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Quality credit evaluation based on TOPSIS: Evidence from air-conditioning market in China

Xiaoqian Zhu^{a,c}, Fei Wang^b, Changzhi Liang^{a,c}, Jianping Li^a, Xiaolei Sun^{a,*}^a *Institute of Policy and Management, Chinese Academy of Sciences, Beijing 100190, P.R. China*^b *College of Engineering, Chinese Academy of Sciences, Beijing 100190, P.R.China.*^c *School of Management, Chinese Academy of Sciences, Beijing 100190, P.R.China.*

Abstract

Quality credit has been an academic and commercial hotspot recently. This paper is mainly devoted into using a quantitative method to evaluate credit quality. Firstly, a plain but logical indicator system of quality credit is established. Then, the classical MCDM method TOPSIS is introduced to evaluate the credit quality of 8 air-conditioning enterprises in China market. The discussion of evaluation results proves the feasibility and effectiveness of TOPSIS and moreover, reflects that indicators affect the evaluation results significantly. At last, some possible further studies are mentioned.

Keywords: quality credit; TOPSIS; China; air-conditioning market

1. Introduction

In recent years Chinese food enterprises have experienced unprecedented crisis of quality credit. The quality credit is gradually put onto the cusp as a crucial social issue. Some related companies collapse instantly owing to their terrible quality credit while others struggle to survive in this battle. As one of the most crucial components in corporate credit, quality credit is then proposed to make the corporate pay more attention to the quality and credit management. As early as 2006, Chinese government institutions have issued relative documents [1] to recommend the framework of quality credit which gradually appears in the academic sight.

Quality credit plays significant role in enhancing the competence of the enterprise and winning the favour of consumers. The quality credit of one enterprise or industry would also be an important reference criterion for consumers when future decision is made. However, it has not been accepted by the academia as an accurate concept. The inconformity of definitions and immaturity of evaluation system also restrict further understanding of quality credit. To fix the gap, some basic elements of quality credit should be included in most definitions. Moreover a more effective index system should also be introduced to improve the evaluation system of quality credit.

* Corresponding author. Tel.: 86-(10)-59358806; fax:86-(10)-59358889-903
E-mail address: xlsun@casipm.ac.cn

In this paper various definitions of quality credit are discussed. Agreed indicators are aggregated to establish the indicator system and the method of TOPSIS is introduced to evaluate the quality credit. Additionally, an empirical experiment on air-conditioning enterprises in China market is designed to verify the feasibility and efficiency of the evaluation system.

2. Quality credit definition and evaluation

Quality credit is first proposed as enterprise's capacity and performance of complying with laws as well as the commitment to its product quality by the General Administration of Quality Supervision, Inspection and Quarantine (GAQSIQ) of the People's Republic of China [1]. In 2009 the GAQSIQ and Standardization Administration of People's Republic of China (SAC) jointly release the recommended national standard in which the quality credit is noted as the capacity to obtain and maintain the credit of quality [2].

The former definition is preferred in this paper, as capacity depicts an enterprise's potential ability to manage quality credit while performance represents the result it has achieved. Moreover the willingness to carry out the promise of quality credit is also covered in this definition. However there exists some confusion about the definition literally as the quality could not possess the credit as a legal entity such as a corporate or a person. The quality credit somehow is perceived as corporate credit in terms of product quality.

The establishment of indicator system is the prerequisite of the evaluation system. Such an indicator system should essentially represent the characters of quality credit. Previous works emphasize on the indicator selection and classification. Sophisticated indicators have been selected aiming to extensively encompass every point mentioned above [3]. However some redundant indicators merely increase the time to evaluate quality credit, while offering no help to the improvement of accuracy. When it comes to the classification, most literatures prefer to break these indicators into three different aspects, namely the willingness to maintain quality credit, capacity of the company and practical performance.

