The coupling coordination relationship between regional economy and transportation industry in China

Abstract: With the rapid development of economy, the discrepancy between regional economy and transportation industry is increasingly prominent for most regions. Coordinated development between regional economy and transportation industry is very important for the sustainable development of cities. This paper utilizes the Coupling Coordination Degree (CCD) model and Entropy Method (EM) to quantitatively study the coupling coordination state between regional economy and transportation industry and its spatial distribution of 30 provinces in China from 2004 to 2017. The results show that: (1) The comprehensive level of regional economy and transportation industry in China's have shown a growing trend, and regional economic development is faster than transportation industry development. The economic development scale and transportation scale are the most influential indicators among all indicators. (2) The CCD between regional economy and transportation industry in China is changing from incoordination to high-level coordination, but the improvement speed is slow. The imbalance of CCD levels among regions vary significantly. The CCD in the eastern region is slightly higher than that in the central, western and northeast regions. (3) In the region with a higher CCD, the development discrepancy between the development of regional economy and transportation industry is higher than that in other regions. This study could provide scientific references to stimulate the coordinated development between regional economy and transportation industry, and also to promote sustainable global development.

Keywords: Reginal economy; Transportation industry; Coupling coordination degree; Spatial distribution

1 Introduction

Regional economy and transportation industry are two important aspects of urban sustainable development. Simultaneously, an inseparable connection exists between regional economy and transportation industry (Vooren, 2004; Limani, 2016; Chunmei, 2018). Increasing investment in transportation infrastructure, expanding transportation scale and reducing transportation cost can stimulate the development of economic (Ge et al., 2019; Vooren, 2004). Correspondingly, the economic scale, economic structure and economic development also have noticeably impact on transportation development (Maparu and Mazumder, 2017; Tong and Yu, 2018). Thence, realizing the common development between regional economy and transportation industry, and achieving a benign interaction bewteen them will effectively promote the urban sustainable development.

Some countries have made efforts to accelerate the development of regional economy and transportation industry. The United States promulgated the "US Strategic Transportation Plan for FY 2018-2022" to balance the rapid increase in material flow, backward infrastructure and achieve economic sustainability. Since the promulgation of the "Future Industrial Plan" in 2015, France has continued to promote the transformation of economic growth mode and sustainable transportation development. China proposed the "The Belt and Road Initiative" in 2015, which includes building an integrated economic zone by strengthening the construction of transportation, network infrastructure, etc. These policies promote the development of economy and transportation industry from the national macro perspective. However, the policies lack of targeted guidance on regional development. Scholars have paid attention to the research on regional economy and transportation industry, and mostly focus on the qualitative analysis of the relationship between them (Ma et al., 2019; Pradhan and Bagchi, 2013; Yang et al., 2019). Only a small part of the research studies has considered the quantitative analysis of its coordination status (Karlaftis, 2004; Yu et al., 2019). There is still a gap in the literature regarding the division of the benign interaction level between regional economy and transportation industry (Lan and Zhong, 2018), which weakens the contributions to generate strategies in formulating urban plans.

The Coupling Coordination Degree (CCD) is often used to evaluate the relationship between two systems, which can be adopted to measure the coordination relationship between the regional economy and the transportation industry (Liu et al., 2018; Liu et al., 2018). Coupling is the earliest concept in physics, commonly used to express the degree of interaction and mutual influence of two or more systems (Tao, 2019). Coordination measures the coordinated development of various elements within a system and reflects the harmony of the system (Li et al., 2020). To promote the coupling coordination of regional economy and transportation industry means that the two systems accomplish common and harmonious development on the basis of interaction. In the context of global sustainable development, the coupling coordination of regional economy and transportation industry is conducive to the recouse allocation and the overall development of economy and transportation. At the same time, common development of multiple modes of transportation is an important feature of modern transportation industry. Fully will make The evaluation of the transportation system will more accurate considering development disparity of various modes of transportation.

This paper utilizes Coupling Coordination Degree (CCD) model to quantitative analysis the coordination level between regional economy and the transportation. Meanwhile, the paper subdivides the 6 development stages of coordination between the regional economy and transportation industry. Taking China as the research area, the researchers explored the differences of the coordinated development level of regional economy and transportation industry in 30 provinces from 2004 to 2017. Under global sustainable development background, the paper also provides suggestions for improving coordination and reducing development discrepancy between regional economy and transportation industry. This study is conducive to the realization of benign interaction between regional economy and transportation industry, which lays a foundation for promoting global sustainable development.

The rest of this article is organized as follows. Section 2 reviews the relevant literature. Section 3 introduces the research area and develops the Coupling Coordination Degree (CCD) Model. Section 4 calculates the comprehensive levels of economic and transportation development of 30 provinces, respectively. The coupling coordination degree and development discrepancy of different provinces are also obtained. Section 5 discusses the reasons of coupling coordination development level and regional differences. The last section presents the conclusions and suggestions.

2 Literature review

Existing literature studies the relationship between regional economy and transportation industry from perspectives. As an important relationship between the regional economy and the transportation industry, coordination is evaluated by different methods. The literature review is divided into two parts: (1)Research perspectives of the relationship between regional economy and transportation industry; (2)Research methods of coordination between regional economy and transportation industry.

2.1 Research perspectives of the relationship between regional economy and transportation industry

Many scholars have explored the relationship between economy and transportation. Adam Smith, the representative of classical political economic theory, proposed that transportation promotes the improvement of economic operation efficiency by promoting social division of labor, and the continuous increase in the level of economic development affects transportation. Afterwards, scholars have conducted multi-level research on the relationship between economy and transportation development from different perspectives. They generally believe that transportation plays a vital role in economic activity either directly. It also as a complement to other factors of production and affects economic activity positively (Pradhan and Bagchi, 2013; Marazzo et al., 2010; Chi and Baek, 2013). Most empirical studies show that transportation infrastructure is a necessary condition for social and economic development, and point out the impact of transportation infrastructure construction on economic development (Sun and Cui, 2018; Farhadi, 2015; Arvin et al., 2015). At the same time, there are mutually promoting forces between transportation and economic development. The type and extent of current regional economic development determine the magnitude of the forces. Subsequently, Han and Yang (2000) improved life cycle theory of the transportation economic belt to explaine the basic characteristics and basic laws of the development of the transportation economic belt. They believed that the formation and development of the transportation economic belt played an important role in promoting regional and national economic construction.

As a kind of relationship between regional economy and transportation industry, coordination is a key factor to the development between them. There is little research direclty addressing the coordination of regional economy and transportation industry. Some scholars study the relationship between urbanization and transportation development from the perspective of urbanization, from which economy is only one of the factors in evaluating the process of urbanization. They believe that the coordination of new urbanization and sustainable transportation is an effective basis for the comprehensive and sustainable development of urbanization theory (Ma et al., 2019; Li et al., 2015). Other studies have investigated the state of coordination with the economy from a certain aspect of transportation such as transportation infrastructure investment, logistics development, etc. They consider that promoting their coordinated development is helpful to raise the efficiency of urban public transportation infrastructure and guide urban planning and investment scientifically (Sun and Cui, 2018; Yang et al., 2019).

In the study of transportation coordination, the comprehensive transportation system as the future development goal of the transportation industry has also attracted attention. Some scholars have studied the low-carbon synergy of transportation modes based on the idea of synergy and evolution. They believe that the low-carbon synergy of China's transportation system basically tends to zero (Cui et al., 2014). Some researchers used the data envelopment analysis method to evaluate the comprehensive validity of the Beijing-Tianjin-Hebei transportation system, and concluded that the coordination development of the transportation modes of the Beijing-Tianjin-Hebei regional transportation system is low (Zhao, 2016). Although studies have shown that the level of comprehensive transportation is relatively low at this stage, the development of comprehensive transportation is an inherent demand and inevitable choice for transportation transformation and upgrading.

In conclusion, the current research on coordination relationship rarely directly connects the regional economy with the transportation industry. At the same time, the discrepancy development of multiple modes of transportation is rarely considered in the transportation industry system. With regards to this, this paper directly studies the CCD of regional economy and transportation industry, and fully considers the multiple modes of transportation in the transportation industry system. It can provide more targeted and accurate guidance for the sustainable development of the region.

