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RESEARCH ARTICLE

Enterprise Credit Risk Decision: Application Based on Improved AHP

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Abstract The credit risk of Shouguang vegetable enterprises in China is the biggest obstacle to corporate loans. Building a credit risk assessment model for Shouguang vegetable enterprises and accurately rating the risk of loan enterprises is the key to successful loans. This article aims to construct an AHP evaluation model for the credit risk of Shouguang vegetable enterprises. The data is sourced from managers, bank credit personnel, university researchers, and enterprise related customers who are familiar with the enterprise, while considering four risk levels: impact degree(I), occurrence probability(P), risk manageability(M), and government support(S). This article uses AHP and risk index scores to evaluate the credit risk of Shouguang vegetable enterprises. This model calculates the risk index score based on survey data from 41 corporate credit risk professionals, constructs a pairwise comparison judgment matrix, and conducts consistency testing. It calculates the risk level membership vectors of impact degree, occurrence probability, risk manageability, and government support level at four risk levels, and then calculates the comprehensive evaluation membership vector of credit risk for Shouguang vegetable enterprise. The calculation results show that the comprehensive credit risk assessment level of Shouguang vegetable enterprise belongs to the general risk level, with a membership value of 0.5836. The results still show that the credit rating of Shouguang vegetable enterprises in the four risk levels of impact degree, occurrence probability, risk manageability, and government support are all average risk levels, but there are differences in membership values. The maximum membership value under the impact degree level is 0.6163, and the minimum membership value under the risk manageability level is 0.5572. This study provides a feasible and practical model for enterprise credit risk assessment and conducts a detailed evaluation of the credit risk of Shouguang vegetable enterprise, providing valuable reference for enterprise managers, bank credit personnel, and related researchers.

Keywords: AHP, Corporate credit, Risk, Shouguang vegetable enterprise, Membership degree.

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Introduction

The China Shouguang Vegetable Industry Cluster has promoted the development of Shouguang vegetable enterprises, promoted technological innovation of vegetable enterprises, and opened up vegetable sales channels [1]. The Shouguang vegetable industry chain starts from farmers, with vegetable wholesale enterprises, vegetable processing enterprises, vegetable transportation enterprises, vegetable sales enterprises, and vegetable seed enterprises in the middle, and finally reaches consumers [2]. Therefore, Shouguang adheres to deepening the construction of the vegetable industry system, promoting the large-scale, standardized, and intensive development of the vegetable industry, independently researching and developing domestic seeds, achieving independent seedling cultivation, and supporting the large-scale development of enterprises [3]. However, the difficulty in financing has always restricted the development of Shouguang vegetable enterprises. Especially in the three years of the COVID-19, many vegetable enterprises have suffered serious impacts on their business activities, faced with financing difficulties, lack of capital supply, and urgently need bank loans.

Shouguang vegetable enterprises are mostly small and micro enterprises, based on traditional credit reporting, which have prominent problems such as weak risk resistance, non-standard financial management, incomplete credit reporting systems, and high financing costs [4]. Therefore, credit issues have become a key issue for Shouguang vegetable enterprise loans. The development of big data technology has provided possibilities for enterprise credit evaluation, bringing opportunities and challenges for enterprise development [5]. Whether the amount of information contained in credit risk assessment can effectively distinguish the level of corporate credit risk is the key to the accuracy of the assessment [6]. The key technology is to construct an evaluation model using the information of credit risk assessment and achieve the mapping from credit characteristics to credit status (level) [7], [8].

This study mainly focuses on the problem of the inability to measure relationships between classes and directly determine the number of classes in traditional clustering models. This paper proposes Bayesian nonparametric PCA and t-SNE models that combine PCA, t-SNE, and nonparametric Bayesian methods. These models are applied to dimensionality reduction of high-dimensional data and obtain clustering results, improving both the convergence speed of clustering and the determination of the number of classes.

Literature Review

1. Corporate Credit Risk

The main object of this study is vegetable enterprises in Shouguang, China. During the development process of these enterprises, they all face the problem of bank loans. Vegetable enterprises hope to obtain credit loans from banks, and banks need to conduct credit assessments on these enterprises. From the enterprise credit loan process diagram (Figure 1), it can be seen that the credit evaluation of a company is a key link and the fundamental factor in whether a company can successfully obtain a loan. The greater the credit risk of a company, the less likely it is that the bank will lend to the company. Conversely, the smaller the credit risk of the company, the more likely it is that the bank will lend to the company.

In this study, the credit risk assessment of Shouguang vegetable enterprises includes four levels, namely the degree of risk impact, the probability of loan default, risk manageability, and government support. The evaluation indicators mainly include six primary indicators, namely the financial status, development planning, management level, technological innovation, survival environment, and cooperation level of the enterprise, as well as 30 secondary indicators under each primary indicator (see Table 1 for details).

