Research on the Index System of Cities' Digital Economy Development Level in the Yellow River Basin

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Keywords: The Yellow River Basin, Digital Economy, Index Measurement, Entropy-TOPSIS Method.

Abstract: By constructing the index system of urban digital economy development, using entropy-TOPSIS method, and combining *China Urban Digital Economy Index* and *China City Statistical Yearbook* from 2020 to 2021, this paper makes index construction and empirical analysis of 22 key cities in the Yellow River Basin, and compares and analyzes with the national development from data information infrastructure, digital government and digital society, digital economy and digital industry. The results of the study show that the overall scores of cities in the Yellow River Basin are higher than the national average in digital information base, digital policy planning, government service digitalization and industrial digitalization. However, in terms of data foundation, government governance digitalization and digital industrialization, it is lower than the national average, indicating that the growth rate of digital economy in the Yellow River Basin is good, but the development is uneven. The overall level of digital economy development is evaluated by entropy-TOPSIS method and the results show that ten cities are star-level, five mediocre-level and seven backward-level. Thus, it is necessary to promote the balanced and high-quality development of the region through adjustment of economic policies in the Yellow River Basin.

1 INTRODUCTION

General Secretary Xi Jinping pointed out that "digital economy is the future direction of global development, and innovation is the wing of the Asia-Pacific economy". The world is entering a period of rapid development in digital economy. New technologies, new business models and new platforms such as 5G, artificial intelligence and smart cities are flourishing, profoundly affecting global scientific and technological innovation, industrial restructuring as well as economic and social development. During the period of the 14th Five-Year Plan, China is actively promoting digital industrialization and industrial digitalization, and promoting the deep integration of digital technology with economic and social development. As a result, the new generation of communication technologies represented by informatization, digitization and intelligence have driven the digital transformation of cities into an accelerated exploration period. Specific governance practices continue to explore and update the path and methods of digital technology applications to integrate resources to promote the modernization of governance system and capacity, forming a good situation in which digital technology drives all-round digital transformation of cities.

However, the gap between the North and the South is widening in that situation, and with the high-quality development of the Yellow River Basin during the 14th Five-Year Plan period, it has become a major agenda for regional coordinated development. The development level of urban digital economy in the Yellow River Basin and whether it can drive regional high-quality development with digital economy have become important issues that need to be resolved urgently in the new period. According to domestic research, scholars focused on the Yellow River Basin from ecological governance (Wang, 2020, Shen, 2020), industrial development (Chen, 2021, Tian, 2021), watershed governance (Liao, 2021, Du, 2021) and other issues. Although (Zhou, et al., 2020) had carried out a logical construction of digital economy development in the Yellow River Basin through macro, meso and micro levels, (Wang, 2021) had explored the ecological protection and high-quality development of the Yellow River Basin through digital technology applications. On the whole, the measurement research on urban digital economy development of

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cities in the Yellow River Basin still needs further attention.

This paper analyzes the comprehensive level of digital economic development in 22 key cities in the Yellow River Basin by combining the indicator construction and empirical analysis of China Urban Digital Economy Index from 2020 to 2021 (the actual statistical data is 2019 to 2020) and China City Statistical Yearbook, and comparing and analyzing the data information infrastructure, digital government and digital social governance, digital economy and digital industry with the national average level of development respectively. The index is designed to provide policy suggestions for accelerating the growth of digital economy and promoting high-quality development of the Yellow River Basin.

2 MODELING METHOD AND INDEX CONSTRUCTION

2.1 Measurement Methods

In this paper, the entropy-TOPSIS method is used to measure the development level of urban digital economy in the Yellow River basin. The core idea is to use the entropy method to assign weight to each indicator on the basis of standardization, and then quantify and sort the relative distance between the evaluation object and the optimal and worst scheme by TOPSIS. This method combines the objective advantages of the entropy method with the advantages of easy calculation and reasonable results of TOPSIS method. Its specific calculation steps are as follows:

First, in order to avoid the influence of dimensional differences such as unit and quantity among the original data on the data results, all the original data are standardized and converted into relative values to make the data comparable. Since there is no negative indicator in this index system, only positive indicator standardization can be carried out. To avoid the influence of extreme data on the results of entropy method, we refer to the standardized formula of (Yin, et al. 2017):

$$y_{ij} = \frac{x_{ij} - \min x_j}{\max x_j - \min x_j} * 0.9 + 0.1 \quad (1)$$

Where x_{ij} is the value $(i = 1,2\cdots,\ n;\ j = 1,2\cdots,\ m)$ of the j-th indicator j for the i-th unit and $\max x_j$ is the maximum value of j, and $\min x_j$ is the minimum value of the j-th indicator.

