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Identification and Analysis of Regional Green Finance Core Factors Based on CRITIC-AHM Coupling

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ABSTRACT

Protecting the environment and green development is an important development strategy for China, and green finance has become one of the development themes of the times. In response to the problems of regional green finance core factors identification using traditional assignment methods, this paper constructs a set of 4-10 green finance index systems from the credit, bond, investment, and carbon finance, based on AHM (Attribute Hierarchy Model) subjective weights and CRITIC (Criteria Importance Though Intercrieria Correlation) objective weights are coupled, an AHM-CRITIC based regional green finance core factor identification and evaluation model is constructed to identify and analyze regional green finance core factors. The study shows that (1) Green credit has a very important position in the green finance indicator system, revealing its role in improving the maturity of green finance construction; (2 Current research on green investment underestimates its operations, and there is great potential for green investment to play a greater role. By studying the identification and analysis of core factors of regional green finance, this paper supplements the empirical research on green finance in China, which is conducive to the formulation of reasonable and scientific development strategies and the rapid development of green finance in China. By identifying and analyzing the core factors of regional green finance, this paper supplements the empirical research of green finance in China, which is conducive to formulating reasonable and scientific development strategies and promoting the rapid development of green finance in China.

Keywords: *regional green finance; AHM-CRITIC; core factors; identification and evaluation*

1. INTRODUCTION

With the rapid development of China's industrialization, the contradiction between economic development and environmental protection is becoming more and more prominent. China's water pollution, waste pollution, other environmental degradation, and resource depletion are becoming increasingly serious, and ecological, environmental protection faces severe challenges. Green finance has played an essential role in improving the development of the ecological environment. The development of green finance is conducive to the harmonious development of both the economy and the environment. It can promote the development of a green economy with high quality so that the ecological environment can be effectively improved and restored. With the rapid growth of green finance, experts and scholars in China have been studying more and more green finance year by year, and green finance has become a popular research topic in recent years.

At present, many experts and scholars have researched this area, for example, Zhang and Wang[1] found that the factors affecting green finance are divided into two levels: economic development, which includes the level of per capita income of residents, the level of per capita savings, the level of consumption of residents and the funds for environmental protection, and the level of knowledge, which includes the level of education of people. Fang and Lin[2] constructed an index system for evaluating China's regional green finance development index and found that the industrial structure upgrading index is the primary influencing factor of green finance. Dong and Fu[3] analyzed that regional gross domestic product has the greatest effect on green finance among the four explanatory variables. Mai and Xu[4] found that the repayment capacity has the most profound influence on green finance through a joint analysis study. Yu and

Xu [5] established a fixed-effects spatial Durbin model. They analyzed that the main factors influencing the evolution of the spatial pattern of green finance development in Guangdong Province are gross regional product, degree of financial development, air quality and education level. Vyas [6] found that the total amount of green finance in China is not large, the market is not yet perfect, the profitability of green finance is low, there are not many profit models, the green finance system is not properly designed, and The policies and regulations are not perfect.

Green finance-related professional data are relatively difficult to obtain, so most of the previous research methods tend to stay at the level of qualitative research without the support of professional data, and most of the research is conducted from a regional perspective. Based on authoritative professional data, this paper adopts the AHM-CRITIC weighting method to construct a set of 4-10 green finance indicators from four aspects, to explore the core factors of regional green finance comprehensively, and to identify the core factors affecting green finance based on the coupling of subjective and objective perspectives. It complements the empirical study of regional green finance to provide some quantitative reference for enhancing the development of regional green finance.

2. INTERPRETATION OF GREEN FINANCE

The Guidance on Building a Green Financial System jointly issued by the People's Bank of China, the Ministry of Finance of China and seven other ministries and commissions on August 31, 2016, points out that green finance is an economic activity to support environmental improvement, climate change and the economic and efficient use of resources. That is, the financial services provided to the operation of projects in environmental protection and energy conservation. Green finance strengthens enterprises' awareness of environmental protection, supports and guides their daily operations, and gradually shifts their investment direction to environmental industries. Green finance affects the public's investment activities for enterprises and can reduce the risk of economic operation. The development of green finance plays a positive role in the development of environmental protection enterprises, and compared with traditional financial methods, green finance supplements the capital needs of this activity and promotes the development of financial institutions, realizing a win-win situation for both energy conservation and emission reduction and green finance. Meanwhile, the development of green finance itself will boost economic growth, creating new value and bringing momentum to economic development.

