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Evaluation of Regional Construction Industry Development Competitiveness based on Entropy-VIKOR Method

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Abstract

As one of the pillar industries of the national economy, the vigorous development of the construction industry plays a pivotal role in the coordinated operation of the whole national economy. Combining the correlation between the regional economy and the development of the construction industry, the regional construction industry development competitiveness evaluation index system is constructed from the aspects of internal and external factors affecting the development of the construction industry. On this basis, the competitiveness of the construction industry development of 31 provinces and municipalities directly under the central government in China in 2018 was evaluated and analyzed using the entropy weighting method and the VIKOR method, taking each province in China as the research unit. The study shows that the level of development of the construction industry in China's provinces is unbalanced, and the level of comprehensive development of the construction industry and the level of regional economic development is unevenly developed between provinces. According to this conclusion, this paper aims to provide the provinces with an empirical basis for adjusting their own construction industry policies and play a certain reference significance for the development of the provinces.

Keywords

Regional Construction Industry; Development Competitiveness Level; Index Evaluation; Entropy Weighting Method; Multi-attribute Decision Making; VIKOR Method.

1. Introduction

Along with the promotion of reform, the construction industry, as one of the pillar industries of the national economy, has been developing rapidly. At present, China has turned to the stage of high-quality development, and the construction industry is also accelerating the transformation of the traditional construction method and sloppy development, taking reform and innovation as the driving force, intelligent and green development as the path, and walking out of an intensive and high-quality development path. This makes the connection between the construction industry and the regional economy more and more closely. On the one hand, the stable development of the regional economy is an effective guarantee for the steady growth of the construction industry, on the other hand, the prosperity of the construction industry is one of the important engines of the regional economic development; the two complement each other and promote each other. Therefore, in the context of the new development stage of scientific and reasonable analysis of the relevance of regional economic and construction industry development, grasp the different regional construction industry development differential impact factors, coordinated linkage of regional economic construction and construction industry, is conducive to city-based policy, promote the construction industry and regional economic positive interaction, improve the development of the construction industry, and promote the sustainable development of the construction industry.

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Currently, the coupling development of regional construction industry and regional economy is an issue of great concern to academics. Among the existing studies, Bu et al. [1] analyzed the interaction between regional economy and construction industry from the perspective of industry contribution rate and industry GDP contribution rate, and the resulting differences in the development of construction industry in different regions. Cai [2] selected indicators from the perspective of construction industry inputs and outputs, analyzed the development trend of construction industry in different provinces of China from 2009-2017, and found that the development level of China's construction industry was progressively distributed by regions. Xu et al. [3] established a sustainable development system based on social, economic, environmental, and ecological indicators, and analyzed the differences in the sustainable development of the construction industry in the east, middle and west regions. Bon [4] showed that the development of the construction industry is consistent with the level of economic development, which is unidirectional and follows an inverted U-shaped curve, and the development level of the construction industry in all countries continues to rise in the LDC (less developed) stage, reaches the peak in the NIC (new industrialization) stage, and reaches the peak in the AIC (highly industrialized) stage. The development level of the construction industry in all countries continues to rise in the LDC (underdeveloped) stage, peaks in the NIC (new industrialization) stage, and declines in the AIC (highly industrialized) stage. Zhao et al. [5] took Beijing, China, as the core, and used data related to the construction industry from 2011-2018 as the basis for examining the current situation of cross-regional development of China's infrastructure industry by constructing a cross-regional influence model and a synergistic coupling evaluation model of China's construction industry considering economic, social, and ecological development. It is found that the regional differences of China's construction industry are significant, and the contribution and development level of the construction industry are usually at low coupling and antagonistic levels. Liu et al. [6] used entropy value method and coupling coordination degree model to calculate the coupling coordination degree between construction industry and regional economy in each province from 2011 to 2017, and found that the importance of regional construction industry differences in economic growth differences, and the coupling coordination degree of regional construction industry and regional economy has obvious spatial distribution characteristics of "high in the east and low in the west".

As mentioned above, there is no consensus on the evaluation index system of regional construction industry development competitiveness. And the method of regional construction industry development competitiveness is mainly based on the calculation of the comprehensive score value to evaluate the development competitiveness. While there are fewer studies on the gap between the actual value and the ideal value, and the development competitiveness is evaluated according to the size of the gap. In order to scientifically and rationally study the regional development competitiveness of the construction industry. This paper investigates the differences in the development of the construction industry in different regions based on the diversified forms of current economic development and the intrinsic relationship between regional economic development and the development of the construction industry. To begin with, a scientific and effective index for the competitiveness of construction industry development is constructed by reviewing the literature. Then a comprehensive evaluation of the competitiveness of construction industry in 31 provinces is conducted based on the VIKOR method. Last but not least, based on the obtained results, we analyze the indicators of different aspects of construction industry competitiveness in each province, explore the shortcomings of construction industry competitiveness, and propose the path to improve the competitiveness of construction industry.