2.2 Research methods of coordination between regional economy and transportation industry

methods have been used to quantitatively study the relevance and coordination of economy and transportation. However, these methods have some shortcomings in studying the coordination level of regional economy and transportation industry. Researchers using the Grey Relation Analysis model analyzed the coordination relationship between the economy and transportation in China (Xu et al., 2010). The results showed the coordination of them is poor, but the development of the transportation system significantly promoted the increase of the index value of the economic system. This method has a strong subjectivity in judging the importance of indicators. Besides, the optimal value of the result is difficult to determine. The Principal Component Analysis (PCA) and Vector Autoregressive model (VAR) are used to evaluate the regional economy and transportation industry development and study the coordination degree between them (Tan and Lu, 2015). However, the principal components need to reduce the dimensionality. This will result in distortion of the original meaning of the data, which ultimately results in an unclear comprehensive evaluation. Some scholars use Tapio Decoupling model to describe the slowing or blocking of the coupling relationship between economic growth and transportation carbon emissions, while the judgment of the coordination level is not clear covered (Xie et al., 2016).

The CCD model is used to measure the coordination relationship between multiple systems. It is a mature model and has been widely used in many fields such as exploring the coordination degree of urban economy and logistics development, the coordination degree of urbanization and air environment, ecological environment, etc. (Lan and Zhong, 2018; Lan and Tseng, 2018; Ding et al., 2015; Liu et al., 2018). The method can also quantify the development status of system itself. This avoids the occurrence of high synergy but in a low development level, which makes the research results more accurate. This paper chooses the CCD model as the research method to study the coupling coordination relationship between regional economy and transportation industry. At the same time, this study adopts the entropy method combined with the CCD model in the process of raw data standardization, which can greatly reduce the subjectivity and uncertainty of data processing.

3 Methodology

3.1 Study area

China is the second largest economy in the world with a population of 1.4 billion at the end of 2019. While China has a vast territory, there are significant differences in the development of transportation in various regions. In recent years, with the rapid development of economy and transportation, problems such as traffic congestion, waste of resources and unbalanced development have appeared. To this end, a new development principle of innovation, coordination, greentech, open-minded and mutural-share has been proposed in China. However, the policies are large coverage and insufficient targeted guidance of different regions development. The lack of reference in formulating coordination policies by regional decision makers leads to problems such as low transportation efficiency and waste of natural resources in the development of regional economy and transportation industry, which restricts the development of them. Therefore, studying the coordination relationship between China’s regional economy and transportation industry and clarifying the coupling coordination degree are necessary.

3.2 Index system design(增加指标选取依据)

Measuring the development level of different systems is the premise of coupling coordination analysis. A reasonable index system is the basis of measuring the CCD accurately. This paper constructs an index system combined with the characteristics of regional economy and transportation industry development. This system contains 8 indicators to evaluate the economy comprehensively development and 9 indicators to assess the transportation comprehensively development of 30 provinces, respectively.

Existing literature indicates that there exist many index systems to evaluate the development level of economy. Most of them have constructed index systems from industrial structure, economic scale, and economic development efficiency, etc. (Liu et al., 2018; Shi et al., 2020). Based on the existing research, this study evaluates the comprehensive development level of regional economy from following three aspects: economic structure, economic development scale and economic growth rate, and their eight secondary indicators (Table 1).

There have some papers constructed an index system for evaluating the performance level of transportation development (Kong et al., 2019; Maparu and Mazumder, 2017). However, the existing studies lack of consideration on the development level of different modes of transportation. Therefore, this study takes the development of different modes of transportation into consideration, which can make the evaluation of transportation development more accurate. Consequently, the index system of transportation system consists of three primary indicators: transportation structure, transportation scale and transportation development efficiency, and nine secondary indicators (Table 2).

The performance data of the indexes in Table 1 and Table 2 are collected from *China Statistical Yearbook* (2004 - 2017), *China Regional Statistical Yearbook* (2004 - 2017) and *China Transport Statistical Yearbook* (2004-2017). The missing data of individual years were determined by regression model.

Table 1

Index system used for evaluation the performance level of economic development.

System		Index	Index type	Weight
Economy Development	**Economic structure**	The secondary industry added value/ GDP (%)	+	0.0254
		The tertiary industry added value/ GDP (%)	+	0.0779
	Economic	GDP per capita (Yuan)	+	0.1405

	development scale	Total investment in fixed assets (Yuan)	+	0.2618
		Per capita disposable income (Yuan)	+	0.1969
		Household consumption level (Yuan)	+	0.2107
	Economic growth rate	Per capita GDP growth rate (%)	+	0.0258
		Fiscal revenue growth rate (%)	+	0.0610

Table 2

Index system used for evaluation the performance level of transportation.

System		**Index**	**Index type**	**Weight**
Transportation Development	**Transportation structure**	Railway conversion turnover (%)	+	0.0626
		Road conversion turnover (%)	+	0.0956
		Port conversion turnover (%)	+	0.0954
		Air conversion turnover (%)	+	0.1174
	Transportation scale	Transportation infrastructure investment (Yuan)	+	0.2214
		Transportation industry output value (ten thousand Yuan)	+	0.0600
		Operating mileage (km)	+	0.2724
	Transportation development efficiency	Transportation Energy intensity (standard coal/ Yuan)	-	0.0143
		Transportation investment profit rate (%)	+	0.0918

3.3 Data standardization and weight calculation

3.3.1 Data standardization

Considering that the raw data are different in dimension and magnitude, this research uses the following equation to standardize the data:

Positive indicator
$$x_{ij}' = \left\{ \frac{x_{ij} - \min\{x_j\}}{\max\{x_j\} - \min\{x_j\}} \right. \tag{1}$$

Negative indicator
$$x_{ij}' = \left\{ \frac{\max\{x_j\} - x_{ij}}{\max\{x_j\} - \min\{x_j\}} \right. \tag{2}$$

where x_{ij}' represents the standardized value of the *j*-th indicator in year *i*, x_{ij} represents the value of the *j*-th indicator in year *i*; $\max\{x_j\}$ and $\min\{x_j\}$ indicate the maximum and minimum values of the *j*-th indicator in all years, respectively.

This paper assumes $u_1, u_2 \ldots\ldots u_p$ and $v_1, v_2 \ldots\ldots v_q$ represent the indices of regional economy and transportation industry; u_e' and v_t' represent the standardized values of u_e and v_t, which can be calculated by Eq. (1) and (2). The performance degree of the comprehensive is calculated by the Eqs. (3) and (4):

$$E(u)=\sum_{e=1}^{p} w_e u_e' \tag{3}$$

$$T(v)=\sum_{t=1}^{p} w_t v_t' \tag{4}$$

where *E(u)* and *T(v)* indicate the composite value of regional economy and transportation industry, w_e and w_t are the weight of u_e and v_t, respectively.

3.3.2 Weight calculation

The weight of the indicator emphasizes the relative importance of each indicator in the whole system, which is an indispensable part of the coupling coordination model of regional economy and transportation industry. This work determines the weights by the entropy method and the steps to determine these weights are as follows:

The proportion of the *j*-th indicator in year *i* (p_{ij}) : $p_{ij}=\dfrac{x_{ij}'}{\sum_{i=1}^{m} x_{ij}'}$ (5)

The information entropy of the *j*-th indicator (e_j) : $e_j=-\dfrac{1}{\ln m}\sum_{i=1}^{m}(p_{ij}\times \ln p_{ij})$ (6)

The redundancy of information entropy (d_j) : $d_j=1-e_j$ (7)

The weight of the *j*-th indicator (w_j) : $w_j=\dfrac{d_j}{\sum_{j=1}^{n} d_j}$ (8)

where *m* represents the number of years and *n* represents the number of indicators in a system.

