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# Development and Evolution of Digital Construction Management Adoption in China's Construction Industry

**Shuwen Cao***

Master, School of Economics and Management, Chang'an University, Xi'an 710061, Shaanxi, China

**Author to whom correspondence should be addressed.*



**Abstract:** The development of digital construction management is an important initiative to promote the digital transformation of the construction industry. But the attention to the regional differences in the development level of digital construction management in China from the industrial level is still relatively scarce. In this paper, the combination assignment method, Dagum's Gini coefficient and Kernel density estimation method, are used to explore the regional differences and their dynamic evolution trends of China's digital construction management development level. The study finds that the overall development level in China's construction industry is on the rise, but it is still at a relatively low level. The overall Gini coefficient has increased, which is mainly due to uneven development between regions. There are large development differences between the eastern region and the other three regions. The interregional Gini coefficients for the Central-Northeastern and Central-Western regions are all growing at a higher rate.

**Keywords:** Digital; Construction management; Regional differences; Dagum's Gini coefficient; Kernel density estimation

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## 1. Introduction

Industrial digitization, as an important part of the digital economy, has a profound impact on the digital transformation and upgrading of traditional industries. It has become a new engine for building a modernized industrial system with high added value [1]. The construction industry is one of the important implementation areas of industrial digitization. But its pace of transformation is still relatively backward, with problems like high energy consumption and pollution, sloppy management methods, and a low level of informatization [2, 3]. Deep-rooted conflicts between the above problems and the increasing projects volume, technical difficulties and society's requirements for the environment, urgently require the promotion of industrial digitization, which empowers the transformation and upgrading of the construction industry [4]. Scholars at home and abroad have focused on the research of digital construction management in the fields of building information modeling (BIM) and digital twin, Internet of Things (IoT), blockchain, and artificial intelligence (AI). There are strong advantages of BIM technology in the management of engineering project entity data and information [5]. At the same time, real-time prediction, optimization, control, and improved decision-making are accomplished through data and simulators by digital twin technology, which has received much attention [6, 7]. Blockchain and IoT, increasingly applied to solve the problems of lack of collaboration, poor supervision, and information occlusion in construction management, are also the focus of research in related fields [8]. Automatic identification of worker behavior, construction prediction using neural network models, and effective management of construction resources of AI technology have also become research hotspots [9–11].

For the problem of inadequate integration and uneven development between digital technology and construction management, scholars mostly focus on the project level, with technology development and improvement as the breakthrough to promote the digital transformation of construction management. However, the problems are difficult to be solved only by technological innovation at the project level. It is urgent to think about the solution from the perspective of the whole industry. However, there is a large gap in the research launched from the industrial level. Whether digital construction management has landed at the industrial level and whether there are differences in the industrial development level, attention to these issues is lacking in the existing research. Therefore, the regional difference and its evolution trend of the development level of digital construction management in China's construction industry are studied from the industrial level in this paper, to promote the integrated and balanced development of digital construction management.

# 2. Methodology and indicator system

## 2.1. Research methods

### 2.1.1. Dagum Gini coefficient decomposition

The Gini coefficient decomposition method proposed by Dagum is an important method to measure the regional development differences [12]. The relative difference of China's digital construction management development in different regions are reflected by decomposing the Gini coefficient into three parts: intra-regional difference contribution, inter-regional difference contribution, and hyper-variable density contribution.

### 2.1.2. Kernel density estimation

Kernel density estimation relies solely on sample data to assess the characteristics of spatial distribution and trends, avoiding discrepancies between actual and measured values that may arise from assuming a predefined functional form. So this method is weakly dependent on the model and has strong stability, and often used to explore the spatial non-equilibrium of the data [13].

## 2.2. Composite indicator system and data sources

Based on existing research experience, this paper constructs a digital construction management evaluation index system with four first-level indicators [14, 15]. The index system takes digital infrastructure as the foundation, digital effect as the core objective, digital input as the driving force, and digital application as the engine. The system includes nine second-level indicators, their weights are shown in **Table 1** below.