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2. Building a Competitive Index System for Construction Industry Development

2.1. Indicators Selection

Table 1. Construction industry development competitiveness indicators

The first-level index	The second-level index	The third-level index	The connotation of the index
Construction industry development competitiven-ess	Industry scale and technical capacity	Total construction industry output value x_1 (billion)	Construction company production results reflect
		Operating income of construction industry x_2 (billion)	Comprehensive index
		Number of enterprises in the construction industry x_3 (pcs)	Number of regional construction enterprises scale
		Construction business assets x_4 (billion)	Economic strength of construction enterprises
		The amount of contracts signed by construction companies x_5 (billion)	Market size of construction companies
		Number of employees in the construction industry x_6 (ten thousand people)	Scale of labor force owned by construction companies
		House construction area x_7 (million/m2)	The amount of work completed by construction
		House completion area x_8 (million/m2)	
		Net value of owned machinery and equipment at the end of the year x_9 (10 million)	Scale of mechanical power equipment for construction enterprises
		Total power of owned machinery at the end of the year x_{10} (million kilowatts)	
		Power Equipment Rate x_{11} (kilowatt/person)	Mechanization level of construction enterprises
		Technical equipment rate x_{12} (yuan/person)	
	Social development level and economic construction	Urbanization rate x_{13}(%)	Regional socio-economic development level
		Average wage in the construction industry x_{14} (yuan)	
		Scale of fiscal spending x_{15} (%)	Government regulation and stimulation of economic construction efforts
		Fixed asset investment scale x_{16} (%)	

Combining the relevance of regional economy and construction industry development, the regional construction industry development competitiveness evaluation index system is constructed from the internal and external factors affecting the development of the construction industry, starting from the internal development capacity and social development level of the construction industry. Determining two secondary indicators and 16 tertiary

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indicators of industrial scale and technical capacity and social development level and economic construction. Details of the index system of the competitiveness of construction industry development are shown in Table 1.

2.2. Data Collection

The data sample used in this paper is derived from the 2018 China Statistical Yearbook database, and 31 major medium and large cities across the country including various provinces and four municipalities directly under the central government: Beijing, Shanghai, Tianjin, and Chongqing, as well as five autonomous regions: the Inner Mongolia Autonomous Region, Guangxi Zhuang Autonomous Region, Tibet Autonomous Region, Ningxia Hui Autonomous Region, and Xinjiang Uygur Autonomous Region, are selected for specific studies.

In this paper, we consider a Multi-attribute decision making problem, which uses i to denote the evaluation object, m to denote the total number of evaluation objects, i.e., $m = 31$, j to denote the evaluation index, n to denote the number of indexes, i.e., $n = 16$, and x_{ij} to denote the value of the jth index of the ith evaluation object. The multi-index evaluation matrix for construction industry development competitiveness evaluation is: $X = (x_{ij})_{31\times16}$.

3. Research Methodology

The VIKOR method, also known as the compromise ranking method, is a compromise Multi-attribute decision making method proposed by Opricovic [7] in 1998. It is both an optimal compromise alternative method and also a management method based on the ideal point method. The central idea of the method is based on the premise of defining positive and negative ideal alternatives, with the core being a compromise planning method, and then using the evaluated values of the alternatives and the proximity of the ideal alternatives to arrive at the final prioritization. Its main feature is the compromise between maximizing the "group benefits" and minimizing the "individual regrets" of the opposing views, mainly using linear normalization and taking into account the utility preferences of the decision makers. Therefore, the VIKOR algorithm is also considered as an optimal compromise alternative in Multi-attribute decision making. In the context of this paper, the specific application steps are as follows.

Step 1. Data processing, constructing the normalization matrix F. Using Eq. (1) to standardize the raw data of 31 provinces, constructing the normalization matrix $F = (f_{ij})_{m\times n}$, where f_{ij} is the standardized value of the jth indicator in the evaluation index system of the development competitiveness of the construction industry in the ith province.

$$f_{ij} = x_{ij} / \sqrt{\sum_{i=1}^{m} x_{ij}^2} \quad (1)$$

i=1,2,...,m; j=1,2,...,n.

