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Keywords: Highway, City globe population impact index, City population change type, Centrality characteristics, Temporal-spatial evolution.

Abstract. Population migration is not only affected by people's living habits, economic development status, the city's geographical location in the region, and regional traffic facilitation also plays an important role. In order to fully study the impact of highway on the regional population change, the paper designs an intercity population impact index and a city population change type index by using the intercity accessibility as the weights. The results show that, during the period of 2004-2016, the population of Henan province has been growing steadily, the outflow of population was serious, and there are significant differences in the characteristics of resident population change among cities. The response sensitivity of city resident population is proportional to the highway mileage increase, the responsiveness has significant difference among cities, the responsiveness of the developed areas are relatively low, and the responsiveness of the marginal areas is obviously higher than that of the central areas. The traffic population input type cities are mainly distributed in the southwest of the province, where has good natural living environment, the city in the central of province has the characteristics of traffic population output type. The changes of city total population spatial distribution tend to be balanced, the city resident population spatial distribution changes greatly, the impact of the highway on the province's population migration tends to be balanced.

Introduction

The temporal-spatial structure and the evolution mechanism of regional interaction are one of the key problems in human geography. Under the influence of many factors, the network formed by regional interaction is dynamically evolved on the temporal and spatial scales. The highway traffic network is one of the main ways of inter-regional linkages, which shortens the distance between cities and adapts to the modern people's pursuit of speed and efficiency, also plays a significant role in reshaping population spatial structure, effectively promotes regional balanced development and socio-economic integration [1-4].

The impact of highway construction on regional social and economic development has attracted the attention of many scholars. The researches mainly focus on the regional suitability evaluation and spatial optimization method of highway network, the impact of highway on regional social economy, and the reasonable promotion of highway economic belt. There are little researches on the difference of regional population structure caused by highway construction [4-10].

Population is one of the most active production factors in economic development. Population migration plays an important role in optimizing the regional distribution of production factors and promoting regional economic growth, which is the result of the spatial interaction between the source and destination, reflecting the regional differences in the economic development level and the employment opportunities. The construction and improvement of the expressway transportation network have been significantly promoting the free flow of population and labor forces and the optimal allocation [1-11].

By using the intercity accessibility coming from the highway network as the weight, this paper designs an intercity population impact index to study the impact of highway construction on the evolution of population spatial-temporal structure in Henan province, in order to provide a scientific...
reference for improving the highway network system, and planning an effective regional population development policy.

Data and Research Methods

Data

From the first highway line opened to traffic in 1995, Henan highway network has been rapidly developing, by the end of 2016, the highway traffic mileage is up to 6600 km, basically formed an excellent rapid communication system with 9 vertical and 12 horizontal national highways as the framework. The network construction shows obvious stage and regional characteristics, in the view of traffic mileage, the highway construction enters a stage of rapid development from 2004, the traffic mileage increases by 3,200km in the four years from 2004 to 2008, and in the eight years from 2008 to 2016, the traffic mileage only increased of 2800 km. In the view of spatial distribution, the network construction mainly focus on national highway construction between 2004 and 2008, the spatial distribution is relatively uniform, in 2008-2012 the construction mainly concentrated in the north of Ningluo highway line, in 2012-2016 the construction mainly concentrated in the south of Lianhuo highway line. Overall, the highway density in the western and southern regions is significantly lower than that in other regions (Fig.1).

Combined with the data of population changes, this paper divides the 12 years (from early 2004 to early 2016) of the rapid development of highway construction in Henan province into 3 stages, on 4 time sections to study the impact of highway construction on the evolution of population spatial-temporal structure in Henan province.

The spatial data of the study are from Henan highway spatial database and meta-database. The time distance is based on the weighted average of the empirical traveling time on lines and intersections from the corresponding years[13]. The shortest distance between cities is calculated by NEDS algorithm [14,15]. The city population data are from Henan Province Statistical Yearbook.

Figure 1. The spatial distributions of Henan highway network from 2004 to 2016.

The Intercity Accessibility

The intercity accessibility coming from the highway network describes the convenience degree of transportation between adjacent cities. In highway network, there are many possible connection routes between adjacent cities. In the study, only these routes within the time thresholds are considered. The time thresholds are set to be the shortest traveling time between cities on the ordinary traffic network, two routes are considered to be the same one, if and only if their repetition rate is greater than 50%.

