Spatial–Temporal Pattern and Influence Factors of Land Used for Transportation at the County Level since the Implementation of the Reform and Opening-Up Policy in China

Baochao Li 1, Xiaoshu Cao 1,2,*, Jianbin Xu 1, Wulin Wang 3, Shishu Ouyang 1 and Dan Liu 1

1 College of Geography and Planning, Sun Yat-Sen University, Guangzhou 510275, China; libch9@mail2.sysu.edu.cn (B.L.); xujb23@mail2.sysu.edu.cn (J.X.); ouyshsh@mail2.sysu.edu.cn (S.O.); liud69@mail2.sysu.edu.cn (D.L.)
2 Academy of Natural Resources and Territorial Space, Shaanxi Normal University, Xi’an 710119, China
3 College of Environment and Resources, Fuzhou University, Fuzhou 350116, China; wangwulin@fzu.edu.cn
* Correspondence: caoxsh@snnu.edu.cn

Abstract: In this paper, we study the characteristics of the spatial–temporal pattern of land used for transportation at the county level since the implementation of the reform and opening-up policy in China and discuss the factors that influence the spatial differences between lands used for transportation in order to provide a reference for the formulation of traffic policies. The authors used ArcGIS spatial analysis, an ordinary least squares (OLS) regression model, and a geographic detector model based on the data of the transportation network at the county level in China from 1978 to 2018. We obtained the following results: (1) The land used for transportation at the county level in China is divided by the Hu Huanyong Line, which is characterized by spatial variation, where the southeastern region is higher than the northwestern region. (2) Counties with a high proportion of land used for transportation show obvious changes, characterized by the transformation from the “corridor” zonal distribution of arteries to the “diamond” group distribution of major city clusters, reducing the gap in land used for transportation at the county level in China. (3) The level of industrialization, per capita gross regional product (PGRP), and ratio of the non-agricultural working population all have an incentivizing impact on the increase in land used for transportation at the county level in China. We conclude that the land used for transportation at the county level in China is jointly decided by the economy, industry, and population. Therefore, we believe that it is necessary to promote fast economic growth, the upgrading of industrial structures, and population density to achieve the balanced development of land used for transportation at the county level in China.

Keywords: land used for transportation; spatial–temporal pattern; geographical detector; influence factors

1. Introduction

Land is the key foundation of transportation infrastructure construction, and transportation infrastructure serves as the basis of transportation development. Transportation is not only a fundamental, pioneering, and strategic industry in the national economy but also a significant service industry [1]. Therefore, as land resources are becoming more and more precious, research on the use of land for transportation has been carried out by various government ministries around the country [2].

Research focusing on both transportation and land together started in 1959. The American scholar Hansen preliminarily discussed the relationship between the two elements in “How Accessibility Shapes Land Use” [3]. Since then, the research on the relationship between transportation and land has gradually become the focus of both domestic and foreign experts [4–9].

The research on land used for transportation can be divided into land used for single modes of transportation and the integrated transportation. The study of the single modes
of transportation mainly include railways and highways at the province or city scale. The types of research on land used for railways can be divided into research on comprehensive development and utilization of railway land [10] and the evaluation of the land footprint of high-speed railway construction [11]. Studies on land used for highways mainly focus on estimating land requirements for expressway construction projects [12], the influence of expressways on population redistribution [13], and the evaluation of land conservation for expressways [14].

The studies on land used for integrated transportation focus on four aspects: impact, the change in urban structure, environmental health, and land use planning. Research on the impact of land used for transportation aims to study the impact of the land-use change required for urban rail transit on the development and use of urban land in the future [15,16]. Research on the change in the urban structure of land used for transportation analyzes the change in the urban development center brought about by the change in the land used for urban transportation [17,18]. Research on the environmental health of land used for transportation aims to evaluate urban pollutant discharge through the model of land use for comprehensive transportation and find measures to bring about improvements [19,20]. Research on land use planning of land used for transportation, on the one hand, aims to research the compact land used for urban transportation to effectively improve public transport and improve the urban living environment, which serves as the guiding policy for long-term urban planning in the future [21–23]. On the other hand, research on land use planning has also constructed a multi-objective decision-making system for regional transportation land supply to improve the effectiveness of transportation land supply [24].

