

# A study on credit strategy for small and medium-sized enterprises based on hierarchical analysis

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**Abstract.** Micro, small and medium-sized enterprises (MSMEs) are enterprises with relatively small staff size and operation scale, which are important subjects for enhancing employment and scientific and technological innovation in China, as well as an important part of China's real economy, and play an irreplaceable role in promoting economic growth and social prosperity. This paper mainly provides research solutions to solve the credit decision problems of banks for MSMEs through quantitative analysis of credit risks of MSMEs, combined with the realistic basis for banks to pursue profit maximization and risk minimization. This paper selects some enterprise data as the research sample, pre-processes the original data, and then selects six indicators to quantify the risk: input invoice efficiency, output invoice efficiency, credit rating, total invoices, total price and tax, and average profit. Based on this, this paper uses AHP hierarchical analysis to calculate index weights of 0.0664, 0.115, 0.0755, 0.1067, 0.2899, and 0.3465, respectively, to weight the indicators of each enterprise to sum up the enterprise's reputation score. Then we derive the enterprise's compliance rate from the scores and build the optimal credit decision model accordingly. Finally, we use the greedy algorithm to solve for the final strategy.

**Keywords:** Micro, Small and Medium Enterprises, Optimal Credit Decision Model, AHP.

## 1. Introduction

MSMEs are enterprises with relatively small staff size and scale of operation. Because of their small size and lack of quality collateral assets, MSMEs have a higher risk of credit default than large enterprises [1-4]. In the pre-credit investigation of MSMEs, the bank will evaluate the strength and reputation of the enterprise, the information of the enterprise's transaction notes, the influence of upstream and downstream enterprises, and other factors to determine whether to lend, the loan amount, interest rate and term, taking into account the credit risk and the bank's profit, giving priority to enterprises with strong strength and stable supply and demand relationship, and giving preferential interest rates to enterprises with high reputation and low credit risk[5]. Assume that the total loan amount of the bank is 100-1 million yuan, the annual interest rate is 4%-15%, and the loan term is 1 year. The credit information of 123 enterprises with credit records is available, and this paper quantifies the credit risk in conjunction with the credit risk and gives the bank's credit strategy for these enterprises when the total annual credit amount is fixed. This study knows the data of 123 enterprises' credit rating, whether they are in default, input invoice information, and output invoice information. If we want to quantify the loan risk of the enterprises, we need to select or construct a number of indicators from the given data, calculate the weights of these indicators, and thus obtain the creditworthiness scores of the enterprises [6-7]. The score is then standardized to obtain the enterprise's compliance rate, and the optimal credit model is built based on the compliance rate and the known data to decide whether to grant the loan and the specific credit strategy [8-10].

## 2. The basic fundamental of BP AHP

AHP hierarchical analysis is a decision-making method that decomposes the relevant elements into different levels, on the basis of which qualitative and quantitative analysis is performed to find out the weights. We set input invoice efficiency, output invoice efficiency, total invoices, total price and tax, credit rating and profit as indexes 1-6 respectively, and use the following three steps to calculate them [11].

Step 1: Fill in the judgment matrix and construct the judgment matrix  $A = (a_{ij})_{n \times n}$ .

**Table 1.** Judgment matrix

Index	Index 1	Index 2	Index 3	Index 4	Index 5	Index 6
Index 1	1	0.5	0.2	0.5	0.3333	0.5
Index 2	2	1	1	1	1	1
Index 3	5	1	1	1	1	1
Index 4	1	1	1	1	1	1
Index 5	3	1	1	1	1	1
Index 6	2	1	1	1	1	1

Step 2: Find the weights of each indicator

We use the square root method to find the eigenvectors. First, the elements of the evaluation matrix are multiplied by rows to obtain a new set of vectors, then the new vectors are squared, and finally normalized to the weight vector.

$$W_i = \frac{\left( \prod_{j=1}^n a_{ij} \right)^{\frac{1}{n}}}{\sum_{i=1}^n \left( \prod_{j=1}^n a_{ij} \right)^{\frac{1}{n}}}, i = 1, 2, \dots, n. \tag{1}$$