The second step is to calculate the proportion of the i-th data under the j-th indicator to the indicator:

$$p_{ij} = y_{ij} / \sum_{i=1}^{n} y_{ij} \quad (2)$$

The third step is to calculate the entropy value of the j-th indicator:

$$e_j = -k \sum_{i=1}^{n} p_{ij} \ln p_{ij} \quad (3)$$

Where $k = 1/\ln(rn)$, r is the year and n is the number of cities.

The fourth step is to calculate the information entropy redundancy:

$$d_j = 1 - e_j \quad (4)$$

The fifth step is to calculate the weight of the j-th indicator:

$$w_j = d_j / \sum_{i=1}^{m} d_j \quad (5)$$

The sixth step is to calculate the weighting matrix of the indicators measuring the development level of the digital economy:

$$R = (r_{ij})_{n \times m} \quad (6)$$

The seventh step is to determine the optimal solution Q_j^+ and the worst solution Q_j^- based on the weighting matrix:

$$d_i^+ = \sqrt{\sum_{j=1}^{m} (Q_j^+ - r_{ij})^2}$$
$$d_i^- = \sqrt{\sum_{j=1}^{m} (Q_j^- - r_{ij})^2} \quad (7)$$

The eighth step is to calculate the relative proximity Ci between each measure scheme and the ideal scheme:

$$C_i = \frac{d_i^-}{d_i^+ + d_i^-} \quad (8)$$

Where the relative proximity Ci lies between 0 and 1. The larger the value of Ci, the better the development level of digital economy in the city i. On the contrary, the development level of digital economy in city i is poor.

2.2 Establishing Index System

Creating a regional economic center city and building a regional digital highland are the strategic priorities of Baotou's economic and social development during the 14th Five-Year Plan period. Digital economy, digital government and digital society led by digital technology have become the main direction of accelerated urban development. In terms of the development trend of digital transformation, indicators based on digital information infrastructure, digital government, digital society and digital industry can effectively measure the basic situation and development direction of urban digital transformation. This paper investigates 8 provinces in the Yellow River Basin. Because of the severe lack of urban measurement indicator data in some provinces, this paper finally selects 22 key cities in the Yellow River Basin for measurement. Considering the data availability and reliability, the research is based on the relevant data of China Urban Digital Economy Index (the actual statistical data is 2019 to 2020) and China City Statistical Yearbook from 2020 to 2021. The index system of digital transformation of 22 key cities in the Yellow River Basin is constructed through the three dimensions of digital infrastructure, digital government, digital society and digital industry. Tertiary indicators are constructed around digital information base, data foundation, digital policy planning, government service digitalization, government governance digitalization, digital industrialization and industrial digitalization. The entropy method is used to measure the weight and evaluate the overall situation of digital transformation and development of 22 key cities in the Yellow River Basin, and compare it with the national average level of digital development, as shown in Table 1.

Table 1: Digital economy development level index system and weight.

