) used the high-speed traffic dominance evaluation model and the tourism economy to conduct a coupling analysis, exploring the relationship between transportation and tourism economy in Liaoning Province [5]. Zhang Yu (2018) analyzed the urban traffic dominance in Nanyang by ArcGIS software and combined with the level of urbanization to exploring relationship between the traffic dominance and urbanization development [6]. Peng Wei et al.(2018) analyzed correlation between traffic dominance and population in Sichuan Province [7]. This study takes Shandong Province as an example to construct a traffic dominance evaluation model, and selects traffic network density (road network), proximity and accessibility as evaluation factors to evaluate regional traffic dominance in Shandong Province.

2. Models and methods
Shandong Province is located in the eastern coast of China and the lower reaches of the Yellow River (figure 1). It is adjacent to the developed countries of Japan and South Korea in the east, and the Yangtze Delta and Beijing-Tianjin-Hebei urban agglomerations in the north and south. As a major economic province and a developed transportation province, Shandong Province is in the forefront of transportation. Therefore, it is meaningful to explore the traffic advantages of Shandong Province. This study selected 16 prefecture-level cities and 138 counties in Shandong Province as research nodes, and selected highways (national highways, highways, general roads) and railways as traffic network research. The point data of Shandong Province is derived from the National Geographic Information Resource Directory Service System. The road network data is from https://www.openstreetmap.org/, and the national traffic GIS vector data is downloaded.
2.1. Traffic network density

Traffic network density is an important indicator for evaluating the level of transportation infrastructure security. It mainly refers to the absolute ratio of the length of the traffic line to the land area of the area. Among all the transportation facilities, the road route contributes the most to the regional traffic dominance, and the influence of the railway on the traffic dominance is mainly reflected in the selection and setting of the site. The influence of the route itself is relatively small. Therefore, it is more meaningful to study the density of road networks. The density is more meaningful, so the main choice is the density of the road network to evaluate the regional traffic dominance. The density of road network is a positive indicator. The greater the density of road network, the denser the road network, and the better the regional traffic conditions.

\[
D_i = \frac{L_i}{A_i}
\]

\(D_i\) represent the road network density of area \(i\), \(L_i\) represent the length of the traffic operation route of area \(i\), \(A_i\) represent the area of land in area \(i\).

2.2. Proximity

Proximity is mainly concerned with the similarity of the distance between the two features. In this study, the proximity is used to describe the influence of railways, highways and other traffic trunks and some important infrastructures on regional traffic dominance. By studying the traffic distance between nodes and central cities. The nodes are affected by the socio-economic radiation capacity and the extent of the location condition of the central city [8]. In this study, qualitative indicators were quantified and the proximity was assigned (table 1).

| Type               | Standard                  | value | Type         | Sub-Type       | Standard                  | value | Type               | Standard                  | value |
|--------------------|---------------------------|-------|--------------|----------------|---------------------------|-------|--------------------|---------------------------|-------|
| Railway            | Large railway passenger station | 1.5   | Type         | Have a highway | 1.5                      |         |                        | Opening to the airport | 1.5   |
|                    | Only small passenger stations | 1     |              | Distance to the main line ≤ 30 km | 1           |         |                        | Distance to the main line ≤ 30 km | 1     |
|                    | Distance to the main line ≤ 30 km | 1     | Road         | 0.5           | Airport                   | 0.5   | National Road        | Opening to the main line > 60 km | 0     |
|                    | 30 km > Distance to the main line ≤ 60 km | 0.5   |              | Distance to the main line > 60 km | 0           |         |                        | Distance to the main line > 60 km | 0     |
|                    | Distance to the main line > 60 km | 0     |              | Have a national road | 1           |         |                        | |

Table 1. Proximity rating table.
\[ f(x_i) = \sum_{i=1, m=1}^{nM} P_{im} \]

\[ i \in (1,2,3, \ldots, n), m \in (1,2,3, \ldots, M) \]

\( f(x) \) is a function represent the proximity of a region \( i \), \( P_{im} \) refer to \( m \) types traffic trunks and important traffic infrastructure in the \( i \) area and proximity to the central city (weight assignment).