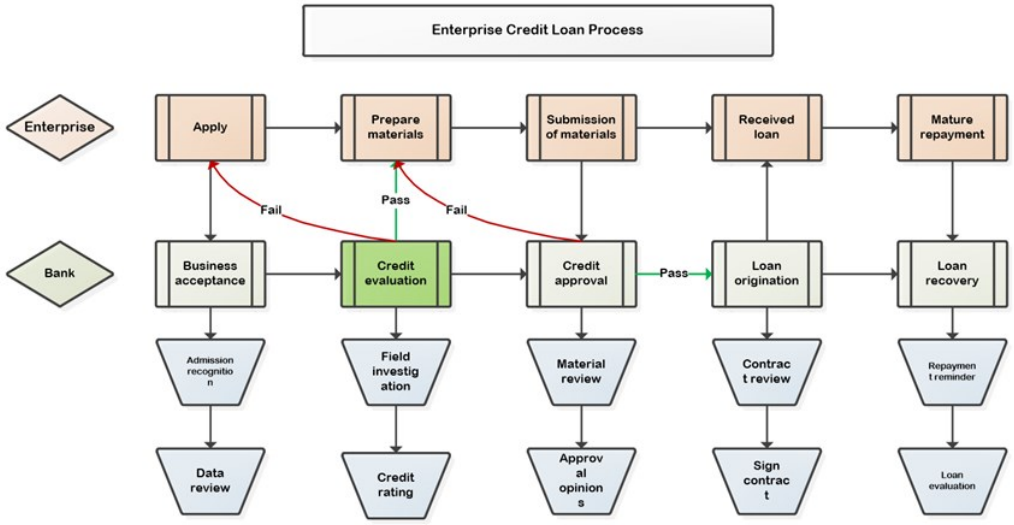

Figure 1. Enterprise Credit Loan Flow Chart

2. Analytic Hierarchy Process Model

Analytic Hierarchy Process (AHP) is a widely recognized decision-making method that is widely used and effective in complex system evaluation [9]. In response to the significant impact of subjective factors

on the evaluation of AHP, the entropy weight method was used to objectively correct the subjective weights obtained from AHP, reducing the impact of subjective factors on indicator weights. Evaluation experiments were conducted based on dynamic correction of indicator weights based on evaluation indicators. The results showed that compared to traditional AHP, the evaluation accuracy of the proposed improved method was significantly improved [10].

AHP is a commonly used method for analyzing multi factor evaluation or multi-attribute decision-making problems. In response to the drawback of AHP's inability to maintain decision independence, the Analytic Hierarchy Process (AHP) was improved through numerical examples to ensure consistent decision ranking results [11]. Afterwards, AHP was widely applied in various fields. For example, using AHP to assess the inundation risk of Shenzhen Metro [12], the evaluation results were verified by 11 flood locations in the flood event that occurred on April 11, 2019.

3. Enterprise Credit Risk Assessment Model

Common credit risk assessment models mainly include credit risk assessment models based on expert experience, credit risk assessment models based on statistical analysis methods, and credit risk assessment models based on machine learning. For example, using the Z-score model to evaluate the credit, risk, and repayment possibility data of loan enterprises, in order to classify and sort them reasonably, reduce credit business procedures, reduce evaluation costs, and face credit risks [13]; Evaluate the credit risk of retailers using payment history data through a logistic regression model, and cluster risk customers by ranking their risk levels [14]; Two credit risk assessment models were established using support vector machines and BP neural networks. The results showed that the SCF credit risk assessment model based on SVM has good generalization ability and robustness, which is more effective than the BP neural network assessment model and can improve the accuracy of good and bad credit classification for small and medium-sized enterprises [15].

Based on previous research, AHP has certain advantages in decision-making problems. Using the AHP model for decision-making has low operating costs, simple operation process, fast calculation speed, and relatively accurate calculation results. Based on the above points, this article adopts the AHP model to evaluate corporate credit risk and compares it with other methods.

Materials and Methods

Figure 2 shows the overall research framework of this paper. The first module describes the process and data sources of identifying credit risk indicators of Shouguang vegetable enterprises, and the second module shows the AHP model of enterprise credit risk assessment. This section mainly includes the following steps: (1) Conduct a questionnaire survey, collect professional opinions and data, and conduct reliability testing on the data; (2) Establish a credit risk evaluation model for Shouguang vegetable enterprises; (3) Calculate the credit risk parameter values of Shouguang vegetable enterprise and make a final evaluation; (4) Discuss research findings.