Guideline	Secondary index	Tertiary index	Weight
Digital Infrastructure (0.2012)	F1 Digital Information Base (0.1064)	F11 Fixed-line broadband application permeability	0.0208
		F12 mobile network application permeability	0.0228
		F13 Urban Cloud Platform	0.0283
		F14 Information Security	0.0345
	F2 Data Foundation (0.0948)	F21 Urban Big Data Platform	0.0342
		F22 Government Data Sharing Platform	0.0276
		F23 Open Data Platform	0.0329
Digital Government with Digital Social (0.4883)	S1 Digital Policy Planning (0.1259)	S11 Number of policies covering livelihood areas	0.0284
		S12 Digital policy projects in the field of livelihood	0.0338
		S13 Number of governance areas covered	0.0321
		S14 Number of digitization projects in the governance area	0.0316
	S2 Digitization of Government Services (0.2001)	S21 Education Digitalization	0.0206
		S22 Healthcare Digitalization	0.0275
		S23 Civil Service Digitalization	0.0370
		S24 Human Services Digitalization	0.0300
		S25 Poverty Alleviation Digitalization	0.0365
		S26 Doing Business Digitalization	0.0206
		S27 Living Environment Digitization	0.0279
	S3 Digitalization of Government Governance (0.1623)	S31 Public Security Governance Digitalization	0.0228
		S32 Information Governance Digitalization	0.0245
		S33 Eco-friendly Digitalization	0.0384
		S34 Municipal Management Digitalization	0.0217
		S35 Emergency Management Digitalization	0.0216
		S36 Digitization of natural resource management	0.0335
Digital Industry (0.3105)	I1 Digital Industrialization (0.0647)	I11 digital industrialization drives industry	0.0301
		I12 digital industrialization main industry	0.0346
	I2 Industry Digitization (0.2457)	I21 Agriculture Digitization	0.0343
		I22 Financial Digitization	0.0311
		I23 Manufacturing Digitization	0.0343
		I24 Energy Digitization	0.0324
		I25 Life Service Digitalization	0.0305
		I26 Transportation and Logistics Digitalization	0.0355
		I27 Science, education, culture and sports digital	0.0240
		I28 Healthcare Digitization	0.0237

3 EMPIRICAL MEASUREMENT

3.1 A Digital Economy Development Level of Each Subsystem

According to the comprehensive evaluation model, the weights of each index can be obtained after standardizing the original data, calculating the entropy value and the entropy redundancy. Then, the weight of urban digital economy development index in the Yellow River Basin from 2020 to 2021 and the comprehensive average level of national digital economy development are obtained, as shown in Figure 1.

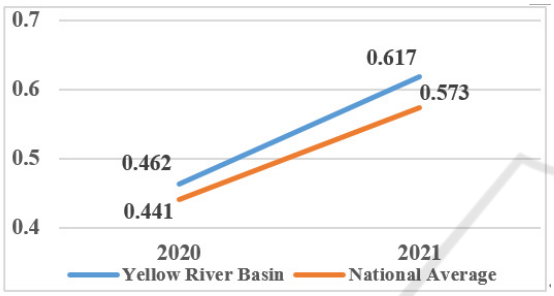

Figure 1a: Overall Scores of Digital Economy Development.

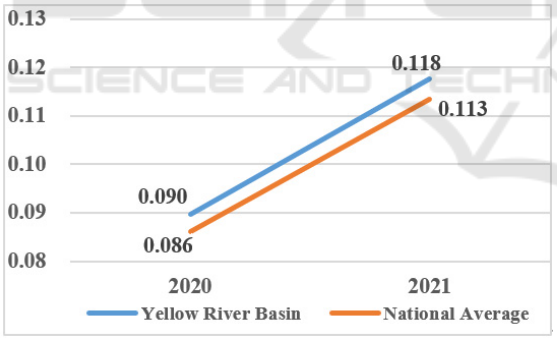

Figure 1b: Digital infrastructure.

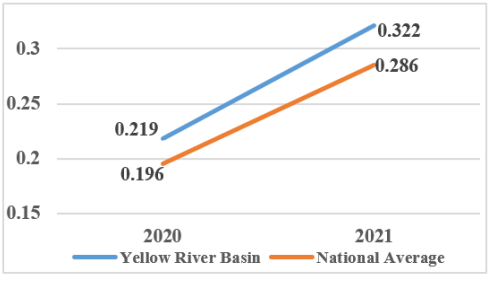

Figure 1c: Digital government and digital society.

