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Analysis of Spatiotemporal Evolution of Coordinated Development Between Transportation Infrastructure and Ecological Environment in the Yangtze River Economic Belt

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Abstract: The coupling and coordinated development of transportation infrastructure and ecological environment is an important way to achieve win-win economic, social, and ecological benefits. This study analyzes the coupling and coordinated development between transportation infrastructure and ecological environment in the Yangtze River Economic Belt. Based on panel data from 11 provinces in the Yangtze River Economic Belt from 2007 to 2022, establish their respective indicator systems and use entropy method to measure the comprehensive level of the two. Through the perspective of spatiotemporal differentiation, this study analyzes the changes in the coupling and coordinated development level of transportation infrastructure and ecological environment in 11 provinces. It is found that the overall coupling and coordinated development level of each province has significantly improved, but there are obvious regional differences. In the future, each province should formulate more precise and effective policy measures based on its own actual situation, strengthen regional cooperation and communication, and jointly promote the coupling and coordinated development of transportation infrastructure and ecological environment protection in the Yangtze River Economic Belt.
Keywords: the Yangtze River Economic Belt, transport construction, ecological protection, coupling coordinated development

1. Introduction

The Yangtze River Economic Belt is one of the most important strategic areas in China. Environmental protection is becoming more and more important with the rapid development of transportation infrastructure. How to protect the ecological environment while promoting the construction of transportation infrastructure has become an important issue to be solved. Environmental protection and transportation infrastructure have complex interaction. On the one hand, the construction and operation of transport infrastructure have certain impact on the ecological environment, such as land use change, environmental pollution, etc. On the other hand, the state of the ecological environment in turn affects the layout, construction and efficient use of transport infrastructure. Therefore, it is of great significance for the Yangtze River Economic Belt to realize the coordinated growth of transportation infrastructure and ecological environment.

The construction of transportation infrastructure can improve regional transportation accessibility and promote economic development. Economic development often drives more resources to be invested in ecological and environmental protection, such as improving the research and application of environmental protection technologies, and promoting the development of green industries. Meanwhile, the improvement of the ecological environment can also provide better natural conditions and ecological support for the construction of transportation infrastructure, reduce construction costs, and improve construction efficiency. However, the construction of transportation infrastructure may have certain impacts on the ecological environment, such as land occupation, energy consumption, pollution emissions, etc. These impacts may disrupt ecological balance, reduce environmental quality, and thus constrain the sustainable development of transportation infrastructure. Therefore, in the process of transportation infrastructure construction, it is necessary to fully consider ecological environment protection, adopt scientific and reasonable planning, design, construction, and operation management measures, and reduce the impact on the environment.

This coupled and interactive relationship requires mutual coordination and promotion between the two in the development process, achieving common development. The development of transportation infrastructure is an important driving force for the economic and social development of the Yangtze River Economic Belt. By improving the transportation network and enhancing the quality and efficiency of transportation facilities, it can promote economic connections and cooperation between provinces and cities along the Yangtze River Economic Belt, and promote coordinated development of regional economy. This development can not only drive the prosperity of related industries, but also improve resource allocation efficiency, optimize industrial layout, and lay a solid foundation for the sustainable development of the Yangtze River Economic Belt. The coupling and coordinated development between transportation infrastructure and ecological environment protection in the Yangtze River Economic Belt requires the comprehensive application of measures such as scientific planning, rational layout, strengthened protection and restoration, policy support, and technological innovation to achieve mutual promotion between transportation development and ecological environment protection.

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2 Literature Review

In the study of the Yangtze River Economic Belt,Feng Jun proposed that the Yangtze River Economic Belt is the main front of the great modernization of China[1]. Li Lu et al. suggested that the Yangtze River Economic Belt should develop in a high quality way[2].

With respect to the Transportation Infrastructure Study,When Yang Dongwei et al. studies Hainan's ecological environment, tourism traffic and star hotels, he thinks that the level of coordination is still at a low level because of the restriction of traffic lag[3]. Xiao Ting thought that the construction of transportation infrastructure is changing with each passing day, so we should further strengthen the construction of infrastructure to maintain the balanced and stable development among various regions[4]. Pfutze et al. point out that urban transport has a significant impact on family welfare and helps drive economic consumption[5]. Smith believed that sustainable development of transport construction requires policy support[6].