3. CONSTRUCTION OF GREEN FINANCE EVALUATION INDEX SYSTEM

3.1. Construction of Green Finance Evaluation Index System

According to the green financial system mentioned in *The research on the coupling of green technology innovation*[7], *On the construction of China's green financial system*[15], *China's green finance development status and system construction-based on the background of sustainable development*[16], and the development of the green financial system and the current situation of Chinese green financial development, the evaluation index system of green finance is constructed. In the ' Local Green Financial Development Index and Evaluation Report (2018) ' issued by the International Research Institute of Green Finance of the Central University of Finance and Economics, it is proposed that the secondary indicators of green finance include green credit, green entrusted loans, green trusts, green off-balance-sheet financing, green financial bonds, and other financial green products. The three-level indicators include 12 sub-items. The specific statistical data cover green agricultural development projects, green forestry development projects, industrial energy-saving, water-saving and environmental protection projects, natural protection, ecological restoration and disaster prevention and control projects, resource recycling projects, waste disposal and pollution prevention and control projects, renewable energy and clean energy projects, rural and urban water projects, building energy conservation and green buildings, green transportation projects, energy conservation and environmental protection services, international practices or international standards[8].

Table 1 Green financial evaluation index system

Objective *A*	Standard *B*	Alternative *C*	Indicator Code
Types of Green Finance *A*	Green Credit B_1	Green Credit Ratio to RMB Loan Balance Ratio (%)	C_{11}
	Green Bond B_2	Number of Green Bond issuances	C_{21}
		Green Bond issue size (Billion Yuan)	C_{22}

		Market Value Growth Rate of Environmental Protection Enterprises (%)	C_{23}
	Green Investment B_3	The proportion of Industrial Pollution Control Investment to GDP (%)	C_{31}
		Energy conservation and environmental protection expenditure (Billion Yuan)	C_{32}
		The adoption rate of special green activities of listed enterprises (%)	C_{33}
	Carbon Finance B_4	Statistics on Environmental Investment of Listed Companies (Number)	C_{41}
		Financial carbon intensity (Yuan / Ton)	C_{42}

3.2. Green Credit

The concept of green credit originates from green finance. Although the understanding of green credit has not been unified, it should generally include the following meanings: First, one of the goals of green credit is to help and promote enterprises to reduce energy consumption, save resources, incorporate ecological and environmental factors into the accounting and decision-making of the financial industry, reverse the extensive management mode of enterprises polluting the environment and wasting resources, and avoid falling into a vicious circle of the first pollution and then treatment, and then pollution and then treatment. Second, the financial industry should pay close attention to environmental protection industry, ecological industry and other " no immediate interests " industry development, pay attention to the long-term interests of humankind, with the future of sound ecological and economic benefits and the environment back to the financial industry, to promote a virtuous circle of finance and ecology.

The introduction of " green credit " has raised the threshold for corporate loans. Credit compliance with environmental testing standards, pollution control effects, and ecological protection are essential prerequisites for credit approval. In order to establish a more reasonable model, this paper selects the data of the proportion of green credit balance to RMB loan balance to quantify this index.

3.3. Green Bond

According to the Green Bond Principles (GDB)[9]issued by the International Capital Markets Association (ICMA) on March 27, 2015, green bonds refer to any bond instrument that specifically uses the proceeds to fund or refinance green projects that meet specified conditions.

In the 18th National Congress of the Communist Party of China (CPC) report, the overall requirements for vigorously promoting the construction of ecological civilization are put forward with independent chapters, and the construction of ecological civilization is placed in a prominent position. It is integrated into all aspects and the whole economic and social construction process and incorporated into the overall layout of socialist modernization. Since green bonds are an effective practice in constructing ecological civilization, which can alleviate the problem of expensive and challenging financing for green enterprises and help expand the business space of financial institutions, it is necessary to develop green bonds[9–10].

In order to facilitate the quantification of green bonds, according to their meaning and domestic development status, this paper selects the number of green bonds issued, the scale of green bonds issued, and the market value growth rate of environmental protection enterprises as indicators for data collection and calculation.