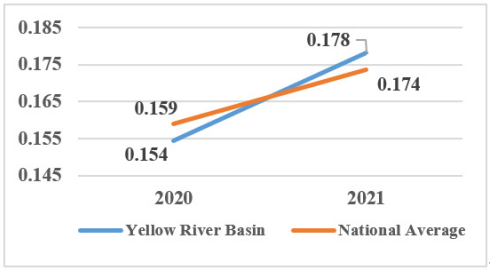

Figure 1d: Digital plus industry.

3.1.1 Overall Development of Digital Economy in the Yellow River Basin

First, from Figure 1a, it can be seen that the overall digital economy development index of cities in the Yellow River Basin as a whole has increased from 0.462 in 2020 to 0.617 in 2021, with a development rate of 33.51%, which is faster than the national average digital economy development growth rate of 29.96% (Figure .1a).

Second, from the dimensions of "digital infrastructure" and "digital government and digital society" (Figure .1b and Figure .1c), cities in the Yellow River Basin as a whole are higher than the national average, with growth rates of 31.29% and 47.14% respectively, among which the development growth rate of digital infrastructure in the Yellow River Basin is lower than the national average of 31.73%, while the development growth rate of digital government and digital society is higher than the national average of 45.96%.

Third, in the dimension of "digital plus industry" (Figure .1d), although the cities in the Yellow River Basin as a whole lag behind the national average of 0.159 from 2020, they exceed the national average of 0.178 in 2021 with a growth rate of 15.49%.

3.1.2 Development Status of Urban Digital Economy in Yellow River Basin

Figure 2 shows the overall scores of 22 cities in the Yellow River Basin on the secondary indicators of digital economy development. From a holistic perspective, the overall scores of cities in the Yellow River Basin are higher than the national average in the dimensions of digital information base (0.066), digital policy planning (0.078), digital government services (0.110), and digital industry (0.135). Among them, cities higher than the national average account for 68.18%, 68.18%, 63.64% and 50% of the total number of cities investigated respectively, while they are lower than the national average in the dimensions of data foundation (0.037), digital government

governance (0.082), and digital industrialization (0.031). Among which cities with lower ratio than the national average accounts for 68.18%, 45.45%, and 50% of cities investigated respectively.

In terms of cities, in the dimension of "digital information base", the top three are Jinan, Taiyuan and Kaifeng, whose digital information base levels are high, with scores of 0.098, 0.096 and 0.095 respectively. While the last three are Linfen, Haidong and Lyu liang, whose digital information base levels are low, with scores of 0.020, 0.018 and 0.014 respectively. In the dimension of "data foundation", Taiyuan, Zhengzhou and Jinan are ranked in the top three, with high data foundation levels and scores of 0.084, 0.081 and 0.072 respectively. While Lüliang, Shizuishan and Erdos are ranked in the bottom three, with low data foundation level and scores of 0.012. In the dimension of "digital policy planning", the top three are Jinan, Yantai and Dongying, which show that their digital policy planning levels are high, with scores of 0.132, 0.131 and 0.128 respectively. While the last three are Lüliang, Linfen and Shizuishan, whose digital policy planning levels are low, with scores of 0.015, 0.014 and 0.012 respectively. In the dimension of "digitalization of government services", the top three are Yantai, Baotou and Kaifeng, whose digitalization levels of government services are high, with scores of 0.172, 0.169 and 0.167 respectively. While the last three are Haidong, Jinchang and Tianshui, whose digitalization levels of government services are low, with scores of 0.037, 0.036 and 0.033 respectively. In the dimension of "government governance digitalization", the top three are Yantai, Yulin and Hohhot, whose digitalization levels of government governance are high, with scores of 0.147, 0.132 and 0.130 respectively. While the last three are Lüliang, Haidong and Shizuishan, whose digitalization levels of government governance are low, with scores of 0.034, 0.031 and 0.027 respectively. In the dimension of "digital industrialization", the top three cities are Zhengzhou, Yinchuan and Yantai, whose digital industrialization development levels are high, with scores of 0.063, 0.058 and 0.057 respectively. While the last three cities are Yan'an, Erdos and Lyu liang, whose digital industrialization levels are low, with scores of 0.007. In the dimension of "industrial digitalization", the top three cities are Taiyuan and Hohhot Zhengzhou, which have high industrial digitalization levels with scores of 0.258, 0.240 and 0.234 respectively. While the last three cities are Tianshui, Haidong and Lüliang, which have low industrial digitalization levels with scores of 0.034, 0.032 and 0.030 respectively.

