# An improved multi-objective grey target decision model for corporate decision making

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**Abstract.** To address the problem of enterprise decision-making, an evaluation index system for the proposed solution is established based on integrating the components of the enterprise decision-making evaluation solution. In the assignment method, the CRITIC assignment method is improved by using Kendall coefficients instead of Pearson coefficients. It overcame the non-linear and non-normal distribution that occurs in the actual situation. The improved CRITIC assignment method is introduced into the attribute hierarchy analysis method, which uses the multiplier normalization synthesis method. It is combined the subjective assignment method with the objective assignment method to determine the weights of the evaluation indexes. The AHM-CRITIC comprehensive assignment method is introduced to establish a multi-objective grey target model, which takes the comprehensive effect of the solution to be selected as the evaluation criterion. An empirical analysis was conducted based on the financing strategy of a labor service company in Wuhan to verify the rationality and feasibility of the method and provide a reference for the evaluation of enterprise decision-making.

**Keywords:** Corporate Decision Making, Kendall Coefficient, AHM-CRITIC Integrated Assignment Method, Multi-objective Grey Target Decision-makers.

## 1. Introduction

Corporate Decision-Making Behaviour (CDMB) is a process in which decision-makers analyze and formulate multiple decision options based on the company's situation and the external environment to achieve its business objectives, compare the multiple decision options and select the best one from them [1]. The choice of a decision can significantly impacts the development and even the survival of an enterprise: a correct decision can lead to a better direction, while a wrong decision can lead to bankruptcy. The choice of the right decision plays a crucial role in developing a company, and so many scholars have conducted extensive research in this area, providing an essential reference for the CDMB.

For CDMB, scholars have proposed different strategies for enterprise decision-making options from various aspects and perspectives: Huijuan Zhang [2] applied financial indicators, namely the solvency, operational capacity, and profitability of enterprises, to enterprise decision-making by analyzing them and proposing corresponding improvements to the problems that exist in them; Hao Jiang et al.[3] delineated a big data-based "big data +" re-modeling and "+ big data" convergence two application models, according to the enterprise's focus, time and budget to choose a different application model, the enterprise decision to observe and analyze so that enterprise decisions can be more effective development and implementation. Mukasa Eldard Ssebbaale et al. [4] used statistical tests to generalize from the sample to the whole, using parametric and non-parametric tests in statistics to show the results of inferential statistics and to analyze business decisions by testing for correlations between variables and differences between groups. Moreover, Iram Naim et al. [5] proposed an assisted decision selection tree based on the type of data using time series characteristics. Datatype is based on time series characteristics for forecasting, improving the existing forecasting method

selection tree and thus enterprise decision making; Uswatun Hasanah et al.[6] applied the linear programming of the simplex method by formulating objective function and constraints to perform sensitivity analysis on the obtained solutions to find the most profitable project, i.e., the best enterprise decision; Jin Guisheng et al. [7] integrated hierarchical analysis with grey The method of grey correlation is used to make up for the shortcomings of the hierarchical analysis method (hereafter referred to as AHP method), making the enterprise decision more scientific and objective.

Most of the above-mentioned studies are based on a large amount of data to select the final decision based on objective experimental data, but in fact, a certain number of subjective factors are needed in making the decision, and the existing studies do not solve this problem well. In this paper, we use an improved approach to business decision making based on the attribute hierarchy model and the CRITIC method (hereafter referred to as AHM-CRITIC) to firstly assess and assign weights to subjective factors with the help of AHM, and secondly determine the weights of objective factors by CRITIC, and then use multiplicative normalization to determine the combined weights. The optimized weights were used to optimize a conventional grey target decision model. Data from Wuhan WL, China, were used for the empirical analysis of the article. This paper is based on the AHM-CRITIC corporate decision assignment model to enable a more objective assessment of the five ways WL can raise capital, providing a more scientific basis for WL's decisions and guiding other companies' decisions.

## 2. Introduction to indicators

### 2.1. Access to finance

The usual financing channels include personal borrowing, bank loans, financial leasing, internet financing, and supplier financing. Personal borrowing mainly refers to lenders granting loans to borrowers. Moreover, bank loans mainly refer to banks' lending funds to those in need of funds at a specific interest rate according to national policies. Therefore, financial leasing refers to the lessor entering into a supply contract with a third party at the request of the lessee, under which the lessor finances the purchase of equipment selected by the lessee. Meanwhile, the lessor enters into a lease contract with the lessee. Internet financing refers to borrowing and lending activities between enterprises or individuals and financial institutions such as banks based on the Internet; supplier financing refers to standardized financing products developed by Minsheng Bank. In summary, this paper selects the above five financing channels as the object of decision-making.