Existing studies have different directions, mostly focusing on the impact of transportation land use, transportation land demand allocation, and other issues. However, there has been an insufficient number of studies on the temporal and spatial pattern changes in transportation land use and the factors influencing this. Moreover, the existing studies mostly use sample data for the whole country or entire provinces or cities. Few studies have focused on land used for transportation at the county level with a small scale and different development stages.

In the past 40 years of reform and opening up, Chinese transportation infrastructure has developed rapidly and made great achievements; the total mileage of high-speed railways and expressways is the first in the world. Traffic construction has been restricted from the early stage of the reform and opening up to the current development to meet the rapid development of the economy and society. As the foundation and guarantee of Chinese transportation infrastructure, the land used for transportation has played an important role in its rapid development. At present, it is necessary to conduct in-depth research on the spatial–temporal changes in transportation land use and the factors influencing them in order to provide a reference for the formulation of future transportation policies in different regions.

In order to better reveal the evolution of the temporal and spatial pattern of Chinese transportation land and the factors influencing this, this study takes the county as the basic unit and collects the data of land used for transportation at the county level in China from 1978 to 2018, covering five types of roads, i.e., high-speed railways, ordinary railways, expressways, national highways, and provincial highways. This study attempts to answer the following two questions: (1) What are the spatial–temporal patterns of land used for transportation at the county level since the reform and opening up in China? (2) What are the factors influencing the change in its spatial pattern?

2. Materials and Methods

2.1. Research Data

The authors used three main sources of research data: the vector data of counties’ administrative regions were taken from the Chinese 1:4,000,000 basic geographic data provided by the Resource and Environment Science and Data Center, Chinese Academy of
The transportation network data are based on the information provided by the Chinese Traffic Atlas published by China Cartographic Publishing House in 1979, 1989, and 1999, and the Chinese Traffic Atlas published by China Communications Press in 2009 and 2019. The vectorization of data was performed on high-speed railways, railways, expressways, national highways, and provincial highways within the transportation network in ArcGIS (Figure 1). The data on the land used for transportation were based on the Code for Design of High-Speed Railway (TB10621-2014) and the Code for Design of Railway Line (TB10098-2017) published by the Ministry of Railways of the People’s Republic of China, the Technical Standard of Highway Engineering (JTG B01-2014) enacted by the Ministry of Transport of the People’s Republic of China. The technical standard states that the width of the roadbed is the sum of the width of the lane and the width of the shoulder. Therefore, the calculated areas of different types of roads can reflect the actual land used for transportation at the county level.

The criteria used to collect datasets in this study are: the standard is six lanes for expressways and two lanes for national and provincial highways. The standard widths of roadbeds for different types of roads are presented in Table 1, and the lengths of different types of roads are included according to ArcGIS and multiplied by the standard width of the roadbed to obtain the area of all road types and calculate the data of the land used for transportation in each county. The research does not include data from Hong Kong, Macau, and Taiwan.

Table 1. Standard width of roadbed for different types of roads.

| Road Type       | Roadbed Width (m) |
|-----------------|-------------------|
| High-Speed Railway | Single Track 8.6   |
|                 | Double Track 13.6 |
| Railway         | Single Track 13.7  |
|                 | Double Track 21.8 |
| Expressway      | Six Lanes 33.5     |
| National Highway| Two Lanes 12       |
| Provincial Highway | Two Lanes 10      |

Figure 1. Cont.
Figure 1. The traffic routes in China from 1978 to 2018.

On 3 July 1997, the 26th Meeting of the 8th Session of the Standing Committee of the National People’s Congress passed the *Highway Law of the People’s Republic of China*. The sixth article stipulated the division of highways into national highways, provincial highways, county roads, and village roads based on their status in the highway network. Before 1997, the road transportation network had only been divided into primary highways and secondary highways. Secondary highways encompassed the category of county roads before 1997. Considering the traffic road grading reform in 1997, the study only analyzed the changes in the proportion of land used for transportation and the influencing factors across the three years of 1998, 2008, and 2018.

Counties in western China are dozens of times larger than those in the central and eastern regions. Therefore, the counties’ areas of land used for transportation in the western regions are obviously larger than those counties in the central and eastern regions in China.