To make the classification more precise in this paper, specific indicators are introduced to evaluate the willingness to maintain quality credit, capacity of the company the practical performance respectively. Some indicators are abandoned as it is improper to evaluate all companies with the same criterions. The indicators of different industries vary as a result of different product characteristics and operation patterns. For this reason, this paper abstracts each aspect as a logical layer and each logical layer will be embodied according to selected industry.

For the willingness to maintain quality credit, the company, law and encouragement layers are adopted. Firstly, the company layer somehow describes the willingness of preserving tangible and intangible assets. For example, the value of a brand is accumulated by years' efforts and ignorance of the quality credit would lead to catastrophe that makes these efforts in vain. Secondly, the willingness is influenced by laws and regulations. For example, the punishment multiples by laws will increase the cost of violating the laws and corporate risk. Finally, the enterprise will be more enthusiastic to preserve its quality credit with encouragement. For example, quality awards will encourage the enterprise to improve its quality credit.

Capacity of the enterprise implies the potential ability to execute the quality commitment. The capacity, which is the synthesis of product quality and corporate credit, is illustrated by the manufacturing and financial layers. The manufacturing layer of a company includes the research investment, technical ability, quality certification and adopted standards, which will influence the manufacturing management and eventually product quality from different dimensions. The financial layer is analogous to part of corporate credit which is mainly concerned with financial affairs. For example, the profit rate, sales growth and market shares are the common issues to depict corporate capacity.

As for the practical performance, the variables are summarized as the law and customer layer. Violation of laws will arouse suspicion about the product quality. For example, illegal records and accidents caused by terrible product quality could devastate an enterprise's quality credit. From the perspective of customers, practical performance of quality credit is concerned with contract with customers. For example, the trueness of the propaganda is the credit of promise made by the enterprise while customer's satisfaction is the credit of execution sensed by customers.

3. TOPSIS for quality credit evaluation

Credit evaluation is a hotspot in researches. Many mathematical models, such as support vector machine (SVM) [4], modified SVM [5,6], decision tree, discriminant analysis, and multi-criteria quadratic programming [7-10], have

been applied. However, it is generally agreed that these models don't perform well concerning model computing complexity and the interpretation of results which are generally deemed to be important in credit evaluation. Technique for order preference by similarity to ideal solution (TOPSIS), first developed by Hwang et al. (1981) [11], is one of the classical multi-criteria decision-making (MCDM) methods widely used in evaluation studies for its simplicity to explain and operate [12]. It is based on the concept that the most preferred alternative should have the shortest distance from the positive ideal solution (PIS) and the largest distance from the negative ideal solution (NIS). The PIS refers to a solution that maximizes the benefit criteria and minimizes the cost criteria, whereas the NIS is the opposite, i.e. minimizes the benefit criteria and maximizes the cost criteria. The TOPSIS method considers simultaneously the distance to both the PIS and the NIS [13].

TOPSIS is widely used in all kinds of evaluation studies, but not yet in quality credit evaluation. Therefore, in this study, TOPSIS is used to evaluate quality credit. The quality credit of an enterprise is reflected by indicators listed in the second section. A high quality credit enterprise should have better indicator values than the low quality credit enterprise. So the ideal quality credit enterprise with the best indicator values and the worst enterprise with the worst indicator values could be benchmarking for evaluating quality credit. The quality credit of an enterprise can be represented as the distance of the enterprise from ideal enterprise and worst enterprise. The closer the enterprise to ideal enterprise and the further to the worst enterprise, the higher quality credit score the enterprise attains, vice versa. Some indicators, so-called benefit criteria, affect the quality credit positively while other indicators, so-called cost criteria, affect the quality credit negatively. The ideal quality credit enterprise should have the greatest positive indicator values and the lowest negative indicator values. The worst quality credit enterprise is just the reverse. The quality credit scoring process using TOPSIS is as follows [14,15]:

Assume there are n enterprises to be evaluated and each enterprise has m evaluation indicators. Let $X=[x_{ij}]_{n \times m}$ denotes decision matrix, where x_{ij} is the j_{th} indicator value of the i_{th} enterprise. Let w_j denotes the weight of the j_{th} indicator.