### 2.2. Selection of financing indicators

The usual financing indicators include the amount of financing, the cost of financing, the probability of availability, the risk of financing, and the financing terms. The financing amount refers to the maximum amount of funds the broker can borrow with a credit account. The financing cost refers to the remuneration paid by the user of funds to the owner of the funds; the findability probability refers to the chance of being able to raise funds; the financing risk refers to the risk of changes in earnings due to the planning of financing activities; the financing conditions refer to certain conditions that need to be met when applying for financing. This paper selects the above five financing indicators as decision objectives.

## 3. Introduction to the conventional grey target decision model

Grey target decision-making is a decision-making method proposed by Professor Deng Julong. With the demand for practical problem solving, Liu Sifeng, Dang Yaoguo, and others have proposed improved methods for grey target decision making, providing new methods for more practical problem-solving. The method has been widely applied in the fields of equipment maintenance[8], risk prediction[9], supplier selection[10], and solution selection[11].

Compared with the grey target decision-making method, the multi-objective weighted grey target decision-making model has two main advantages: (i) it increases the number of weights, which fully considers the different degrees of importance of different decision targets in practical applications. (ii) it entirely considers the target effect value and the target effect vector in the target and off-target two different situations, which greatly improves the resolution of the comprehensive effect measure. The model steps are as follows:

A problem is studied and solved, or a thing to be dealt with. The current state of a system's behavior is collectively referred to as events, and all events within the study area are collectively referred to as the set of events within the study area and are denoted as $A=\{\mathrm{a}_1,\mathrm{a}_2,\cdots,\mathrm{a}_n\}$ where $a_i\,(i=1,2,\cdots,n)$ is the $i$ event.

$S=A\times B=\{(\mathrm{a}_i,b_j)\,|\,a_i\in A,b_j\in B\}$ The set of all possible responses is called the response set and is denoted as $B=\{b_1,b_2,\cdots,b_n\}$, where $b_j\,(j=1,2,\cdots,m)$ is the $j$ response; the Cartesian produce of the event set $A=\{\mathrm{a}_1,\mathrm{a}_2,\cdots,\mathrm{a}_n\}$ and the response set $B=\{b_1,b_2,\cdots,b_n\}$ is called the decision solution set, and for any $\mathrm{s}_{ij}=(a_i,b_j)$ is called the decision solution; set $S=\{s_{ij}=(a_i,b_j)\,|\,a_i\in A,b_j\in B\}$ as the decision solution set, then $u_{ij}^{(k)}$ is the practical value of the decision solution $s_{ij}$ under the $k$ objective; if $\max\limits_{1\le j\le m}\{r_{ij}\}=r_{ij_0}$, then $b_{j_0}$ is the optimal response to the event $a_i$; if $\max\limits_{1\le i\le n}\{r_{ij}\}=r_{i_0j}$, then $a_{i_0}$ is the optimal event $b_j$ for the response; and if $\max\limits_{1\le j\le m}\max\limits_{1\le i\le n}\{r_{ij}\}=r_{i_0j_0}$, then $s_{i_0j_0}$ is the optimal solution.

The problem to be solved and the corresponding countermeasures are set as the set of events $A=\{\mathrm{a}_1,\mathrm{a}_2,\cdots,\mathrm{a}_n\}$ and the countermeasures $B=\{b_1,b_2,\cdots,b_n\}$, respectively. On this basis, the set of decision options $S=\{s_{ij}=(a_i,b_j)\,|\,a_i\in A,b_j\in B\}$ is constructed, the decision objectives $k\,(k=1,2,\cdots,s)$ are determined according to the actual needs, then the decision rights of each objective $\eta_1,\eta_2,\cdots,\eta_{\mathrm{s}}$ are determined using the AHP method, and the corresponding sample matrix of objective effects is then found for the objective $k\,(k=1,2,\cdots,s)$.

$$U^k=\left(u_{ij}^{(k)}\right)=\begin{bmatrix}u_{11}^{(k)} & u_{12}^{(k)} & \cdots & u_{1m}^{(k)}\\ u_{21}^{(k)} & u_{22}^{(k)} & \cdots & u_{2m}^{(k)}\\ \vdots & \vdots & \vdots & \vdots\\ u_{n1}^{(k)} & u_{n2}^{(k)} & \cdots & u_{nm}^{(k)}\end{bmatrix} \tag{1}$$

Target effect thresholds are set according to the different types of effect goals (effect-based goals, cost-based goals, moderate goals) $u_{i_0j_0}^{(k)}$. To ensure that the effective measures for each type of goal meet the normative, i.e., $r_{ij}^{(k)}\in[-1,1]$ rule.