3.4. Green Investment

At present, the research on green investment theory is still in its infancy, and the theoretical explanation of green investment has not been unified. From the current research results, some scholars, starting from personal investment and financing, believe that green investment is based on internationally accepted moral standards to screen actual investment and financing activities. The selection criteria are better social image and no record of hyping land or damaging the environment. Those facilitate can greatly emphasis by financial institutions on social responsibility and public interest[11].

With the recognition of sustainable development, the rise of green consumption since the 21st century, and the increasing green barriers in global international trade, the necessity of developing green investment is becoming more evident. Green investment requires investors to make decisions according to the criteria conducive to realizing the triple principles of economic, social and ecological benefits when choosing investment projects and combining the relevant measures of rational utilization of resources and pollution prevention with production investment. At the same time, the circular economy of green investment for development requires the implementation of the principles of reduction,

resource utilization and reuse in production and consumption activities, which is conducive to the realization of the economic model of protecting resources and the environment and promoting sustainable development. Therefore, green investment is conducive to solving the resource bottleneck and environmental constraints in economic growth highlighted with development[11-12].

Combined with the development status of green investment and green finance in China, this paper selects the proportion of completed investment in industrial pollution control in GDP, energy-saving and environmental protection expenditure, and the adoption rate of special green activities of listed companies indicators for quantitative analysis.

3.5. Carbon Finance

Carbon finance is defined as improving environmental rights driven by financial capital. According to laws and regulations, carbon finance products and their derivatives can be traded or circulated on a market-oriented platform by financial means and ultimately achieve low-carbon, green, and sustainable development.

"carbon finance " means more financial activities relying on CDM in China. China is currently the largest supplier of carbon dioxide certified emission reductions in the CDM mechanism, accounting for about 70 % of the total market supply. Under the '"Kyoto Protocol ", as a developing country, China does not have to undertake emission reduction obligations before 2012. According to the CDM mechanism, all the reduced greenhouse gas emissions in China can be sold to developed countries. According to World Bank projections, developed countries completed five bn tonnes of carbon reduction targets in 2012, at least three bn of which came from Chinese market supply[12]. So '"carbon finance " based on CDM has extensive space for development in China and contains substantial business opportunities[13].

Combined with China's green finance's development status and related requirements, this paper selects the number of environmental investment statistics and financial carbon intensity of listed companies as indicators to measure carbon finance quantitatively.

4. HIERARCHICAL STRUCTURE OF GREEN FINANCE IDENTIFICATION

The paper divides the hierarchical structure into three-level. The highest is the goal level, i.e., identifying the core factors of green finance; the middle level refers to the criterion level containing the intermediate elements involved in achieving the goal. According to the reference[14], These elements function as decision-making analysis criteria. Specifically, there are four criteria: green credit, green bonds, green investment, and carbon finance. Then comes the bottom level, the indicator level, with a total of 9 indicators. The overview of the structure is shown in Figure 1.

5. WEIGHTING MODELS CONSTRUCTION

5.1. AHM Weighting

5.1.1. Modelling procedure

Step 1 Model Specification: In terms of AHP (Analytic Hierarchy Process), the relative scale between μ_i and μ_j is determined by b_{ij}. Çalık, Çizmecioğlu, and Akpınar (2019)[17] confirm the effectiveness of AHP in determining core criteria. Regarding the AHM model that improves AHP, the relative measure of attributes between μ_i and μ_j is generated by μ_{ij}. Formulae (1) describes the relationship between μ_{ij} and b_{ij}. Besides, μ_{ii} =0 and k is a positive integer greater than 2.