2.2. Research Method

2.2.1. Analysis of Spatial–Temporal Change in Land Use

The research mainly uses R, the proportion of change in land used for transportation, to quantitatively describe the extent of change in the amount of regional land used for transportation to reflect the difference in the change in land used for transportation in a certain period of time. The formula is as follows:

\[
R = \frac{K_a - K_b}{c}. \tag{1}
\]
In this formula, $K_a$ and $K_b$ represent the areas at the analyzed period of the research on regional land used for transportation, while $c$ represents the area of the regional land in the research.

2.2.2. Study of Influence Factors and Intensity of Proportion of Land Used for Transportation Based on Multiple Linear Regression Model and Geographic Detector

The proportion of land used for transportation is the result of multiple factors. The multiple linear regression model is an important way to study the regression of multiple independent variables. It is used to analyze the main influence factors affecting economic and social phenomena. Therefore, this research uses the multiple linear regression OLS model to judge and analyze the significance level of each factor that affects the proportion of land used for transportation. The model is as follows:

$$y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \ldots + \beta_n X_n + \mu.$$  \hspace{1cm} (2)

In the formula, $y$ is the dependent variable; $\beta_0$ is a constant term; $\beta_1, \beta_2, \ldots, \beta_n$ are the coefficients of independent variables; $X_1, X_2, \ldots, X_n$ are independent variables, and $\mu$ is a stochastic error term.

The geographic detector was initiated and systematically summarized by Wang Jingfeng [25,26]. The geographical detector is a powerful tool for exploratory analysis of spatial data, measuring, mining, and exploiting spatial heterogeneity. The theoretical core of the geographical detector is to detect the consistency of the spatial distribution pattern between the dependent variable and the independent variable through spatial heterogeneity, which is used to measure the explanatory degree $q$ of the independent variable to the dependent variable.

The geographic detector has a stronger power than general statistics and is more certain, strongly suggesting causality. The geographic detector can detect the interaction between two factors on dependent variables so as to judge whether there is an interaction between the two factors and the intensity, direction, and linearity of the interaction [25]. It has been extensively applied to the issues of poverty [27], urban environment [28], housing prices [29], and other aspects of study.

This research uses the geographic detector to explore the intensity and direction of interaction among factors influencing the proportion of land used for transportation at the county level. The geographic detector value of each influence factor can be expressed as:

$$q = \frac{1 - \sum_{h=1}^{L} N_h \sigma^2_h}{N \sigma^2}.$$  \hspace{1cm} (3)

In the formula, $h = 1, L$ represents the hierarchy of independent variable $Y$ or factor $X$, $N_h$ and $N$ represent the number of elements in hierarchy $h$ and the entire zone, respectively, and $\sigma^2_h$ and $\sigma^2$ represent the variance of hierarchy $h$ and the entire zone $Y$, respectively. The threshold value of $q$ is $[0, 1]$, and a higher value means the more obvious spatial differentiation of $Y$. If the hierarchy is generated by the independent variable, a higher $q$ value represents a higher explanatory power of the independent variable $X$ for attribute $Y$; otherwise, the explanatory power is lower.

2.3. Index Selection of Influence Factors

The change in the proportion of land used for transport is due to the construction of transport infrastructure, whose main purpose is to meet the needs of economic development. The economic, industrial, and demographic factors are crucial to economic development [30]. Therefore, the authors selected the index construction model based on relevant studies carried out by previous researchers [30–32]. Based on the particularity of land used for transportation at the county level, the proportion of land used for transportation served as a dependent variable. Additionally, the variable construction model was selected based on economic factors, industrial factors, and demographic factors, including...
PGRP \((x_1)\), fixed asset investment \((x_2)\), fiscal revenue \((x_3)\), level of industrialization \((x_4)\), industrial intensification \((x_5)\), population density \((x_6)\), and non-agricultural working population ratio \((x_7)\), to study the main factors that influence the proportion of land used for transportation at the county level in China (Table 2).