Environmental protection research,in the context of ecological development, Huang Zixuan et al. have scientifically measured the harmonious relationship between tourism economy and ecological environment. It is proposed to further enhance the accessibility of tourism destinations, rationally plan land and other ecological resources, and strengthen the protection and development of land ecosystems with high leisure cultural services and support services such as forest resources and natural wetlands[7]. Chen Xingyu et al studied the dilemma of ecological environment synergetic governance in the Yangtze River Delta, and put forward some optimized approaches[8]. Xue Ding et al proposed that the ecological environment has a typical regional dependence, with the strengthening of economic development, the protection of ecological environment is more in the middle level[9].Chunting Liu et al pointed out that ecological environment has important influence on regional sustainable development, and regional cooperation should be strengthened to cope with the adverse effects of ecological environment change[10]. Zoican et al considered that the variation of ecological environment would have a significant impact on agricultural production.Attention should be paid to greenhouse gas monitoring and ecosystem protection should be strengthened[11].

On the coordinated development of transportation and the environment. Taking Chengdu-Chongqing Economic Circle as an example, Ren Xiaohong et al analyzed the coordinated development of transportation, population, economy and environment, and believed that coordinated development requires a longer period of complementarity[12]. Wang Zhaofeng et al constructed a coupling coordination model of regional tourism resources, transportation network and ecological environment, and proposed that strengthening the complementary advantages will help the development of tourism, transportation and environment[13]. Xiao Hong pointed out that the harmony between communication and transportation and ecological environment is conducive to the development of local economic advantages and the promotion of internal and external synergy[14].Taking the Guanzhong Plain as an example, Da Cheng et al analyzed the coupling and coordinated development of transportation, industry and environment, and proposes that we should adhere to the concept of sustainable development, and pay attention to environmental protection while increasing the construction of transportation infrastructure[15]. Zhang Nian et al proposed to optimize communication and transportation net, reduce the damage and consumption of communication and transportation industry to the ecological environment, realize the protection in the development, develop in the protection[16]. Yuan Wang et al thought that the coupling coordinated development key lies in both sustainable development, as well as regarding the economic development promotion function[17]. Han Ruiling et al proposed that attention should be paid to the adverse effects on the atmospheric environment during the development of urban transportation and strengthen the construction of vegetation greening[18].

Domestic and foreign scholars have conducted extensive research on the relationship between transportation infrastructure and Ecological Environmental protection, but there is a lack of in-depth discussion on the coupling and coordinated development mechanism between the two. Therefore, this study aims to take the Yangtze River Economic Belt as an example to analyze the relationship between transportation infrastructure and Ecological Environmental protection. Based on the data collected from the transportation infrastructure and ecological environment of the Yangtze River Economic Belt, the relationship between them is analyzed. At the same time, combined with the actual situation of the Yangtze River Economic Belt, this paper discusses some regional disparities of the transport infrastructure and Ecological Environmental protection, and puts forward some pertinent policies and suggestions. Through this study, it is expected to deepen the understanding of the relationship between the Yangtze River Economic Belt traffic infrastructure and Environmental protection, to provide theoretical support for promoting the Yangtze River Economic Belt to develop high-quality, and to provide reference for the coordinated growth of traffic and ecological environment in other regions.

This article is based on panel data from 11 provinces in the Yangtze River Economic Belt, including Shanghai, Jiangsu, Zhejiang, Anhui, Jiangxi, Hunan, Hubei, Chongqing, Sichuan, Yunnan, and Guizhou, for a total of 16 years from 2007 to 2022.The data sources are mainly Rui Si database and statistical yearbooks of all provinces. The map data is based on the standard maps of the national geographic information resource directory service system. The map number is GS (2016) 2556, and the base map is not modified. Some missing values are interpolated.

3 research methodology

3.1 entropy evaluation method

The collected data are processed using the entropy method, and the specific steps are as follows:

Step 1, Data Matrix, $A=\begin{pmatrix} X_{11} & \cdots & X_{1m} \\ \vdots & \vdots & \vdots \\ X_{n1} & \cdots & Xnm \end{pmatrix}$, Where X_{ij} is the value of the j indicator of the i program.