This paper selects data from 31 provinces (administrative regions) in China other than Hong Kong, Macao, and Taiwan as the research sample, spanning the period from 2014 to 2022. The data for the research are all obtained from *China Statistical Yearbook*, *China Statistical Yearbook on Construction*, *China Statistical Yearbook on Science and Technology*, statistical yearbooks of various provinces in China, and the National Bureau of Statistics (NBS).

**Table 1.** Digital construction management evaluation index system

| First-level indicators | Second-level indicators | Weight | Indicator attribute |
|---|---|---|---|
| Digital input | Enterprise digital R&D expenses | 0.12 | + |
| | Total internal expenditure of R&D funds | 0.18 | + |
| | R&D personnel in full-time equivalents | 0.16 | + |
| Digital application | Enterprise innovation rate | 0.17 | + |
| | Number of patent applications | 0.20 | + |
| Digital infrastructure | Total number of digital construction machinery and equipment | 0.09 | + |
| | Digital technical equipment rate | 0.05 | + |
| Digital effect | Total energy consumption | 0.01 | - |
| | Labor productivity | 0.02 | + |

# 3. Empirical results

## 3.1. Measuring the development level of digital construction management in China

**Figure 1** shows the trend of the development level in the regions. From a general perspective, the development level in the whole country as well as in each region showed an overall upward fluctuating trend. However, the digitalization development index of each province is in the lower-middle level and has a large gap between different provinces. By region, the average development level in the eastern region is the highest and the overall increase is the largest, which indicates that the digital construction management in the eastern region is not only better developed, but also ranks first in the country in terms of the speed of development. The development level in the northeastern region and the western region are both lower than the national average.

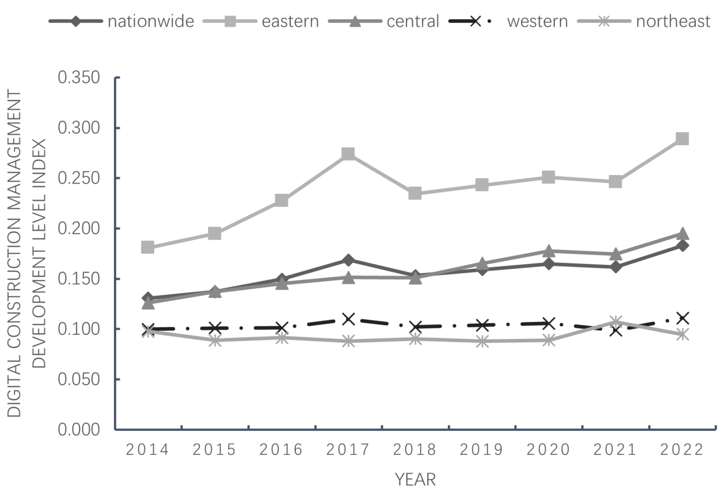


**Figure 1.** Trend of the composite index of the development level of digital construction management

## 3.2. Regional differences in the development level of digital construction management in China

Dagum Gini coefficient decomposition method was used to further analyze the regional differences, and the results of which are shown below.

### 3.2.1. Overall and intra-regional differences

As shown in **Figure 2**, the overall Gini coefficient of the development level showed a fluctuating upward trend. Sub-regionally, the Gini coefficient of the Eastern region is the largest and fluctuates the most. The Gini coefficient of the Central and Western regions is relatively close to each other. The Gini coefficient for the Central region has a growth rate of 5.17%, while the growth rate of the Western region is 75.51%. In addition, the Gini coefficient of the Northeast region is at the lowest level except for 2021, and the decline rate is 40.68%. The above results show that the regional differences in the eastern region is always in the first place in the country, and the northeast region has the smallest development differences among the four regions.