Table 2. Index selection of influencing factors.

| Factor            | Independent Variable                          | Computing Method                                                                 |
|-------------------|-----------------------------------------------|---------------------------------------------------------------------------------|
| Economic          | PGRP (RMB) \((x_1)\)                         | Gross Regional Product/Registered Population at the End of Year                  |
|                   | Fixed Assets Investment Ratio \((%)\) \((x_2)\) | Total Fixed Assets Investment/Gross Regional Product                            |
|                   | Fiscal Revenue Ratio \((%)\) \((x_3)\)        | Public Fiscal Revenue/Gross Regional Product                                     |
| Industry          | Level of Industrialization \((%)\) \((x_4)\)  | Sum of Added Value between Secondary and Tertiary Industries/Gross Regional Product |
|                   | Degree of Industrial Intensification \((%)\) \((x_5)\) | Total Industrial Output Value above Scale/Gross Regional Product                |
| Population        | Population Density \((\text{people/km}^2)\) \((x_6)\) | End of Year/Prefecture Land Area                                                 |
|                   | Non-agricultural Working Population Ratio \((%)\) \((x_7)\) | Population in Secondary and Tertiary Industries/Registered Population          |

3. Results

3.1. Spatial–Temporal Pattern of Land Used for Transportation at the County Level in China

3.1.1. Pattern of Land Used for Transportation at the County Level in China

The results of the proportion of land used for transportation at the county level in 1978, 1988, 1998, 2008, and 2018 in China are shown in Figure 2. As secondary roads included provincial highways and some county roads before the traffic road grading reform in 1997, comparative analyses were conducted for the period between 1978 and 1988 as one group and for the years 1988, 2008, and 2018 as another group.

Based on the result, the counties with a high proportion of land used for transportation were mostly distributed in the Plain of North China, the Yangtze Plain, and the Pearl River Delta Plain in 1978. As for counties in northwest China, apart from some counties around major cities, the proportion of land used for transportation was extremely low, and the proportion of most counties was below 0.28\%.

In 1988, the proportion of land used for transportation increased, but the Plain of North China still maintained the highest proportion used. However, it can be seen from Figure 2b that the proportion of land used for transportation in counties near main arteries obviously increased as compared to that in 1978.

In 1998, after the traffic road grading reform, the counties with a high proportion of land used for transportation began to converge towards the central and eastern regions and the main arteries, such as Longhai Line, Jingjiu Line, and Jinghu Line, thus taking on a “corridor” distribution, especially in Hebei, Shandong, Jiangsu, Henan, Guangdong, etc. However, many counties with a low proportion of land used for transportation were still distributed in the northwest. Counties in Xinjiang, Gansu, Qinghai, Tibet, etc., had the lowest proportion of land used for transportation on a national scale. This phenomenon reflects the slow development of the transportation network construction in the northwest of China.
Figure 2. The land used for transportation at the county level in China from 1978 to 2018.

In contrast with 1998, a large number of counties with a high proportion of land used for transportation increased in 2008. However, these counties were still concentrated in Hebei, Henan, Shandong, Jiangsu, and Guangdong, or were counties along main arteries such as the Jinghu Line, Jingjiu Line, Jingguang Line, Jiaoliu Line, Huhanrong Line, Longhai-Lanxin Line, and Hukun Line.

In 2018, counties with a high proportion of land used for transportation were more concentrated along the southeast of the Hu Huanyong Line (Line of correlation found by Hu Huanyong (1901–1998), a Chinese geographer, to divide the Chinese population density: 96% of the population lived on the 36% of land southeast of the line), while the
counties with a high proportion of land used for transportation took on a “diamond” shape. Those at the top were the Beijing, Tianjin, and Hebei Urban Agglomeration and the Central Hunan Urban Agglomeration. The one at the bottom was the Pearl River Delta Urban Agglomeration. The one on the left was the Chengdu and Chongqing Urban Agglomeration, the one on the right was the Yangtze River Delta Urban Agglomeration, and the one in the middle was the urban agglomeration along the middle reaches of the Yangtze River. The cross structure was mainly supported by the main arteries of the Jingjiu Line, Jingguang Line, and Yangtze River Line.

3.1.2. Evolution of Spatial–Temporal Pattern of Land Used for Transportation at the County Level in China

Concerning the traffic road grading reform in 1997, studies were carried out to analyze the change in the proportion of land used for transportation across the three years of 1998, 2008, and 2018. The result is shown in Figure 3.

![Figure 3](image_url)

**Figure 3.** Changes in the land used for transportation at the county level in China from 1998 to 2018.

It can be seen from Figure 3a that the proportion of land used for transportation at the county level changed drastically between 1998 and 2008, especially along the southeast of the Hu Huanyong Line. The fastest-growing regions were concentrated in the Beijing, Tianjin, and Hebei Urban Agglomeration, the Yangtze River Delta Urban Agglomeration, the Pearl River Delta Agglomeration, and the Central Henan Urban Agglomeration. In the meantime, apart from a few counties, the proportion of those in the northwest regions increased by varying degrees.