Step1: normalize the decision matrix

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^n x_{ij}^2}}, i = 1, \dots, n, j = 1, \dots, m \tag{1}$$

Where r_{ij} represents the normalized value of j_{th} indicator of the i_{th} enterprise.

Step2: weight the normalized decision matrix

$$v_{ij} = w_j r_{ij}, i = 1, \dots, n, j = 1, \dots, m \tag{2}$$

Where v_{ij} represents the weighted normalized value of j_{th} indicator of the i_{th} enterprise. Weights are always set subjectively by experts or regulators.

Step3: determine PIS and NIS

$$A^+ = \{v_j^+, j = 1, \dots, m\} \tag{3}$$

$$A^- = \{v_j^-, j = 1, \dots, m\}$$

Where A^+ and A^- respectively represent the PIS and the NIS. $v_j^+ = \max\{v_{ij}, i = 1, \dots, n\}$ if indicator j_{th} is benefit criteria, otherwise $v_j^+ = \min\{v_{ij}, i = 1, \dots, n\}$. $v_j^- = \min\{v_{ij}, i = 1, \dots, n\}$ if j_{th} indicator is benefit criteria, otherwise $v_j^- = \max\{v_{ij}, i = 1, \dots, n\}$. PIS and NIS are the weighted normalized best and worst enterprises. Meanwhile, it is notable that experts or regulators can also determine what the best and the worst quality credit enterprises are according to their opinions and needs.

Step4: calculate the distance from each enterprise to PIS and NIS

$$S_i^+ = \sqrt{\sum_{j=1}^m (v_{ij} - v_j^+)^2}, i = 1, \dots, n \quad (4)$$

$$S_i^- = \sqrt{\sum_{j=1}^m (v_{ij} - v_j^-)^2}, i = 1, \dots, n$$

Where S_i^+ and S_i^- respectively represent the distance between the i_{th} enterprise and the PIS, the distance between the i_{th} enterprise and the NIS.

Step5: calculate the quality credit score

$$C_i = \frac{S_i^-}{S_i^- + S_i^+}, i = 1, \dots, n \quad (5)$$

Where C_i is called quality credit score in this study representing the degree of closeness of the i_{th} enterprise to PIS and NIS.

TOPSIS is an attractive method in quality credit scoring because it has some notable advantages. On one hand, it is easy to consider the expert advice based on TOPSIS. A cogent enterprise quality credit scoring is a comprehensive evaluation process that should consider both objectively model result and subjectively expert advice. TOPSIS can easily combine expert opinion in the following aspects. First, experts can set weights for each evaluation indicators according to their significance. Second, experts or regulators can set what an ideal high quality credit enterprise is, i.e. set the most preferred indicator values. Third, experts or regulators can set thresholds for quality credit score to attain credit rating result. For example, for an percentile score, regulators can set 80, 60 as thresholds according to their opinions, so enterprises with credit score greater than 80 are classified as grade A, enterprise with credit score greater than 60 while less than 80 are classified as grade B, enterprise with credit score lower than 60 are classified as grade C. On the other hand, some advice can be given to evaluated enterprises because it is easy to explain the quality credit scoring result of TOPSIS. The comparison of each indicator value between the evaluated enterprises and the ideal enterprise, between high score enterprises and low score enterprise does make some sense. According the comparison, low score enterprise can realize which indicators they should improve.