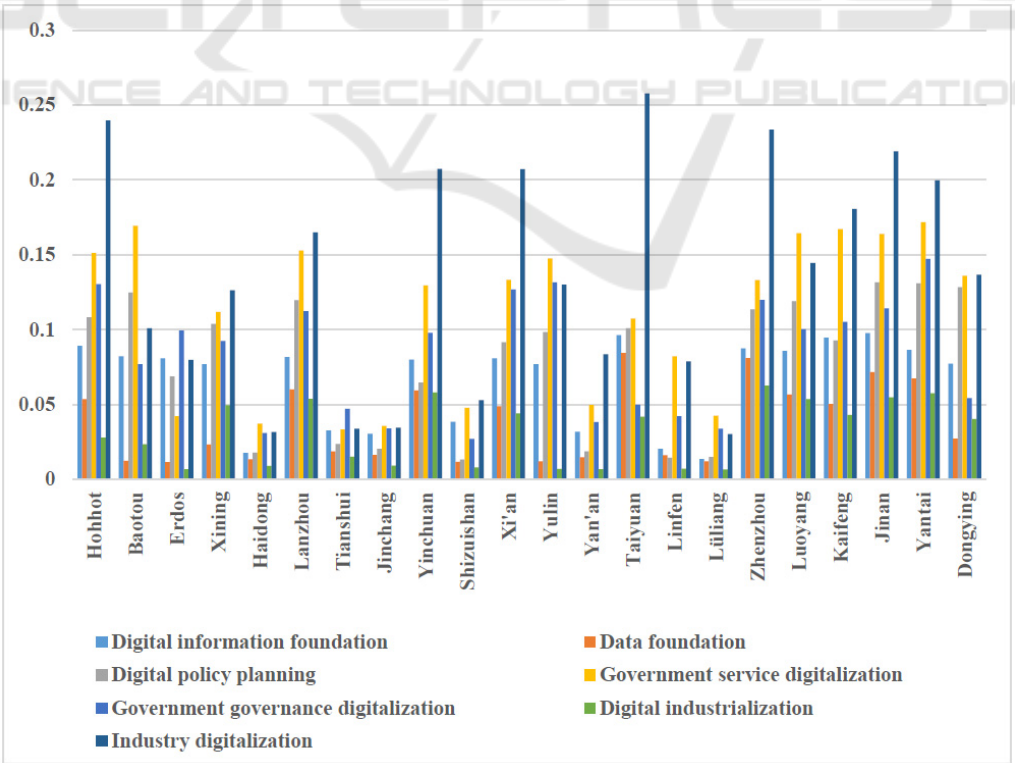

Figure 2: Measurement of the Development Level of Urban Secondary Indexes in the Yellow River Basin from 2020 to 2021.

3.1.3 Measurement of Urban Development Indicator in Yellow River Basin

From Figure 3, we can intuitively understand the overall scores of cities in the Yellow River Basin on the development level of the tertiary indicators of digital economy. First of all, in the dimension of "digital infrastructure", the development level of digital information base of cities in the Yellow River Basin is higher than the national average. However, the data infrastructure lags behind the national average, especially in the construction of urban big data platform and open data platform, which is obviously different from the national average, seriously restricting the overall digital transformation and upgrading of cities in the Yellow River Basin. Second, in the dimension of "digital government and digital society", cities in the Yellow River Basin as a whole are higher than the national average in digital policy planning, digital construction of government services and digital construction of government governance. However, the digitalization of poverty alleviation, business environment and ecological environmental protection lags behind the national average development level, especially the digitalization of ecological environmental protection is far from the national average level, which restricts the "green benefits" of digital economy development in the Yellow River Basin. At the same time, it is difficult to form a new pattern of overall digital urban development in the Yellow River Basin. Finally, in the dimension of "digital plus industry", cities in the Yellow River Basin lag behind the national average in financial digitalization, manufacturing digitalization, transportation and logistics digitalization, as well as medical and health digitalization, which is not only detrimental to the industrial integration of cities in the Yellow River Basin, but also restricts the transformation and upgrading of industrial digitalization of cities in the Yellow River Basin.