For benefit-based targets, set $k$ a target under Decision Grey.

$$u_{ij}^{(k)}\ge 2u_{i_0j_0}^{(k)}-\max_i\max_j\left\{u_{ij}^{(k)}\right\} \tag{2}$$

For cost-based targets, let $k$ target the grey target for decision making under the target.

$$u_{ij}^{(k)} \le 2u_{i_0 j_0}^{(k)} - \min_i \min_j \left\{ u_{ij}^{(k)} \right\} \tag{3}$$

For cases where the effect value of a moderate target is less than the lower effect threshold $A - u_{i_0 j_0}^{(k)}$, let $k$ target the lower decision on the grey target.

$$u_{ij}^{(k)} \ge A - 2u_{i_0 j_0}^{(k)} \tag{4}$$

For cases where the effect value of a moderate target is greater than the upper effect threshold at $A + u_{i_0 j_0}^{(k)}$, the set $k$ target under the decision grey target.

$$u_{ij}^{(k)} \le A + 2u_{i_0 j_0}^{(k)} \tag{5}$$

To find the consistent effect measure matrix under $k$ target: Due to the different meanings, properties, scales, etc., of different target effect values, their target effect values are often not directly comparable. To obtain comparable values, it is necessary to convert the target sample effect values $u_{ij}^{(k)}$ into consistent effect measure values and thus form the target sample consistent effect measure matrix, i.e.

$$R^k = \left( r_{ij}^{(k)} \right) = \begin{bmatrix} r_{11}^{(k)} & r_{12}^{(k)} & \cdots & r_{1m}^{(k)} \\ r_{21}^{(k)} & r_{22}^{(k)} & \cdots & r_{2m}^{(k)} \\ \vdots & \vdots & \vdots & \vdots \\ r_{n1}^{(k)} & r_{n2}^{(k)} & \cdots & r_{nm}^{(k)} \end{bmatrix} \tag{6}$$

The combined effect measure matrix is calculated $r_{ij} = \sum_{k=1}^{s} \eta_k \square r_{ij}^{(k)}$.

$$R = \left( r_{ij} \right) = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1m} \\ r_{21} & r_{22} & \cdots & r_{2m} \\ \vdots & \vdots & \vdots & \vdots \\ r_{n1} & r_{n2} & \cdots & r_{nm} \end{bmatrix} \tag{7}$$

Whether the grey target is hit or not is based on the combined effect measure: when $r_{ij}^{(k)} \in [0,1]$ the grey target is hit at $k$ the target effect value; when $r_{ij}^{(k)} \in [-1,0]$ the grey target is off-target at $k$ the target effect. Following this, the target is said to be off-target according to $\max_{1 \le j \le m} \left\{ r_{ij} \right\} = r_{ij_0}$, and the $b_{j_0}$ is the event $a_i$ that determines the optimal response $b_{j_0}$ and the optimal decision $s_{i_0 j_0}$.

Note that the consistent effect measure matrix calculation under the $k$ objectives is carried out following the following rules.

When $k$ is a benefit-based target, i.e., the larger the sample value of the target effect, the grey target for decision making under the $k$ target is set to $u_{ij}^{(k)} \in \left[ u_{i_0 j_0}^{(k)}, \max_i \max_j \left\{ u_{ij}^{(k)} \right\} \right]$, i.e., $u_{i_0 j_0}^{(k)}$ is the critical value of the $k$ target effect, then the benefit-based target effect function measure function is

$$r_{ij}^{(k)} = \frac{u_{ij}^{(k)} - u_{i_0 j_0}^{(k)}}{\max_i \max_j \left\{ u_{ij}^{(k)} \right\} - u_{i_0 j_0}^{(k)}} \tag{8}$$

When $k$ is a cost-based target, i.e., the smaller the sample value of the target effect, the grey target for decision making under the $k$ target is set to $u_{ij}^{(k)} \in \left[ \min_i \min_j \left\{ u_{ij}^{(k)} \right\}, u_{i_0 j_0}^{(k)} \right]$, i.e., $u_{i_0 j_0}^{(k)}$ is the critical value of the $k$ target effect, then the cost-based target effect function measure function is

$$r_{ij}^{(k)} = \frac{u_{i_0 j_0}^{(k)} - u_{ij}^{(k)}}{u_{i_0 j_0}^{(k)} - \min_i \min_j \left\{ u_{ij}^{(k)} \right\}} \tag{9}$$

When $k$ is a moderate target, i.e., the closer the target effect sample value is to a moderate value $A$, the better, the decision grey target under $k$ target is set to $u_{ij}^{(k)} \in \left[ A - u_{i_0 j_0}^{(k)}, A + u_{i_0 j_0}^{(k)} \right]$,i.e. $A - u_{i_0 j_0}^{(k)}$, $A + u_{i_0 j_0}^{(k)}$ are the lower and upper effect thresholds under $k$ target respectively, when $u_{ij}^{(k)} \in \left[ A - u_{i_0 j_0}^{(k)}, A \right]$, then the lower effect measure function of the moderate target is

$$r_{ij}^{(k)} = \frac{u_{ij}^{(k)} - A + u_{i_0 j_0}^{(k)}}{u_{i_0 j_0}^{(k)}} \tag{10}$$