Step 2, non-negative numbering of the data,
For bigger is better metrics:

$$X_{ij} = \frac{x_{ij} - \min(X_{1j}, X_{2j}, X_{3j}, \cdots, X_{nj})}{\max(X_{1j}, X_{2j}, X_{3j}, \cdots, X_{nj}) - \min(X_{1j}, X_{2j}, x_{3j}, \cdots X_{nj})} + 1$$

For indicators as small as possible:

$$\mathrm{X}_{ij} = \frac{\max(X_{1j}, X_{2j}, X_{3j}, \cdots, X_{nj}) - X_{ij}}{\max(X_{1j}, X_{2j}, X_{3j}, \cdots, X_{nj}) - \min(X_{1j}, X_{2j}, X_{3j}, \cdots, X_{nj})} + 1$$

Among them $i = 1,2,\cdots,n \;\; j = 1,2,\cdots m$.

Step 3, calculate the proportion of the i option under the j indicator to that indicator, $\mathrm{P}_{ij} = \frac{X_{ij}}{\sum_{i=1}^{n} X_{ij}} (j = 1,2,3\cdots m)$.

Step 4. The entropy of Item j is calculated, $e_j = -k * \sum_{i=1}^{n} P_{ij} \log(P_{ij})$,among them $k > 0$, $\ln$ is a natural logarithm, $e_j \geq 0$ .The constant k in the formula is related to the number of samples m ,General order $k = \frac{1}{\ln m}$,then $0 \leq e \leq 1$.

Step 5. Calculating the coefficient of difference of Item j , For indicator j ,The greater the difference in indicator values X_{ij} ,The greater the effect on scheme evaluation, the smaller the entropy value. $g_j = 1 - e_j$, the bigger g_j is, the more important item is.

Step 6. Find the weights, $\mathrm{W}_j = \frac{g_j}{\sum_{j=1}^{m} g_j}, j = 1,2,3\cdots m$.

Step 7. A combined score for each scheme is calculated, $\mathrm{S}_i = \sum_{j=1}^{m} W_j * P_{ij} (i = 1,2,3,\cdots n)$.

3.2 Calculation method of coupling coordination degree

Using the following coupling degree model for coupling coordination analysis, $\mathrm{C} = \frac{\mathrm{U}_1 * \mathrm{U}_2}{[(\mathrm{U}_1 * \mathrm{U}_2)/2]^{1/2}}$, C indicates the degree of coupling, $U1$, $U2$ respectively represent the comprehensive scores of transportation infrastructure and ecological environment protection, And use the coupling coordination model to analyze the coordinated development between various indicators. $\mathrm{T}(\mathrm{U}_1, \mathrm{U}_2) = \beta_1 \mathrm{U}_1 + \beta_2 \mathrm{U}_2$, $\mathrm{D}(\mathrm{U}_1, \mathrm{U}_2) = \sqrt{\mathrm{C}(\mathrm{U}_1, \mathrm{U}_2) * \mathrm{T}(\mathrm{U}_1, \mathrm{U}_2)}$, among them, T represents the comprehensive contribution index between multiple indicators, D representing coupled co scheduling, β is an exponential weight. Due to the equal status of transportation infrastructure construction and ecological environment protection, so $\beta_1 = \beta_2 = 0.5$.

And classify the score of coupling coordination into the following levels:

Table 1 Coupled Co scheduling

Index	(0,0.2)	[0.2,0.4)	[0.4,0.6)	[0.6,0.8)	[0.8,1)
Standard	Low coordination	Moderate coordination	Good coordination	Better coordination	Best coordination

3.3 Moran index method

Using Moran's index to analyze the spatial autocorrelation of the coupling and coordinated development level of transportation infrastructure and ecological environment in the Yangtze River Economic Belt, in order to observe whether

the coupling and coordinated development level of the Yangtze River Economic Belt is similar to the observed values of neighboring provinces. The calculation formula is as follows:

$$I = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}(Y_i - \bar{X})(Y_j - \bar{X})}{S^2 \sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}}, S^2 = \frac{1}{n}\sum_{i=1}^{n}(Y_i - \bar{Y})^2, Y_i$$ represents the observations of the i province, n is the total number of provinces, W_{ij} is the element of row i column j of the spatial weight matrix.