Step 2. According to the normalization matrix F, the value of each indicator determines the positive ideal alternative f_j^+ and the negative ideal alternative f_j^-. In China's economic development, the evaluation criteria of industrial scale and technical capability indicators are the larger the better, therefore, all indicators in Table 1 are efficiency-type indicators. f_j^+ denotes the maximum value of the jth indicator in the index system of the competitiveness of construction industry development, and f_j^- denotes the minimum value of the jth indicator in the index system of the competitiveness of construction industry development.

$f_j^+ = \max_i f_{ij}$; $f_j^- = \min_i f_{ij}$, When the evaluation criterion is a benefit-based criterion, i.e., the criterion is judged as the greater the value of the indicator, the better.

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$f_j^+ = \min_i f_{ij}$; $f_j^- = \max_i f_{ij}$, When the evaluation criterion is a cost-based criterion, i.e., the criterion is judged as the smaller the value of the index, the better.

Step 3. Use the entropy weighting method, i.e., Eq. (2), to determine the weight of each indicator in the construction industry development competitiveness index system. In Eq. (2), e_j indicates the entropy of the jth index in the index system, and ω_j indicates the weight of the jth index in the index system.

$$e_j = -(\sum_{i=1}^{m} f_{ij} ln f_{ij}) / \ln(m); \quad (2)$$

$$\omega_j = (1 - e_j) / \sum_{j=1}^{n} (1 - e_j) . \quad (3)$$

Step 4. Calculate the weighted distance S_i of the positive ideal alternative and the weighted distance R_i of the negative ideal alternative by using Eqs. (3)-(4), in which S_i represents the weighted distance from the value of construction competitiveness of province i to the positive ideal alternative; R_i represents the weighted distance from the value of construction competitiveness of province i to the negative ideal alternative.

$$S_i = \sum_{j=1}^{n} \omega_j (f_j^+ - f_{ij}) / (f_j^+ - f_j^-); \quad (4)$$

$$R_i = max \omega_j (f_j^+ - f_{ij}) / (f_j^+ - f_j^-). \quad (5)$$

Step 5. In Eq. (5), Q_i denotes the VIKOR value of construction industry development competitiveness in province i. $Smax$ and $Smin$ denote the maximum and minimum values of the weighted distance S from construction industry development competitiveness to the positive ideal alternative, respectively. Similarly, $Rmax$ and $Rmin$ denote the maximum and minimum values of the weighted distance R from construction industry development competitiveness to the negative ideal alternative, respectively. v is the coefficient of decision mechanism, and v equals to 0.5 is used in the VIKOR calculation to indicate the simultaneous pursuit of maximizing the group utility and minimizing the individual regret of the construction industry development competitiveness.

$$Q_i = v(S_i - Smin)/(Smax - Smin) + (1 - v)(R_i - Rmin)/(Rmax - Rmin) \quad (6)$$

Step 6. Rank the competitiveness of the construction industry according to the calculated S_i, R_i and Q_i. Three different ranking sequences are obtained by ranking the S_i, R_i and Q_i values from smallest to largest, and the one in the front is better than the one in the back. The final order of superiority of the final construction industry development competitiveness is determined according to the following two rules.

First, $Q^2 - Q^1 \geq 1/(m-1)$. Where: Q^1 denotes the Q value of the 1st ranked province after the ranking of construction industry development competitiveness value Q ; Q^2 denotes the Q value of the 2nd ranked province in construction industry development competitiveness. m=31, $1/(m-1)$ denotes the acceptable threshold value, that is, only the 2nd ranked province in construction industry development competitiveness Q is greater than or equal to the threshold value than the 1st ranked province in construction industry development competitiveness, can indicate that the 1st ranked. Otherwise, the 1st and 2nd ranked provinces are comparable for construction industry development competitiveness; then, the evaluation value of the 3rd

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ranked province is compared with the 1st ranked value one by one in turn until it is greater than or equal to the acceptable threshold value.

Second, after satisfying the first rule of ranking, compare the S_i and R_i of each province. if the province ranked 1st in construction industry development competitiveness ability and its S_i value or R_i value is also ranked 1st, then the construction industry development competitiveness of the 1st ranked province is stable and optimal, otherwise it is equivalent.

4. Empirical Research

Take the evaluation of the development competitiveness of construction industry development in 31 provinces nationwide as an example.

Step 1. Using Eq. (1) to the data and construct the normalization matrix F.

