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Measurement of the Digital Infrastructure Development Level and Regional Disparities in Guangdong Province

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Abstract

Based on panel data for prefecture-level cities in Guangdong Province from 2015 to 2024, this paper constructs an evaluation index system for digital infrastructure, assesses the level of digital infrastructure development using the entropy method, and analyzes development disparities at both the regional and city levels. Research findings indicate that regional disparities in the development of digital infrastructure in Guangdong Province are quite pronounced. While the overall level of digital infrastructure development across cities is on the rise, there is a marked gradient of differentiation between cities, resulting in a multi-tiered development pattern. Accordingly, this paper propose measures to strengthen regional coordination and policy support, and to promote complementary strengths and coordinated development.

Keywords

Digital Infrastructure; Entropy Method; Regional Disparities.

1. Introduction

As a key strategic pillar driving high-quality economic development, the development of digital infrastructure serves not only as a short-term policy tool to boost consumer demand and stabilize economic growth, but also as a long-term institutional arrangement to strengthen the foundation of economic development and foster new competitive advantages on the global stage. This strategic initiative not only reflects practical considerations regarding current macroeconomic regulation but also embodies a forward-looking approach to restructuring the nation's competitiveness. At its core, it aims to achieve a fundamental shift in the economic development paradigm-from scale-driven growth to quality-led growth-through the systematic accumulation of technological innovation. In 2020, the Standing Committee of the Political Bureau of the CPC Central Committee convened a special meeting and explicitly called for accelerating the construction of new infrastructure systems, including fifth-generation mobile communication (5G) networks and data centers. This decision marks a key policy direction for China to optimize its economic structure through the transformation and upgrading of infrastructure in the era of the digital economy, serving as a new engine to drive economic growth and high-quality development in Guangdong.

International experience shows that moderately forward-looking investment in digital infrastructure can generate an economic multiplier effect of more than 1:3. The core mechanism lies in optimizing the underlying architecture of the innovation ecosystem to continuously unlock the spillover benefits of technological innovation. Ultimately, this provides sustained momentum for improving total factor productivity and upgrading the industrial structure, enabling structural transformation to secure the initiative in high-quality development and drive high-quality economic growth [1].

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2. Literature Review

With the development of the digital economy, digital infrastructure has gradually become a key pillar underpinning the growth of the digital economy, driving industrial digital transformation, and promoting high-quality economic development. In 2020, the National Development and Reform Commission (NDRC) issued an official interpretation of the concept and scope of new infrastructure, stating that it is an infrastructure system guided by the new development philosophy, driven by technological innovation, and based on information networks. It is designed to meet the needs of high-quality development by providing services such as digital transformation, intelligent upgrading, and convergent innovation, and comprises three key components: information infrastructure, converged infrastructure, and innovation infrastructure[2].

How to scientifically measure the level of development of digital infrastructure has become a key issue of concern in academic circles. Most scholars, however, evaluate digital infrastructure by categorizing it into three types of infrastructure based on these concepts: information, convergence, and innovation. For example, scholars such as Li Haigang [3] and Tan Haofang et al. [4] use the number of projects constructed in areas such as communication network infrastructure, computing power infrastructure, intelligent transportation, energy infrastructure, and major scientific and technological infrastructure as metrics for assessment. Furthermore, given the difficulty of obtaining data, scholars such as Jin Haiyan [5], Fan Hejun et al. [6], and Ding [7]have evaluated digital infrastructure based on both its construction and application. Taking an information and communications infrastructure perspective, they selected indicators such as the number of internet broadband connections, the length of fiber-optic cables, mobile phone penetration rates, and computer penetration rates to measure the level of development of digital infrastructure. Unlike the research conducted by other scholars, Chao Xiaojing et al. [8-9] used Python software to extract relevant terms from government annual work reports in order to assess the development of new digital infrastructure across various prefecture-level cities.

Overall, the evaluation indicators for digital infrastructure are shifting from a single communication metric to multi-dimensional comprehensive metrics. However, there are still differences in indicator selection and weight setting among various studies. Therefore, based on existing research, this paper selects indicators from the aspects of information infrastructure, convergence infrastructure, and innovative infrastructure for investment and construction, and constructs a comprehensive evaluation index system for the development level of digital infrastructure. Thereby providing a more comprehensive reflection of the development level of digital infrastructure construction in Guangdong's prefecture-level cities.

3. Research Methods

The entropy method is based on the theory of information entropy proposed by Shannon (1948), this method determines weights by measuring the amount of information in indicators, making it highly objective. Compared with subjective weighting methods, the entropy method determines weights based on the inherent variability of the data, thereby effectively reducing human bias and enhancing the objectivity and scientific rigor of the evaluation results.