The value of Moran's index is between [-1, 1], less than 0 indicates negative correlation, equal to 0 indicates uncorrelated, greater than 0 indicates positive correlation, and the closer it is to -1, the greater the difference between provinces and the less concentrated the distribution; The closer it is to 1, the closer the relationship between provinces is, and closer to 0, the unrelated provinces are.

4 Research Finding

4.1 Transportation infrastructure evaluation

The Yangtze River Economic Belt is an important economic corridor in China. Through improving the traffic net, we can strengthen the economic relation and cooperation among the provinces and cities along the Yangtze River Economic Belt. Referring to the research proposed by He Xionglang et al [19] and Lu Yuanquan et al [20], the following 20 evaluation indicators are established from the four dimensions of transportation infrastructure construction and investment, traffic flow and transportation efficiency, traffic management and service level, and transportation planning and development.

These indicators include not only the construction scale and investment of transportation facilities, but also the operating capacity and transportation efficiency, and also take into account the government investment and social ownership, which can reflect the comprehensive level of transportation infrastructure construction in multiple dimensions and in an all-round way. It is helpful to comprehensively and objectively evaluate the development status and future potential of transportation infrastructure.Among them, the amount of fixed assets investment directly reflects the city's investment in traffic infrastructure construction, the area of urban road traffic facilities construction land and the number of overpasses, The number of urban bridges and other indicators reflect the perfection of the urban road traffic network, the length of the installed street lamp road is closely related to traffic safety, they not only affect the fluency of traffic operation, but also directly related to the travel safety of the public. Road freight traffic, road passenger traffic, road cargo turnover, road passenger turnover, the number of motor vehicle drivers, the number of road transport vehicles and other indices directly reflect the transport capacity and efficiency of transport infrastructure. The expenditure of communication and transportation in the final accounts of local public finance and the ownership of public transport vehicles per ten thousand urban residents reflect the government's investment in the cause of communication and transportation, which helps to understand the government's policies and financial support in the construction of transportation infrastructure. Air postal length, inland waterway mileage, railway business mileage, class highway mileage, highway mileage, first class highway mileage and other indicators provide the development of different modes of transport and coverage.

Table 2 Index system of transportation infrastructure construction in the Yangtze River Economic Belt

Criterion layer	Index	Effect
Transportation Infrastructure Construction and Investment	Investment in Fixed Assets of Roads and Bridges in Construction of Municipal Public Facilities	Positive
	Land of construction of urban traffic facilities	Positive
	Number of overpasses	Positive
	Number of urban bridges	Positive
	Installation of street lights Length of road	Positive
Traffic flow and transport efficiency	Road freight volume	Positive
	Highway passenger traffic	Positive
	Turnover of freight traffic by waterway	Positive
	Road turnover of freight traffic	Positive
	Road turnover of passenger traffic	Positive
	Motor Vehicle Operators	Positive
	Number of Road Transport Vehicles	Positive
Traffic Management and Service Level	Communication and transportation expenditure in local public finance final accounts	Positive
	Public transport vehicles per 10,000 inhabitants	Positive
Transportation Planning and Development	Air mail route length	Positive
	Length of inland waterway	Positive
	Railway operating mileage	Positive
	Mileage of classified highways	Positive
	Length of expressway	Positive
	Mileage of first class highway	Positive

The comprehensive level of transport infrastructure construction in the 11 provinces of the Yangtze River Economic Belt is calculated by the entropy-based method as follows:

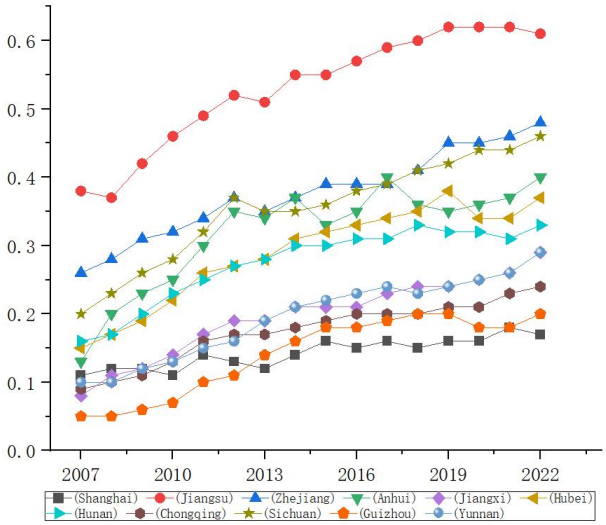


Figure 1 Evolution of comprehensive level of transportation infrastructure construction