When $u_{ij}^{(k)} \in \left[ A, A + u_{i_0 j_0}^{(k)} \right]$, it is used, then the moderate target upper effect measure function is

$$r_{ij}^{(k)} = \frac{A + u_{i_0 j_0}^{(k)} - u_{ij}^{(k)}}{u_{i_0 j_0}^{(k)}} \tag{11}$$

## 4. An improved AHM-CRITIC based approach to business decision empowerment

The Attribute Hierarchy Model (AHM) was proposed by Qian-Sheng CHENG in 1997, which inherits the advantages of the hierarchical analysis method (AHP), but is more convenient in calculation and application than the hierarchical analysis method, without the need to calculate feature vectors and to perform consistency tests. The CRITIC (Criteria Importance Though Intercrieria Correlation) method is an objective weighting method proposed by DIAKOULAKI, which is based on the idea of comparison strength and conflict between evaluation indicators. This paper uses the improved CRITIC assignment method.

In this paper, the objective weights of the indicators are calculated using the improved CRITIC weighting method, and the different coefficient of the entropy weighting method is used instead of the contrast intensity of the traditional CRITIC method to enhance the comparability between indicators. The correlation Coefficient requires the data to be continuous, normally distributed, and show a linear relationship, so this paper uses the Kendall Correlation Coefficient instead of the Pearson Correlation Coefficient [13]. Finally, the product of the coefficient of variation and the coefficient of conflict is combined to determine the objective weights of the indicators.

In this paper, the two subjective and objective weighting methods, AHM and CRITIC, are combined and improved to reflect better the difference between subjective knowledge and experience and actual objective data in the weights.

### 4.1. AHM Empowerment Method

First, a hierarchy is established, which is divided the decision problem into three layers: the objective layer G, the criterion layer $C$, and the solution layer $C_i$. Noting $C = \{C_i(\mathrm{i} = 1,2,\dots,\mathrm{n})\}$ is the set of evaluation indicators formed by the criterion layer, and $C_i = \{C_{ij}(j = 1,2,\dots,m)\}$ is the set of evaluation indicators formed at the solution level.

Secondly, the attribute weight matrix is constructed. Let $C$ be the criterion and $a_i(\mathrm{i} = 1,2,\dots,\mathrm{n})$ be the $n$ elements under criterion $C$. For criterion $C$, compare two different elements $a_i$ and $a_j(\mathrm{i} \neq \mathrm{j})$ of relative importance, denoted as $a_{ij}$ and $a_{ji}$, and $a_i$ is compared with itself denoted as $a_{ii}$. For any $a_{ij}$, the requirements of the attribute measure are satisfied by the following equation.

$$\begin{gathered} a_{ij} \geq 0, a_{ji} \geq 0, a_{ij} + a_{ji} = 1, a_{ii} = 0 \\ i \neq j, 1 \leq i \leq \mathrm{n}, 1 \leq j \leq \mathrm{n} \end{gathered} \tag{12}$$

For the $n$ factors in $C$, the comparison judgment matrix can be obtained according to the Satty scale and the expert scoring method $B = (b_{ij})_{n\times n}$, where $b_{ij}$ denotes the factor $i$ and factor $j$ relative to the target importance, the comparative judgment matrix has the following properties.

$$\begin{cases} b_{ij} > 0 \\ b_{ii} = 1 \\ b_{ji} = 1 / b_{ij} \\ i \neq j, 1 \leq i, j \leq n \end{cases} \tag{13}$$

According to the AHM method, consisting of relative attributes $a_{ij}$ composed of $n$ matrix of order $A = (a_{ij})_{n\times n}$, called the attribute judgment matrix, where the relative attributes $a_{ij}$ can be determined by the scale is $b_{ij}$, and it is determined by the following conversion formula.

$$a_{ij} = \begin{cases} \dfrac{2k}{2k+1}, b_{ij} = k, i \neq j \\ \dfrac{1}{2k+1}, b_{ij} = \dfrac{1}{k}, i \neq j \\ 0.5, b_{ij} = 1, i \neq j \\ 0, b_{ij} = 1, i = j \end{cases} \tag{14}$$

In the above equation: $k \in \mathbb{N}$ and $k \geq 2$, from which the attribute judgment matrix A can be determined. Finally, it is determined that the relative attribute weights are calculated according to the following equation.

$$W_{Ci} = \frac{2}{n(n-1)} \sum_{j=1}^{n} a_{ij}, 1 \leq i \leq n \tag{15}$$

In the above equation: $n$ is the number of sub-indicators belonging to the same indicator. After obtaining the weights of each relative attribute, the weights of the evaluation indicators can be obtained according to the formula of synthetic weights $W_{AHM}$. The synthetic weight formula is where the synthetic weight formula is

$$W_{AHM} = W_{Cij} \times W_{Ci} \tag{16}$$

In the above equation: $W_{AHM}$ is the program level assessment indicator $C_i$ relative to the weights under the objective $G$. $W_{C_i}$ is the relative attribute weight of each element in the criterion-level assessment indicator $C$ relative to the target $G$. $W_{C_{ij}}$ is the program level assessment indicator $C_i$ is the relative attribute weight of each element of the $C_{ij}$ is the relative attribute weight of each element of the scheme level assessment indicator $C$ relative to the target $G$.