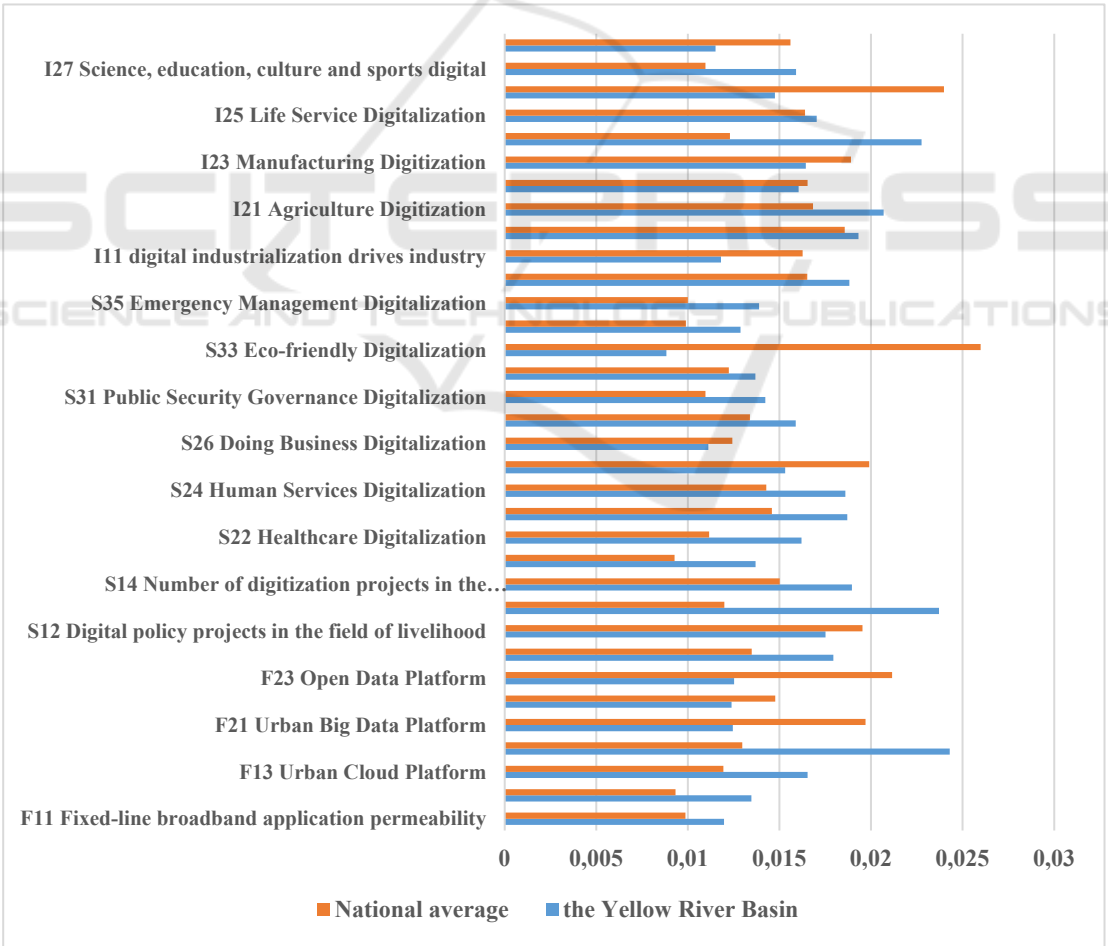

Figure 3: Score of tertiary indexes of data infrastructure.