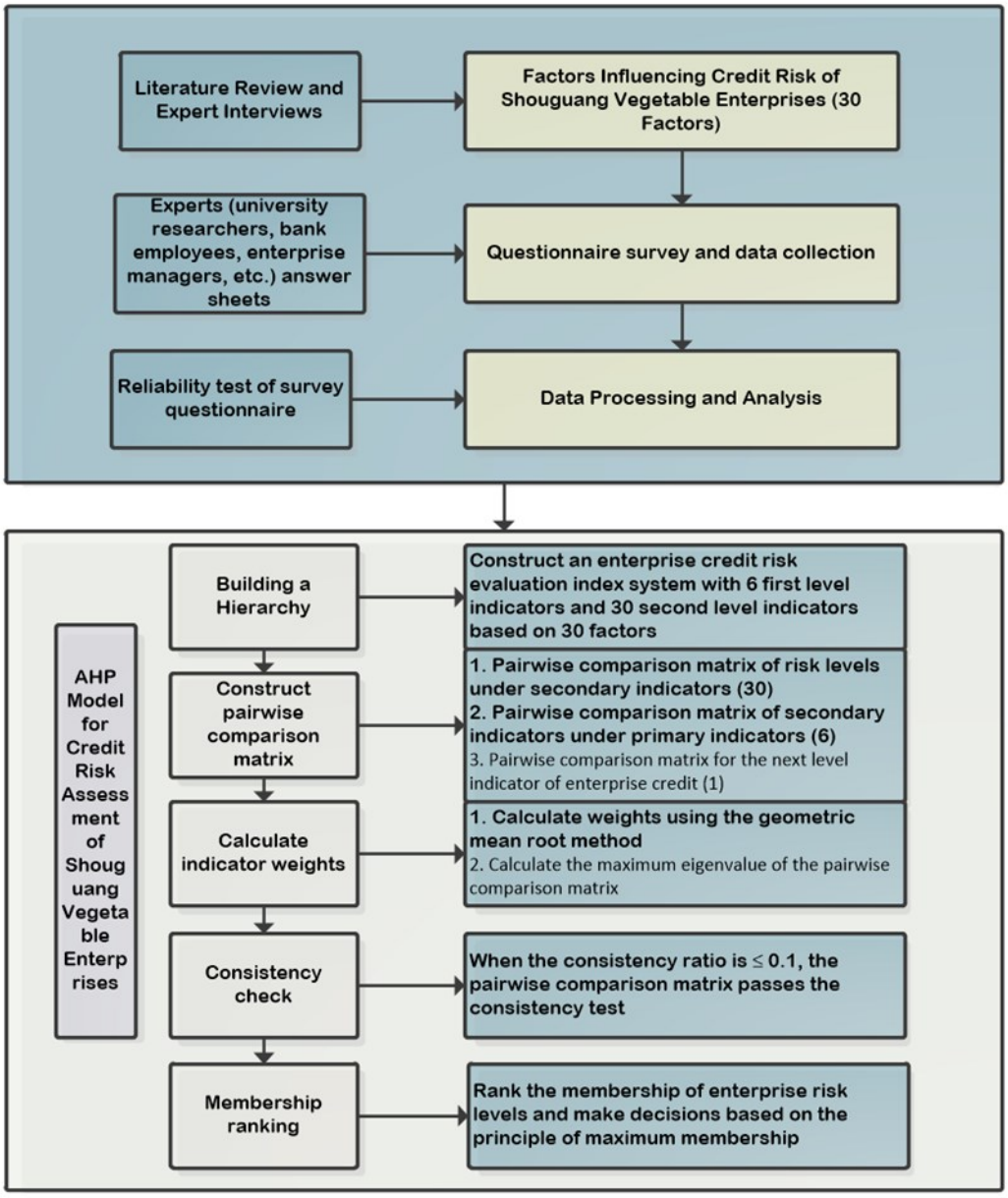

Figure 2. Improved AHP model for enterprise credit risk assessment

1. Factors Influencing Credit Risk of Shouguang Vegetable Enterprises

The key to selecting the influencing factors for enterprise credit risk evaluation is that the influencing factors can effectively distinguish whether the enterprise has defaulted, that is, the influencing factors have the ability to distinguish default; The construction of an indicator system is also the same, that is, the optimal indicator system has the strongest ability to distinguish default. Through literature analysis and expert interviews, 6 primary and 30 secondary influencing factors of credit risk in Shouguang vegetable enterprises were summarized, as shown in Table 1.

Table 1. Factors Influencing Credit Risk of Shouguang vegetable enterprises

N	Level 1 risk factors	Secondary risk factors	
1	Enterprise financial position	Lack of professional financial personnel	[22], [24]
2		Financial personnel lack work experience	[22], [24]
3		Imbalance between income and expenditure	[17], [18], [19]
4		Lack of investor funding support	[18], [19], [20], [22]
5		Poor cash flow	[16], [17], [19]
6	Enterprise development planning	Unclear development goals	[22], [24]
7		Inaccurate development positioning	[24]
8		Delayed marketing and sales planning	[17], [21], [22], [24]
9		No corporate culture formed	[24]
10		The prospects for sustainable development are not optimistic	[16], [22], [24]
11	Enterprise management level	The scale of the enterprise is relatively small	[18], [24]
12		Lack of experience among management personnel	[18], [23], [24]
13		Insufficient professional knowledge of employees	[22], [24]
14		The actual controller's management level is not high	[18], [23], [24]
15		Unreasonable management structure	[22], [24]
16	Enterprise technological innovation	Lack of technical innovation personnel	[24]
17		Low enthusiasm for technological innovation	[24]
18		Low investment in technological innovation funds	[24]
19		Low level of technical research and development personnel	[24]
20		Low number of patent authorizations	[24]
21	Enterprise survival environment	Industry development is sluggish	[16], [18], [21], [24]
22		Low level of regional economic development	[17], [21], [23], [24]
23		Poor network environment	[24]
24		Enterprise location difference	[23]
25		High level of economic inflation	[21], [24]
26	Enterprise cooperation level	Lack of cooperation with supply enterprises	[17], [23]
27		Lack of cooperation with sales platforms	[17], [23]
28		Few cooperation projects with universities	[24]
29		Few technical cooperation projects with research institutes	[24]
30		Few cooperation projects with local governments	[17], [23]

2. Questionnaire survey and data analysis

The questionnaire consists of three parts and is designed to collect opinions from experts and professionals who have knowledge of the credit risks of Shouguang vegetable companies. The first part is to collect information on the basic situation of the respondents, including age, years of working in the company, knowledge of corporate credit risks, etc. Part 2 is a scale involving secondary influencing factors, using an ordinal scale to evaluate the impact level (impact degree), occurrence probability, risk manageability and government support of risk factors (see Table 2). Part 3 is filled in by the investigator, which mainly includes information about the company being investigated and the location of the investigation.

Table 2. Scale of secondary influencing factors in four aspects of Shouguang vegetable enterprise credit

Scales	Impact level(I)	Probability of occurrence(P)	Manageability of risk(M)	Support level of government(S)
1	Very low	<20%	Very Easy	Very big
2	Low	20%-40%	Easy	Big
3	Moderate	40%-60%	Medium Easy	Moderate
4	High	60%-80%	Difficult	Small
5	Very Hight	>80%	Considerably Difficult	Very small

First, one bank credit staff, two Shouguang vegetable enterprise managers and four Weifang University of Science and Technology management experts were invited to participate in the questionnaire survey to verify the questionnaire and adjust the questionnaire based on feedback. After the revision, questionnaires will be distributed one-to-one to relevant personnel (relevant university researchers, corporate staff, bank staff, etc.) Through WeChat, email, links, etc. For testing, and the questionnaires will be collected. A total of 50 questionnaires were distributed, and 41 valid questionnaires were finally recovered, with an effective rate of 82%.