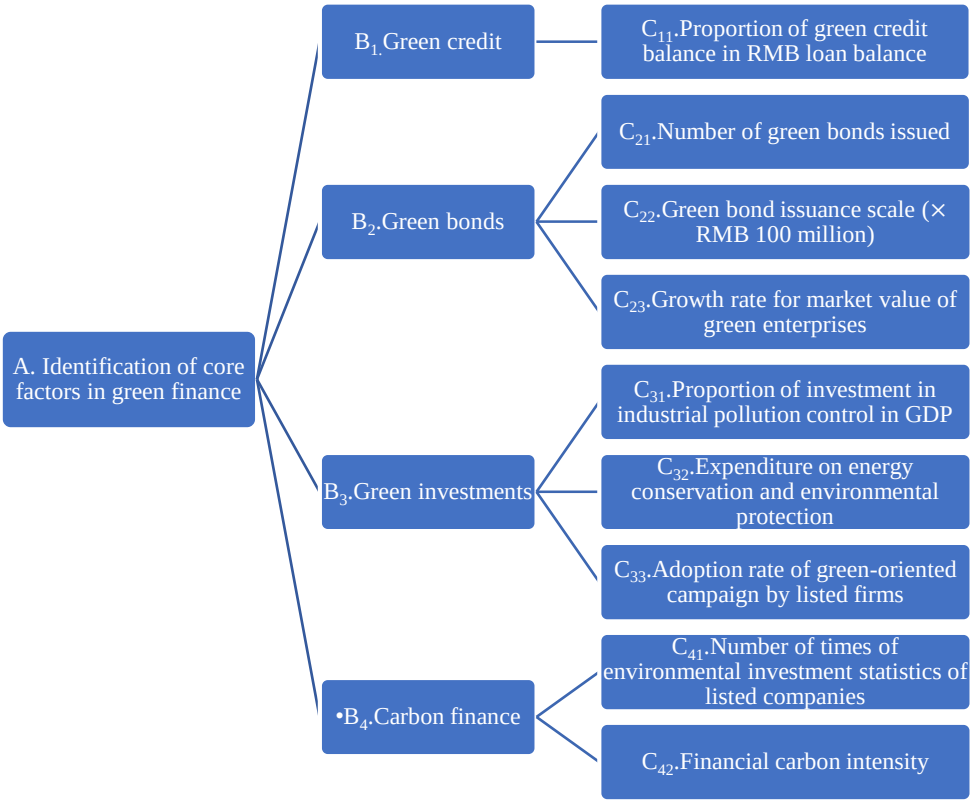

Figure 1 Hierarchy of Attributes

$$\mu_{ij}=\begin{cases}\dfrac{k}{k+1}, & b_{ij}=k,\\ 0.5, & b_{ij}=1,\\ \dfrac{1}{k+1}, & b_{ij}=\dfrac{1}{k},\end{cases} \tag{1}$$

Step 2 Relative Scale: The relative scale is obtained as an odd number within 1 to 9, and each even number in scope is between the corresponding two adjacent odd numbers. Descriptions with opposite semantics imply that the corresponding magnitude is the reciprocal of the relative scale. For example, A_i is extremely less important than A_j, given $\frac{1}{9}$. Formulae (2) displays the attribute judgment matrix with relative weights in the last column $\omega_{Ai}=\dfrac{2}{n(n-1)}\sum_{j=1}^{n}\mu_{ij}$.

$$\begin{bmatrix}\mu_{11} & \mu_{12} & \cdots & \mu_{1n} & \omega_{A1}\\ \mu_{21} & \mu_{22} & \cdots & \mu_{2n} & \omega_{A2}\\ \vdots & \vdots & \ddots & \vdots & \vdots\\ \mu_{n1} & \mu_{n2} & \cdots & \mu_{nn} & \omega_{An}\end{bmatrix} \tag{2}$$

Step 3 Composite Weight (ω_{AHM}) Calculation: The procedure for calculating the composite weight of the indicator level relative to the goal (denoted by $C_{ij}\longrightarrow$A) is shown in Formulae (3).

$$C_{ij}\rightarrow A=\left(C_{ij}\rightarrow B_i\right)\times\left(B_i\rightarrow A\right) \tag{3}$$

5.1.2. Hierarchical Attribute Judgment Matrix

The attribute judgment matrix and relative attribute weights of the four criteria are shown in Table 2. The associated matrices and weights of the indicators are exhibited respectively in Table 3, Table 4 and Table 5. Since there is only one indicator under criterion B_1 (Green credit), the weight of C_{11} in B_1 is supposed to be 100%. Thus, the weight of C_{11} in A is equal to the weight of B_1 in A, that is, 0.435.