3.4 Coupling Coordination Degree (CCD) model

In this paper, the interaction between regional economy and transportation industry is measure by CCD model. The formulas are as follows:

$$C=\sqrt{\frac{E(u)\times T(v)}{\left[\frac{E(u)+T(v)}{2}\right]^2}} \tag{9}$$

$$T=\alpha E(u)+\beta T(v) \tag{10}$$

$$D=\sqrt{C\times T} \tag{11}$$

where *C* is the coupling degree of the regional economy and transportation industry. *T* indicates the comprehensive evaluation index of the regional economy and transportation industry, *D* is the coupling coordination degree, which represents the coordination level, and $D \in [0,1]$.

Coefficient α and β represents the contributions of *E(u)* system and *T(v)* system to the coordination level, and $\alpha+\beta=1$. Most previous studies subjectively defined the values of α and β, and considered that α is equal to β, i.e., $\alpha=\beta=0.5$ (Cui et al., 2019; Liu et al., 2018). Subjective judgments may cause errors in the calculations and affect the results. Therefore, this paper uses an improved way to calculate α and β, which can help to eliminate errors and makes the results more convincing (Shen et al., 2018). The formulas are as follows:

$$\alpha=\frac{T(v)}{E(u)+T(v)} \tag{12}$$

$$\beta=\frac{E(u)}{E(u)+T(v)} \tag{13}$$

As Table 3 shows, the CCD of regional economy and transportation industry is divided into three different development stages (Incoordination period, Transition period and Highly coordination period) (Zhang and Li, 2020; Liu et al., 2018; Tang, 2015).

Table 3

The development stages of CCD between regional economy and transportation industry.

Primary development stages		Secondary development stages	Tertiary division of development stages	
Incoordination period	[0, 0.2]	Incoordination	$0 \leqslant \lvert E(u)-T(v) \rvert \leqslant 0.15$	Incoordination
			$T(v)-E(u) > 0.15$	Incoordination; economic development is blocked
			$E(u)-T(v) > 0.15$	Incoordination; transportation development is blocked
Transition period	[0.2, 0.3]	On the verge of imbalance	$0 \leqslant \lvert E(u)-T(v) \rvert \leqslant 0.15$	On the verge of imbalance
			$T(v)-E(u) > 0.15$	On the verge of imbalance; economic development is blocked
			$E(u)-T(v) > 0.15$	On the verge of imbalance; transportation development is blocked
	[0.3, 0.4]	Low-level coordination	$0 \leqslant \lvert E(u)-T(v) \rvert \leqslant 0.15$	Low-level coordination
			$T(v)-E(u) > 0.15$	Low-level coordination; economic development is blocked
			$E(u)-T(v) > 0.15$	Low-level coordination; transportation development is blocked
	[0.4, 0.5]	Reluctant coordination	$0 \leqslant \lvert E(u)-T(v) \rvert \leqslant 0.15$	Reluctant coordination
			$T(v)-E(u) > 0.15$	Reluctant coordination; economic development is blocked
			$E(u)-T(v) > 0.15$	Reluctant coordination; transportation development is blocked
	[0.5, 0.6]	Basic coordination	$0 \leqslant \lvert E(u)-T(v) \rvert \leqslant 0.15$	Basic coordination
			$T(v)-E(u) > 0.15$	Basic coordination; economic development is blocked
			$E(u)-T(v) > 0.15$	Basic coordination; transportation development is blocked
Highly coordination period	[0.6, 1]	High-level coordination	$0 \leqslant \lvert E(u)-T(v) \rvert \leqslant 0.15$	High-level coordination
			$T(v)-E(u) > 0.15$	High-level coordination; economic development is blocked
			$E(u)-T(v) > 0.15$	High-level coordination; transportation development is blocked

4 Results

This paper utilizes the CCD model to evaluate the coordinated status of regional economy and transportation industry in 30 provinces of China. In addition, according to the classification standard of *China Statistical Yearbook*, 30 provinces of China are divided into four major economic regions (i.e. East, Central, West and Northeast) to conveniently compare the results(Li et al., 2019). The detailed categorization is presented in Table 4.

Table 4

Categorization of researched regions (data from NBSC).

Region	Province
East	Beijing, Tianjin, Hebei, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, Hainan
Central	Shanxi, Anhui, Jiangxi, Henan, Hubei, Hunan
West	Chongqing, Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai, Inner Mongolia, Guangxi, Ningxia, Xinjiang
Northeast	Liaoning, Jilin, Heilongjiang

4.1 The comprehensive levels of regional economy and transportation industry

4.1.1 The weight of each factor

This study calculates the weight of each influencing factor by Entropy Method (EM), which can effectively judge the weight of the index and improve the accuracy of the comprehensive development level judgment (Eqs. (4)-(7)). In the regional economy system, the economic development scale accounts for the largest proportion and reaches 80.94%, including total investment in fixed assets (26.18%), household consumption level (21.07%), per capita disposable income (19.69%) and GDP per capita (14.00%). Economic structure and economic growth rate account for 10.00% and 9.06%, respectively. In terms of transportation industry, transportation scale, transportation structure and transportation development efficiency account for 55.00%, 36.00% and 9.00%, respectively. Among them, the secondary indicators with the greatest impact are operating mileage (27.24%) and transportation infrastructure investment (22.14%).

4.1.2 The comprehensive level of the regional economy and transportation industry

The comprehensive level of regional economy and transportation industry have calculated by Eqs. (1)-(3). The calculation results are shown in the Appendix A and Appendix B. Some results can be drawn by comparing the development between 2004 and 2017 in 30 provinces (Fig. 1 and Fig. 2).

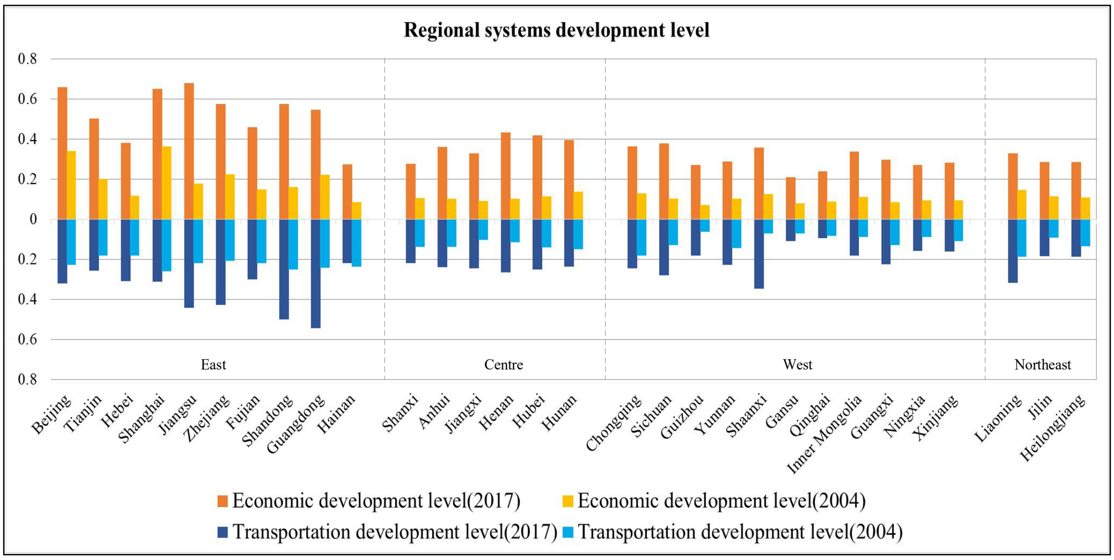


Fig. 1. The comprehensive level of the regional economy and transportation industry studied in 2004 and 2017.