Calculate consistency metrics  $CI$  :

$$CI = \frac{\lambda_{\max} - n}{n - 1}. \tag{2}$$

where  $\lambda_{\max}$  is the maximum eigenvalue of the judgment matrix

**Table 2.** Results of AHP hierarchical analysis

	Eigenvector	Weighting value	Maximum characteristic root	CI
Index 1	0.4503	0.0664	6.0934	0.0187
Index 2	1.1225	0.1150		
Index 3	1.3077	0.0755		
Index 4	1.1225	0.1067		
Index 5	1.2009	0.2899		
Index 6	1.1225	0.3465		

Table 2 above shows the results of the weight calculation of the hierarchical analysis method, and the weights of indicators 1-6 are 0.0664, 0.115, 0.0755, 0.1067, 0.2899, and 0.3465, respectively.

Step 3: Use the consistency test to determine whether there are errors in the constructed matrix

Find consistency indicators  $CR$  :

$$CR = \frac{CI}{RI}. \tag{3}$$

From the above equation, it is calculated that  $CR = 0.0149 < 0.1$ , passed the consistency test.

**Table 3.** Consistency test results

Maximum characteristic root	CI	RI	CR	Test results
6.0934	0.0187	1.25	0.0149	Pass

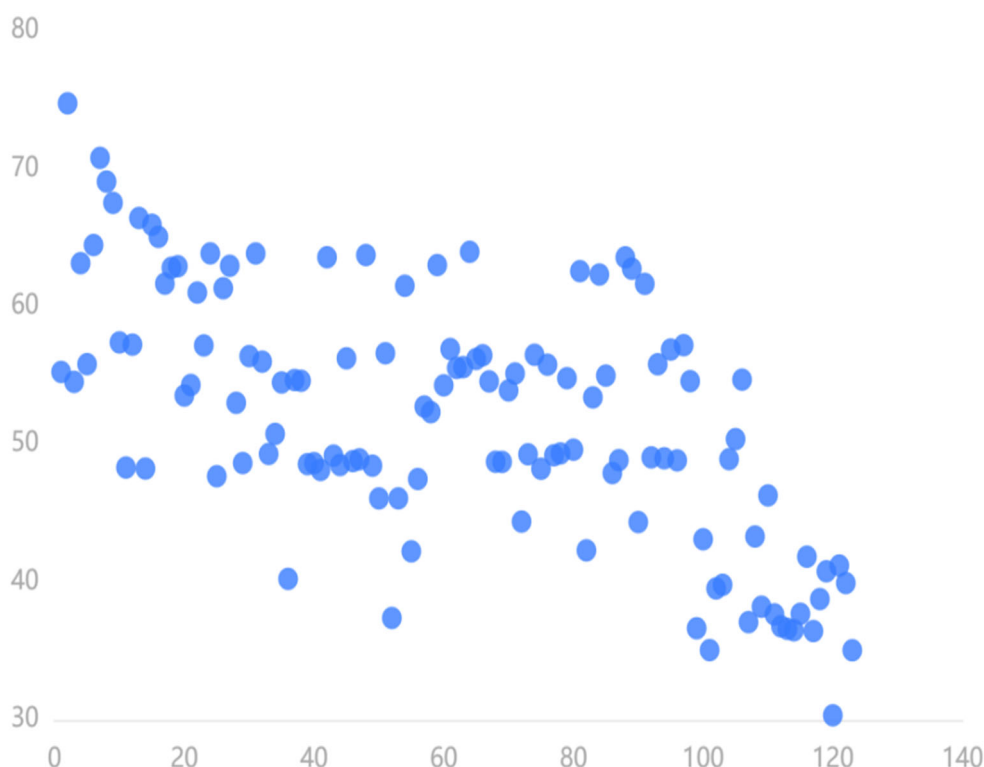
### 3. Results

#### 3.1 3.1 The establishment of simulation model

We multiplied the above values of the six indicators obtained through normalization and normalization with the corresponding indicator weights and summed them, then multiplied by 100 to obtain the scores of 123 enterprises, with lower scores representing higher credit risk. The scores of selected enterprises are given in Table 4.