According to Figure 3b, although the proportion of land used for transportation at the county level was still increasing between 2008 and 2018, the regional difference was more obvious. The proportion of land used for transportation in the northwest along the Hu Huanyong Line changed slowly, while the change in the ratio in the southwest differed prominently. The proportion of land used for transportation at the county level in Beijing, Tianjin, Hebei, Shandong, Jiangsu, Henan, and Guangdong still grew sharply. However, the proportion in the exceptionally poor mountainous areas in China grew sluggishly, such as the Yanshan Taihang Mountainous Area, Lvliang Mountainous Area, Liupan Mountainous Area, and the other contiguous destitute areas in China. The specific areas are presented in Figure 4.
3.1.3. Evolution of Spatial–Temporal Pattern of Land Used for Transportation at the County Level in China

China can be divided into three regions according to development levels (Figure 5). Based on data on the proportion of land used for transportation in different counties in China, Fisher’s LSD method was used to analyze the differences in land used for transportation in the eastern, central, and western counties (Figures 6 and 7). The results show that there are significant differences in the proportion of land used for transportation in the eastern and western counties on the basis of $p \leq 0.001$. The proportion of land used for transportation at the county level is the highest in the eastern region, middle in the central region, and the lowest in the western region in China. However, the proportion values in the central and eastern regions are significantly different, with a high degree of dispersion, while the proportion values in the western regions are distributed more centrally. The parallel graph in Figure 7 also demonstrates this research finding.

Figure 4. The spatial distribution of the 11 contiguous destitute areas in China.

It can be seen from the change in the proportion of land used for transportation at the county level that China carried out large-scale construction of railways, highways, and other transportation infrastructure to meet the surging demand for transportation and economic development. Therefore, apart from some mountainous areas and plateau sections, the proportion of land used for transportation at the county level in relatively flat regions increased sharply.
A possible reason for this phenomenon is that the eastern and central regions have a high level of economic development and a large demand for transportation. However, in the north of the central and eastern regions, there are wide plains and good traffic construction conditions, while in the south there are more mountains and hills, so it is more difficult to construct traffic facilities, resulting in a large difference in the proportion of land used for transportation at the county level in the central and eastern regions of China.

Overall, most counties in the western region have large areas, lag behind the central and eastern regions in terms of economic development, and are multi-plateaued and mountainous regions. This means that transportation construction in western regions bears higher costs and longer construction cycles, which may lead to limited or small proportions of land being used for transportation. Therefore, as shown in Figure 7, there is very little difference in the proportion of land used for transportation at the county level.

Figure 5. The eastern, central, and western regions of China.

Figure 6. Paired comparison plot of land used for transportation at the county level in the eastern, central, and western regions of China.

3.2. Analysis of Influence Factors of Land Used for Transportation at the County Level in China

3.2.1. Main Influence Factors of Land Used for Transportation at the County Level in China

As mentioned in Section 2.1, the traffic road grading was reformed in 1997, the proportions of land used for transportation at the county level in 1998, 2008, and 2018 were dependent variables. As mentioned in Section 2.3, seven factors were chosen as independent variables, including PGRP (x1), fixed asset investment (x2), fiscal revenue (x3), level of industrialization (x4), industrial intensification (x5), population density (x6), and non-agricultural working population ratio (x7), in a regression analysis to study the factors with a major impact on the proportion of land used for transportation. SPSS was used for the standard processing of the seven variables, and the variance inflation factor (VIF) was used for the multicollinearity test. The VIF of all variables was less than five, and there...
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As mentioned in Section 2.1, the traffic road grading was reformed in 1997, the proportions of land used for transportation at the county level in 1998, 2008, and 2018 were dependent variables. As mentioned in Section 2.3, seven factors were chosen as independent variables, including PGRP ($x_1$), fixed asset investment ($x_2$), fiscal revenue ($x_3$), level of industrialization ($x_4$), industrial intensification ($x_5$), population density ($x_6$), and non-agricultural working population ratio ($x_7$), in a regression analysis to study the factors with a major impact on the proportion of land used for transportation. SPSS was used for the standard processing of the seven variables, and the variance inflation factor (VIF) was used for the multicollinearity test. The VIF of all variables was less than five, and there were no multiple collinearities among the variables. The model specification is rational (Table 3).