Table 2 Attribute Judgment Matrix for Criteria to Goal

A	B_1	B_2	B_3	B_4	ω_A
B_1	0.000	0.875	0.833	0.900	0.435
B_2	0.125	0.000	0.250	0.750	0.188
B_3	0.167	0.750	0.000	0.833	0.292
B_4	0.100	0.250	0.167	0.000	0.085

Table 3 Attribute Judgment Matrix for Indicators to Criterion (B_2)

B_2	C_{21}	C_{22}	C_{23}	ω_{B2}
C_{21}	0.000	0.250	0.750	0.333
C_{22}	0.750	0.000	0.833	0.528
C_{23}	0.250	0.167	0.000	0.139

Table 4 Attribute Judgment Matrix for Indicators to Criterion (B_3)

B_3	C_{31}	C_{32}	C_{33}	ω_{B3}
C_{31}	0.000	0.250	0.750	0.333
C_{32}	0.750	0.000	0.833	0.528
C_{33}	0.250	0.167	0.000	0.139

Table 5 Attribute Judgment Matrix for Indicators to Criterion (B_4)

B_4	□41	□42	ω_{B4}
□41	0.000	0.125	0.125
□42	0.875	0.000	0.875

5.1.3. ω_{AHM} Calculation

Following Formulae (3), the corresponding weighting is stated in Table 6.

Table 6 Composite Weights (ω_{AHM}) for Indicators to Goal

Indicators	$C_{11}\rightarrow A$	$C_{21}\rightarrow A$	$C_{22}\rightarrow A$
Weight	0.435	0.063	0.099
Indicators	$C_{23}\rightarrow A$	$C_{31}\rightarrow A$	$C_{32}\rightarrow A$
Weight	0.026	0.097	0.154
Indicators	$C_{33}\rightarrow A$	$C_{41}\rightarrow A$	$C_{42}\rightarrow A$
Weight	0.041	0.011	0.074

5.2. CRITIC Weighting

5.2.1. Modelling procedure

Step 1 Model Specification: CRITIC refers to Criteria Importance Through Inter-criteria Correlation. Assume that there are n samples to be evaluated and m evaluation indicators to form the original indicator matrix which is denoted by X and shown in Formula (4). In the matrix x_{ij} represents the value of the j_{th} item evaluation indicator of the i_{th} sample ($i \le n, j \le m$).

$$X = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1m} \\ x_{21} & x_{22} & \cdots & x_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ x_{n1} & x_{n2} & \cdots & x_{nm} \end{bmatrix} \quad (4)$$

Step 2 Dimensionless Processing: Because all the indicators adopted are positive indicators, meaning that greater value gives a good performance, positive processing is used via Formulae (5).

$$x'_{ij} = \frac{x_j - x_{\min}}{x_{\max} - x_{\min}} \quad (5)$$

Step 3 Measure of Indicator Variability: The standard deviation is reckoned to be appropriate in gauging the indicator variability. Formulae (6) gives the mean of x_j in n samples, and Formulae (7) shows the standard deviation of the j_{th} indicator.

$$\overline{x_j} = \frac{1}{n}\sum_{i=1}^{n} x_{ij} \quad (6)$$

$$\sigma_j = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}\left(x_{ij} - \overline{x_j}\right)^2} \quad (7)$$

Step 4 Inter-criteria Correlation: As Formulae (8) shows, the correlation coefficient is expected to reveal the correlation between indicators. The stronger the correlation between one indicator and another, the less resistance between them could be found, which reflects that the stories the two indicators told overlap each other. To some extent, it weakens the indicator's effectiveness, leading to reducing its weight. x_i_bar gives the mean of indicator value x_i for all samples, x_j_bar gives the mean of indicator value x_j for all indicators, and r_{ij} describes the correlation coefficient.

$$r_{ij} = \frac{\sum_{i=1}^{m}\left(x_i - \overline{x_i}\right)\left(x_j - \overline{x_j}\right)}{\sqrt{\sum_{i=1}^{m}\left(x_i - \overline{x_i}\right)^2 \sum_{j=1}^{m}\left(x_j - \overline{x_j}\right)^2}} \quad (8)$$

Step 5 Composite Weight (ω_{CRITIC}) Calculation: Formulae (9) shows how ω_j is brought into being. Greater ω_j indicates the j_{th} indicator matters more in the whole assessment and deserves more weight allocation. The ω_{CRITIC} is generated through Formulae (10).

$$\omega_j = \sigma_j \sum_{i=1}^{m}\left(1 - r_{ij}\right) \quad (9)$$

$$\omega_{CRI} = \frac{\omega_j}{\sum_{j=1}^{m}\omega_j} \quad (10)$$

5.2.2. Dimensionless-Processed Matrix

There are 3 samples to be evaluated and 9 evaluation indicators to form the original indicator matrix. Upon dimensionless processing, the resultant matrix X' is given in Formula (11).

$$X' = \begin{bmatrix} 0.000 & \cdots & 0.000 \\ 0.333 & \cdots & 0.584 \\ 1.000 & \cdots & 1.000 \end{bmatrix} \quad (11)$$

5.2.3. ω_{CRITIC} calculation

The ω_{CRITIC} is generated in line with Formulae (10), and the results are displayed in Table 7.