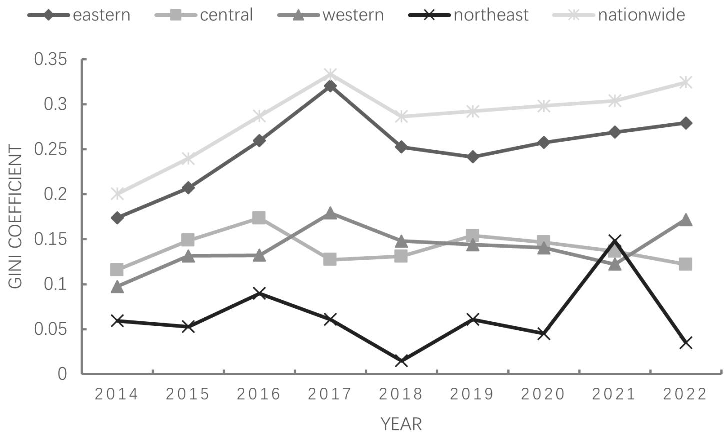


**Figure 2.** Overall and regional Gini coefficient and its evolution trend

### 3.2.2. Inter-regional differences

The inter-regional differences and their development trends between the four regions are shown in **Figure 3**, from which it can be seen that the Gini coefficient between the regions generally shows a fluctuating upward trend. The East-Northeast region has the largest inter-regional Gini coefficient and a larger fluctuation and the Gini coefficient growth rate of the central-northeast region is the largest. The Gini coefficient of the West-Northeast region is the lowest and fluctuates more gently. The above analysis indicates that the inter-regional differences in the development level of China's digital construction management have been expanding. The inter-regional differences between the Eastern region and the Western region, the Northeastern region are the largest.

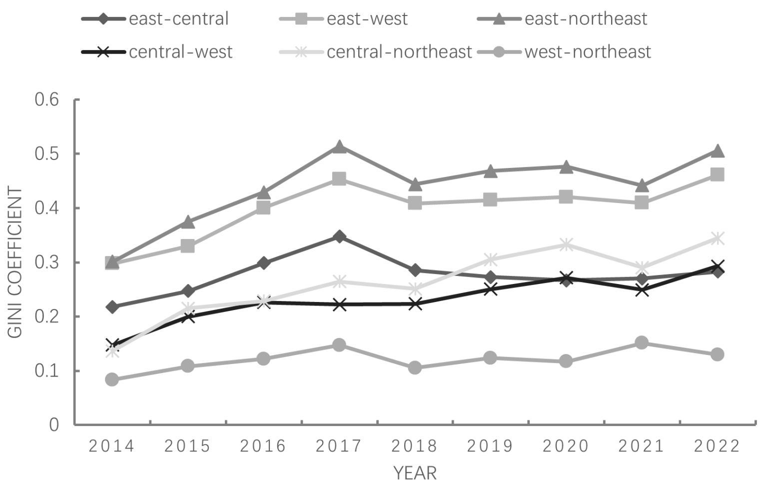


**Figure 3.** Inter-regional Gini coefficients and evolution trend

### 3.2.3. Sources and contributions of differences

**Figure 4** shows the sources and the contribution rate of regional differences in the development level of digital construction management in China during the research period. The contribution rate of inter-regional difference is 70.89% on average, indicating that inter-regional difference is the main source of the overall development difference. The intra-regional difference and hyper-variable densities did not have a significant impact on the difference. Therefore, to solve the problem of the difference in development, it is crucial to reduce the development difference between regions.