From 2007 to 2022, the level of Jiangsu, Zhejiang and Sichuan increased rapidly, Chongqing, Hubei, Anhui, Hunan, Jiangxi and Yunnan were medium, and Guizhou and Shanghai were relatively low. The variation of the comprehensive level of transportation infrastructure construction in the 11 provinces of the Yangtze River Economic Belt reflects the differences and advantages of different provinces in terms of economic growth, geographical location and political support. Jiangsu is one of the most important economic provinces in China, and its sustained and rapid economic growth provides a solid financial support for the construction of transportation infrastructure.Zhejiang's private economy is developed, enterprise investment is active, and it also provides strong financial support for the construction of transportation infrastructure. Sichuan is an important province in the western region, which has been supported by the national strategy of developing the western region, and has promoted the construction of transportation infrastructure. Relatively speaking, Guizhou and other provinces are located in mountainous areas, the geographical environment is complex, the difficulty of transport infrastructure construction is greater, affecting the construction of transport infrastructure. Shanghai's transportation infrastructure construction has been relatively complete, so the improvement in the comprehensive level may not be as obvious as other provinces.

4.2 Ecological Environment Evaluation

The Yangtze River Economic Belt has abundant natural resources and ecosystems. By studying its level of ecological environment protection, we can gain a deeper understanding of the current ecological situation, formulate and implement targeted protection measures. The ecological environment is also an important foundation for sustainable economic and social development. By improving the level of ecological environment protection in the Yangtze River Economic Belt, we can ensure that economic development is coordinated with the ecological environment, achieve a development model of resource conservation and environmental friendliness, reduce environmental pollution and ecological damage, and enhance the happiness and satisfaction of residents.Referring to the research of Hu Angang et al[21] and Wang Zhaofeng et al[22], develop the following 20 evaluation indicators from four dimensions: environmental protection investment and construction, environmental quality and pollution control, natural resources and ecological protection, urban greening and sanitation.

Among them, the environmental protection expenditure in local financial final accounts directly reflects the government's investment in ecological environment protection. Indicators such as fixed assets investment in landscaping and investment in forestry and grassland reflect the investment and attention of cities in landscaping and ecological construction. The emission indicators of pollutants such as ammonia nitrogen emissions, sulfur dioxide emissions, and average PM2.5 concentration are directly related to air and water quality, and are key indicators for evaluating the degree of environmental pollution and the effectiveness of environmental quality improvement.Forest coverage, total standing timber volume, area of national nature reserves, area of artificial forests, and number of nature reserves reflect the protection status and biodiversity of natural ecosystems. Indicators such as soil erosion area, per capita water resources, and ecological water consumption are related to the sustainable use of land resources and the protection of water resources. Indicators such as per capita public green space area, green coverage rate of built-up areas, number of urban parks, and total number of urban sanitation machinery reflect the construction and management level of the city in public space and sanitation facilities. Indicators such as garbage harmless treatment capacity and sewage treatment rate reflect the city's ability and efficiency in pollutant treatment and resource utilization.

Table 3 Environmental protection index system of the Yangtze River Economic Belt

Criterion layer	Index	Effect
Environmental	Environmental protection expenditure in local public finance final accounts	Positive

Protection Investment and Construction	Investment in Fixed Assets of Landscaping in Construction of Urban Municipal Public Facilities	Positive
	Forestry and grassland investment	Positive
Environmental Quality and Pollution Control	Ammonia nitrogen discharge	negative
	Sulphur dioxide emissions	negative
	Average PM2.5 concentration	negative
Natural Resources and Ecological Conservation	Forest coverage	Positive
	Total volume of standing timber	Positive
	Area of National Nature Reserve	Positive
	Artificial forest area	Positive
	Number of nature reserves	Positive
	Soil erosion area	negative
	Per capita water resources	Positive
	Ecological water consumption	Positive
Urban afforestation and greening	Per capita public green space area in cities	Positive
	Green coverage rate in built-up areas	Positive
	Number of urban parks	Positive
	Total number of urban sanitation machinery	Positive
	Harmless treatment capacity of garbage	Positive
	Sewage treatment rate	Positive