3.2 Comprehensive Level of Digital Economy Development

The TOPSIS empirical measurement results of digital economy development level of 22 cities in the Yellow River Basin from 2020 to 2021 are shown in Table 2 and Fig.4. It can be found that the comprehensive scores of digital economy development of cities in the Yellow River Basin during the investigation period are distributed between 0.0535 and 0.7531. The city with the lowest score is Haidong (0.0535), and the city with the highest score is Yantai (0.7531). The mean score (M) of the comprehensive level of digital economy development in 22 cities in the Yellow River Basin is 0.4547, and the standard deviation (SD) is 0.2275, indicating that the comprehensive level of digital economy development in cities in the Yellow River Basin is generally good from 2020 to 2021. According to the relationship between mean score (M) and standard deviation (SD), 22 cities can be divided into three types: star level (score > M+0.5SD), mediocre level (M-0.5SD < score < M+0.5SD) and backward level (score < M-0.5SD).

Table 2: evaluation calculation results based on TOPSIS.

City	Optimal solution d_i^+	Worst solution d_i^-	Relative Proximity C_i
Yantai	0.0441	0.1346	0.7531
Jinan	0.0516	0.1342	0.7222
Zhengzhou	0.0618	0.1349	0.6859
Hohhot	0.0573	0.1245	0.6849
Xi'an	0.0599	0.1099	0.6472
Lanzhou	0.0740	0.1234	0.6250
Taiyuan	0.0776	0.1248	0.6165
Kaifeng	0.0763	0.1223	0.6159
Luoyang	0.0748	0.1194	0.6149
Yinchuan	0.0842	0.1184	0.5845
Dongying	0.0977	0.1056	0.5195
Yulin	0.1004	0.1078	0.5177
Xining	0.1007	0.1012	0.5014
Baotou	0.1039	0.1044	0.5012
Ordos	0.1291	0.0771	0.3737
Linfen	0.1423	0.0494	0.2576
Yan'an	0.1457	0.0441	0.2323
Shizuishan	0.1515	0.0332	0.1799
Tianshui	0.1490	0.0230	0.1338
Jinchang	0.1524	0.0164	0.0970
Lüliang	0.1558	0.0147	0.0862
Haidong	0.1546	0.0087	0.0535
Yantai	0.0441	0.1346	0.7531
Jinan	0.0516	0.1342	0.7222
Zhengzhou	0.0618	0.1349	0.6859
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Taiyuan	0.0776	0.1248	0.6165
Kaifeng	0.0763	0.1223	0.6159

The overall scores of digital economy development in star-level cities are higher than 0.5684, including 10 cities, Yantai, Jinan, Zhengzhou, Hohhot, Xi'an, Lanzhou, Taiyuan, Kaifeng, Luoyang and Yinchuan. The overall scores of digital economy development are 0.7531, 0.7222, 0.6859, 0.6849, 0.6472 and 0.6250 respectively. The overall scores of digital economy development in