### 4.2. Improving the CRITIC empowerment method

Based on the raw data collected, an indicator matrix was constructed $\boldsymbol{S} = (s_{ij})_{m \times n}$, $i$ represents the $i$ class level, and $j$ represents the $j$ assessment indicator. Since there are $m$ classes and $n$ assessment indicators in the indicator matrix, $i = 1, 2, \cdots, m, j = 1, 2, \cdots, n.$ it needs to be standardized first to obtain the standardization matrix as the indicators have different scales $\boldsymbol{S'}$.The standardization process is as follows.

The standardized treatment of efficiency-based indicators is given by

$$s_{ij}' = \frac{s_{ij} - \min(s_j)}{\max(s_j) - \min(s_j)} \tag{17}$$

The standardized treatment of cost-based indicators is given by

$$s_{ij}' = \frac{\max(s_j) - s_{ij}}{\max(s_j) - \min(s_j)} \tag{18}$$

The standardized treatment of interval-type indicators is given by

$$s_{ij}' = \begin{cases} 1 - \dfrac{s_{op} - s_{ij}}{s_{op} - q_1}, q_1 < s_{ij} < s_{op} \\ 1 - \dfrac{s_{ij} - s_{op}}{q_2 - s_{op}}, s_{op} < s_{ij} < q_2 \\ 0, q_1 < s_{ij} < q_2 \end{cases} \tag{19}$$

Where $q_1$ represents the left boundary of the interval, $q_2$ represents the right boundary of the interval and $s_{op}$ is the optimal attribute value of the interval.

Using the efficacy factor method to obtain the dimensionless normalization matrix $\boldsymbol{S}'$, then we have

$$s_{ij}'' = \alpha + \beta \frac{s_{ij} - \min(s_j)}{\max(s_j) - \min(s_j)} \tag{20}$$

In the above equation: $\alpha$ , $\beta$ are constants generally taken $\alpha = 0.4$ , $\beta = 0.6$ , and choose the maximum and minimum data of the evaluation data instead of $\max(s_j)$ and $\min(s_j)$ to obtain the normalization matrix $\boldsymbol{S}'$.

Let $p_{ij}$ be the value of the $j$th assessment indicator as a proportion of the total value of that indicator, then

$$p_{ij} = \frac{s_{ij}''}{\sum_{i=1}^{m} s_{ij}''} \tag{21}$$

Let $e_j$ be the entropy value of the $j$th assessment indicator, then

$$e_j = -\frac{1}{\ln m} \sum_{i=1}^{m} p_{ij} \ln p_{ij} \tag{22}$$

Let $\xi_j$ be the coefficient of variation of the $j$th assessment indicator, then

$$\xi_j = 1 - e_j \tag{23}$$

Due to the limitation of Pearson's correlation coefficient, this paper uses the Kendall correlation coefficient[13], improved by Hu Tao et al., to measure the correlation degree of each class variable, denoted as $\eta_{ij}$ which represents the Kendall correlation coefficient of the $i$th assessment indicator and the $j$th assessment indicator.

Where the Kendall coefficient is calculated using the tau-b formula.

$$\eta_{ij} = \frac{C - D}{\sqrt{(N_1 - \sum_{e=1}^{ee} \frac{1}{2} E_e(E_e - 1))(N_1 - \sum_{f=1}^{ff} \frac{1}{2} F_f(F_f - 1))}} \tag{24}$$

Where $C$ and $D$ represent the number of pairs of variables with the same elemental ranking value and the number of pairs of variables with unequal elemental values in two sets of column vectors, respectively, $N$ represents the number of elements in one set of column vectors. $N_1 = \frac{1}{2} N(N-1)$ $E$ is the small set of the same elements in one set of vectors. Moreover, $ee$ represents the number of small sets with $E$ in the column vector, $ee$ represents the number of small sets of the column vector that have $E$ and $E_e$ represents the number of elements in the $e$th vector, $F$ represents the number of small sets of the same elements in another set of column vectors, $ff$ represents the number of small sets with $F$, $F_f$ representing the number of elements contained in the $f$th small set.