The comprehensive level of ecological and environmental protection in the Yangtze River Economic Belt is calculated using the entropy method, which is the same as the evaluation method for the construction level of transportation infrastructure mentioned earlier, as shown in the figure below:

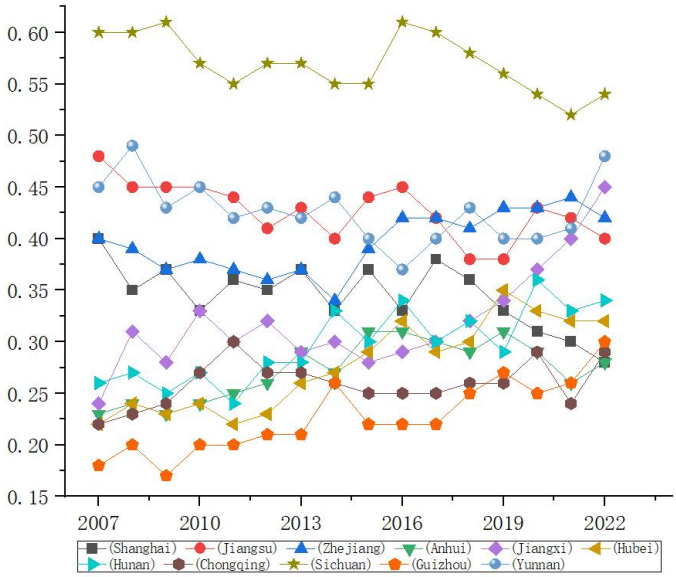


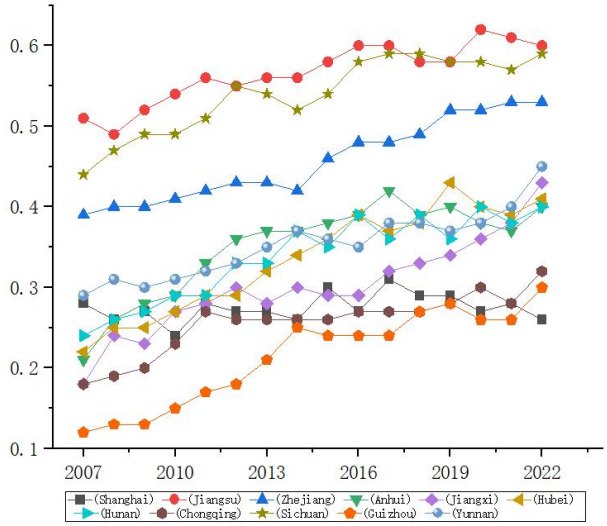
Figure 2 Evolution of Comprehensive Level of Ecological Environment Protection

When the comprehensive level of ecological environment protection in the 11 provinces of the Yangtze River Economic Belt changed from 2007 to 2022, Sichuan, Yunnan, Jiangsu, Zhejiang, and Jiangxi were relatively high, while Chongqing, Guizhou, Hunan, Hubei, Anhui, and Shanghai were relatively low. Sichuan, Yunnan, Jiangxi and other regions have abundant natural resources and diverse ecological environments, and their ecosystems are relatively stable, providing them with a high ecological foundation. Economically developed provinces such as Jiangsu and Zhejiang may pay more attention to the development of green industries while developing their economies, reducing the proportion of high polluting and high-energy consuming industries, thereby reducing the damage to the ecological environment.Chongqing, Guizhou, Hunan, Hubei, Anhui and other regions may be in a stage of rapid economic development, with rapid industrialization and urbanization processes, which have put certain pressure on the ecological environment. Compared to economically developed provinces, these provinces may have insufficient investment in environmental protection, leading to lagging construction of environmental protection facilities and insufficient environmental governance capabilities. The reason for the low comprehensive level of ecological and environmental protection in Shanghai may be related to factors such as urban size and population density.

4.3 Analysis of coupling coordination degree

Based on the analysis of the coupled co scheduling model, the coupling coordination index between transportation infrastructure and ecological environment in the Yangtze River Economic Belt is obtained as shown in the figure below.

Figure 3 Coupling Coordination of Transportation Infrastructure Construction and Ecological Environment Protection in the Yangtze River Economic Belt



From 2007 to 2022, overall, each province showed an upward trend, with Jiangsu, Zhejiang, and Sichuan provinces showing a more prominent coupling index between transportation infrastructure construction and ecological environment protection in the Yangtze River Economic Belt compared to other provinces.