Table 3 summarizes the respondent information. 43.9% of the respondents have more than 5 years of working experience in vegetable companies and are relatively familiar with Shouguang vegetable companies. 46.3% of the respondents are professional and technical personnel from universities and are relatively familiar with corporate credit risk knowledge. In summary, the results in Table 3 show that the test data is credible.

Table 3. Respondent information

N	Options	Frequency	Percent(%)
Gender	Male	15	36.6
	Female	26	63.4
Age	21-30 age	3	7.3
	31-45 age	35	85.4
	46-60 age	3	7.3
Education level	College junior college and undergraduate	17	41.5
	Graduate students and above	24	58.5
Working experience in vegetable enterprise	Within 5 years	23	56.1
	5-10 years	5	12.2
	11-15 years	6	14.6
	16-20 years	6	14.6
	More than 20 years	1	2.4
Identity	Vegetable business managers	2	4.9
	Bank loan manager	1	2.4
	University professional and technical personnel	19	46.3

N	Options	Frequency	Percent(%)
Shouguang vegetable industry understanding level	Vegetable business customers	2	4.9
	Other	17	41.5
	Very knowledgeable	6	14.6
	Relatively knowledgeable	18	43.9
	General understanding	11	26.8
	Relatively unfamiliar	6	14.6
Corporate credit risk understanding	Very knowledgeable	4	9.8
	Relatively knowledgeable	11	26.8
	General understanding	15	36.6
	Relatively unfamiliar	11	26.8

Secondly, the software SPSS24 was used to conduct reliability analysis on the questionnaire data. It was found that the values of Cronbach's alpha were all >0.8, which is considered to be high reliability. The specific values of Cronbach's alpha are shown in Table 4. It can be seen that the data reliability of this questionnaire is very good and suitable for continued analysis.

Table 4. Reliability Test Results of the Survey Questionnaire

Target layer	**Impact level(I) α-cronbach**	**Primary indicators**	**Impact level(I) α-cronbach**
Enterprise Credit Risk Assessment	0.995	Enterprise einancial position	0.973
		Enterprise development planning	0.973
		Enterprise management level	0.979
		Enterprise technological innovation	0.977
		Enterprise survival environment	0.969
		Enterprise cooperation level	0.967
Target layer	Probability of occurrence(P) α-cronbach	Primary indicators	Probability of occurrence(P) α-cronbach
Enterprise Credit Risk Assessment	0.995	Enterprise einancial position	0.973
		Enterprise development planning	0.973
		Enterprise management level	0.979
		Enterprise technological innovation	0.977
		Enterprise survival environment	0.969
		Enterprise cooperation level	0.967
Target layer	Manageability of risk(M) α-cronbach	Primary indicators	Manageability of risk(M) α-cronbach
Enterprise Credit Risk Assessment	0.995	Enterprise einancial position	0.973
		Enterprise development planning	0.973
		Enterprise management level	0.979
		Enterprise technological innovation	0.977
		Enterprise survival environment	0.969
		Enterprise cooperation level	0.967

Target layer	Support level of government(S) α-cronbach	Primary indicators	Support level of government(S) α-cronbach
Enterprise Credit Risk Assessment	0.995	Enterprise einancial position	0.973
		Enterprise development planning	0.973
		Enterprise management level	0.979
		Enterprise technological innovation	0.977
		Enterprise survival environment	0.969
		Enterprise cooperation level	0.967

3. AHP Model

3.1 Building a Hierarchy

Build a hierarchical structure based on goals and influencing factors. See Table 5 for details.

Table 5. Hierarchy table

Target layer	Target	U			
Criterion layer	First level indicator	U_1	U_2	…	U_s
	Secondary indicators	$U_{11},U_{12},\cdots,U_{1t_1}$	$U_{21},U_{22},\cdots,U_{2t_2}$	…	$U_{s1},U_{s2},\cdots,U_{st_s}$
	Level three indicators	…	…	…	…
	…	…	…	…	…
Decision-making level	Decision plan	V_1	V_2	…	V_m

3.2 Construct a Pairwise Comparison Judgment Matrix

Experts use the 1-9 scale to construct a pairwise comparison judgment matrix. See Table 6 for details of the 1-9 scale.

Table 6. 1-9 scale

Scale	Definition	Meaning
1	Equally important	Two elements i and j are equally important to a certain criterion as the other element j
3	Slightly important	Two elements i and j are slightly more important to a certain criterion as the other element j
5	Obviously important	Two elements i and j are Obviously important to a certain criterion as the other element j
7	Strongly important	Two elements i and j are strongly important to a certain criterion as the other element j
9	Extremely important	Two elements i and j are extremely important to a certain criterion as the other element j
2,4,6,8	Median of adjacent scales	Represents a scale that is a compromise between two adjacent scales
The reciprocal of the above scale	Counter comparison	The scale of element i to element j is a_{ij}, and vice versa is $1/a_{ij}$.