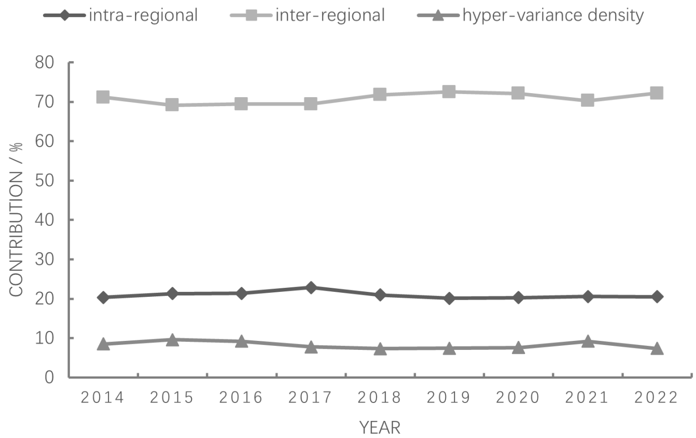


**Figure 4.** Sources and contributions of regional differences

## 3.3. Dynamic evolution of the differential development levels of digital construction management in China

This paper analyzes the location, shape, and ductility of the distribution of the development level index by means of the Kernel density estimation, as shown in **Figure 5**. From the position of the wave peak, the overall position of the main peak shifted to the right, which indicates that the development level has improved nationwide. However, the height of the main peak declined and the width increased, indicating that the regional development imbalance has increased. In addition, there are side peaks and the gap between the main side peaks widens between 2014 and 2019, indicating that there is bipolar or even multipolar polarization, and the gap is gradually increasing.

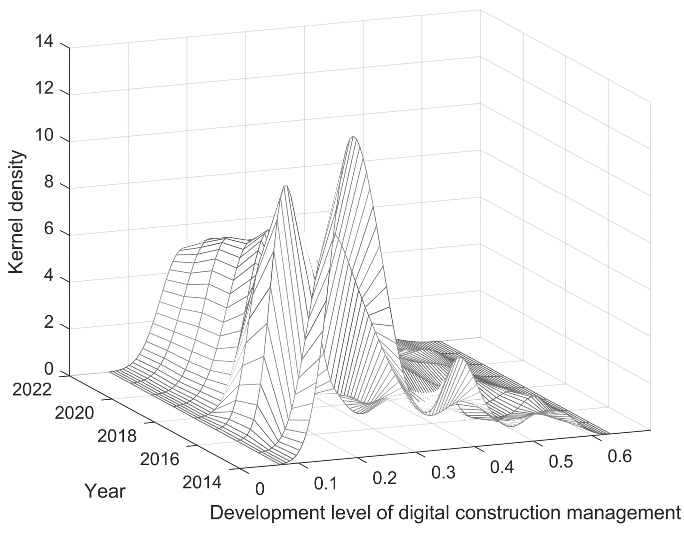


**Figure 5.** Dynamics of distribution of digital construction management development index in China

As shown in **Figure 6** is the distribution dynamics of the development level in the four regions. As seen in **Figure 6(a)**, the development level in the Eastern region shows an upward trend and the unevenness has increased. From the analysis of **Figure 6(b)**, it can be seen that the regional development differences in the Central region have been increasing. Side peaks exist until 2019, indicating that the polarization phenomenon is obvious. As can be seen in **Figure 6(c)**, the development level in the Western region has increased, but the degree of imbalance has worsened and the phenomenon of polarization is serious. As can be seen in **Figure 6(d)**, the development level in the Northeast has polarized and intensified as the number of years has increased.