In the highway network, the accessibility \( A_{ij} \) from city \( j \) to city \( i \) is defined as the sum of the inverse of time distance from \( j \) to \( i \) of all routes, on which the traveling times are less than the time threshold defined before, and do not travel through the third city.

\[
A_{ij} = \sum C_{ij}^{-1} , \quad (1)
\]

The larger \( A_{ij} \) means better traffic convenience degree from \( j \) to \( i \), the greater attractiveness of population migration, and the greater impact of resident population changes, sometimes \( A_{ij} \neq A_{ji} \).

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Intercity Global Population Impact Index

The intercity highway shortens the time (cost) distance between cities, and strengthens the interaction, which makes the regional development tend to be integrated.

The intercity global population impact number $G_{hp,i}$ of $i$, coming from the highway network, is defined as the intercity accessibility weighted average of the total population of all adjacent cities,

$$G_{hp,i} = \sum \frac{T_{p,j} A_{j}}{A_{i}} \tag{2}$$

where $T_{p,j}$ is the total population of $j$, is the impact factor of population migration of $j$ to $i$. The larger $G_{hp,i}$ means the greater impact of $j$ to the resident population change of $i$.

The intercity global population impact index $p_{\alpha,i}$ of $i$, coming from the highway network, is defined as the ratio of the intercity global population impact number to the total population,

$$p_{\alpha,i} = \frac{G_{hp,i}}{T_{p,i}} \tag{3}$$

which shows that because of the change of traffic conditions, the impact of adjacent city population on the total population of $i$. The larger $p_{\alpha,i}$ means the greater impact.

City Population Change Type Index

Large cities have high attractiveness to the population of adjacent cities due to their high employment opportunities, while the small cities are also attracted to the population of the large cities for their convenience of living conditions.

In order to give full consideration on the impact of city size on city resident population changes, the intercity local population impact number $L_{hp,i}$ of $i$, coming from the highway network, is defined as the intercity accessibility weighted average of the population densities of all adjacent cities, shows the impact of adjacent cities on the population density of $i$ due to the change of traffic conditions,

$$L_{hp,i} = \sum \frac{P_{\mu,j} A_{j}}{A_{i}} \tag{4}$$

Population migration is mainly affected by people's living habits, economic development, and the traffic convenience. City population change type index, affected by the traffic convenience, is defined as the ratio of the intercity local population impact number to the city resident population density, describes the change of the city resident population density caused by the change of traffic conditions,

$$P_{\beta,i} = \frac{L_{hp,i}}{R_{p,i}} \tag{5}$$

which shows the impact of adjacent city population on the resident population of $i$. The larger $p_{\alpha,i}$ means the greater impact, the city is traffic population input type city.

Centrality characteristics. The construction of highway network has been promoting population migrating in the region, and the change of city resident population has certain relativity with the city location in the region. The total population center $T_{pc}$, the resident population center $R_{pc}$, and the intercity population impact center $G_{pc}$ respectively are defined as the total population, the resident population, and the intercity global population impact number weighted average of city geographic coordinates

$$T_{pc} = \sum \frac{T_{p,i}}{T_{p}}, \sum \frac{T_{p,i} x}{T_{p}}, \sum \frac{T_{p,i} y}{T_{p}} \tag{6}$$

$$R_{pc} = \sum \frac{R_{p,i}}{R_{p}}, \sum \frac{R_{p,i} x}{R_{p}}, \sum \frac{R_{p,i} y}{R_{p}} \tag{6}$$

$$G_{pc} = \sum \frac{G_{pc,i}}{G_{pc}}, \sum \frac{G_{pc,i} x}{G_{pc}}, \sum \frac{G_{pc,i} y}{G_{pc}} \tag{6}$$

where $(x,y)$ is the geographic coordinates of $i$.  

The population distribution impact analysis of highway network in Henan province

The population Temporal-spatial Evolution Analysis in Henan Province

Since 2004, the total population of the cities has increased steadily, the growth rates show the parabolic characteristics, except for Jiyuan. The resident population of the province increased slightly, the population outflow is enormous, the proportion of outflow population increase from 2.60% in 2004 to 11.99% in 2016 (Fig. 2, unit million). The change characteristics of resident population have significant differences in different cities. The resident population of 10 cities increases gradually, in which the annual growth of Zhengzhou and Jyuan are more than 1%, but that of the rest 8 cities are less than 0.5%. The resident population of 8 cities decreases gradually, in which the annual reduction of Zhumadian and Zhoukou are more than 1%, but that of the rest 6 cities are less than 0.5% (Fig.3, unit million).