**Table 4.** Some companies score

Enterprise number	2	10	80	122
Scores	74.75560	57.40028	49.61357	39.93302



**Figure 1.** Scatterplot of enterprise score distribution

From Figure 1 we find that the scores of these 123 enterprises are mainly concentrated in the range of 35-70 points, and the distribution is relatively uniform. In order to facilitate statistical analysis and subsequent calculations, we divided the enterprises into four categories based on the calculated scores: 40 and below, 40-50, 50-60, and above 60 (the lower limit is not included), and in order to verify the accuracy of our calculated scores, the normality tests were conducted next. There are two main types of normality tests, Shapiro-Wilk (S-W test) or Kolmogorov-Smirnov (K-S test).

According to the normality test to check the significance, if it does not show significance (p-value greater than 0.05 or 0.01, strictly 0.05, not strictly 0.01), it means that it is in line with the normal distribution, and vice versa, it means that it is not in line with the normal distribution. However, it is difficult to satisfy the test in the real study situation, so if the absolute value of its sample kurtosis is less than 10 and the absolute value of skewness is less than 3, combined with the histogram of normal distribution can also be considered as basically conforming to the normal distribution.

**Table 5.** Normality test results

Obs	Median	Mean	Sd	Skewness	Kurtosis	S-W test
123	53.014	51.948	9.077	-0.082	-0.508	0.057

Since the score sample size did not exceed 5000, the S-W test was used. At a significance level of 0.01, the significance p-value was 0.057, and the level did not present significance, and the original hypothesis could not be rejected, so the data satisfied a normal distribution. Then we drew the histogram of the normality test for the score data, and the normality graph basically showed a bell shape (high in the middle and low at the ends), indicating that the data, although not absolutely normal, were basically acceptable as a normal distribution.

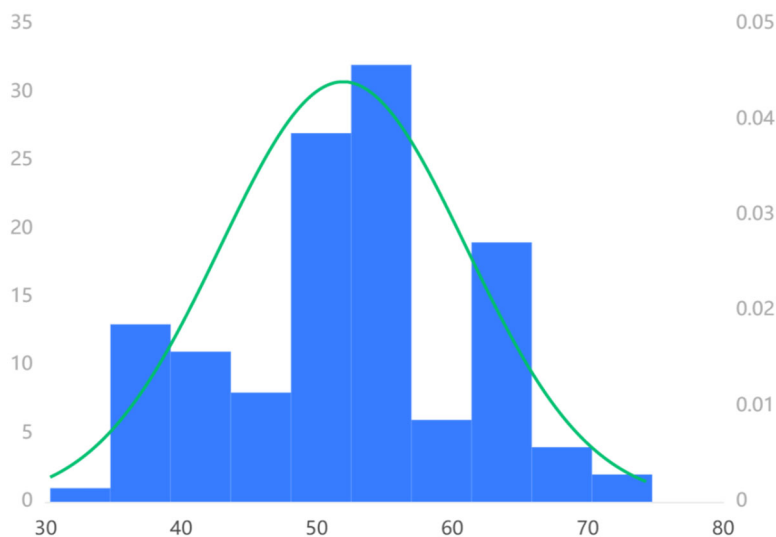


Figure 2. Histogram of normal distribution

To quantify the credit risk of each firm, we normalize each firm's score obtained from the above calculation and define the firm's compliance rate as  $p_i$ ,  $p_i \in [0,1]$ , then  $1 - p_i$  denotes the loss rate of credit risk. Table 6 shows the compliance rates for selected firms.