The pairwise comparison judgment matrix between each decision under the secondary indicator U_{ij} is:

$$R_{ij}=\begin{bmatrix} r_{ij11} & r_{ij12} & \cdots & r_{ij1m} \\ r_{ij21} & r_{ij22} & \cdots & r_{ij2m} \\ \cdots & \cdots & \cdots & \cdots \\ r_{ijm1} & r_{ijm2} & \cdots & r_{ijmm} \end{bmatrix}_{m\times m} \quad (1)$$

Where $r_{ij11}, r_{ij22}, \cdots, r_{ijmm}$ are both 1, $r_{ij12}=1/r_{ij21}, r_{ij1m}=1/r_{ijm1}, \cdots$.

The pairwise comparison judgment matrix of each secondary indicator under the primary indicator U_i is:

$$R_i=\begin{bmatrix} r_{i11} & r_{i12} & \cdots & r_{i1t_i} \\ r_{i21} & r_{i22} & \cdots & r_{i2t_i} \\ \cdots & \cdots & \cdots & \cdots \\ r_{it_i1} & r_{it_i2} & \cdots & r_{it_it_i} \end{bmatrix}_{t_i\times t_i} \quad (2)$$

Where $r_{i11}, r_{i22}, \cdots, r_{it_it_i}$ are both 1, $r_{i12}=1/r_{i21}, r_{i1t_i}=1/r_{it_i1}, \cdots$.

The pairwise comparison judgment matrix of each first-level indicator under target U is:

$$R=\begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1s} \\ r_{21} & r_{22} & \cdots & r_{2s} \\ \cdots & \cdots & \cdots & \cdots \\ r_{s1} & r_{s2} & \cdots & r_{ss} \end{bmatrix}_{s\times s} \tag{3}$$

Where $r_{11}, r_{22}, \cdots, r_{ss}$ are both 1, $r_{12}=1/r_{21}, r_{1s}=1/r_{s1}, \cdots$.

This study uses questionnaire data to construct a pairwise comparison judgment matrix, which is an improvement on AHP. Taking the construction of the pairwise comparison judgment matrix R_i of each secondary indicator under the primary indicator U_i as an example, the specific method is as follows:

(1) Calculate the risk index score of each secondary indicator U_{ij} under the primary indicator U_i

Calculation formula：

$$M_{ij}=f_{ij1}*1+f_{ij2}*2+\cdots+f_{ijm}*m=\sum_{k=1}^{m}f_{ijk}*k \tag{4}$$

Among them, f_{ijk} is the frequency of secondary index U_{ij} belonging to decision V_k.

(2) Calculate the difference Δ_i between the maximum and minimum values of the U_i second-level indicator U_{ij} risk index score under the first-level indicator

Calculation formula：

$$\Delta_i=\max\left\{M_{ij}\right\}-\min\left\{M_{ij}\right\} \tag{5}$$

(3) Determine the 1-9 scale value interval range under the first-level indicator

(4) Determine the 1-9 scale value based on the pairwise comparison of the risk index scores of the secondary indicators and combined with Δ_i.

Compare secondary indicators U_{ik} and U_{il} and calculate $\Delta_{i(kl)}=M_{ik}-M_{il}$

(1) When $\Delta_{i(kl)}>0$, the comparison scale value of secondary index U_{ik} and U_{il} is $1,2,3,\cdots,9$;

(2) When $\Delta_{i(kl)}=0$, the comparison scale value of secondary index U_{ik} and U_{il} is 1;

(3) When $\Delta_{i(kl)}<0$, the comparison scale value of secondary index U_{ik} and U_{il} is $1,\frac{1}{2},\cdots,\frac{1}{9},$.

3.3 Calculate Indicator Weight

There are three main methods for calculating indicator weights in AHP, namely the characteristic root method, the radical method (geometric mean) and the sum method (arithmetic mean). This paper uses the radical method (geometric mean) for research.

(1) Calculate the product M_i of the elements in each row of the pairwise comparison judgment matrix $(R)_{m\times m}$, where $1\le i\le m$.

(2) Calculate the nth root of all M_i and get the vector $a=(a_1,a_2,\cdots,a_m)^T$.

(3) The vector a is normalized and the calculation formula is $w_i=a_i\Big/\sum_{k=1}^{m}a_k$, thereby obtaining the

weight vector W, that is, the eigenvector corresponding to the maximum eigenvalue of the pairwise comparison judgment matrix $(R)_{m\times m}$ is $W=(w_1,w_2,\cdots,w_m)^T$.

(4) Calculate the maximum eigenvalue $\lambda_{\max}$ of the pairwise comparison judgment matrix $(R)_{m\times m}$. The calculation formula is

$$\lambda_{\max}=\frac{1}{m}\sum_{i=1}^{m}\frac{(AW)_i}{w_i} \quad (6)$$

3.4 Pairwise Comparison Judgment Matrix Consistency Test

(1) Calculate the consistency index CI of the pairwise comparison judgment matrix

Calculation formula: $CI=\frac{\lambda_{\max}-m}{m-1}$

(2) Look up the table to determine the random consistency index RI of the pairwise comparison judgment matrix

The random consistency index is shown in Table 7.

Table 7. Random consistency index values

Matrix order m	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0	0	0.52	0.89	1.12	1.26	1.36	1.41	1.46	1.49	1.52	1.54	1.56	1.58	1.59

(3) Calculate the consistency ratio CR of the pairwise comparison judgment matrix

Calculation formula: $CR=\frac{CI}{RI}$

The smaller CR is, the better the consistency of the pairwise comparison judgment matrix. Generally, when $CR\le 0.1$, the pairwise comparison judgment matrix passes the consistency test.