Let $R_j$ be the conflict coefficient of the $j$th assessment indicator with other assessment indicators, then

$$R_j = \sum_{i=1}^{m} 1 - |\eta_{ij}| \tag{25}$$

Let $C_j$ denote the amount of information contained in the $j$th assessment indicator, then

$$C_j = \xi_j R_j \tag{26}$$

In summary, the weights of each assessment indicator relative to the target $G$ can be obtained as follows.

$$W_{CRI} = \frac{C_j}{\sum_{j=1}^{m} C_j} \tag{27}$$

### 4.3. Determining the combined weighting of assessment indicators

As the multiplier normalization synthesis method can effectively reflect the relative weight relationship of each indicator and its weight share in the whole, the comprehensive model is constructed as follows, where: $W$ is the comprehensive weight of each assessment indicator.

$$W = \frac{W_{CRI} W_{AHM}}{\sum_{j=1}^{n} W_{CRI} W_{AHM}} \tag{28}$$

## 5. Example analysis

This paper takes as an example the financing route decision of Wuhan University of Technology Labour Dispatch Company (WL) in Wuhan in September 2020. According to the actual situation of this company, there are five financing routes for it: personal borrowing, bank loan, financial leasing, internet financing, and supplier financing. Based on an improved multi-objective grey target decision model and the AHM-CRITIC weighting method, this paper analyses the company's financing amount, financing cost, findability probability, financing risk, and financing conditions and concludes that the company should choose the financing leasing method for financing. Given the relatively common type of project and the relatively large amount of financing, this paper can use it as a case decision. The decision-making process is as follows.

Step1 Create an event set, a response set, and a decision solution set.

Taking as an event that WL decides which financing route to use for financing $a_1$ then the event set is $A = \{a_1\}$; the choice of personal borrowing, bank loan, financial leasing, Internet financing, and supplier financing as the respective responses $b_1, b_2, b_3, b_4, b_5$, then the set of responses is $B = \{b_1, b_2, b_3, b_4, b_5\}$; Construct the set of decision options from the event set A and the decision set B.

$$S = \{s_{ij} = (a_i, b_j) \mid a_i \in A, b_j \in B\} = \{s_{11}, s_{12}, s_{13}, s_{14}, s_{15}\} \tag{29}$$

Step2 Identify decision objectives.

After expert consultation, the paper identifies the five areas of "financing amount," "financing cost," "financing probability," "financing risk," and "financing conditions" as the objectives of these

five financing options. "The objectives of these five financing options are to ensure that the financing is as high as possible, the financing cost is low, the financing probability is high, the financing risk is low, and the financing conditions are high. After analyzing the actual financing data, the types of these objectives were identified and homogenized. The results of the data are shown in Table 1.

**Table 1**. Normalized data and types of decision objectives

| Indicators / Pathways | Amount of financing | Financing costs | Payable probability | Financing risks | Financing conditions |
|---|---|---|---|---|---|
| Personal loans | 0.045 | 0.138 | 1 | 0.134 | 0.083 |
| Bank Loans | 0.064 | 0.156 | 1 | 0.152 | 0.093 |
| Finance Leasing | 0.086 | 0.347 | 1 | 0.171 | 0.166 |
| Internet financing | 0.061 | 0.191 | 0.9 | 0.202 | 0.211 |
| Supplier finance | 0.047 | 0.198 | 1 | 0.336 | 0.098 |
| Boundaries | 0.045 | 0.120,0.450 | 0.8 | 0.427 | 0.079 |
| Type | Benefit Type | Interval Type | Benefit Type | Cost Type | Benefit Type |

Step3 Calculate the Kendall correlation coefficient matrix
Below are the results of the calculation of the Kendall correlation coefficient matrix.

$$\begin{pmatrix} 1 & 0.4 & 0 & 0 & 0.4 \\ 0.4 & 1 & 0 & 0.6 & 0.6 \\ 0 & 0 & 1 & 0.3162 & 0.6325 \\ 0 & 0.6 & 0.3162 & 1 & 0.6 \\ 0.4 & 0.6 & 0.6325 & 0.6 & 1 \end{pmatrix} \tag{30}$$

It was also used for the correlation coefficient matrix heat map. The results are shown in Figure 1.