A possible reason for this phenomenon is that the eastern and central regions have a high level of economic development and a large demand for transportation. However, in the north of the central and eastern regions, there are wide plains and good traffic construction conditions, while in the south there are more mountains and hills, so it is more difficult to construct traffic facilities, resulting in a large difference in the proportion of land used for transportation at the county level in the central and eastern regions of China. Overall, most counties in the western region have large areas, lag behind the central and eastern regions in terms of economic development, and are multi-plateaued and mountainous regions. This means that transportation construction in western regions bears higher costs and longer construction cycles, which may lead to limited or small proportions of land being used for transportation. Therefore, as shown in Figure 7, there is very little difference in the proportion of land used for transportation at the county level.

Figure 7. Parallel plot of the proportion differences of land used for transportation at the county level in the eastern, central, and western regions of China.
Table 3. Results of the OLS model.

| Independent Variable                  | Coefficient | Standardized Coefficient | Sig.   | VIF |
|---------------------------------------|-------------|--------------------------|--------|-----|
| Constant Term                         | -0.012      |                          | 0.540  |     |
| Per Capita Gross Regional Product \(x_1\) | 0.101       | 0.101                    | 0.000  | 1.549 |
| Fixed Assets Investment \(x_2\)       | 0.005       | 0.005                    | 0.823  | 1.162 |
| Fiscal Revenue \(x_3\)                | -0.010      | -0.010                   | 0.630  | 1.092 |
| Level of Industrialization \(x_4\)    | 0.131       | 0.130                    | 0.000  | 1.556 |
| Industrial Intensification \(x_5\)    | 0.097       | 0.099                    | 0.000  | 1.414 |
| Population Density \(x_6\)            | 0.402       | 0.393                    | 0.000  | 1.447 |
| Non-agricultural Working Population Ratio \(x_7\) | 0.073       | 0.073                    | 0.000  | 1.622 |
| \(R^2\)                               | 0.442       |                          |        |     |
| \(R^2\)-adjust                        | 0.439       |                          |        |     |
| F-statistics                          | 132.20      |                          |        |     |
| Sig.                                  | 0.000       |                          |        |     |

The regression model built in this study was based on the non-standard coefficient and intercept:

\[
y = -0.012 + 0.101x_1 + 0.131x_4 + 0.097x_5 + 0.402x_6 + 0.073x_7. \tag{4}
\]

The estimated results of the model indicate that the fixed asset investment and fiscal revenue failed the significance test. The other five variables, including PGRP, level of industrialization, industrial intensification, population density, and non-agricultural working population ratio, passed the test. The significance of the five influence factors is far below 0.01, indicating that these factors have extremely prominent impacts on the land used for transportation at the county level and positive correlations with the difference in the proportion of land used for transportation at the county level.

PGRP belongs to economic factors and largely reflects the overall level of county economic development and peoples’ living standards. A high level of economic development inevitably causes a close inter-regional distribution of labor and cooperation. Meanwhile, high living standards increase residents’ demand for travel. Therefore, PGRP exerts a positive impact on the proportion of land used for transportation at the county level. The level of industrialization and industrial intensification as industrial factors reflect positive incentive impacts on the land used for transportation at the county level through the regression model. As the ratio and scale of secondary and tertiary industries directly determine the flow rate and scale of production factors in counties, they exert positive impacts on the proportion of land used for transportation at the county level. The population density and non-agricultural working population ratio belong to the population factor and directly determine the flow scale and the demand for transportation among the people of each county. Therefore, they are positively correlated to the proportion of land used for transportation.

3.2.2. Difference of Intensity of Influence Factors on Land Used for Transportation at the County Level in China

A further analysis was carried out on the five significant influence factors in the regression model through a geographic detector model to study the difference in the intensity of impact on the land used for transportation at the county level in China. The proportions of land used for transportation at the county level in 1998, 2008, and 2018 were selected as dependent variables, and five significant influence factors obtained from the regression model were selected as independent variables, including PGRP \((x_1)\), level of industrialization \((x_4)\), industrial intensification \((x_5)\), population density \((x_6)\), and non-agricultural working population ratio \((x_7)\). SPSS was used for discrete classification, and a geographic detector was used to regulate the grade (Table 4).
Table 4. Factor q value detection.

