



# The Temporal and Spatial Characteristics of Urban Modernization in the Yangtze River Delta

Zhengliang Zhang

College of Geomatics, Xi'an University of Science and Technology, Xi'an 710054, Shaanxi, China

2312633950@qq.com

**Abstract.** Modernization refers to the process of transformation from agricultural society to industrial society and then to knowledge society. Based on the socio-economic statistical data of the Yangtze River Delta cities in China from 2010 to 2020, this study constructs a modernization level measurement index system from four dimensions: economic development, social development, knowledge development and environmental development, and analyzes the modernization level measurement and spatial-temporal evolution characteristics. The results show that: (1) From 2010 to 2020, the modernization level index of the Yangtze River Delta shows an overall increasing trend, and the increasing trend is significant. In terms of dimensions, the economic development index and the environmental development index are the highest, the social development index is the second, and the knowledge development index is the lowest. (2) The cities with high level of modernization in the Yangtze River Delta are mainly composed of provincial capitals and cities flowing through the Yangtze River, and then gradually spread to the surrounding areas. In 2020, they will shrink, but the level of modernization of cities flowing through the Yangtze River is still relatively high. (3) The priority way to improve the level of modernization in the Yangtze River Delta region is to focus on industrial structure, increase the proportion of non-agricultural economy, improve the ecological environment, and adhere to sustainable development.

**Keywords:** modernization ; evaluation indicators ; entropy method ; space-time evolution ; yangtze River Delta

## 1 Introduction

Modernization is a process in which a country or region changes from an agricultural society to an industrial society, and then to a knowledge society. It is an important manifestation of the degree of economic and social development and its coordination with the ecological environment. The measurement of modernization level is an important way to understand the level and development stage of China's modernization. It has important theoretical and practical significance for scientific understanding of the evolution characteristics of China's modernization development.

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M. F. b. Sedon et al. (eds.), *Proceedings of the 2024 3rd International Conference on Social Sciences and Humanities and Arts (SSHA 2024)*, Advances in Social Science, Education and Humanities Research 851, [https://doi.org/10.2991/978-2-38476-259-0\\_36](https://doi.org/10.2991/978-2-38476-259-0_36)

The level of modernization is a comprehensive concept. Different scholars have proposed a number of indexes to characterize the level of modernization from different perspectives. Among them, the most widely recognized is the United Nations Human Development Index (HDI), which is used to measure the level of economic and social development of member states of the United Nations. Domestic scholars have also carried out a lot of research on the measurement of modernization, forming a more fruitful research results. On the whole, the existing research on modernization can be divided into three aspects: first, qualitative research, with descriptive and explanatory research as the main characteristics, explores the scientific connotation, basic characteristics, necessary path and dynamic mechanism of modernization; the second is quantitative research, which is mainly characterized by empirical and model research. The research contents are mostly regional modernization, field modernization, industry modernization, regional differences of modernization, driving factors[1-3], etc. Among them, Xia Cheng et al[4], calculated the realization rate of modernization level in eastern China, and concluded that Beijing, Shanghai, Yangtze River Delta and Guangdong, Hong Kong and Macao have the highest level of modernization. Xie Baojian[5] analyzed the spatial and temporal characteristics of the modernization level of China's major urban agglomerations, and concluded that the gradient pattern of 'East-Central-West' is gradually weakening[6]; compared the modernization level of the Yangtze River Economic Belt with that of the Yellow River Basin, and concluded that the modernization level of the Yangtze River Economic Belt was ahead of that of the Yellow River Basin. The third is the combination of qualitative and quantitative, through the cross perspective to explore the law of development in the process of modernization.

## **2 Materials and Methods**

### **2.1 Data Collection**

This paper takes 27 cities in the Yangtze River Delta region as the research object, and uses the data collected from the 'China City Statistical Yearbook' (2010-2021), the 2010-2020 statistical bulletin of national economic and social development. The Yangtze River Delta cities include Shanghai, Nanjing, Suzhou, Wuxi, Changzhou, Yangzhou, Nantong, Yancheng, Zhenjiang, Taizhou, Hangzhou, Ningbo, Jiaxing, Huzhou, Shaoxing, Zhoushan, Wenzhou, Jinhua, Taizhou, Hefei, Wuhu, Ma'anshan, Chuzhou, Xuancheng, Tongling, Chizhou and Anqing.