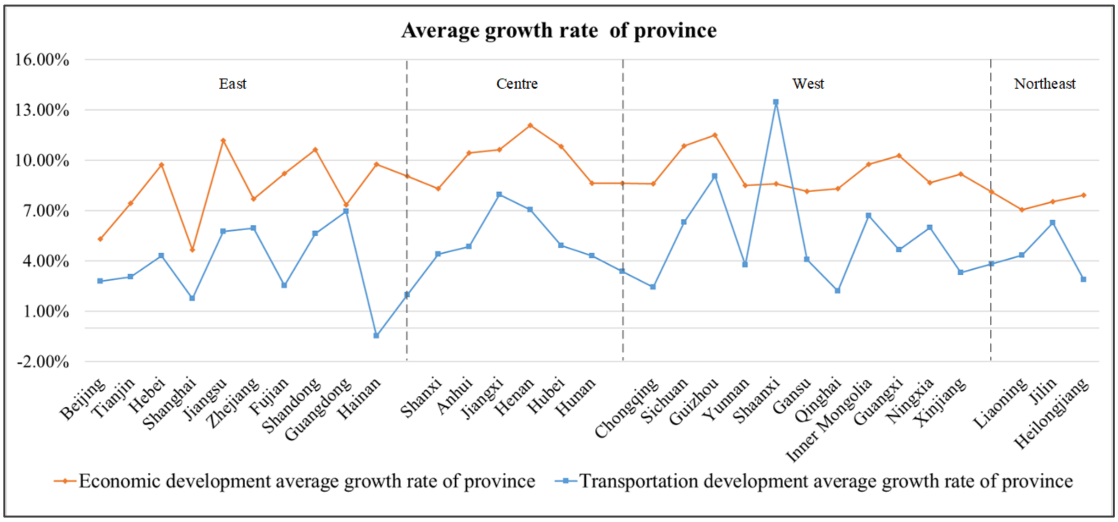


Fig. 2. The average growth rates in regional economy and transportation industry.

The Fig. 1 shows the comprehensive level of the regional economy and transportation industry in the studied provinces in 2004 and 2017. In the regional economy system, the comprehensive level of economic development in 2017 has significantly improved compared to 2004 in all provinces, and the four economic regions are in the different development situation. The east is the most advanced development region, followed by the central and northeast regions, while the economic development in the western region is relatively slow. The current economic development status of different provinces in China can also receive from the data of 2017. Beijing, Shanghai, Guangzhou, Jiangsu, Zhejiang and Shandong have better comprehensive economic level than other regions(>0.5), and these regions belong to the eastern region. The comprehensive economic level of Hainan, Shanxi, Guizhou, Yunnan, Gansu, Qinghai Guangxi Ningxia, Xinjiang, Jilin and Heilongjiang are less than 0.3, and most provinces belong to the western region. The comprehensive economic level in other regions are between 0.3-0.5. The above phenomenon shows the current situation of unbalanced economic development in different regions of China.

The comprehensive level of transportation in the eastern region is significantly higher than that in others, and the development of provinces in same regions is quite different (Fig. 1). Except Hainan, the comprehensive level of transportation development in 2017 is higher than in 2004 in most provinces. In 2017, Jiangsu, Zhejiang, Guangdong and Shandong have better comprehensive transportation level (>0.4), the comprehensive transportation level in Beijing, Tianjin, Hebei, Shanghai, Fujian and Hainan are between 0.3-0.4. The comprehensive transportation level of the central region is lower than that of the eastern region, between 0.2-0.3. The results show that there is a large disparity in the level of transportation development among provinces in the western region, with the highest in Shaanxi at 0.347, and only 0.094 in Qinghai. In Northeast China, the transportation level in Jilin and Heilongjiang are both 0.18, while that of Liaoning is 0.31. In short, there are obviously differences in regional transportation development.(相关政策缺乏对区域发展有针对性的指导，同时区域协调水平划分不明确)

The average growth rate of the comprehensive development level of regional economy and transportation industry during 2004-2017 are presented in Fig. 2. The average growth rates of regional economy development in most provinces are between 8%-12%, which means that the economy is at an increasing development level. However, there are significant differences in the average growth rate of transportation development in different provinces. Shaanxi has the highest growth rate of 13.44%, while Hainan's growth rate is -0.48%. The average growth rates of transportation development in most provinces are between 1%-10% and greater than zero.

Through comparing the comprehensive level of regional economy and transportation industry, it could be known that: although both the development level of regional economy and transportation industry have been continuously improved, there is a large disparity in the development speed and current state of both. In 2004, the comprehensive level of the regional economy and transportation industry were at a similar state, and the transportation level in some areas was higher than the economy. But in 2017, the level of regional economy is obviously higher than that of transportation, which shows that China's comprehensive transportation development is relatively lagging behind the economy.

4.2 Coupling coordination degree of regional economy and transportation industry

4.2.1 The average level of the coupling coordination degree

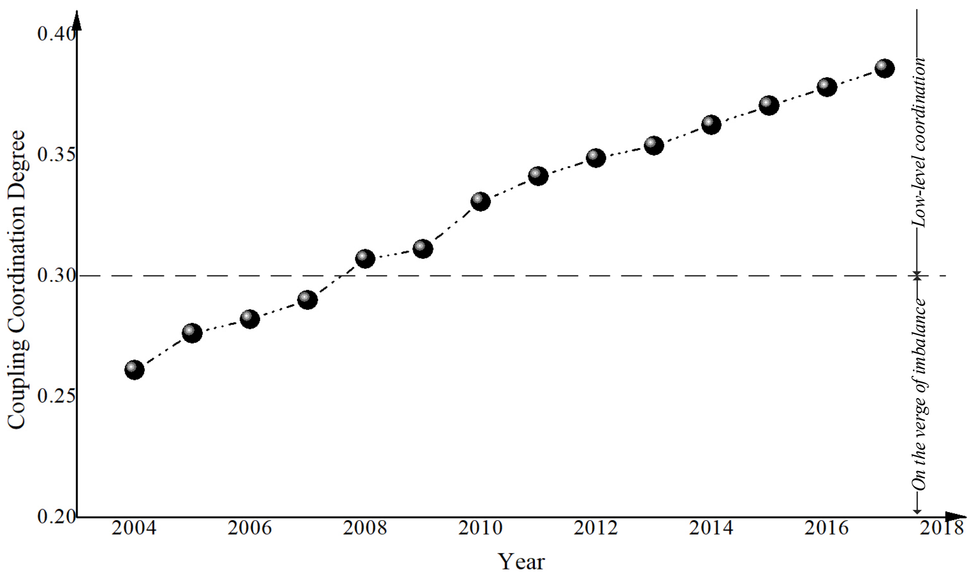
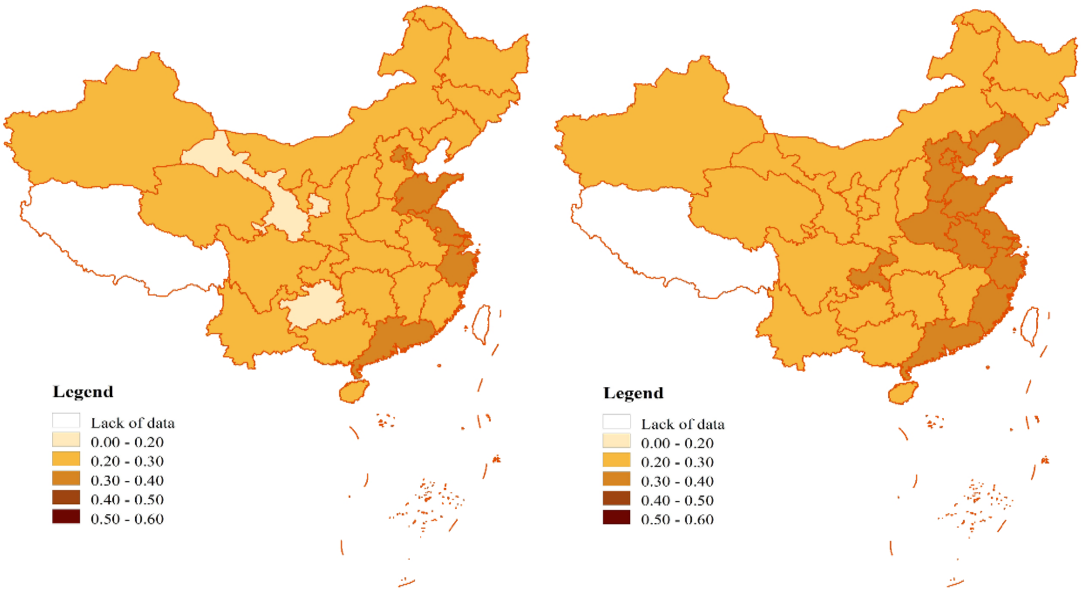