3.5 Calculate the Membership Ranking of the Target Decision and Make a Decision

According to the membership streamline diagram of target U (Figure 3), calculate the membership degree w_{v_i} $(1\le i\le m)$ of decision V_i of target U. The calculation formula is as follows:

$$\begin{aligned}w_{v_i}&=w_1*(w_{11}*w_{11i}+w_{12}*w_{12i}+\cdots+w_{1t_1}*w_{1t_1i})\\&+w_2*(w_{21}*w_{21i}+w_{22}*w_{22i}+\cdots+w_{2t_2}*w_{2t_2i})\\&\cdots+w_s*(w_{s1}*w_{s1i}+w_{s2}*w_{s2i}+\cdots+w_{st_s}*w_{st_si})\end{aligned} \quad (7)$$

Finally, the membership vector of the decision-making target U is obtained as

$$W=(w_{v_1}\quad w_{v_2}\quad\cdots\quad w_{v_m}),$$

Sort the decisions and make the final decision based on the principle of maximum membership.

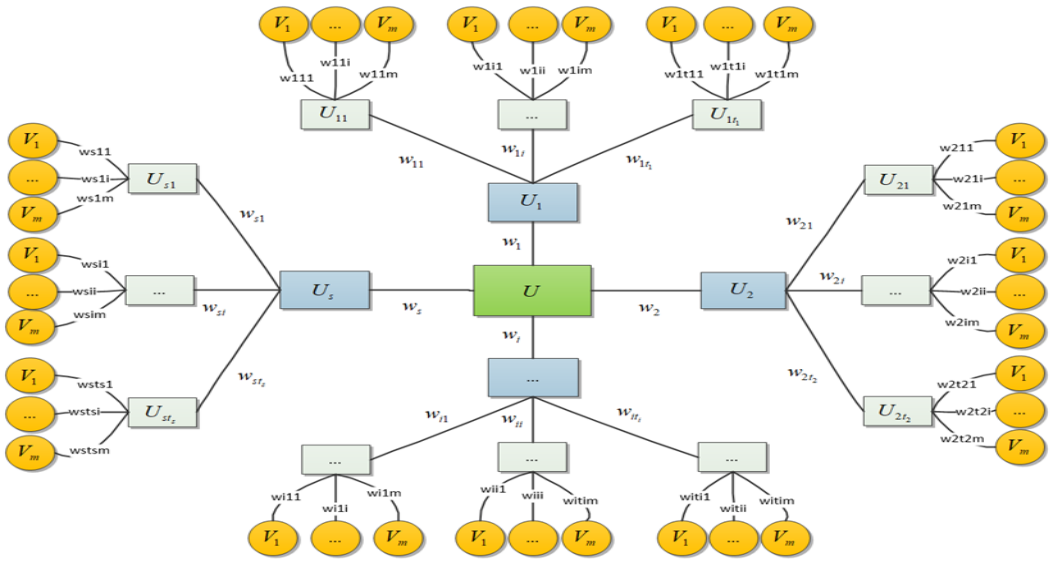

Figure 3. Decision-making membership flow diagram of the target

Shouguang Vegetable Enterprise Credit Risk AHP Evaluation Model

1. Building a Hierarchy

The level of credit risk evaluation of Shouguang vegetable enterprises consists of the target layer, the criterion layer and the decision-making layer. The criterion layer is divided into the first-level indicator layer and the second-level indicator layer. See Table 8 for details.

Table 8. Shouguang vegetable enterprise Credit Risk Assessment Hierarchy Structure

Target layer	Target	Shouguang Vegetable Enterprise Credit Risk Assessment					
Criterion layer	First level indicator	Enterprise financial position	Enterprise development planning	Enterprise management level	Enterprise technological innovation	Enterprise survival environment	Enterprise cooperation level
	Secondary indicators	1.Lack of professional financial personnel 2.Financial personnel lack work experience 3.Imbalance between income and expenditure 4.Lack of investor funding support 5.Poor cash flow	1.Unclear development goals 2.Inaccurate development positioning 3.Delayed marketing and sales planning 4.No corporate culture formed 5.The prospects for sustainable development are not optimistic	1.The scale of the enterprise is relatively small 2.Lack of experience among management personnel 3.Insufficient professional knowledge of employees 4.The actual controller's management level is not high 5.Unreasonable management structure	1.Lack of technical innovation personnel 2.Low enthusiasm for technological innovation 3.Low investment in technological innovation funds 4.Low level of technical research and development personnel 5.Low number of patent authorizations	1.Industry development is sluggish 2.Low level of regional economic development 3.Poor network environment 4.Enterprise location difference 5.High level of economic inflation	1.Lack of cooperation with supply enterprises 2.Lack of cooperation with sales platforms 3.Few cooperation projects with universities 4.Few technical cooperation projects with research institutes 5.Few cooperation projects with local governments
Decision-making level	Decision plan	The risk is very small, the risk is relatively small, the risk is average, the risk is relatively high, the risk is very high					

2. Construct a Pairwise Comparison Judgment Matrix

A pairwise comparison judgment matrix is constructed through questionnaire data processing and comparison. This article only gives the impact (effect) level between the decisions between the second-level indicators U_{11}, the second-level indicators under the first-level indicator U_1, and the first-level indicators under the target U. Two comparison judgment matrices, and other pairwise comparison judgment matrices are shown in the attached data.