Using ArcGIS software natural breakpoint classification method, analyze the spatiotemporal evolution of coupling coordination degree in 11 provinces of the Yangtze River Economic Belt.

Figure 4 Distribution of coupled and coordinated development levels in 2007

Figure 5 Distribution of coupled and coordinated development levels in 2022

From 2007 to 2022, provinces such as Sichuan, Zhejiang, and Jiangsu have shown significant improvements in coupling coordination, with Yunnan, Hubei, Hunan, Jiangxi, and Anhui being in the middle, while Chongqing, Guizhou, and Shanghai have lower levels. There are regional differences in the coupling between transportation infrastructure construction and ecological environment protection in the Yangtze River Economic Belt, which are closely related to factors such as economic development level, resource endowment, and geographical location in different regions. Economically developed provinces often have more funds invested in transportation infrastructure construction and ecological environment protection, thereby promoting the coupling development between the two. There may also be

differences in the priority and strategy of ecological environment protection and transportation construction among different provinces, which further affects the performance of coupling coordination. The phenomenon of regional differences does not mean that certain provinces are in a backward position in the coupling development of transportation and environmental protection. Each province has its unique development conditions and challenges, and the key is to formulate appropriate development strategies and policy measures based on its own situation, promoting the coordinated development of transportation infrastructure construction and ecological environment protection. Strengthening cooperation and exchange between regions, sharing resources and experiences, is also an important way to narrow regional differences and improve overall coupling and coordination.

4.4 Spatial autocorrelation analysis

In order to test the existence of spatial autocorrelation among provinces in the Yangtze River Economic Belt, the Moran index test was carried out, and the test results were obtained in the following table.

Table 4 Moran Index of the Coordinated Development Level of Transportation Infrastructure and Ecological Environment from 2007 to 2022

year	Moran's I	z	p-value*
2007	-0.172	-0.395	0.346
2008	-0.244	-0.783	0.217
2009	-0.263	-0.892	0.186
2010	-0.316	-1.192	0.117
2011	-0.308	-1.161	0.123
2012	-0.334	-1.285	0.099
2013	-0.345	-1.341	0.09
2014	-0.35	-1.37	0.085
2015	-0.353	-1.378	0.084
2016	-0.387	-1.542	0.062
2017	-0.353	-1.366	0.086
2018	-0.353	-1.364	0.086
2019	-0.407	-1.62	0.053
2020	-0.375	-1.479	0.07
2021	-0.356	-1.369	0.086
2022	-0.36	-1.38	0.084

And draw Moran scatter plots for 2007 and 2022 to study the spatial effects between provinces in the Yangtze River Economic Belt and surrounding provinces.