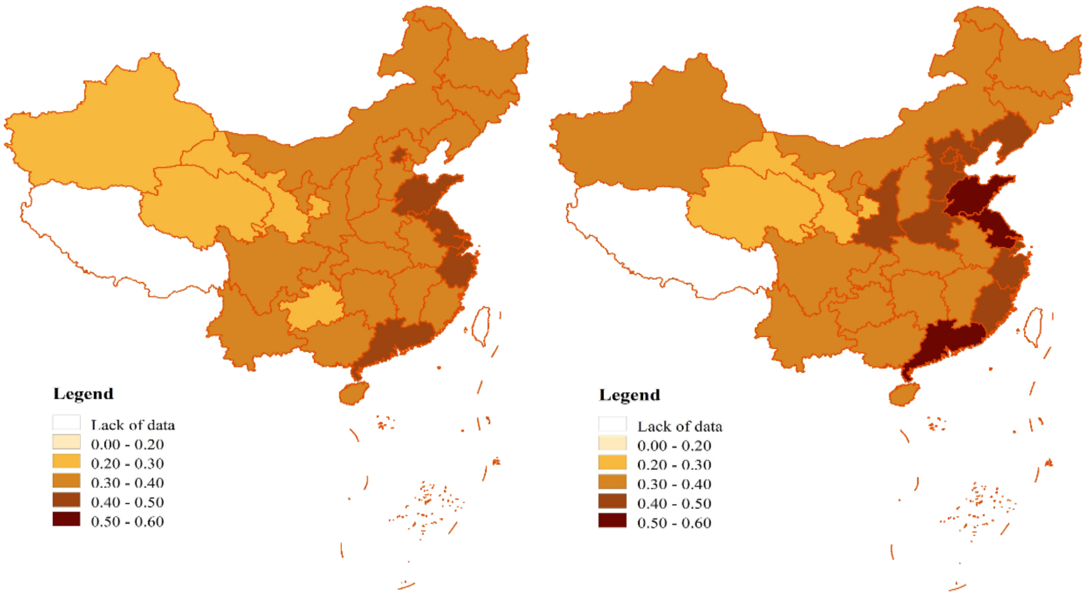
Fig. 3. The CCD between China's regional economy and transportation industry from 2004 to 2017.

The coupling coordination degree is obtained by Eqs. (8)-(10). The calculation results are shown in the Appendix C. The average level of CCD of 30 provinces during the surveyed period can be presented graphically in Fig. 3. The state of coordination changes from the verge of imbalance (0.2-0.3) to low-level coordination (0.3-0.4), which is a transitional periodshows. It shows that average CCD of regional economy and transportation industry has been increasing across the country during the surveyed period, but the growth rate is slower and the coordination degree is low.

4.2.2 The CCD between regional economy and transportation industry



(a) 2004 (b) 2008



(c) 2013 (d) 2017（图例增加划分解释）

Fig. 4. The spatial distribution of CCD in the 2004, 2008, 2013, and 2017.

To research the spatial distribution of regional economy and transportation industry coupling coordination state in China, this study applies ArcGIS to analysis the spatial layout and selects four cross-sectional years to show the developments and changes, namely 2004, 2008, 2013 and 2017(Fig. 4). The results can be obtained from the figure: (a) In 2004, Guizhou and Gansu are in incoordination state (0.00-0.20) and no province is at incoordination state in other years. (b) In 2004 and 2008, most provinces were on the verge of imbalance. By 2013 and 2017, the state of Low-level coordination and above accounted for the majority, and the overall development was on the rise. (c) From a spatial point of view, as the geographic location changes from the inland to coastal, the coordination status of regional economy and transportation industry gradually increase. In general, the coupling coordination statuses between regional economy and transportation industry of all provinces evolved from incoordination to high-level coordination during the surveyed period.

4.2.3 Regional economy and transportation industry development discrepancy

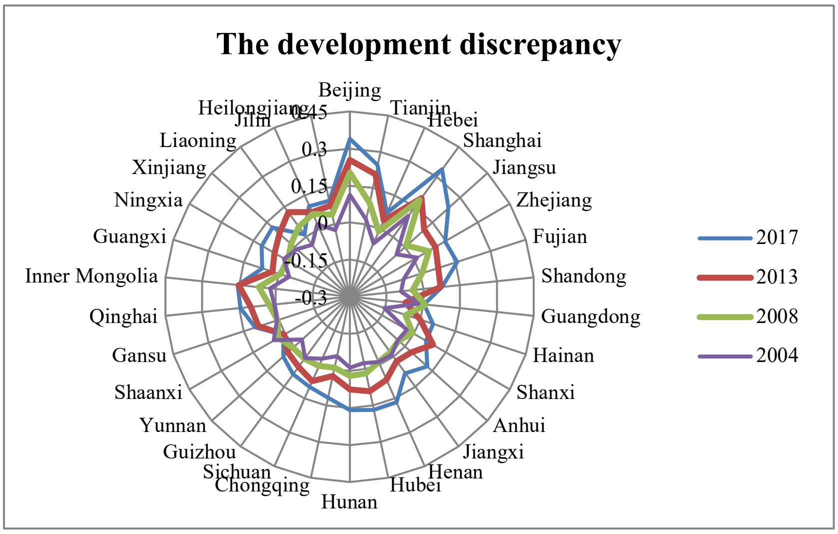


Fig. 5. The development discrepancy between the regional economy and transportation industry.

The development discrepancy between regional economy and transportation industry can evaluate whether the two are developing simultaneously (Fig. 5) (Zhang and Li, 2020; Liu et al., 2018; Tang, 2015). The results show that from 2004 to 2017, the development discrepancy between the two systems was growing, but the disparity in most provinces was still within 0.15. Especially in 2004 there was no difference greater than 0.15. In addition, the $E(u)-T(v)>0$ and $T(v)-E(u)>0$ coexists simultaneously. By 2017, there are no cases where $T(v)>E(u)$ in 2017. The difference in individual provinces is relatively large, Jiangsu and Tianjin are 0.23 and 0.24 respectively, and Beijing and Shanghai have reached 0.33, indicating that the economy of these regions is at an advanced level. The development discrepancy only in Guangdong, Shaanxi and Liaoning is close to zero, which indicates that the regional economy and transportation industry level in these areas are approach.

5 Discussions

5.1 Analysis the comprehensive level of regional economy and transportation industry

5.1.1 The analysis of main influencing factors

The main influencing factors can be obtained by analyzing the weight of the index system. In terms of regional economy, the economic development scale is the key factor to promote the economic development in China, which is consistent with the current actual development situation (see Table 1 and Table 2). The expansion of economic scale is a prerequisite for high-quality economic development, which can increase returns to scale and thereby achieve higher per capita economic output (Zhao et al., 2016). In terms of transportation industry, a significant observation in this paper is that transportation structure accounted for the highest factor (44%).It shows that the coordinated development of multiple transportation modes has a non-negligible impact on the development of transportation system. This conclusion is in line with the ultimate goal of China's transportation policy: development the comprehensive transportation.

5.1.2 The analysis of the comprehensive level of regional economy and transportation industry

From Fig. 1 and Fig.2, we can know that although the development level of China's regional economy and transportation industry continue to rise, the development quality is low. Therefore, it is necessary to effective improve the development quality of regional economy and transportation industry. The average annual growth rate of China's economy over the past 30 years is close to 10%, and the world share of GDP has rapidly increased from 2.7% to nearly 15% at present. Nevertheless, the problems such as imbalanced urban and rural development and excessive consumption of natural resources have appeared, which may be related to the allocation of urban and rural resources and the lack of green development concepts. Therefore, it is necessary to promote moderate transfer of resourcesto township areas to realize the linkage development of urban and rural areas. At the same time, we must establish the development concept of coexistence of economy and ecological environment protection to achieve sustainable development.