This paper uses the entropy method to calculate the level of digital infrastructure development in each prefecture-level city in Guangdong Province from 2015 to 2024. The specific steps are as follows:

Step 1: Data Standardization

Standardize the data for each indicator: x_{ijt} denote the raw value of the jth indicator for the ith city in the tth year ($i = 1,2\ldots n$; $j = 1,2\ldots m$; $t = 1,2\ldots s$).

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$max(x_{ijt})$ and $min(x_{ijt})$ represent the maximum and minimum values of the jth indicator, respectively. To avoid zero values, the standardized data is adjusted by adding 0.0001.
Positive indicators:

$$x'_{ijt} = \frac{x_{ijt} - min(x_{ijt})}{max(x_{ijt}) - min(x_{ijt})} + 0.0001 \quad (1)$$

Negative indicators:

$$x'_{ijt} = \frac{max(x_{ijt}) - x_{ijt}}{max(x_{ijt}) - min(x_{ijt})} + 0.0001 \quad (2)$$

Step 2: Weight Calculation
Normalize the jth indicator:

$$P_{ijt} = \frac{x'_{ijt}}{\sum_{i=1}^{n}\sum_{t=1}^{s} x'_{ijt}} \quad (3)$$

Calculate the information entropy of the jth indicator:

$$e_j = -\frac{1}{ln(n \times s)}\left(\sum_{i=1}^{n}\sum_{t=1}^{s} P_{ijt} \times ln(P_{ijt})\right) \quad (4)$$

Calculate the weight of the jth indicator:

$$w_j = \frac{1 - e_j}{\sum_{j=1}^{m}(1 - e_j)} \quad (5)$$

Step 3: Calculate the annual composite score for each city's digital infrastructure development:

$$D_{it} = \sum_{j=1}^{m} w_j \, x'_{ijt} \quad (6)$$

4. Data Source and Index Selection

4.1. Data Source

The data in this section is primarily sourced from the "Guangdong Statistical Yearbook" and the statistical yearbooks of various cities in Guangdong Province. Supplementary data is drawn from the "Industry Market Outlook and Investment Planning Analysis Report on China's New Infrastructure Construction", with additional data provided by publicly available data from the National Development and Reform Commission.

4.2. Index Selection

Based on the National Development and Reform Commission's definition of new infrastructure, this study will construct an indicator system for assessing the development level of digital infrastructure across three dimensions: information infrastructure, converged infrastructure, and innovation infrastructure.
Drawing on the research by Zhang Shuhui et al. [10], this paper constructs an indicator system for assessing the development level of digital infrastructure based on three dimensions:

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information infrastructure, convergence infrastructure, and innovation infrastructure. Specifically, information infrastructure is measured by fixed-asset investment in the information transmission, software, and information technology services sector. Innovation infrastructure is primarily measured by fixed-asset investment in the scientific research and technical services sector and in the health and social work sector. And convergence infrastructure is primarily measured by fixed-asset investment in the production and supply of electricity, heat, gas, and water; in transportation, warehousing, and postal services; and in water conservancy, environmental protection, and public facilities management. The specific indicators are shown in Table 1.

Table 1. Indicator System for Evaluating the Development Level of Digital Infrastructure

Level 1 Indicator	Level 2 Indicator	Level 3 Indicator
Digital Infrastructure Development Level	Information Infrastructure	Fixed-asset investment in the information transmission, software, and information technology services sector
	Innovation Infrastructure	Fixed-asset investment in the scientific research and technical services sector
		Fixed-asset investment in the health and social work sector
	Convergence Infrastructure	Fixed-asset investment in the electricity, heat, gas, and water production and supply sector
		Fixed-asset investment in the transportation, warehousing, and postal services sector
		Fixed-asset investment in water conservancy, environmental protection, and public facilities management

5. Analysis of Measurement Results

5.1. Digital Infrastructure Development Level by Region

Using the entropy method, this study evaluates the level of digital infrastructure development in four economic regions, The final results are shown in Figure 1.