Table 6. 123 companies' compliance rate (partial)

Enterprise number	1	2	3	4
Compliance rate	0.561075	1	0.544846	0.738755

Denote  $x_i$  by the amount of credit for the  $i$ th ( $i = 1, 2, \dots, 123$ ) firm, the annual interest rate on credit is  $r_i$ , then the bank's return is  $r_i x_i$ , the credit risk, i.e., the possible loss is  $[r_i - (1 - p_i)] x_i$ , and since the bank lends the loan while seeking to minimize risk and maximize profit, our objective function is

$$\max \sum_{i=1}^{123} [r_i - (1 - p_i)] x_i. \tag{4}$$

Then the constraints are as follows.

- 1) The amount of loans granted by the bank is not negative,  $x_i \geq 0$ .
- 2) If the bank issues loans to enterprises, the amount of loans to each enterprise is 10 - 1 million yuan,  $10 \leq x_i \leq 100$ .
- 3) Combining the above two constraints, the total amount of loans granted by the bank should satisfy  $1230 \leq \sum_{i=1}^{123} x_i \leq 12300$ .
- 4) The annual interest rate of the bank granting the loan is 4%-15%, i.e.
- 5) The constraint of annual interest rate of loan on customer loss rate: Assuming that the customer loss rate is  $x$ , the annual interest rate of loan is  $y$ , and assuming that the research object satisfies the cubic function  $f(x) = p_1 x^3 + p_2 x^2 + p_3 x + p_4$ , the curve of customer loss rate and annual interest

rate of loan can be obtained as shown in Figure 3. At 95% confidence level, it is known that  $p_1 = 0.2314$ ,  $p_2 = -0.2054$ ,  $p_3 = 0.1206$ ,  $p_4 = 0.03231$ .

In summary, the optimal credit decision model we develop is

$$\begin{aligned} & \max \sum_{i=1}^{123} [r_i - (1 - p_i)] x_i, i = 1 \cdots 123. \\ & s.t. \begin{cases} x_i \geq 0, \\ 10 \leq x_i \leq 100, \\ 1230 \leq \sum_{i=1}^{123} x_i \leq 12300, \\ 4\% \leq r_i \leq 15\%. \end{cases} \end{aligned} \tag{5}$$

### 3.2 Analysis of experimental results

We finally came out with which companies to give loans, loan amounts, and interest rates, and some of the results are shown in Table 7. Based on the analysis performed for the business operation, the final decision result of whether to make a loan or not can be obtained.

**Table 7.** Banks' credit decisions for 123 firms

Company code	Compliance rate	Whether loan	Loan amount (Million yuan)	rate
E1	0.5611	NO	-	-
E2	1.0000	YES	100.000000	0.0985
E3	0.5448	YES	100.000000	0.1105
E4	0.7388	YES	12.011225	0.1105
E5	0.5738	NO	-	-
E6	0.7684	YES	100.000000	0.0985
E7	0.9109	YES	100.000000	0.0985
E8	0.8721	YES	100.000000	0.0985
E9	0.8373	YES	100.000000	0.0985
E10	0.6093	YES	97.167594	0.1065

From the comparison between prediction data and actual data, the BP neural network has better prediction performance and relatively small error, which can meet the demand completely, and has fast prediction speed and convenient operation.

### 4. Conclusions

In this paper, we give the data of 123 enterprises' creditworthiness rating, whether they are in default or not, input invoice information, and output invoice information. If we want to analyze the loan risk of enterprises quantitatively, we need to select or construct several indicators from the given data, calculate the weights of these indicators, and thus obtain the creditworthiness score of enterprises. The score is then standardized to obtain the enterprise's compliance rate, and the optimal credit model is built based on the compliance rate and the known data to decide whether to issue a loan and the specific credit strategy. This paper analyzes the credit strategy of MSMEs based on the principal component analysis model, and innovatively evaluates the model subjectively to improve the efficiency of credit management and approval. The analysis of this problem can also be applied to the approval and monitoring of other loans, e.g., microfinance companies, etc., and the parameters can be adjusted with reference to this model to solve the problem. In addition, this model has some implications for the operation and model selection of online marketing platforms.

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