### **2.2 Index System of Modernization Evaluation**

Referring to He Chuanqi's world modernization recommendation index[7], this paper constructs a modernization level measurement index system from four dimensions: economic development, social development, knowledge development and environmental development. Among them, the modernization level is the first-level index, and the evaluation result is the modernization level index (Table 1).

**Table 1.** Index System of Modernization Evaluation

First-level	Secondary	Criteria Layer	Third-level	Positive / Negative
Level of modern	Economic development	Production	A1 GDP per capita ( yuan / person )	Positive
			A2 GDP ratio of tertiary industry ( % )	Positive
		Industrial structure	A3 Proportion of tertiary industry employment ( % )	Positive
			A4 Proportion of primary industry employment ( % )	Negative
	Social development	Population	B1 Natural growth rate ( % )	Positive
		Level of living	B2 Total social consumer goods per capita	Positive
			B3 Primary school teacher-student ratio ( % )	Positive
			B4 Number of doctors per capita	Positive
	Knowledge development	Science and technology	C1 The proportion of fiscal expenditure on science and technology ( % )	Positive
			C2 Number of mobile phones per capita ( units )	Positive
		Knowledge dissemination	C3 Number of broadband users per capita ( person )	Positive
			C4 Library per capita collections ( books )	Positive
	Environmental development	Ecological environment	D1 Sewage centralized treatment rate ( % )	Positive
			D2 Per capita SO <sub>2</sub> emissions ( tons / person )	Negative
		International environment	D3 Share of foreign investment in GDP ( % )	Positive
			D4 Number of foreign-invested enterprises per capita ( number / person )	Positive

**2.3 Calculating Procedure**

The entropy method is used to assign weights to the three-level indicators to calculate the urban modernization index value in the Yangtze River Delta region. The data are standardized using the value  $x_{ij}$ , the maximum value  $x_{max}$ , and the minimum value  $x_{min}$  of the  $x$  dimension, the  $i$ -year, and the  $j$ -index, as follows[8]:

Positive indexes:

$$y_{xij} = \frac{x_{xij} - x_{min}}{x_{max} - x_{min}} \tag{1}$$

Negative indicators:

$$y_{xij} = \frac{x_{max} - x_{xij}}{x_{max} - x_{min}} \tag{2}$$

Secondly, the information entropy  $E_{xj}$  of the index  $j$  is obtained by the number of cities  $z$ , and the calculation formula is as follows:

$$E_{xj} = -\left(\frac{1}{\ln z}\right) \sum_{i=1}^z \frac{y_{xij}}{\sum_{i=1}^z y_{xij}} \ln\left(\frac{y_{xij}}{\sum_{i=1}^z y_{xij}}\right) \tag{3}$$

Calculate the second-level index score  $G_{xi}$  and the modernization level index  $G_i$  of each region in the  $i$ -year,  $x$ -dimension, where  $n$  is the latitude.

$$G_{xi} = \sum_{i=1}^m y_{xij} \frac{1 - E_{xj}}{\sum_{i=1}^z y_{xij}} \tag{4}$$

$$G_i = \sum_{x=1}^n G_{xi} \tag{5}$$

The contribution of modernization driving factors is analyzed by the proportion of each index in the modernization level index, as shown in Equation ( 6 ) :

$$P_j = \frac{y_j}{G} \times 100\% \tag{6}$$

### 3 Result

#### 3.1 Time variation characteristics of modernization in Yangtze River Delta

From 2010 to 2020, the modernization level index of the Yangtze River Delta showed an overall increasing trend, from 0.34 in 2010 to 0.48 in 2020, with a significant increasing trend and an annual increasing rate of 0.0148 (  $p < 0.05$  ) ( Fig. 1a ).