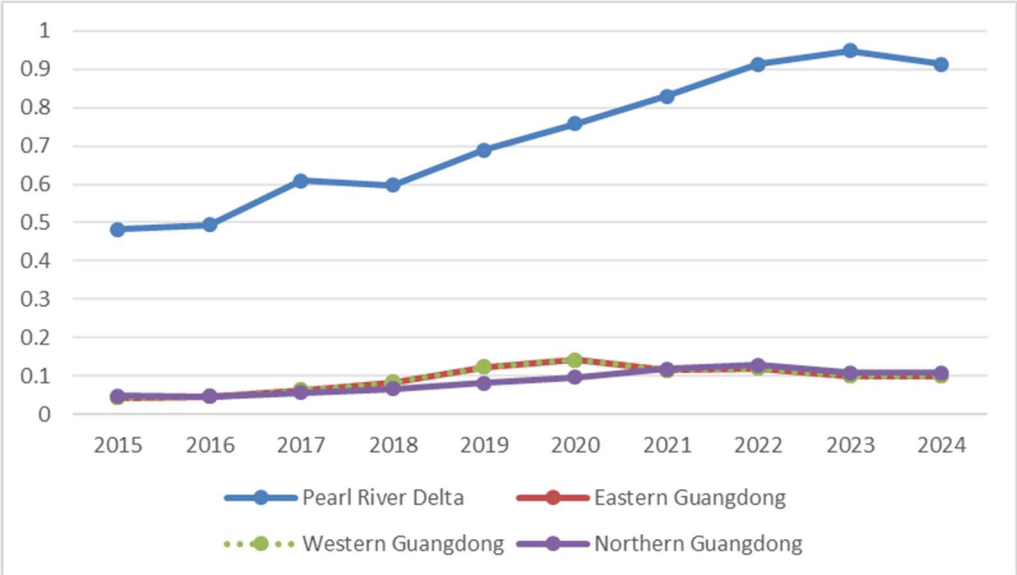


Figure 1. Composite Scores of Digital Infrastructure Development by Region in Guangdong Province, 2015-2024

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As shown in Figure 1, there are significant regional disparities in the level of digital infrastructure development in Guangdong Province. Among these regions, the Pearl River Delta region has the highest composite score for digital infrastructure development, The lowest score was recorded in 2015, with a composite score of 0.4816, which is much higher than that of the three regions in the east, west, and north of Guangdong. Additionally, it can be observed that except for the comprehensive score in 2024 (0.9133) which declined, the scores have shown a trend of year-on-year growth in all other years.

While the level of infrastructure development in Eastern, Western, and Northern Guangdong was largely similar, significant disparities emerged between 2018 to 2020. In 2018, Northern Guangdong's composite score was only 0.0656, lower than the 0.0829 recorded for Eastern and Western Guangdong. The gap widened in 2019 and 2020, with Northern Guangdong scoring 0.081 and 0.0966, respectively, while Eastern and Western Guangdong scored 0.1224 and 0.1413 in those two years. Since 2020, the level of digital infrastructure development in Northern Guangdong has gradually improved, even showing a trend of surpassing that of Eastern and Western Guangdong.

5.2. Digital Infrastructure Development Level by City

Based on the entropy method and the selected indicators, the level of digital infrastructure development in various cities across Guangdong Province was assessed. Table 2 shows the comprehensive scores for each city.

Table 2. Composite Scores of Digital Infrastructure Development for Cities in Guangdong Province, 2015–2024

city	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Guangzhou	0.4623	0.4126	0.4494	0.4104	0.5287	0.6310	0.7091	0.6993	0.6773	0.6832
Shenzhen	0.2299	0.2910	0.3621	0.3948	0.4935	0.4844	0.5834	0.6903	0.7604	0.7861
Zhuhai	0.0603	0.0469	0.0824	0.0977	0.1132	0.1156	0.0846	0.0940	0.0831	0.0739
Shantou	0.0363	0.0370	0.0725	0.0872	0.1426	0.1820	0.1190	0.1269	0.1062	0.1040
Foshan	0.0992	0.0886	0.1362	0.1059	0.1300	0.1374	0.1425	0.1773	0.1859	0.1749
Shaoguan	0.0390	0.0395	0.0412	0.0496	0.0629	0.0710	0.0671	0.0581	0.0653	0.0709
Heyuan	0.0231	0.0213	0.0282	0.0371	0.0542	0.0612	0.0810	0.0503	0.0557	0.0422
Meizhou	0.0271	0.0270	0.0389	0.0531	0.0521	0.0591	0.0448	0.0588	0.0643	0.0633
Huizhou	0.0555	0.0560	0.0739	0.0896	0.0889	0.1227	0.1371	0.1697	0.2103	0.1785
Shanwei	0.0372	0.0425	0.0393	0.0481	0.0640	0.0682	0.1045	0.1117	0.0903	0.0910
Dongguan	0.0869	0.0733	0.0903	0.0938	0.1165	0.1473	0.1311	0.1352	0.1377	0.1187
Zhongshan	0.0334	0.0533	0.0454	0.0492	0.0646	0.0871	0.0945	0.1326	0.1824	0.1338
Jiangmen	0.0767	0.1025	0.1532	0.1129	0.1006	0.1038	0.1048	0.1054	0.1090	0.0718
Yangjiang	0.0465	0.0397	0.0321	0.0375	0.0401	0.0541	0.1047	0.0666	0.1004	0.0988
Zhanjiang	0.0608	0.0883	0.1002	0.0989	0.0975	0.1210	0.1595	0.1860	0.1466	0.1149
Maoming	0.0512	0.0496	0.0615	0.0744	0.0864	0.0723	0.0722	0.0972	0.1322	0.1351
Zhaoqing	0.0453	0.0572	0.0845	0.0907	0.0834	0.0901	0.0921	0.1000	0.0969	0.1228
Qingyuan	0.0246	0.0301	0.0358	0.0297	0.0398	0.0513	0.0821	0.1183	0.0807	0.0782
Chaozhou	0.0216	0.0252	0.0317	0.0348	0.0462	0.0397	0.0387	0.0380	0.0326	0.0352
Jieyang	0.0415	0.0416	0.0534	0.0960	0.1307	0.1334	0.0845	0.0827	0.0759	0.0875
Yunfu	0.0354	0.0278	0.0249	0.0281	0.0292	0.0285	0.0376	0.0605	0.0517	0.0544