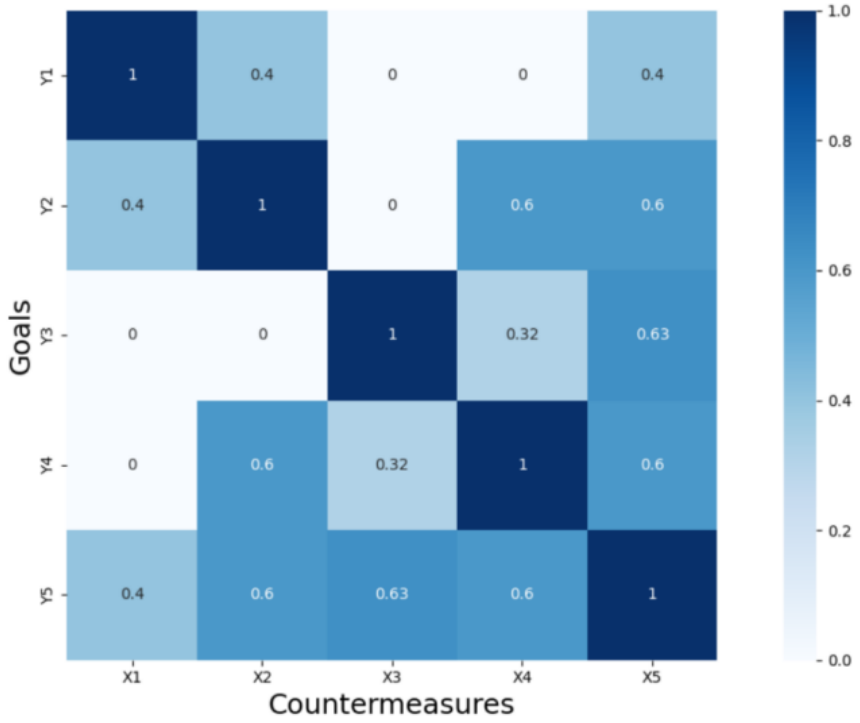



**Figure 1**. Heat map of the correlation coefficient matrix

Step4 Determine the weights of the five decision objectives.

In this paper, the decision weight coefficients of the five decision objectives are determined using the improved AHM-CRITIC assignment method, and the final decision weights are obtained, as shown in Table 2.

**Table 2.** Target decision weights

| Serial number | Decision Objective (k) | AHM | CRITIC | AHM-CRITIC decision weighting ($\eta_k$) |
|---|---|---|---|---|
| 1 | Amount of financing | 0.0755 | 0.1654 | 0.0573 |
| 2 | Financing costs | 0.2882 | 0.22 | 0.2911 |
| 3 | Payable probability | 0.3244 | 0.295 | 0.4393 |
| 4 | Financing risks | 0.1009 | 0.1955 | 0.0906 |
| 5 | Financing conditions | 0.211 | 0.1256 | 0.1217 |

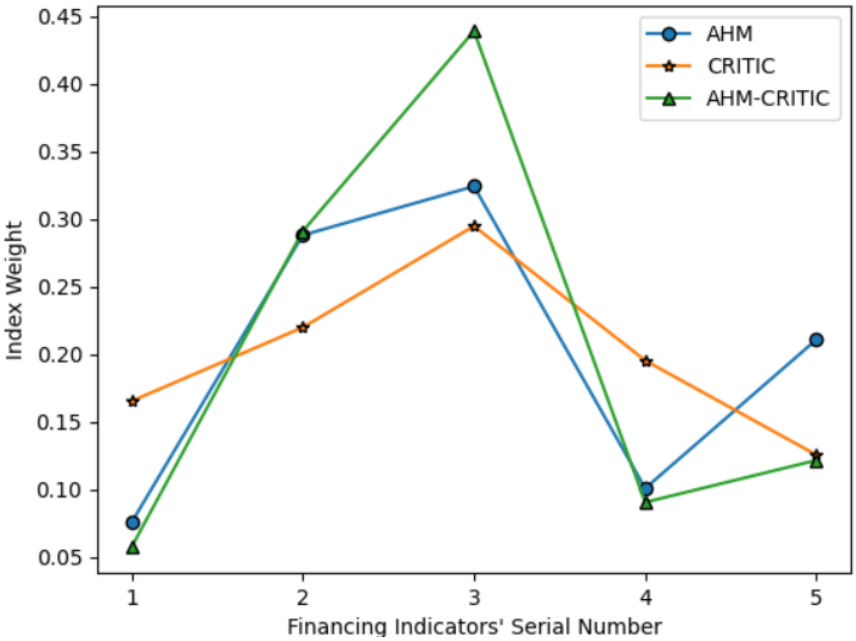



**Figure 2.** Weight comparison by three methods

The comparative weight values of the indicators for the three assignment methods AHM, CRITIC, and AHM-CRITIC can be obtained from Table 2, as shown in Figure 2. From Figure 1, it can be seen that: the extreme difference between the AHM method is larger and more subjective, which is because, for most enterprises, there is a greater preference for bank loans and finance leases; the weights obtained through the CRITIC method are relatively more objective, and in the model test, it is found that the Kendall coefficient eliminates some indicators with weak correlation compared to the Pearson coefficient, thus making the weights behave more evenly. As both subjective and objective factors have an impact on actual financing decisions, and as objective factors generally need to be taken into account more, the AHM-CRITIC is more in line with the actual situation. In Figure 2, relative to the other indicators, the weights of the two options, bank loans and finance leases, are higher in all three methods, and the weight of the finance lease option under the AHM-CRITIC method has been enlarged. In contrast, the area where it takes up less weight has been reduced to a certain extent, which shows that the AHM-CRITIC method considers the weights of both the AHM and CRITIC methods and has the greater advantage, thus enabling more accurate results to be obtained.