In terms of transportation industry, the rapid development of the transportation industry is mainly reflected in the substantial increase in transportation mileage and volume. From 2008 to 2018, the total mileage of various transportation routes (except aviation) increased from 4.0196 million kilometers to 5.3198 million kilometers, a growth rate of 32.36%. Passenger turnover increased from 2319.67 billion person-kilometers to 3241.82 billion person-kilometers, a growth rate of 39.75%; and freight turnover increased by 85.57%. However, it brings problems such as low transportation efficiency, high transportation cost and waste of transportation resources, which are inconsistent with the green and low-carbon development goals of the transportation industry. At present, the total amount of transportation CO_2 emissions is showing a rapid growth trend (Du et al., 2020). Only by adopting strong policies and measures can it be possible to peak carbon emissions around 2030 (Mahmoudi et al., 2019). To this end, the Chinese governmenthas promulgated *the Outline of Building a Powerful Country for Transportation* to promote sustainable and high-quality development of the transportation industry.

Fig. 1 and Fig.2 reveal that the development of the eastern region is superior to other regions in both economic system and transportation system. This is closely related to the special geographical location of the eastern region. Eastern cities near the ocean and have a gentle terrain, which can provide good conditions for industrial and agricultural development. Other regions especially the western regions are remote areas and ethnic minorities, with vast areas and sparse populations. Its relatively backward economic and transportation conditions eventually led to unbalanced regional development. At the same time, it is may related to the coexistence of aging and urbanization in Chinese cities. China's urbanization rate has risen from 26.41% in the 1990s to 59.58% in 2018, and the proportion of people over 65 years of age has risen from 5.57% in 1990 to 11.9% in 2018 (Kai, 2020). The aging population has reduced the labor productivity of society, the large-scale movement of youth labor to cities and developed regions will exacerbate the imbalance of regional development.

5.2 Analysis of coupling coordination degree

5.2.1 The analysis of average level of the coupling coordination degree in China

Fig. 3 analyzes the average level of the coupling coordination degree between regional economy and transportation industry in China. The result shows that the CCD between regional economy and transportation industry is rising. It reflects the deepening of the interaction between economic and transportation systems and increasing coordination. The increase in the construction of regional transportation infrastructure has promoted the development of the local transportation industry and boosted the local GDP (Farhadi, 2015). At the same time, the regional economic growth will increase the demand for transportation capacity, which could improve the transportation structure optimization within regions (Ng et al., 2017). Thus, the government planning needs to continue to strengthen the benign interaction between them in the future.

5.2.2 The analysis of the coupling coordination degree between regional economy and transportation industry

From spatial distribution of coupling coordination status between regional economy and transportation industry in China, the coupling coordination status of all provinces is evolving from Incoordination to High-level coordination. However, the CCD of the regional economy and transportation industry in different regions is uneven. The state of coordination across the country gradually decreases from east to west. The eastern region is in the best state of coordination. The central and northeastern regions have the same CCD, and the western region has the lowest CCD. In other words, although the regional economy and transportation industry is also developing, the degree of coordination is not high.

There are many reasons for this result. First, eastern region has a wealth of resources and high population density. Its economic development is at the leading level in the country, so this region has higher requirements for the transportation industry. Moreover, most of the eastern provinces are coastal, which have well-developed aviation and water transport. Lots of passenger and freight transportation are used to meet people’s living needs and commodity circulation, which provides impetus for economic development. There is still a large disparity between the development of the central and northeastern regions compared with the eastern region. In terms of transportation, the central and northeastern regions have not yet formed a comprehensive transportation network. The connection between various transportation modes is not strong enough. Therefore, the transportation in terms of operation or planning needs to be improved. Moreover, compared with the Beijing-Tianjin-Hebei and Yangtze River Delta Economic Zones in eastern, the central and northeast are currently just a regional concept and have not formed a complete economic zone. This has resulted in relatively independent development between regions, with a low degree of integration. The Western region has the lowest level of coordination. Due to the complex terrain and changing climate in the west, the transportation infrastructure construction has a longer period than other regions, which ultimately leads to the slow development of the transportation industry. In addition, the relative scarcity of resources and the insufficient construction of transportation infrastructure have also limited economic development, which is one of the important reasons for the low CCD between regional economy and transportation industry in Western region.

5.2.3 The analysis of the regional economy and transportation industry development discrepancy

Based on the analysis of Fig. 4 and Fig. 5, we found that the CCD in the eastern region is higher. The development disparity between regional economy and transportation industry is higher than in other regions. This phenomenon is most prominent in Beijing and Shanghai, which means the development of the transportation industry in Beijing and Shanghai has a significant hysteresis relative to the economic development. Beijing and Shanghai have good primitive economic foundations supported by resources and political factors. This advantage has been continuously exerted to make economic development more rapid. Nevertheless, economic development requires strong support from the transportation industry. Therefore, the transportation in Beijing and Shanghai has developed rapidly. However, some complex contradictions such as traffic congestion and low transportation efficiency have emerged. The probably reason is the urban planning and transportation planning are disconnect, which ultimately leads to the unsatisfactory CCD. For example, Beijing has made some huge progress in the construction of a mass transit-based public transportation system. However, Beijing is experiencing problems with the poor management of population, urban and rural land use and vehicle ownership beyond the overall planning control indicators. As a result, the supply-demand relationship of transportation is seriously unbalanced, and diseases in large cities, which are represented by urban traffic congestion, are becoming increasingly serious (Zhang, 2016).

In comparison, the development disparity between regional economy and transportation industry in Guangdong, Shaanxi, and Liaoning are close to zero, indicating that the two systems are in a similar state of development. Guangdong has the smallest development disparity and the highest CCD. As the largest province in China’s GDP, Guangdong’s huge export scale and port throughput have provided an indispensable support for its economic development. The study found that for every 10%

increase in the throughput of Guangdong ports, the GDP of the region increased 5% (Xie, 2014). At the same time, Guangzhou is also a hub port for the *21st Century Maritime Silk Road*, which also facilitates local economic development. Xi'an is the political, economic, cultural and transportation hub center of Northwest China. The rich tourism resources and the wide coverage transportation network not only made tremendous contributions to the development of economy and transportation in Shaanxi, but also promote the development of other cities in Shaanxi. Liaoning is a major part of *Northeast Revitalization*. At present, Liaoning has formed a high road grid bureau with highways as its main skeleton and a number of provincial, county, and village roads that are closely connected. The construction of ports including Dalian Port, Yingkou Port and Dandong Port make breakthrough progress. Passenger and freight transport capacity have been greatly improved. Based on this, although the regional economy and transportation industry development of Shaanxi and Liaoning are not at the leading level, but similar development conditions makes them have a higher coordination state.

In general, China's the regional economy development is usually faster than transportation development. However, this seems to be different from some current research results. Shen (2019) studied the coupling state of county-level highway traffic and economic development in Anhui Province, and obtained the concluded that the development of highway transportation in most counties (cities) is ahead of economic development. Meng (2012) studied the spatial coupling between transportation superiority and economy in Central plain economic zone. They believed that transportation infrastructure has developed ahead of schedule, but it did not fully play its role in supporting economic development. However, our research takes multiple modes of transportation as the research object, which is different with previous research. Therefore, the existing research differences also fully illustrate that although a separate transportation may be at a relatively good level of development, the coordinated development of China's multiple modes of transportation system is not perfect. Thus, the government needs to pay more attention on researching and planning.

6 Conclusions and policy implication

In the context of sustainable development, studies the CCD between the regional economy and transportation industry are critical for guiding transportation policy-making and high-quality economic development strategies. This study has evaluated the CCD between regional economy and transportation industry and analyzed the development disparity between the two systems. In addition, the CCD model and Entropy Method was used to quantitatively study the coordination relationship and spatial distribution between regional economy and transportation industry. Some results are obtained as follows:

First, China's regional economy and transportation industry are growing fast but lack of quality. In the economic development system, the economic development scale is the most influential indicator, and large-scale economic development can promote economic growth. In the transportation development system, the scale of transportation is the greatest impact indicators. Increasing transportation volume and infrastructure investment will help enhance regional competitiveness.

Second, the coordination status between regional economy and transportation industry in China is complex. Its CCD growth trend is changing from incoordination to High-level coordination, but the growth rate is slower. The imbalance of CCD levels between regions is significant. The CCD in the eastern region is slightly higher than that in the central, western and northeast regions.