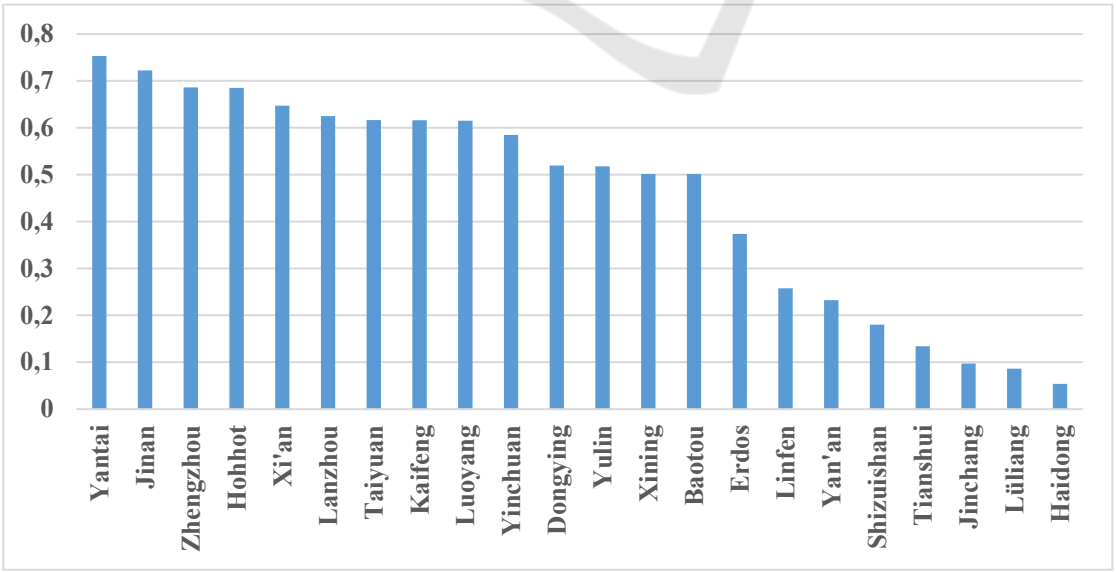

Figure 4: Overall scores of urban digital economy development of the Yellow River Basin from 2020 to 2021.

mediocre-level cities range from 0.3410 to 0.5684, including Dongying, Yulin, Xining, Baotou and Erdos, and their overall scores of digital economy development are 0.5195, 0.5177, 0.5014, 0.5012 and 0.3737 respectively, accounting for 23% of the total number of cities investigated. The overall scores of digital economy development in backward-level cities are lower than 0.3410, including Linfen, Yan'an, Shizuishan, Tianshui, Jinchang, Lüliang and Haidong. The overall scores of digital economy development are 0.2576, 0.2323, 0.1799, 0.1338, 0.0970, 0.0862 and 0.0535 in respectively, accounting for 32% of the total number of cities investigated.

4 CONCLUSIONS AND SUGGESTIONS

By constructing the indicator measurement system of digital economy development, the entropy-TOPSIS method is used to measure the overall development of digital economy and the level of each subsystem in 22 cities in the Yellow River Basin from 2020 to 2021. Through data analysis, this paper mainly draws the following conclusions:

In terms of secondary indicators, Jinan, Taiyuan and Kaifeng are the cities with better development in digital information infrastructure, while Linfen, Haidong and Lyu liang are the cities with poorer development. The cities with better development in data infrastructure are Taiyuan, Zhengzhou and Jinan, while the cities with poorer development are Lüliang, Shizuishan and Erdos. The cities with better development in digital policy planning are Jinan, Yantai and Dongying, while the cities with poorer development are Lyu liang, Linyi and Shizuishan. The cities with better digital construction of government services are Yantai, Baotou and Kaifeng, while the cities with poorer development are Haidong, Jinchang and Tianshui. The cities with better development in the digital construction of government governance are Yantai, Yulin and Hohhot, while the cities with poorer development are Lyu liang, Haidong and Shizuishan. The cities with better development in digital industrialization construction are Zhengzhou, Yinchuan and Yantai, while the cities with poorer development are Yan'an, Erdos and Luliang. Taiyuan, Hohhot and Zhengzhou are the cities with better development in industrial digitalization construction, while Tianshui, Haidong and Lyu liang are the cities with poorer development.

The overall scores of cities in the Yellow River Basin are higher than the national average in digital information base (0.066), digital policy planning (0.078), digital government services (0.110), and digital industry (0.135), with cities above the national average accounting for 68.18%, 68.18%, 63.64% and 50% of the total number of cities investigated respectively, while they are lower than the national average in data foundation (0.037), digital government governance (0.082) and digital industrialization (0.031), with 68.18%, 45.45%, and 50% of the total number of cities investigated being below the national average respectively. It shows that the growth rate of urban digital economy development of Yellow River Basin is generally good, but the development is uneven. By evaluating the overall level of digital economy development by entropy-TOPSIS method, 22 cities are classified into 10 star-level cities, 5 mediocre-level cities and 7 backward-level cities, accounting for 45%, 23% and 32% of the total number of cities investigated respectively.

In conclusion, to achieve the goal of realizing the overall digital transformation of cities in the Yellow River Basin and improving the overall level of digital economy development through technology empowerment, it is necessary to clarify the top-level design and transformation stage planning around the development law of digital transformation. Specifically, it is essential to build a digital industrial system and a digital economic development pattern, effectively improve the security level of digital social governance, promote the integrated development of urban digital government services with multiple parties, and vigorously draw on the experience of advanced cities in promoting digital construction, so as to comprehensively promote the high-quality development of cities in the Yellow River Basin.

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