The pairwise comparison judgment matrix between each decision under the secondary indicator U_{11} is:

$$R_{11}=\begin{bmatrix} 1 & 1/3 & 1/9 & 1/2 & 1/2 \\ 3 & 1 & 1/6 & 2 & 2 \\ 9 & 6 & 1 & 7 & 7 \\ 2 & 1/2 & 1/7 & 1 & 1 \\ 2 & 1/2 & 1/7 & 1 & 1 \end{bmatrix}$$

The pairwise comparison judgment matrix of each secondary indicator under primary indicator U_1 is:

$$R_1=\begin{bmatrix} 1 & 2 & 1/2 & 1/7 & 1/3 \\ 1/2 & 1 & 1/3 & 1/8 & 1/4 \\ 2 & 3 & 1 & 1/5 & 1/2 \\ 7 & 8 & 5 & 1 & 4 \\ 3 & 4 & 2 & 1/4 & 1 \end{bmatrix}$$

The pairwise comparison judgment matrix of each first-level indicator under target U is:

$$R=\begin{bmatrix} 1 & 4 & 6 & 2 & 9 & 7 \\ 1/4 & 1 & 2 & 1/3 & 6 & 3 \\ 1/6 & 1/2 & 1 & 1/5 & 4 & 2 \\ 1/2 & 3 & 5 & 1 & 9 & 6 \\ 1/9 & 1/6 & 1/4 & 1/9 & 1 & 1/3 \\ 1/7 & 1/3 & 1/2 & 1/6 & 3 & 1 \end{bmatrix}$$

3. Calculate Indicator Weight

This article uses the radical method to calculate indicator weights, and only uses the pairwise comparison judgment matrix R of each first-level indicator under target U as an example to explain the weight calculation.

(1) Calculate the product M_i of the elements in each row of R, we have
$M_1=3024$, $M_2=3$, $M_3=0.1333$, $M_4=405$, $M_5=0.0002$, $M_6=0.0119$.

(2) Calculate the 6th root a_i of all M_i to get the vector:
$a=(3.8027,1.2009,0.7148,2.72,0.2357,0.4778)^T$。

(3) Normalize the vector a and obtain the eigenvector corresponding to the maximum eigenvalue of R as
$W=(0.4155,0.1312,0.0781,0.2972,0.0258,0.0522)^T$.

(4) Calculate the maximum eigenvalue of R is $\lambda_{\max}=6.1986$.

4 Consistency Check

This article only takes the pairwise comparison judgment matrix of each first-level indicator under the target as an example to explain the consistency test.

(1) Calculate the consistency index of R is $CI = 0.0397$.

(2) Look up the table to get the random consistency index of R is $RI = 1.26$.

(3) Calculate the consistency ratio of R is $CR = 0.0315 < 0.1$, and compare the pairwise judgment matrix R to pass the consistency test.

5. Calculate the Membership Vector of Credit Risk of Shouguang Vegetable Enterprise

Calculate the attribute vector of the credit risk of Shouguang vegetable enterprise and explain it with the impact level (I) as an example.

The membership vector of the credit risk of Shouguang vegetable enterprises under the impact (effect) level is:

$$\begin{aligned}W_1^{(I)} &= 0.4155*(0.0745*0.0507+0.0479*0.0544\\&+0.1237*0.0430+0.5579*0.0557+0.1960*0.0360)\\&+0.1312*(0.0898*0.0600+0.0574*0.0692\\&+0.3544*0.0547+0.1441*0.0541+0.3544*0.0541)\\&+0.0781*(0.0385*0.0473+0.1168*0.0623\\&+0.1936*0.0555+0.5342*0.0610+0.1168*0.0632)\\&+0.2972*(0.0415*0.0647+0.0858*0.0672\\&+0.4447*0.0627+0.2951*0.0482+0.1329*0.058)\\&+0.0258*(0.1878*0.0593+0.1255*0.0601\\&+0.0774*0.0716+0.0373*0.125+0.5721*0.0699)\\&+0.0522*(0.0587*0.0723+0.0587*0.0783\\&+0.2981*0.0672+0.4482*0.0792+0.1363*0.0662)\\&=0.0556\end{aligned}$$

。

In the same way, we can get:

$W_2^{(I)} = 0.0932, W_3^{(I)} = 0.6163, W_4^{(I)} = 0.1740, W_5^{(I)} = 0.0609$。

Results and Findings

1. Membership vectors of various levels of credit risk of Shouguang vegetable enterprises

Using AHP to calculate the membership vectors of each level of Shouguang vegetable enterprise's credit risk (see Table 9), we can get:

(1) At the level of Impact level (I), the membership vector of credit risk of Shouguang vegetable enterprise is

$W^{(I)} = (0.0556, 0.0932, 0.6163, 0.1740, 0.0609)$.

(2) At the level of probability of occurrence (P), the membership vector of credit risk of Shouguang vegetable enterprise is

$W^{(P)} = (0.0771, 0.1279, 0.5737, 0.1795, 0.0418)$.

(3) At the level of Manageability of risk(M)), the membership vector of credit risk of Shouguang Vegetable Enterprise is

$$W^{(M)} = (0.0738, 0.1064, 0.5572, 0.2213, 0.0412)$$

(4) At the level of Support level of government(S)), the membership vector of credit risk of Shouguang vegetable enterprise is

$$W^{(S)} = (0.0770, 0.1263, 0.5888, 0.1648, 0.0431)$$

Table 9. Risk membership and mean variance at each level of Shouguang vegetable enterprise's credit risk

Risk level	V1	V2	V3	V4	V5	Average value	variance
Impact level(I)	0.0556	0.0932	0.6163	0.1740	0.0609	0.2000	0.0564
Probability of occurrence(P)	0.0771	0.1279	0.5737	0.1795	0.0418	0.2000	0.0463
Manageability of risk(M)	0.0738	0.1064	0.5572	0.2213	0.0412	0.2000	0.0445
Support level of government(S)	0.0770	0.1263	0.5888	0.1648	0.0431	0.2000	0.0494
Geometric mean	0.0703	0.1125	0.5836	0.1837	0.0461	0.1992	0.0489