From 2010 to 2020, China 's economic index, social index, knowledge index and environmental index are between 0.11-0.16,0.08-0.12,0.04-0.07 and 0.11-0.14, respectively ( Fig. 1b ). The modernization level index of the four dimensions shows an increasing trend, among which the economic index and environmental index are the highest, the social index is the second, and the knowledge index is the lowest.

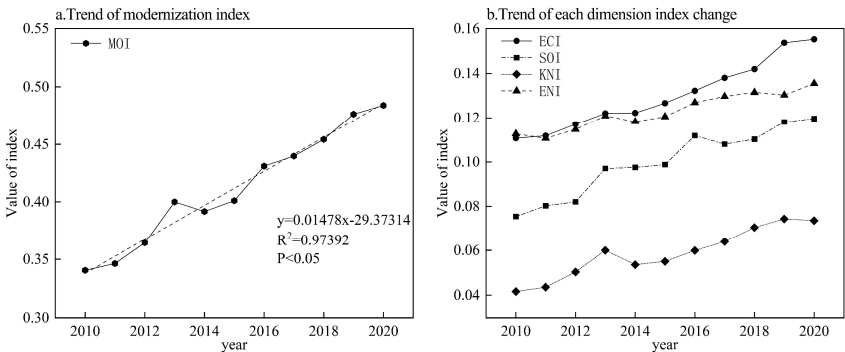


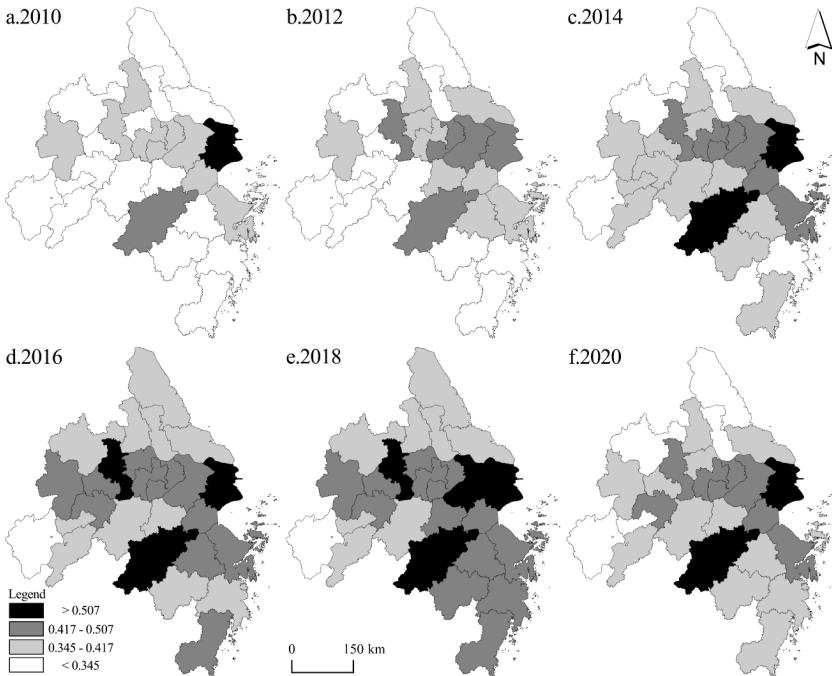
Fig. 1. The time trend of modernization level index from 2001 to 2020

### 3.2 Spatial variation characteristics of modernization level

Using the natural discontinuity method, the measured modernization level index is divided into four categories ( Table 2 ).

**Table 2.** Modernization level classification standard

Classification	Score values
Ultra-high level	>0.507
High level	0.417-0.507
Intermediate level	0.345-0.417
Common level	<0.345



**Fig. 2.** Spatial distribution characteristics of modernization level from 2010 to 2020

In 2010, Shanghai 's modernization level was at an ultra-high level, followed by Hangzhou at a high level. The medium-level cities were provincial capital cities ( Nanjing, Hefei ), cities where the Yangtze River flows through ( Yangzhou, Changzhou, Wuxi, Suzhou ) and coastal cities ( Jiaxing, Ningbo ) ( Fig. 2a ). From 2012 to 2016, the modernization level of all cities improved significantly( Fig. 2b, Fig. 2c, Fig. 2d ). In 2018, Shanghai, Hangzhou, Nanjing and Suzhou were at ultra-high levels ; all cities in the Yangtze River Delta of Zhejiang Province have reached a high level ; all the cities in the Yangtze River Delta of Jiangsu Province have reached the middle level, and the modernization level of the cities passing through the Yangtze River is higher and reaches a high level( Fig. 2e ). The modernization level of the Yangtze River Delta