Table 7 Composite Weights (ω_{CRITIC}) for Indicators to Goal

Indicators	$\omega_{CRI.C11}$	$\omega_{CRI.C21}$	$\omega_{CRI.C22}$
Weight	0.081	0.084	0.080
Indicators	$\omega_{CRI.C23}$	$\omega_{CRI.C31}$	$\omega_{CRI.C32}$
Weight	0.155	0.185	0.080
Indicators	$\omega_{CRI.C33}$	$\omega_{CRI.C41}$	$\omega_{CRI.C42}$
Weight	0.078	0.178	0.079

5.3. Weight Coupling

With obtained ω_{AHM} and ω_{CRITIC}, Formulae (12) states the coupled weight calculation considering the multiplication synthesis normalization method can effectually reflect the relative weight of various indicators, and they are significant in the whole system. The results are presented in Table 8.

$$\omega = \frac{\omega_{AHM}\,\omega_{CRITIC}}{\sum_{j=1}^{m} \omega_{AHM}\,\omega_{CRITIC}} \tag{12}$$

Table 8 Coupled Weights (ω_{Cij}) for Indicators to Goal

Indicators	ω_{C11}	ω_{C21}	ω_{C22}
Weight	0.372	0.057	0.086
Indicators	ω_{C23}	ω_{C31}	ω_{C32}
Weight	0.044	0.193	0.131
Indicators	ω_{C33}	ω_{C41}	ω_{C42}
Weight	0.034	0.020	0.063

5.4. Results and implications

Figure 2 indicates that coupled weighting combining AHM and CRITIC can balance subjective and objective weights at large, making the assessment more reasonable and less unbiased. Regarding the ranking, the proportion of green credit balance in RMB loan balance (C_{11}) comes first. It can be explained in three ways. First, green credit accounts for the largest amount in China's green finance scale. Second, the enhancement of green credit helps guide funds to energy-saving enterprises and resource recycling projects, which greatly promote the R&D of new energy technologies. Third, the asset structure of commercial banks become more reasonable, and financial products are diversified. Meanwhile, the loan threshold for enterprises is raised to reduce the risk of bad debts. The proportion of investment in industrial pollution control in GDP (C_{32}) and Expenditure on energy conservation and environmental protection (C_{33}) are also among the top three, which implies the great significance of green investment. It can maintain the local ecological environment and even improve the well-being of residents as the investment activities are carried out smoothly. Such investment activities fully take environment-associated factors into investing and financing decision-making and promote the symbiosis of the economy and ecology through the guidance of economic resources.

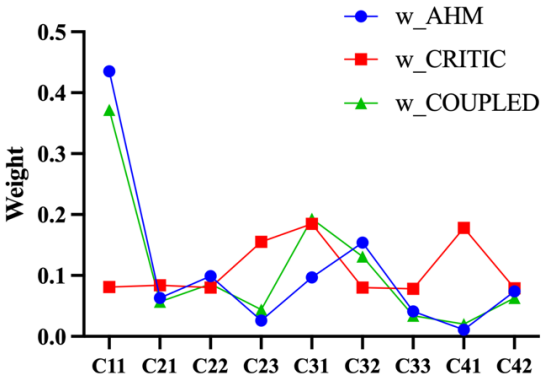

Figure 2 Three Weightings for Each indicator

6. CONCLUSION

This investigation aimed to assess the significance of numerous factors associated with green finance and pinpoint the most influential ones. AHM-CRITIC coupling weighting is innovatively adopted to identify green finance-related indicators combining industry expertise with theoretical consideration.Interestingly, green credit was shown to achieve prominence in the green finance indicative system, which discloses its scale and significance in enhancing the maturity of green financial construction.This paper also found that green investments have the potential to play a bigger role despite some current underestimation.Further studies of carbon finance and green bonds cannot be overlooked the need to be undertaken for a better-established green finance scheme.

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The author's name is in alphabetical order, and the workload of each author is equivalent.

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