| Influence Factor                          | q Value | p-Value |
|-------------------------------------------|---------|---------|
| Per Capita Gross Regional Product ($x_1$) | 0.3910  | 0.0000  |
| Level of Industrialization ($x_4$)       | 0.4993  | 0.0000  |
| Industrial Intensification ($x_5$)       | 0.3395  | 0.0000  |
| Population Density ($x_6$)               | 0.3047  | 0.0000  |
| Non-agricultural Working Population Ratio ($x_7$) | 0.3511  | 0.0001  |

It can be seen from Table 4 that the q values of all five influence factors are high, meaning that they can effectively reflect the difference in intensity of the influence factors. The order of contribution of a single factor to the proportion of land used for transportation at the county level is $x_4 > x_1 > x_7 > x_5 > x_6$, according to the geographic detector. The corresponding q values are 0.4993, 0.3910, 0.3511, 0.3395, and 0.3047, respectively. $x_4$, $x_1$, and $x_7$ lead the differentiation of land used for transportation at the county level, while $x_5$ and $x_6$ play a secondary role due to their lower q values.

The geographic detector can not only identify the intensity of a single factor but can also detect the interaction between two factors. In this study, the five significant influence factors were detected in pairs, and the corresponding results are presented in Table 5. It can be seen that the interaction between two factors is higher than the intensity of a single factor, including two-factor enhancement and non-linear enhancement.

Table 5. Interactive exploration of the impact factors of land used for transportation at the county level in China.

| C       | A + B     | Result Explanation | Explanation         |
|---------|-----------|--------------------|---------------------|
| $x_1 \cap x_4 = 0.9381$ | $x_1 + x_4$ | $C > A + B$         | Non-linear Enhancement |
| $x_1 \cap x_5 = 0.4225$ | $x_1 + x_5$ | $C > \text{Max} (A, B)$ | Two-factor Enhancement |
| $x_1 \cap x_6 = 0.7091$ | $x_1 + x_6$ | $C > A + B$         | Non-linear Enhancement |
| $x_1 \cap x_7 = 0.6412$ | $x_1 + x_7$ | $C > \text{Max} (A, B)$ | Two-factor Enhancement |
| $x_4 \cap x_5 = 0.5049$ | $x_4 + x_5$ | $C > \text{Max} (A, B)$ | Two-factor Enhancement |
| $x_4 \cap x_6 = 0.8412$ | $x_4 + x_6$ | $C > A + B$         | Non-linear Enhancement |
| $x_4 \cap x_7 = 0.6015$ | $x_4 + x_7$ | $C > \text{Max} (A, B)$ | Two-factor Enhancement |
| $x_5 \cap x_6 = 0.6762$ | $x_5 + x_6$ | $C > A + B$         | Non-linear Enhancement |
| $x_5 \cap x_7 = 0.7119$ | $x_5 + x_7$ | $C > A + B$         | Non-linear Enhancement |
| $x_6 \cap x_7 = 0.7724$ | $x_6 + x_7$ | $C > A + B$         | Non-linear Enhancement |

The interactive impact of PGRP and the level of industrialization ($x_1 \cap x_4$) is the highest, up to 0.9381. The interactive impact of PGRP and industrial intensification ($x_1 \cap x_5$) is the lowest, down to 0.4225. PGRP and the level of industrialization have higher interactive impacts with other factors.

4. Discussion

4.1. The Spatial and Temporal Evolution of Land Used for Transportation Are Jointly Determined by Natural and Human Factors at the County Level in China

Previous studies on this topic paid more attention to the internal traffic land-use problems of cities, and an inadequate level of research has been conducted on the nationwide use of land for traffic [33,34]. Based on the basic data of land used for transportation at the county level over the past 40 years, since the implementation of the reform and opening-up policy in China, this study explored the spatial–temporal evolution pattern of land used for transportation at the county level in China. Additionally, an evaluation index of the factors influencing the use of land for transportation at the county level was constructed to analyze the influencing factors and study the differences in the effect intensity among the influencing factors, i.e., economic factors, industry factors, and population factors.