cities in Anhui Province is relatively low, and the provincial capital Hefei is at a high level. In 2020, the modernization level of the Yangtze River Delta has declined, Shanghai and Hangzhou remain at an ultra-high level, and the modernization level of other regions has shrunk. Jiaxing, Ningbo and the Yangtze River have maintained a good level of modernization( Fig. 2f ).

The cities with high modernization level in the Yangtze River Delta are mainly composed of provincial capitals and cities flowing through the Yangtze River, and then gradually spread to the surrounding areas( Fig. 2 ). In 2020, they will shrink, but the modernization level of cities flowing through the Yangtze River is still relatively high.

### 3.3 Driving factors of modernization in Yangtze River Delta

From the perspective of contribution proportion, the contribution of economic indicators, social indicators, knowledge indicators and environmental indicators to modernization development accounted for 31.61 %, 24.27 %, 14.27 % and 29.85 % respectively. The top three of the three indicators are the proportion of agricultural labor force, per capita sulfur dioxide emissions and centralized sewage treatment rate, with the contribution rates of 12.93 %, 12.15 % and 10.81 % respectively ( Fig. 3 ).

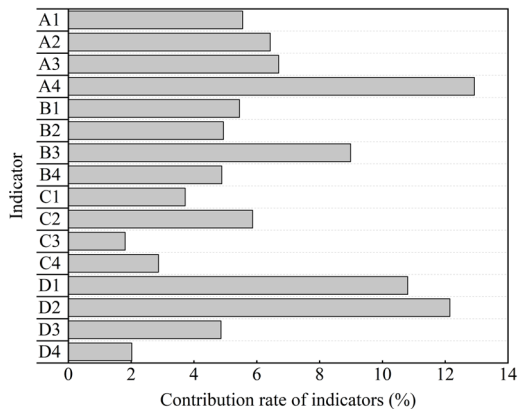


Fig. 3. Contribution proportion of each index

## 4 Discussion

The evaluation results of modernization are affected by the evaluation index system. This paper selects the four dimensions of economy, society, knowledge and environment to construct a modern evaluation index system and measure it.

In the process of modernization, economic construction is the center[9]. In the eastern coastal areas, the economic development is earlier, the modernization level is higher, and the modernization process is faster. The modernization level index of the eastern region has always been at the forefront, but recently it has been impacted by the economic downturn at home and abroad, and the development growth rate is relatively

slow. Considering the possible impact of the new coronavirus epidemic, it just explains the decline in the modernization level of the Yangtze River Delta region in 2020. Chen Minghua et al.[10] pointed out that the positive spillover effect of capital cities in most provinces in the central region is significant, which has a significant driving effect on neighboring cities, which is the same as the spillover effect of the Yangtze River flowing through cities. The Beijing-Tianjin-Hebei, Yangtze River Delta and Pearl River Delta regions are also more advanced in the development coordination degree in the modernization process[11].

The modernization discussed in this paper does not involve foreign regions, and the next research can consider incorporating foreign regions to explore the modernization development under bilateral or multilateral cooperation.

## 5 Conclusions

From 2010 to 2020, the modernization level index of the Yangtze River Delta showed an overall increasing trend, and the increasing trend was significant. Economic index and environmental index are the highest, followed by social index, and knowledge index is the lowest. The cities with high modernization level in the Yangtze River Delta are mainly composed of provincial capitals and cities flowing through the Yangtze River, and then gradually spread to the surrounding areas. In 2020, they will shrink, but the modernization level of cities flowing through the Yangtze River is still relatively high. In general, the level of modernization in the Yangtze River Delta region has improved significantly. The priority way to improve the level of modernization is to focus on the industrial structure, increase the proportion of non-agricultural economy, improve the ecological environment, and adhere to sustainable development.

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