From a temporal perspective, the level of digital infrastructure development in cities across Guangdong Province has been rising year by year. Specifically, Guangzhou and Shenzhen have consistently held the leading positions. The comprehensive assessment value of digital

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infrastructure construction in Guangzhou has been higher than that of Shenzhen from 2015 to 2022. From 2023 to 2024, the comprehensive assessment values of digital infrastructure construction in Shenzhen were 0.7604 and 0.7861 respectively, which were significantly higher than the infrastructure development levels of Guangzhou in 2023 (0.6773) and 2024 (0.6832). Second, cities in the second tier include Foshan, Dongguan, and Huizhou. As shown in Table 2, Foshan's level of digital infrastructure development has grown slowly, rising gradually from 0.0992 to 0.1749. In contrast to Foshan, Huizhou showed a relatively strong growth trend in 2020 (0.1227) and even surpassed Foshan's level of digital infrastructure development after 2023 (0.2103).

6. Conclusion and Recommendations

6.1. Conclusion

Based on panel data for prefecture-level cities in Guangdong Province from 2015 to 2024, this paper evaluates the level of high-quality economic development across the province's 21 prefecture-level cities. The main conclusions are as follows:

First, at the regional level, there are significant disparities in the development of digital infrastructure across Guangdong Province, with an overall spatial pattern characterized by "the Pearl River Delta leading the way, Eastern and Western Guangdong in the middle, and Northern Guangdong lagging behind." Specifically, leveraging its robust economic foundation and policy advantages, the Pearl River Delta region has consistently achieved the highest overall score in digital infrastructure development, maintaining a significant lead over the other three major regions and demonstrating sustained and rapid growth. The levels of development in Eastern and Western Guangdong are relatively similar, and their overall scores have remained largely in step with one another. Although they started from a lower baseline, they have shown a steady upward trend overall and, driven by policy initiatives, have gradually narrowed the gap with the Pearl River Delta. The level of digital infrastructure development in Northern Guangdong is generally lower than that in Eastern and Western Guangdong. While its development remains relatively lagging, it is showing signs of catching up. Overall, although all regions are experiencing upward trends, significant disparities in development remain evident.

Second, at the city level, the overall standard of digital infrastructure development has been rising year by year, but there are significant disparities among cities, reflecting a clear pattern of tiered differentiation. Guangzhou and Shenzhen have consistently maintained a leading position, with Guangzhou sustaining a high level of performance over the long term thanks to its comprehensive hub functions and focus on public services. Cities such as Foshan, Dongguan, and Huizhou are in the middle tier. Among them, Foshan focuses primarily on supporting the digital transformation of traditional manufacturing and has experienced relatively steady growth. Dongguan has seen steady improvement driven by industrial synergy. And Huizhou, bolstered by projects such as large-scale data centers, has seen rapid growth in digital infrastructure development, surpassing Foshan in some years.

Overall, differences among cities in terms of their developmental foundations, industrial needs, and construction priorities have resulted in a clearly tiered structure and diverse development paths for digital infrastructure construction in Guangdong Province.

6.2. Recommendations

Firstly, propose strengthening regional coordination and policy support to leverage the spillover and driving effects of leading regions. Fully leverage the technological and resource advantages of the Pearl River Delta region to drive the development of eastern, western, and northern Guangdong through cross-regional network interconnection, shared computing resources, and industrial collaboration. At the same time, we will increase policy support and

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financial investment in relatively underdeveloped regions such as Northern Guangdong, address shortcomings in digital infrastructure, and promote balanced development of digital infrastructure across the province.

Secondly, promote differentiated development paths for cities to foster complementary strengths and coordinated development. We should promote differentiated development approaches based on the developmental foundations and industrial needs of different cities, and support Guangzhou and Shenzhen in continuously enhancing their high-end digital infrastructure and innovation leadership capabilities to serve as models and drivers of progress. Guide cities such as Foshan, Dongguan, and Huizhou to integrate the digital transformation of their manufacturing sectors with major infrastructure projects, enhance the application and capacity of their digital infrastructure, and promote complementary strengths and coordinated development among these cities.

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