2. Comprehensive Degree of Credit Risk of Shouguang Vegetable Enterprises

The credit risk of Shouguang vegetable enterprises is affected by the Impact level (I), the probability of occurrence (P), the Manageability of risk (M), and the Support level of government(S), so it is necessary to combine the four levels of membership to calculate the comprehensive membership degree of the credit risk of Shouguang vegetable enterprises. The calculation formula is as follows:

$$W = \sqrt[4]{W^{(I)} * W^{(P)} * W^{(M)} * W^{(S)}}$$

The comprehensive membership degree of credit risk of Shouguang vegetable enterprise can be calculated as:

$$W = (0.0703, 0.1125, 0.5836, 0.1837, 0.0461)$$

It shows that the credit risk of Shouguang vegetable enterprise belongs to the general risk level.

Discussion

This paper proposes a practical model for credit risk assessment and applies it to the credit risk assessment of China's Shouguang vegetable enterprises. The results show that the credit risk of China's Shouguang vegetable companies belongs to the general level, and its comprehensive membership degree is 0.5836. This result is compared with previous research results [25]. The credit risk of the company is low. As expected, this is related to the region and the nature of the company.

(1) Overall Analysis

It can be seen from the comprehensive membership vector of the credit risk of Shouguang vegetable companies that the credit risks of Shouguang vegetable companies are ranked from size to average risk (58.36%), high risk (18.37%), low risk (11.25%), low risk Very small (7.03%), very risky (4.61%). The membership value with higher risk is larger than the membership value with lower risk, and the ratio reaches 1.63. Generally speaking, the credit risk of Shouguang vegetable enterprises tends to be higher. Therefore, banks should conduct on-site inspections as much as possible when conducting credit assessment. .

(2) Level Analysis

At the level of impact level, the proportion of general risk level is 61.63%, which is the largest weight among the four levels. The proportion of relatively high risk and very high risk reaches 23.49%%; at the level of occurrence probability, the proportion of general risk level is 57.37%. The proportion of relatively high risk and very high risk reaches 22.13%%; in terms of risk manageability, the proportion of general risk level is 55.72%, which is the smallest weight among the four levels, and the proportion of high risk and very high risk reaches 26.25%% ; In terms of government support level, the proportion of general risk level is 58.88%, and the proportion of high risk and very high risk reaches 20.79%. It can be seen that the level of risk manageability has the greatest impact on the credit risk of Shouguang vegetable

companies, followed by the degree of impact, probability of occurrence, and degree of government support.

(3) First-level Indicator Analysis

Summarizing the weights of first-level indicators at each level (see Table 10), it can be seen that the weight values of lower-level indicators at different levels are ranked differently.

At the level of impact degree, the ranking of the weights of the first level indicators is: enterprise financial status (0.4155), enterprise technological innovation (0.2972), enterprise development planning (0.1312), enterprise management level (0.0781), enterprise cooperation level (0.0522), and enterprise survival environment (0.0258).

At the level of probability of occurrence, the ranking of the weights of the first level indicators is: enterprise technological innovation (0.3819), enterprise financial condition (0.1986), enterprise management level (0.1636), enterprise cooperation level (0.1607), enterprise development planning (0.0663), and enterprise survival environment (0.0290).

At the level of risk manageability, the ranking of the weights of the first level indicators is: enterprise technology innovation (0.5463), enterprise development planning (0.1378), enterprise management level (0.1147), enterprise cooperation level (0.1135), enterprise financial condition (0.0574), and enterprise survival environment (0.0304).

The ranking of the weights of the first level indicators at the level of government support is: enterprise management level (0.3797), enterprise technological innovation (0.2516), enterprise development plan (0.2516), enterprise financial status (0.0525), enterprise cooperation level (0.0323), and enterprise survival environment (0.0323).

It can be seen from this that corporate technological innovation has a greater impact on credit risk, and companies with strong technological innovation capabilities also have strong risk resistance capabilities. The financial status of an enterprise and the level of its management have a relatively greater impact on credit risk, while the impact of an enterprise's living environment on credit risk is relatively minimal.

Table 10. Weight values of first-level indicators at each level of Shouguang vegetable enterprise's credit risk

Primary indicators	Code	Impact level(I)	Probability of occurrence(P)	Manageability of risk(M)	Support level of government(S)
Financial position	U1	0.4155	0.1986	0.0574	0.0525
Enterprise development planning	U2	0.1312	0.0663	0.1378	0.2516
Enterprise management level	U3	0.0781	0.1636	0.1147	0.3797
Enterprise technological innovation	U4	0.2972	0.3819	0.5463	0.2516
Enterprise survival environment	U5	0.0258	0.0290	0.0304	0.0323
Enterprise cooperation level	U6	0.0522	0.1607	0.1135	0.0323

Conclusions

Corporate loans are an inevitable trend for corporate survival. In order to reduce the probability of loan default, accurate, fast and low-cost assessment of corporate credit risks is a major test faced by banks. This study designed the AHP assessment model to solve the credit risk assessment problem of Shouguang vegetable enterprises. The model conducts risk assessment based on four levels: impact degree, occurrence probability, risk manageability and government support. Data is collected through questionnaires and geometric mean is used. Calculate the pairwise comparison judgment matrix using the method, determine the index weights, and conduct consistency tests to finally complete the overall ranking of corporate credit risks and determine the risk level. The model is novel and reliable, with accurate results, and can be extended to other regions and other types of corporate credit risk assessments.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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