2.3. Accessibility

Accessibility reflects the convenience of regional network traffic and communication. And traffic accessibility is also an important indicator for measuring the structure of regional transportation networks and their external links [9]. This study selected the shortest spatial distance to measure the traffic accessibility of the area. The shortest spatial distance, with the ArcGIS10.6 software, the O-D matrix analysis module is available in the network dataset. And the network analysis method is used to calculate the shortest distance of each node on the network:

\[ L_i = \sum_{j=1}^{m} l_j \]

\[ i \in (1,2,3, \ldots, n), j \in (1,2,3, \ldots, m) \]

\( L_i \) indicate the sum of the shortest distance from a node to all central cities, \( l_j \) represent the shortest distance from a node to a central city, \( n \) indicate all node, \( m \) represents number of all central cities.

For each node’s shortest distance to the central city, the average value is obtained, and the shortest space access distance of each node is obtained. The shorter the distance, the higher the accessibility:

\[ l_i = \frac{L_i}{m} \]

\[ i \in (1,2,3, \ldots, n) \]

2.4. Traffic dominance integration method

In the integration of traffic dominance, we first use the inverse method to forward the inverse index. Then, we use the range method to standardize the process. And finally add weights to the processed data. In this study, we assigned the weights of the three indicators is \( 1 \) [4].

The function of \( F(x) \) represent the traffic dominance of area \( i \). The formula as follows:

\[ F(x_i) = \sum_{i=1}^{n} (D_i + P_i + l_i) \]

\[ i \in (1,2,3, \ldots, n) \]

\( D_i, \ P_i, \ l_i \) represent the traffic network density, the proximity and normalized values shortest space distance respectively. \( a_1, \ a_2, \ a_3 \) represent threshold for three indicators respectively.

3. Results and discussion

3.1. Traffic network density analysis

As can be seen from the density distribution of road networks (figure 2), Shandong Province has a clear spatial pattern of high west, central and eastern regions. Including the low-lying areas of the road network in Dongying City and Weihai City. The most highest of transportation network density is Dezhou City and Liaocheng City. Traffic network density values are 1 and 0.963 respectively. This is inseparable from the topographical conditions of Shandong Province. The terrain in the southwest and northwest is flat, the central mountains are undulating, and the eastern part is mostly hilly. Jinan City and Qingdao City as the two cities with the best economic development in Shandong Province. Jinan City and Qingdao City are not very high in road network density due to constraints such as topography and geomorphology. Traffic network density values are 0.486 and 0.374 respectively.
3.2. Proximity analysis

The proximity is not only expressed as the technical level of the same kind of transportation facilities, but also in the composition of different modes of transportation. The comprehensive traffic trunk network formed by various transportation facilities can better reflect the difference in traffic advantages of each region. In this study, the cities of Shandong Province were selected as the central cities. And this study calculated the proximity of each county and city to the central cities. Firstly, according to the Table1, each county and city are assigned values. And the proximity value is obtained after adding. Then, using ArcGIS10.6 software. The IDW interpolation method is used to draw the spatial distribution map of the proximity (figure 3). From the Figure 3, we can see that most of Shandong Province not has a high degree of proximity. In most areas, the proximity value is between 1.00 and 1.965, especially in the western region and some central regions, such as Liaocheng City, Jining City, and Zibo City. The result of the transportation proximity and the density of the road network are quite different. The road network facilities in the southwestern region are higher, but the connection with the surrounding central cities is not close. The economically developed areas of Shandong Province are mostly concentrated in the central and eastern regions, such as Jinan City, Weifang City, Yantai City, Qingdao City and other central and eastern regions. Jinan City and Qingdao City have the highest proximity values, with values between 3.576 and 4.000 respectively, and the proximity values of other regions are also above 2.694. As the leading economic development area in Shandong Province, Jinan City and Qingdao City have relatively complete transportation facilities. The economic development of the southwestern regions such as Jining City, Heze City and Zaozhuang City is relatively slow. The degree of economic development has certain impact on the proximity of regional traffic. Qingdao City has a high degree of proximity and a low density of road networks. Although Qingdao's road network density is limited by topography, Qingdao City is the most developed city in Shandong Province. And its influence is the most extensive. Qingdao City has
two national special trains. Qingdao Station is a century-old station, Qingdao North Station is the second largest railway passenger station in Shandong Province.