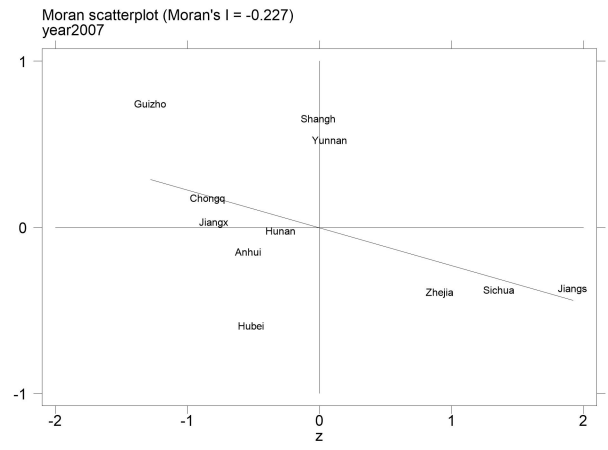


Figure 6 2007 Moran scatter

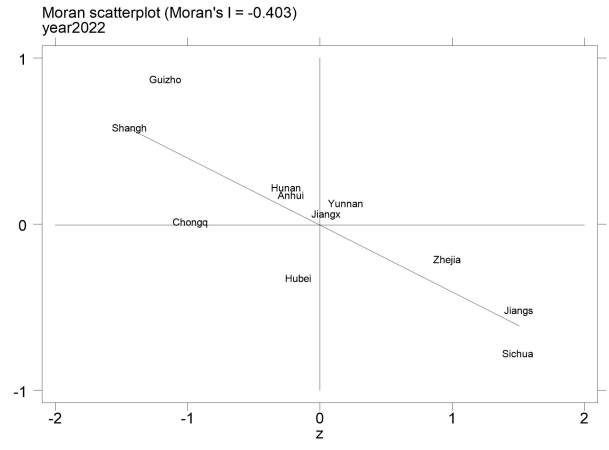


Figure 7 2022 Moran scatter

There is a negative spatial autocorrelation in the coupling and coordinated development level of transportation infrastructure and ecological environment among the 11 provinces in the Yangtze River Economic Belt. Given the

significant heterogeneity between different provinces, it is necessary to develop more differentiated policies to promote the coordinated development of transportation infrastructure and ecological environment. At the same time, strengthen regional cooperation, promote coordinated development through resource sharing and mutual exchange.

5 Conclusion and Suggestions

This study conducted an in-depth analysis of the coupling and coordinated development level of transportation infrastructure and ecological environment in the Yangtze River Economic Belt. The results showed that during the inspection period (2007-2022), although the construction level of transportation infrastructure showed a steady and rapid upward trend, the level of ecological environment protection showed significant fluctuations, but the overall trend was also on the rise. The level of coupling and coordinated development between the two is also showing an upward trend, indicating that the Yangtze River Economic Belt has achieved a certain balance between promoting transportation development and ecological environment protection. From the perspective of regional distribution, Jiangsu, Sichuan, Zhejiang and other provinces have a high level of coupled and coordinated development, while Yunnan, Jiangxi, Hubei, Hunan and other provinces are at a moderate level, while Guizhou, Shanghai, Chongqing and other regions are slightly behind. However, the gap in the level of coupling and coordinated development between provinces in the Yangtze River Economic Belt is gradually narrowing, indicating a trend of regional coordinated development. In terms of spatial autocorrelation, research has found that the spatial autocorrelation of the Yangtze River Economic Belt is weak, meaning that the mutual influence of provinces on the level of coupled and coordinated development is limited. This not only indicates that the Yangtze River Economic Belt still has room for improvement in promoting regional coordinated development, but also implies that each province has a certain degree of independence in the development process. Predictive analysis shows that the level of coupled and coordinated development of the Yangtze River Economic Belt will continue to improve in the coming years, providing a positive prospect for achieving regional sustainable development.

Based on the above analysis, improvements can be made in the following areas.

(1) Continuously strengthen the construction of transportation infrastructure. Although significant progress has been made in the level of transportation infrastructure construction, it is still necessary to increase investment and improve the coverage and quality of transportation networks to better support the economic and social development of the Yangtze River Economic Belt.

(2) Strengthen ecological environment protection. In response to the significant fluctuations in the level of ecological environment protection, a long-term ecological environment protection mechanism should be established, environmental monitoring and governance should be strengthened, green development and low-carbon transformation should be promoted, and the quality of the ecological environment should be continuously improved.

(3) Strengthen regional coordination and cooperation. Although the gap in coupling and coordinated development levels between provinces is narrowing, it is still necessary to further strengthen regional coordination and cooperation, promote resource sharing, complementary advantages, and coordinated development, in order to achieve the goal of overall coordinated development of the Yangtze River Economic Belt.

(4) Optimize policy formulation and implementation. When formulating regional development policies, full consideration should be given to the actual situation and needs of each province, and differentiated policies should be formulated to ensure the effectiveness and targeting of the policies. At the same time, it is necessary to strengthen the supervision and evaluation of policy implementation, and timely adjust and improve policies.

(5) Increase public participation. Strengthen public awareness of ecological environment protection and sustainable development, and encourage all sectors of society to participate in the coordinated development of the Yangtze River Economic Belt. Through publicity and education, public participation, and public opinion supervision, a good atmosphere is formed for the whole society to jointly promote the coordinated development of the Yangtze River Economic Belt.

(6) Strengthen scientific research and technological support. Increase support for scientific research institutions and universities, and promote the application of technological innovation in transportation infrastructure construction and ecological environment protection. By introducing new technologies, materials, and methods, we aim to improve development efficiency and quality, providing strong support for achieving sustainable development in the Yangtze River Economic Belt.

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