Table 2. The weight of the construction industry development competitiveness index

The first-level index	The second-level index	The third-level index	Weight
Construction industry development competitiven-ess	Industry scale and technical capacity	Total construction industry output value x_1 (billion)	0.056
		Operating income of construction industry x_2 (billion)	0.062
		Number of enterprises in the construction industry x_3 (pcs)	0.071
		Construction business assets x_4 (billion)	0.065
		The amount of contracts signed by construction companies x_5 (billion)	0.060
		Number of employees in the construction industry x_6 (ten thousand people)	0.048
		House construction area x_7 (million/m2)	0.043
		House completion area x_8 (million/m2)	0.042
		Net value of owned machinery and equipment at the end of the year x_9 (10 million)	0.055
		Total power of owned machinery at the end of the year x_{10} (million kilowatts)	0.056
		Power Equipment Rate x_{11} (kilowatt/person)	0.090
		Technical equipment rate x_{12} (yuan/person)	0.073
	Social development level and economic construction	Urbanization rate x_{13}(%)	0.076
		Average wage in the construction industry x_{14} (yuan)	0.097
		Scale of fiscal spending x_{15} (%)	0.076
		Fixed asset investment scale x_{16} (%)	0.032

Step 2. Determine the positive ideal alternative f_j^+ and the negative ideal alternative f_j^- for each index value according to the normalization matrix F. Where

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$f_j^+ = (0.527,0.515,0.441,0.499,0.431,0.544,0.622,0.629,0.509,0.605,0.296,0.609,0.383,0.329,0.661,0.787)$;
$f_j^- = (0.003,0.006,0.009,0.006,0.007,0.003,0.002,0.001,0.003,0.002,0.072,0.045,0.012,0.132,0.062,0.012)$.

Step 3. Calculation of index weights. This article uses the entropy weight method to calculate the index weights, as shown in Eqs. (2)-(3). The development of the regional construction industry competitiveness evaluation index system and the weights of each index are shown in Table 2.

Step 4. Using Eqs. (4)-(5), the values of S_i and R_i can be calculated.

Table 3. Competitiveness ranking of construction industry development by provinces and cities

Province and City	Q_i	Rank
Jiangsu	0.220	1
Beijing	0.299	2
Guangdong	0.350	3
Hebei	0.363	4
Henan	0.406	5
Hubei	0.406	6
Gansu	0.415	7
Shandong	0.451	8
Anhui	0.527	9
Qinghai	0.551	10
Tianjin	0.554	11
Zhejiang	0.563	12
Guizhou	0.564	13
Xinjiang	0.565	14
Sichuan	0.594	15
Shaanxi	0.612	16
Fujian	0.622	17
Chongqing	0.630	18
Jiangxi	0.646	19
Liaoning	0.646	20
Shanxi	0.668	21
Hunan	0.694	22
Xizang	0.694	23
Shanghai	0.697	24
Yunnan	0.760	25
Neimenggu	0.804	26
Guangxi	0.823	27
Ningxia	0.836	28
Heilongjiang	0.854	29
Jilin	0.870	30
Hainan	1	31

Step 5. The development competitiveness of construction industry development in 31 provinces nationwide is measured according to the entropy VIKOR method mentioned above

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and the order of merit rule of the VIKOR method. In this paper, the ranking of the development competitiveness of construction industry development is determined according to the ranking of Q value from smallest to largest.The smaller Q value indicates the proximity to the ideal alternative, i.e., the development competitiveness of construction industry development is stronger. The ranking of the development competitiveness of construction industry development of each province in 2018 is shown in Table 3.

Step 6. According to the ranking rules in Step 6, the competitive ranking of provinces and cities for the development of the construction industry is given, as shown in Table 3.

From the evaluation score and ranking of the development competitiveness of the construction industry in each province in Table 3, we found that Jiangsu, Beijing, and Guangdong ranked steadily in the top 3 in 2018. These provinces are more economically developed, with convenient land and water transportation, representing the highest level of construction industry development in China. The low ranking is mainly in the western region and the northeast, such provinces as Ningxia and Hainan have a large population of their own, the market size is small and the demand for construction and its related products is low. Heilongjiang, Jilin and other less economically developed regions, the level of development of the construction industry to slow and slow, the construction industry development degree is low. The provinces with the faster development level of construction industry are concentrated in the eastern coastal areas, and the regions with faster economic development, while the western regions have weaker development level of the construction industry, and the overall presentation of the eastern coastal areas to the western inland areas, the gradient distribution of construction industry development from fast to slow. In summary, it can be seen that the development level of China's regional construction industry is "strong in the east and weak in the west" spatial distribution is quite obvious, the development of the construction industry and the development of the regional economy is closely related.