Finally, we found that regional economic development is faster than transportation industry development, and each province have development disparity. Simultaneously, the development disparity of the four economic zones also have their own characteristics. In the eastern region with a higher CCD, the development discrepancy between economic development and transportation development is higher than that in other regions.

Based on the above findings, this study makes the following recommendations to promote the coordination relationship between regional economy and transportation industry:

- First of all, it is necessary to improve the development quality of the regional economy and transportation industry. While expanding the scale of production and operations, we must incorporate emerging technologies into development plans. Integrate smart operation and maintenance, smart construction, new infrastructure and other technologies into construction and development. In addition, strengthen the connection between various modes of transportation to ensure the construction of a comprehensive transportation system. This will promote the high quality and sustainable development of the economy and transportation.

- Secondly, it is essential to balance the CCD level of each region. It is necessary to give full play to the advantages of urban agglomerations and realize the leading role of priority development areas. Since the advantages of different regions are different, strengthening the construction of urban agglomerations and clarifying the positioning and characteristics of regional development. In this way, various regions can complement each other's advantages and reduce the waste of resources caused by blind investment and construction. In addition, the transportation planning and the city planning departments communicate in a timely manner when formulating development plans and policies, useless lines should not be built to increase operational mileage, lest economic and transportation development be separated.
- The third point is to narrow the development gap between the regional economy and the transportation industry through the rational allocation of resources. The first is the rational allocation of transportation resources (including human, material and financial resources). Reasonable transportation resource allocation can increase investment in transportation infrastructure and strengthen the overall function of the regional transportation system. The new demand for production factors will drive the development of related industries, thus stimulate the growth of the regional economic aggregate. Moreover, based on ensuring the development conditions of priority regions, we will appropriately tilt resources to backward regions. This can ensure that the development of infrastructure in backward areas is promoted as soon as possible.

This article focuses on the coordination development levels of regional economy and transportation industry. Although this article considers the differences of various transportation modes in the indicators, the accuracy of its measurement is limited. The application of emerging technologies in the future will continue to increase the complexity of the transportation industry. In this context, how to define the internal relationship between economy and transportation and rebuild the evaluation system will be the focus of research.

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Appendix

Appendix A

The comprehensive level of regional economy in 30 provinces from 2004 to 2017.

Province	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Beijing	0.339	0.375	0.399	0.438	0.428	0.453	0.475	0.493	0.509	0.531	0.558	0.604	0.637	0.659
Tianjin	0.201	0.244	0.254	0.270	0.296	0.316	0.352	0.376	0.392	0.421	0.447	0.482	0.513	0.501
Shanghai	0.362	0.390	0.403	0.431	0.426	0.445	0.484	0.489	0.491	0.513	0.551	0.594	0.637	0.649
Chongqing	0.127	0.137	0.146	0.176	0.179	0.186	0.223	0.249	0.244	0.264	0.300	0.328	0.351	0.362
Shanxi	0.106	0.149	0.169	0.147	0.170	0.165	0.198	0.210	0.227	0.240	0.249	0.265	0.276	0.275
Hebei	0.116	0.155	0.167	0.183	0.193	0.219	0.246	0.262	0.279	0.293	0.314	0.338	0.364	0.378
Liaoning	0.145	0.191	0.199	0.223	0.246	0.271	0.311	0.335	0.366	0.391	0.398	0.360	0.309	0.328
Jilin	0.114	0.147	0.157	0.181	0.195	0.208	0.222	0.241	0.253	0.253	0.261	0.276	0.288	0.283
Heilongjiang	0.108	0.129	0.142	0.146	0.171	0.175	0.202	0.222	0.228	0.245	0.249	0.255	0.273	0.285
Jiangsu	0.176	0.234	0.251	0.277	0.293	0.329	0.370	0.400	0.429	0.498	0.557	0.608	0.650	0.679
Zhejiang	0.222	0.269	0.288	0.305	0.307	0.334	0.368	0.388	0.408	0.439	0.476	0.521	0.554	0.573
Anhui	0.100	0.124	0.142	0.157	0.173	0.190	0.224	0.232	0.250	0.267	0.289	0.317	0.345	0.359
Fujian	0.147	0.182	0.198	0.218	0.226	0.244	0.274	0.294	0.309	0.335	0.364	0.397	0.428	0.457
Jiangxi	0.091	0.120	0.124	0.139	0.154	0.167	0.206	0.217	0.229	0.243	0.261	0.291	0.309	0.326
Shandong	0.159	0.217	0.238	0.247	0.268	0.299	0.331	0.352	0.381	0.424	0.469	0.514	0.565	0.574
Henan	0.101	0.141	0.155	0.171	0.180	0.204	0.234	0.243	0.267	0.304	0.337	0.373	0.406	0.431
Hubei	0.112	0.141	0.156	0.171	0.178	0.198	0.224	0.263	0.268	0.305	0.339	0.374	0.399	0.417
Hunan	0.135	0.147	0.154	0.171	0.179	0.199	0.225	0.249	0.257	0.285	0.315	0.351	0.371	0.394
Guangdong	0.220	0.261	0.271	0.294	0.299	0.323	0.353	0.363	0.381	0.411	0.444	0.486	0.519	0.545
Hainan	0.084	0.105	0.116	0.132	0.138	0.143	0.176	0.171	0.184	0.205	0.220	0.244	0.254	0.273
Sichuan	0.101	0.132	0.144	0.165	0.165	0.196	0.226	0.237	0.254	0.276	0.301	0.325	0.351	0.376

Guizhou	0.069	0.098	0.107	0.124	0.124	0.133	0.146	0.173	0.181	0.194	0.209	0.230	0.250	0.269
Yunnan	0.100	0.112	0.121	0.134	0.141	0.142	0.163	0.181	0.194	0.217	0.221	0.244	0.265	0.287
Shaanxi	0.124	0.132	0.146	0.165	0.172	0.186	0.214	0.246	0.240	0.266	0.291	0.306	0.319	0.357
Gansu	0.079	0.102	0.105	0.123	0.131	0.121	0.141	0.157	0.164	0.184	0.196	0.209	0.224	0.209
Qinghai	0.086	0.112	0.118	0.131	0.135	0.138	0.152	0.170	0.175	0.194	0.205	0.219	0.223	0.237
Inner Mongolia	0.110	0.167	0.170	0.206	0.220	0.245	0.258	0.283	0.298	0.322	0.357	0.348	0.365	0.337
Guangxi	0.085	0.114	0.122	0.133	0.145	0.164	0.186	0.195	0.213	0.228	0.246	0.267	0.286	0.295
Ningxia	0.094	0.122	0.130	0.142	0.149	0.159	0.185	0.203	0.199	0.214	0.225	0.243	0.255	0.268
Xinjiang	0.093	0.114	0.123	0.133	0.138	0.132	0.167	0.193	0.206	0.223	0.235	0.245	0.249	0.280

Appendix B

The comprehensive level of transportation industry in 30 provinces from 2004 to 2017.

Province	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Beijing	0.226	0.221	0.215	0.213	0.226	0.236	0.260	0.273	0.266	0.278	0.286	0.308	0.314	0.320
Tianjin	0.181	0.193	0.191	0.173	0.208	0.181	0.189	0.195	0.190	0.214	0.211	0.222	0.230	0.254
Shanghai	0.257	0.252	0.245	0.240	0.241	0.235	0.296	0.307	0.317	0.318	0.333	0.308	0.307	0.311
Chongqing	0.181	0.190	0.190	0.181	0.185	0.184	0.211	0.210	0.212	0.236	0.226	0.231	0.238	0.244
Shanxi	0.138	0.123	0.138	0.147	0.176	0.132	0.139	0.143	0.151	0.150	0.153	0.161	0.165	0.217
Hebei	0.179	0.187	0.185	0.187	0.203	0.198	0.219	0.244	0.256	0.255	0.263	0.271	0.279	0.306
Liaoning	0.186	0.188	0.178	0.197	0.198	0.212	0.242	0.261	0.271	0.269	0.276	0.300	0.307	0.317
Jilin	0.091	0.081	0.083	0.083	0.128	0.129	0.141	0.152	0.163	0.178	0.180	0.178	0.180	0.182
Heilongjiang	0.133	0.125	0.113	0.115	0.130	0.122	0.139	0.154	0.166	0.169	0.182	0.188	0.189	0.186
Jiangsu	0.218	0.240	0.252	0.272	0.283	0.280	0.354	0.382	0.392	0.391	0.399	0.408	0.419	0.441
Zhejiang	0.205	0.211	0.220	0.232	0.236	0.262	0.321	0.326	0.327	0.338	0.355	0.381	0.409	0.426
Anhui	0.137	0.135	0.134	0.141	0.204	0.202	0.218	0.230	0.233	0.232	0.233	0.231	0.234	0.237
Fujian	0.217	0.222	0.219	0.217	0.218	0.224	0.242	0.248	0.253	0.259	0.270	0.283	0.292	0.299