Step5 Set target effect thresholds. As the data have been homogenized, the matrix of critical values for the target effect is given in Table 1.

$$u_{i_0 j_0} = \begin{bmatrix} 0.086 \\ 0.45 \\ 1 \\ 0.134 \\ 0.211 \end{bmatrix} \tag{31}$$

Step6 Find the consistent effect measure matrix under $k$ objectives. The consistent effect measure matrix was calculated as

$$R^{(k)} = (r_{ij}^{(k)}) = \begin{bmatrix} 0.00 & 0.46 & 1 & 0.39 & 0.049 \\ 0.11 & 0.22 & 0.62 & 0.43 & 0.47 \\ 1 & 1 & 1 & 0.5 & 1 \\ 1 & 0.94 & 0.87 & 0.77 & 0.31 \\ 0.03 & 0.11 & 0.66 & 1 & 0.14 \end{bmatrix} \tag{32}$$

Step7 Calculate the composite effect measure matrix form $r_{ij} = \sum_{k=1}^{5} \eta_k r_{ij}^{(k)}$ . The matrix of decision rights under $k$ objectives can be obtained from Table 2.

$$\eta_k = \begin{bmatrix} 0.0573 \\ 0.2911 \\ 0.4393 \\ 0.0906 \\ 0.1217 \end{bmatrix} \tag{33}$$

The combined effect measure matrix is then

$$R = \eta_k^T R_k = \begin{bmatrix} 0.565 & 0.627 & 0.837 & 0.558 & 0.625 \end{bmatrix} \tag{34}$$

Step8 Determine the optimal response $b_{j_0}$. From $R > 0$ it can be seen that all five responses hit the grey target, indicating that the screened responses are reasonable. The grey targets are plotted below, and the results are shown in Figure 3.

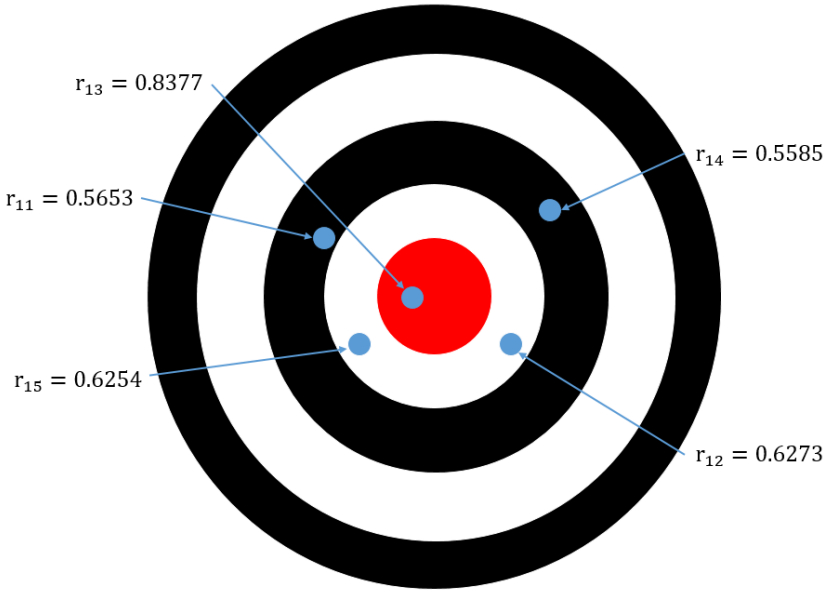



**Figure 3.** Grey target diagram

The combined effect measures of the five responses can be found that of the five combined effect measures $r_{13} > r_{12} > r_{15} > r_{11} > r_{14}$, so the multi-objective grey target decision model can be used to obtain a preferred quantitative option: WL should give preference to financing using financial leasing. After verification, WL did choose the finance lease method for financing in practice.

## 6. Conclusions

This paper proposes an improved multi-objective grey target decision-making model to solve the enterprise decision-making problem. In response to the problem that the attribute hierarchy analysis method can only carry out a single subjective assignment, the improved CRITIC objective assignment method is introduced to combine the subjective and objective assignment methods, thus making up for the shortcomings of the single assignment method and making the obtained results is accurate. The feasibility of the method is also verified in the case study.

(1) An improved decision model is used in the case study to evaluate and analyze the five ways of financing for WL using a comprehensive weighting method, which improves the accuracy and rationality of the decision results and provides a more scientific basis for WL's decision.

(2) The final decision result of the case study is consistent with the actual result, which shows that the decision model used in this study is reasonable and feasible in determining the best decision method.

This paper addresses the problem of selecting the existing decision options in corporate decision-making. The improved AHM-CRITIC model can provide a feasible way of thinking and method for decision-makers of various companies on combining subjective and objective factors, which is conducive to a more rational and accurate approach to corporate decision making.

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