5. Suggestions to Improve the Market Competitiveness of the Construction Industry

5.1. Layout Strategy is the Direction of the Construction Industry Market Competitiveness

When planning for the development region and development direction of the enterprise, managers should clearly understand that different regions, countries and areas, their degree of development, geographical topography, human environment, these external environment is unchangeable and different, regionalization development mode can be for a region unique characteristics of long-term deep plowing, the final result for the enterprise is a strong accumulation of technology, product localization of the landing. Managers should pay attention to the use of technology and products, geographical environment and regional characteristics to form a protective barrier for enterprises, so that they can win the first opportunity in the free market competition.

After making a good strategic plan, construction companies need to decide what kind of main business to carry out. Due to the uneven development of each province in China, different needs will arise. Construction companies need to judge the development direction according to their own ability, experience, qualification and local conditions. In addition, the development of the construction industry is influenced by macro factors such as policy tendencies, economic level, social culture, and technological development, which bring opportunities and challenges to the construction industry in every aspect. Among them, the influence of policy factors is often huge, such as the disappearance of the demographic dividend and industrial transfer. Therefore, construction companies grasp the direction in real-time and keep changing to cope with all changes.

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5.2. Rational Resource Allocation

Rationalization of internal support resources to cope with business expansion in new areas. In terms of organizational structure, it is necessary to equip localized organizations and to clarify the division of functions among units at all levels, to shorten the management chain and optimize the management efficiency to improve the overall coordination and cooperation ability. In terms of capacity building, we need to establish a clear training system and an effective incentive system. In terms of talent training, we cannot be greedy for more and faster, which is also not in line with the law of natural development. In terms of resource allocation, it should be scientific and reasonable, too much will cause waste and too little will lead to poor development.

5.3. Technology is the Basis for Enhancing the Competitiveness of the Construction Industry Market

Within the situation of fierce market competition, technological innovation is the fundamental driving force for enterprises to develop, win and maintain their competitive advantages in the competition. The most critical core ability to support the development of the enterprise's financial and technical capabilities is the ability to create technology, because scientific and technological innovation is the source of vitality for enterprises to form core competitiveness and continuously maintain development. Therefore, construction enterprises should lead the enterprise forward with scientific and technological innovation, and support the transformation and upgrading of the enterprise with scientific and technological innovation to realize the sustainable development of construction enterprises.

Specifically, it can be started by uniting technical innovation subjects such as construction technology service providers, product manufacturers and research institutes, establishing a platform for construction innovation technology demand, bridging the demand side and supply side of construction technology, and optimizing the technical environment of the construction industry to improve the industrialization and modernization of the construction industry, alleviate the reliance of the construction industry on labor, and promote the development of the construction industry. Besides, it can actively promote the application of construction information technology, and jointly carry out research and development of special information technology applications with relevant units. Efforts are made to construct the foundation of information technology application in the project department, and on this basis, the information system and network platform of construction enterprises are established and improved to realize the networking of office, information release and data exchange, and the application of software such as comprehensive project information management system is carried out.

5.4. Green Energy-saving Development is the Way to Improve the Competitiveness of the Construction Industry Market

Encourage support for the development of clean energy and energy conservation and environmental protection industries; establish a system for the paid use of water use rights, sewage disposal rights and carbon emission rights; improve the assessment and evaluation system with the core objective of environmental quality improvement, etc., to improve the degree of regional green development, support the promotion and popularization of green buildings, assembly-type buildings and other environment-friendly buildings, thus promoting the development of regional green economy and providing guarantees for the sustainable development of the construction industry.

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6. Conclusion

The evaluation of the competitiveness of the construction industry is a systematic project, and the selection of its indicators is characterized by diversity and multidimensionality. This paper finds through literature research that the factors affecting the competitiveness of the construction industry are closely related to the level of social development and economic construction investment as well as to the scale of the construction industry itself.

The results of this study indicate that the VIKOR evaluation model is applicable to measure the level of regional construction industry development. In addition, the spatial distribution of construction industry development in mainland China is uneven. In general, the construction industry development in the southeast region is better than that in the northwest region. The more developed regions are concentrated in the Beijing-Tianjin-Hebei region, Jiangsu, Zhejiang and Guangdong and Chongqing. They have different development paths according to their geographical characteristics. Provinces and cities should formulate policies for the development of the construction industry in conjunction with the current state of economic development, to give full play to the competitive advantages of the regional construction industry and promote the sustainable and healthy development of the construction industry.

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