![Figure 3. The transportation proximity of Shandong Province](image)

### 3.3. Accessibility analysis

In this study, the shortest spatial distance is used to measure the accessibility of each county to the central city. And the shortest spatial distance between the county-level cities and prefecture-level cities and railways in Shandong Province is calculated. The IDW interpolation method in ArcGIS10.6 is used to draw the transportation accessibility distribution map. And the superposition analysis of the road accessibility map and the railway accessibility map. The comprehensive traffic accessibility map (figure 4).

Overall, Shandong Province has a high degree of accessibility. With high accessibility in the western and eastern regions. The accessibility of Jinan City and the northeastern part of Jining City is low. According to figure 5, the traffic accessibility of Qingdao City and Heze City is relatively high, and the average accessibility is 1.7426 and 1.7170. As the most economically developed region in Shandong Province, Qingdao City has close traffic links within the city. The density of highway network in Heze City is relatively large, its area is flat, and the roads between cities are closely connected. The average accessibility of Dongying City, Taian City and Liaocheng City were 1.6726, 1.6320 and 1.6131 respectively. In the provincial economic circle (Jinan City, Zibo City, Taian City, Dezhou City, Liaocheng City and Binzhou City) Binzhou City, Jining City and Zibo City have weak accessibility and the distance between the county and the surrounding cities is not too close. Traffic accessibility averages are 1.1842, 1.2265, and 1.2818, respectively. Although the shortest space distance access performance reflects the degree of spatial geographic location, the attenuation of the distance and the force scale of each point are ignored.
3.4. Analysis of traffic dominance

Comprehensive road network density analysis, transportation proximity analysis and traffic accessibility analysis, the regionality of the regional traffic is obtained by the same weight value integration (figure 6). From the perspective of the spatial pattern of traffic dominance, first of all, the traffic advantages of Shandong Province show obvious spatial differences. Taking Jinan City and Qingdao City as the center, the surrounding areas have certain traffic advantages, including Taian...
City, Dezhou City and Weifang City. However, another area with obvious traffic advantages is Heze City (Dingtao County, Dongming County, and Caoyuan County). According to the above, the high degree of road network in Heze City has a certain impact on Heze City's traffic dominance. In addition, the areas with less traffic dominance are dotted and distributed, and the southwestern parts of Shandong Province (Chengwu County, Jinxiang County, Yutai County, and Shan County) exhibit a low-value aggregation state. The southwestern part of Shandong Province, Jinxiang City and Yutai City of Jining City, Chengwu County and Dan County of Heze City, Hekou District of Dongying City in the Northern Region, Qingyun County and Ningjin County of Dezhou City, and Zibo in the Central Region In the city of Xichuan, its traffic dominance is significantly lower.

![Figure 6. The traffic dominance of Shandong Province](image)

4. Conclusion

By analysing the traffic advantages of Shandong Province, the following conclusions can be drawn:

There is a high spatial coupling between traffic dominance and economic development level. The traffic advantages and economic development levels of Qingdao City and Jinan City are located in the first and second locations of the province, reflecting the advantages of the transportation network hub and economic development centre. There is a certain difference between Heze's traffic dominance and economic development level. The reason is that due to the analysis of traffic dominance, Heze City is located in a relatively flat area in the southwest. The road network is relatively dense, although Heze's economic development level is not high, but its traffic advantage. The degree is obvious. Traffic dominance is closely related to the level of economic development in Shandong Province. Strengthening the development of transportation is of great significance for promoting economic and social development [10, 11].

The spatial coupling between traffic network density and economic development level in Shandong Province is not high. It shows that the road traffic infrastructure in Shandong Province is greatly restricted by the topography and geomorphology. Although the economic development level of Qingdao City is the first in Shandong Province, the landforms are mostly hilly and mountainous, and
the road network facilities are not developed, indicating the economically developed cities of Shandong Province. The road network infrastructure needs to be further improved.

For the single factor, the traffic accessibility only considers the shortest space distance. Due to the influence of the “space distance attenuation law”, some county and city in the central region have higher accessibility level but their economic development ranking is not advanced. As each prefecture-level city is regarded as the central city, and the prefecture-level cities are more distributed in the central and western regions, the accessibility level of some cities with better economic development in the east is low, and the regional internal transportation network is emphasized by the accessibility level. Convenience and connectivity, while ignoring the degree of contact between the region and the external region, geographical factors have a significant role in determining the level of accessibility.

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