The results show that the spatial–temporal evolution of land used for transportation is influenced by both natural and human factors at the county level in China and presents
the characteristic from the point to line to network, which conforms to the “point-axis” development theory [35]. From the perspective of spatial and temporal distribution, in the early stage of reform and opening up, the areas with a high proportion of land used for transportation at the county level were mostly located around economically developed cities, mainly in plain areas. This is because the difficulty and cost of transportation infrastructure construction were low in plain areas. With the rapid development of the national economy, the connections among regions became increasingly close, and technology, talents, resources, and other elements needed to be better connected by transportation. In order to meet the needs of economic and social development, a large number of transportation infrastructures have been built to connect economically developed cities. Therefore, counties with a high proportion of land used for transportation were distributed along the axis. At present, the counties with a high proportion of land used for transportation are found to have a “diamond-shaped” distribution, with most of them located in the five core urban agglomerations. The pattern of land used for transportation at the county level has changed from an axis structure to a hub-and-spoke structure, with a preliminary ordered network in China.

4.2. Economy, Industry, and Population Have Significant Influence on the Utilization of Land Used for Transportation at the County Level

One of the important research areas in geography is to find out the underlying factors behind geographical phenomena and reveal their mechanisms. Through this study, we found that the factors influencing the land used for transportation construction are similar to those of urban construction land in China [36]. The level of economic development is the dominant factor and reflects the degree of close connection between regions, and this inevitably affects the transportation land. The next factor is the level of industrial structure. The last is the population factors, such as population density and the proportion of the non-agricultural employed population, which directly determine the flow of people in counties and the demand for transportation.

4.3. Future Research Directions of Land Used for Transportation

It should be noted that this study only considered the spatial and temporal pattern of land used for transportation and its influencing factors at the county level in China and did not involve the study of the coordination and adaptation of transportation land and economic development levels. However, China has significant regional differences and has formed an economic development pattern centered on urban agglomeration. According to China’s 14th five-year plan for economic and social development, authors will develop and expand urban agglomerations and metropolitan coordinating regions, promote the integrated development of urban agglomerations, and form a comprehensive urbanization strategic pattern of ‘Two Horizontal and Three Vertical Axes’. The connections of talents, resources, technology, and other elements between regions need to be made possible by transportation. However, Chen et al. [34] and Chen et al. [37] found that the current transportation construction in China has entered a new stage and is now aimed at improving quality and efficiency. Since land resources are becoming more and more precious, authors can study the land used for transportation within and among urban agglomerations. The degree of coordination of transportation land and economic development can be measured quantitatively and accurately to analyze the scale and spatial coverage of transportation land and its economic and social attributes. It is of practical significance for future transportation policy-making to avoid an excess of transportation facilities, insufficient economic benefits, and the waste of land and capital caused by large-scale transportation construction. In addition, authors could discuss how the conventional network datasets can be complemented with emerging urban big data sources [38–40] (e.g., land transactions, housing prices, and human movements) as one of the future research trends.
5. Conclusions

Based on the transportation network at the county level in China from 1978 to 2018, this study analyzed the spatial characteristics and evolutionary pattern of land used for transportation at the county level in China over five item sections in 1978, 1988, 1998, 2008, and 2018. In 1997, the Chinese traffic road grade classification reform was carried out. Based on the scientific and consistent principles, the OLS model and geographical detector were used to explore the factors influencing the land used for transportation at the county level in China from 1998 to 2018. The main conclusions are as follows:

(1) Since 1978, there have been significant regional differences in the land used for transportation at the county level in China. Taking the Hu Huanyong Line as the boundary, the land used for transportation in the southeast region is higher than that in the northwest region. From 1998 to 2018, the land used for transportation at the county level in China increased significantly in the southeast of the Hu Huanyong Line, but the change in contiguous destitute areas was small.

(2) The counties with a high proportion of land used for transportation in the southeast of the Hu Huanyong Line gradually changed from a “corridor type” distribution along the Chinese main traffic trunk to a “diamond type” group distribution around major urban agglomerations, while the differences of land used for transportation among counties tended to converge.

(3) The land used for transportation at the county level in China was mainly affected by economic factors, industry factors, population factors, and other factors. The level of industrialization, PGRP, and the proportion of the population employed in non-agricultural professions played a leading role in the spatial differentiation of land used for transportation at the county level. PGRP and the level of industrialization had the highest interactive impact and were highly interactive with other factors. A high economic level and upgrading of the industrial structure exerted a positive incentive impact on the land used for transportation at the county level.

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