Jiangxi	0.100	0.095	0.101	0.112	0.175	0.167	0.182	0.193	0.215	0.220	0.214	0.216	0.218	0.244
Shandong	0.250	0.269	0.274	0.279	0.311	0.298	0.347	0.361	0.368	0.353	0.383	0.418	0.452	0.498
Henan	0.113	0.113	0.121	0.146	0.192	0.207	0.221	0.231	0.244	0.236	0.253	0.251	0.259	0.263
Hubei	0.138	0.134	0.126	0.127	0.160	0.178	0.196	0.202	0.212	0.214	0.228	0.239	0.238	0.250
Hunan	0.148	0.149	0.193	0.149	0.159	0.153	0.186	0.197	0.211	0.211	0.220	0.225	0.230	0.235
Guangdong	0.239	0.251	0.252	0.289	0.291	0.298	0.420	0.454	0.487	0.484	0.508	0.516	0.541	0.542
Hainan	0.235	0.241	0.206	0.203	0.200	0.193	0.204	0.223	0.217	0.205	0.205	0.208	0.209	0.216
Sichuan	0.127	0.134	0.138	0.142	0.158	0.159	0.179	0.187	0.200	0.203	0.226	0.240	0.256	0.278
Guizhou	0.061	0.071	0.081	0.098	0.115	0.103	0.111	0.123	0.133	0.143	0.155	0.162	0.173	0.181
Yunnan	0.142	0.132	0.140	0.133	0.131	0.139	0.158	0.169	0.175	0.180	0.189	0.203	0.213	0.225
Shaanxi	0.071	0.076	0.086	0.094	0.139	0.163	0.196	0.211	0.240	0.259	0.285	0.301	0.323	0.347
Gansu	0.070	0.070	0.078	0.096	0.125	0.110	0.104	0.110	0.119	0.096	0.098	0.099	0.103	0.106
Qinghai	0.080	0.078	0.080	0.071	0.108	0.107	0.110	0.112	0.107	0.091	0.093	0.093	0.094	0.094
Inner Mongolia	0.087	0.086	0.091	0.100	0.150	0.140	0.159	0.173	0.187	0.171	0.177	0.177	0.197	0.181
Guangxi	0.128	0.121	0.121	0.119	0.149	0.157	0.173	0.188	0.198	0.199	0.204	0.209	0.215	0.224
Ningxia	0.087	0.087	0.086	0.095	0.161	0.169	0.170	0.186	0.191	0.163	0.161	0.164	0.159	0.156
Xinjiang	0.106	0.101	0.106	0.113	0.120	0.120	0.133	0.131	0.143	0.140	0.147	0.154	0.160	0.160

Appendix C

The CCD of regional economy and transportation industry in 30 provinces from 2004 to 2017.

Province	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Beijing	0.374	0.377	0.378	0.383	0.391	0.399	0.413	0.422	0.421	0.428	0.434	0.450	0.457	0.462
Tianjin	0.309	0.328	0.330	0.325	0.351	0.342	0.354	0.362	0.362	0.378	0.380	0.390	0.399	0.409
Shanghai	0.392	0.393	0.392	0.395	0.397	0.397	0.430	0.435	0.439	0.441	0.453	0.448	0.454	0.457
Chongqing	0.274	0.285	0.290	0.299	0.302	0.304	0.329	0.337	0.336	0.352	0.356	0.365	0.373	0.378
Shanxi	0.245	0.260	0.275	0.271	0.294	0.271	0.286	0.291	0.301	0.303	0.306	0.314	0.319	0.346

Hebei	0.267	0.292	0.297	0.304	0.315	0.322	0.340	0.355	0.365	0.368	0.376	0.385	0.394	0.408
Liaoning	0.285	0.307	0.306	0.323	0.331	0.344	0.368	0.382	0.394	0.397	0.401	0.402	0.392	0.401
Jilin	0.226	0.232	0.236	0.243	0.279	0.283	0.294	0.306	0.315	0.322	0.324	0.326	0.329	0.329
Heilongjiang	0.244	0.252	0.251	0.253	0.272	0.268	0.287	0.301	0.309	0.314	0.322	0.326	0.331	0.332
Jiangsu	0.312	0.344	0.355	0.371	0.379	0.388	0.425	0.442	0.452	0.465	0.479	0.490	0.500	0.512
Zhejiang	0.327	0.344	0.353	0.362	0.366	0.383	0.413	0.420	0.425	0.435	0.448	0.465	0.481	0.490
Anhui	0.241	0.255	0.262	0.272	0.307	0.314	0.332	0.340	0.347	0.351	0.357	0.362	0.370	0.374
Fujian	0.297	0.318	0.324	0.330	0.333	0.341	0.358	0.366	0.372	0.380	0.391	0.403	0.412	0.421
Jiangxi	0.218	0.230	0.236	0.249	0.287	0.289	0.310	0.319	0.332	0.339	0.341	0.349	0.354	0.370
Shandong	0.314	0.349	0.358	0.363	0.381	0.386	0.412	0.422	0.432	0.437	0.456	0.477	0.497	0.513
Henan	0.231	0.250	0.260	0.280	0.305	0.321	0.337	0.344	0.357	0.363	0.377	0.384	0.394	0.400
Hubei	0.249	0.262	0.264	0.269	0.290	0.305	0.322	0.337	0.343	0.352	0.367	0.379	0.382	0.392
Hunan	0.265	0.272	0.295	0.281	0.290	0.294	0.318	0.331	0.339	0.346	0.357	0.367	0.373	0.380
Guangdong	0.338	0.358	0.361	0.382	0.384	0.393	0.441	0.453	0.467	0.475	0.490	0.502	0.516	0.521
Hainan	0.261	0.285	0.281	0.290	0.290	0.290	0.309	0.315	0.318	0.320	0.325	0.333	0.336	0.344
Sichuan	0.237	0.258	0.265	0.275	0.284	0.295	0.315	0.322	0.334	0.340	0.357	0.368	0.381	0.396
Guizhou	0.180	0.203	0.215	0.233	0.244	0.240	0.251	0.267	0.276	0.285	0.296	0.306	0.316	0.326
Yunnan	0.243	0.247	0.256	0.258	0.260	0.265	0.283	0.295	0.303	0.312	0.318	0.330	0.341	0.352
Shaanxi	0.218	0.222	0.234	0.246	0.278	0.294	0.319	0.336	0.346	0.362	0.379	0.389	0.401	0.419
Gansu	0.193	0.205	0.212	0.232	0.252	0.240	0.244	0.254	0.262	0.252	0.256	0.259	0.265	0.264
Qinghai	0.204	0.215	0.218	0.216	0.245	0.245	0.252	0.260	0.258	0.251	0.254	0.256	0.258	0.261
Inner Mongolia	0.222	0.243	0.246	0.263	0.300	0.301	0.314	0.328	0.339	0.334	0.345	0.341	0.355	0.340
Guangxi	0.227	0.243	0.246	0.250	0.271	0.283	0.299	0.309	0.320	0.324	0.332	0.340	0.347	0.354
Ningxia	0.213	0.226	0.228	0.238	0.279	0.286	0.297	0.311	0.312	0.303	0.304	0.310	0.310	0.311
Xinjiang	0.222	0.231	0.238	0.247	0.253	0.251	0.271	0.279	0.290	0.292	0.299	0.305	0.309	0.317