Figure 2. The temporal-spatial evolution of total population in Henan province from 2004 to 2016.

Figure 3. The temporal-spatial evolution of resident population in Henan province from 2004 to 2016.

Table 1. The intercity population impact index in Henan Province from 2004 to 2016.

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### The intercity Global Population Impact Index in Henan Province

First, based on the highway network and the time-consuming empirical data, use Eq.1 calculate the intercity accessibilities, then, use Eq.2, Eq.3 ,and the city population data calculate the intercity global population impact indices on each time section. The results are shown in Table 1.

The change rate of the global population impact index reflects the response sensitivity of the total population to highway construction. As showed in Table 1 and Fig.4, the responsiveness is gradually reducing in the 3 stages of the study.

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#### City population Change Type Analysis

Using Eq.4 and Eq.5 calculate the city population change type index, the results are list in the last part of Table 1, and showed in the Fig.5.

With the construction and improvement of Henan highway network, the impact differences of the city population change types gradually expand, showing obvious marginal characteristics.

The population change type indices of Zhengzhou, Jiaozuo and Luohe have remained at the lowest level on the 4 time sections of the study, contrary to their economic development and resident population change trends, indicating that the increase of resident population in the three cities are mainly coming from the attraction of their developed economies, they are the traffic population export type cities.

The population change type indices of the west and southwest cities always have been higher than other regions of the province, and the highest level cities, as Jiyuan, Sanmenxia, Nanyang and
Xinyang, are the traffic population import type cities, their common characteristics are that the economic development is relatively backward, the ecological environment is relatively good, indicating that relying on the superior natural environment, they attract the population of developed areas to move in, but due to economic development constraints, there are a lot of population move out.

**The Centrality Distribution Analysis**

Using Eq.6 calculate the total population centers, the resident population centers, and the intercity population impact centers, the results are shown in Fig. 6.

![Figure 6. The distribution of centers from 2004 to 2016.](a) (b) (c)

Between 2004 and 2016, the total population centers, resident population centers and city impact index center are located between Zhengzhou and Xuchang, with the average distance of 67km, 75km and 84km from Zhengzhou. The total population center remains basically unchanged, the three stages respectively moving 0.12 km to south, 0.28 km to northwest and 0.20 km to north (Fig.6a).

The resident population center moves gradually to the northwest (to Zhengzhou), and the moving speeds are obviously greater than that of the total population center. In the first stage, the moving tendency is as the same as the total population center, moving 0.12km to the southeast, in the second stage, the moving speed obviously accelerate, moving 5.60 km along the orthogonal direction of the total population center moving, in the third stage, the moving speed is less than that of the previous stage, moving 0.6km to the northwest (Fig.6b).

The moving speeds of the intercity population impact center in the three stages are nearly same, the basic position remains unchanged. In the first stage, the moving tendency is as the other two centers, but its moving speed is significantly higher (moving 1.14 km to southeast), in the second stage, the moving speed is between the other two centers, moving 0.98km to the northwest, in the third stage, the center move to the northwest by 1.09 km (Fig.6c).

In general, in the 12 years, the total population of the cities gradually increases, the distribution of resident population changes greatly, the impact of the highway on the province's population migration tends to balance.

**Conclusion**

Population migration is not only affected by people's living habits, economic development status, the city's geographical location in the region, and regional transport facilitation also plays an important role. Large city have high attractiveness to the population of adjacent cities due to its high employment opportunities,while the small city is also attracted the population of the large cities for its convenience of living conditions.

In order to fully study the impact of highway on the regional population change, the paper designs an intercity population impact index and a city population change type index by using the intercity accessibility as the weights. The results show that,

(1) During the period of 2004-2016, the population of Henan province has been growing steadily, the outflow of population is serious, Zhengzhou and Jiyuan resident population grow at a faster rate, Zhumadian and Zhoukou population outflow speed is accelerating.

(2) The response sensitivity of city resident population is proportional to the highway mileage increase, the responsiveness has significant difference among cities, the responsiveness of the
developed areas are relatively low, and the responsiveness of the marginal areas is obviously higher than that of the central areas.

(3) The traffic population input type cities are mainly distributed in the southwest of the province, where has good ecological environment, the cities in the central of province have the characteristics of traffic population output characteristics.

(4) The changes of city total population spatial distribution tend to be balanced, the city resident population spatial distribution changes greatly, the impact of the highway on the province's population migration tends to be balanced.

Acknowledgement
This research was financially supported by the Henan Science Development Foundation (1323004 410376).

References