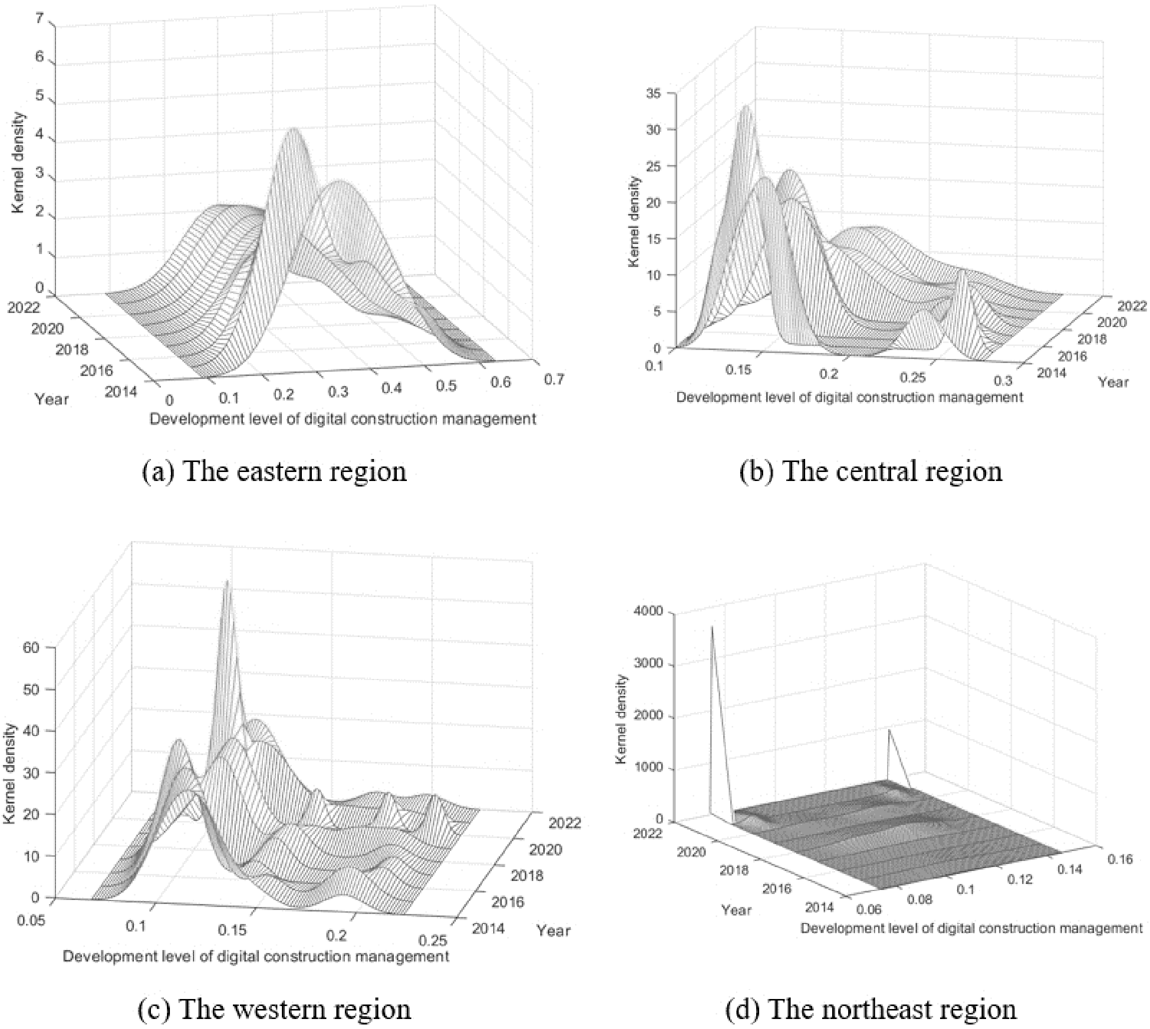


**Figure 6.** Distribution of digital construction management development index in four regions

## 4. Conclusions

This paper measures the development level of digital construction management in China's construction industry from the industrial level. The Dagum Gini coefficient decomposition method is used to decompose the development differences across the country and the four regions. And finally, the Kernel density estimation is used to analyze the spatio-temporal dynamic distribution and evolution trend of the development level. The empirical results show that:

(1) The development level has risen in waves. However, most provinces are still at a low level and pace of

development, and there are large differences between regions. Motivating industrial transformation and promoting quality and efficiency in digital development remain key points.

(2) The development level of regional differences show a trend of expanding. Excessive differences may pose risks and obstacles in terms of resource allocation and development dynamics. The Northeast region has the smallest intra-regional development difference. However, this is not necessarily a good thing, implying a lack of development drivers and regional "bellwether".

(3) The development differences mainly come from inter-regional development differences. The inter-regional differences between the Eastern region and the Western, Northeast regions are the largest. Therefore, narrowing the inter-regional differences is the key to solving China's development imbalance problem.

(4) The emergence of the phenomenon of polarization indicates that the unevenness of development has been serious. The government should give full play to the means of macro-control, for the digital transformation of construction management escort.

## Disclosure statement

The author declares no conflict of interest.

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