4. Experiment

4.1. Evaluation indicators

The quality credit evaluation system described in section two is a relatively comprehensive one. However, in this empirical section, the quality credit evaluation system is slightly adjusted according to air-conditioning industry

Table 1. Quality credit evaluation indicators of air-conditioning enterprises

Evaluation aspect	Specific Indicator	Type	Detail
Willingness	Chinese Well-Known Mark (CWKM)	numerical	How many years the enterprise trademark has become Chinese Well-Known Mark
	Rewards Amount(RA)	numerical	How many China national rewards the enterprise has attained
Capacity	Research and Development Ratio(R&D)	numerical	R&D investment/sales
	ISO9000 System Certification(ISC)	numerical	How many years the enterprise has attained ISO9000 system certification
	Sales Margins(SM)	numerical	Gross profit/ sales
	Market Share(MS)	numerical	What percentage the sales of the enterprise accounts for of the total sales of the top 10 enterprises
Performance	Customer Satisfaction(CS)	numerical	How much degree the product meets the customers' needs and expectations

characteristics and data availability. Three aspects are considered in evaluating quality credit of air-conditioning enterprises, i.e. willingness, capacity and performance. The three aspects are measured by 7 specific indicators shown in table 1. All indicators are beneficial.

4.2. Data description

In this section, TOPSIS is applied to evaluate the quality credit of air-conditioning enterprises in China market. According to customer satisfaction, 10 top enterprises consist of 8 Chinese enterprises and 2 Japanese enterprises are chosen in this study. Two Chinese enterprises are finally abandoned owing to the lack of data. The name of the remaining 8 enterprises are replaced by C1, C2, C3, C4, C5, C6 for Chinese enterprises and J1, J2 for Japanese enterprises considering data confidentiality.

According to the specific indicators in table 1, the data is shown in table 2. All indicator names in table 2 are simplified to acronyms. Among these indicators, CWKM is attained from Chinese Well-Known Mark website [16]. RA, R&D, ISC, SM are respectively attained from annual reports 2010 and official websites of related enterprises. MS and CS are attained from Chinese annual air-conditioning market report 2010.

Table 2. Quality credit data of air-conditioning enterprises

ID	Enterprise	CWKM (year)	RA	R&D (%)	ISC (year)	SM (%)	MS (%)	CS	Score	Grade
1	C1	12	8	5.44	15	22.54	29.75	75.7	88	A
2	C2	12	8	4	16	17.69	28.9	74.9	80	
3	C3	20	6	3.95	17	17.79	13.06	74.8	70	
4	J1	-	-	3.59	12	33.86	3.75	74.5	41	B
5	C4	12	5	5	17	11.67	5.8	73	36	
6	J2	-	-	6.4	18	5.82	2.42	71.1	26	
7	C5	7	1	1.15	14	19.27	6.89	66.7	10	C
8	C6	2	4	1.26	12	19.5	5.68	69.1	9	
	best	20	8	6.4	18	33.86	29.75	75.7	100	
	worst	2	1	1.15	12	5.82	2.42	66.7	0	

Notes: Six Chinese enterprises are evaluated from all 7 indicators while the two Japanese enterprises J1 and J2 are only evaluated from the last 5 indicators, i.e. $best=(6.4,18,33.86,29.75,75.7)^T$ and $worst=(1.15,12,5.82,2.42,66.7)^T$ when evaluating J1 and J2.

4.3. Evaluation steps

In this application, the quality credit of 8 air-conditioning enterprises is to be evaluated with 7 evaluation variables. The steps of quality credit scoring using TOPSIS are as follows:

Step1: normalize data by Eq.(1)

Step2: weight the normalized data by Eq.(2)

$$W = (w_1, w_2, \dots, w_7)^T = (1, 1, \dots, 1)^T$$

Weights are usually set by experts or regulators, nevertheless, in order to simplify this experiment, equal weights are set to all indicators in this experiment, thus step2 can be skipped.

Step3: determine PIS and NIS by Eq.(3)

PIS and NIS are the normalized best and worst enterprises. The non-normalized best and worst enterprises data is shown in the last two rows of table 2.

$$best = (20, 8, 6.4, 18, 33.86, 29.75, 75.7)^T$$

$$worst = (2, 1, 1.15, 12, 5.82, 2.42, 66.7)^T$$

The best enterprise presents an in-existent enterprise in the best quality credit condition, i.e. this enterprise's trademark has become Chinese Well-Known Mark in the earliest year, the enterprise attains the most national rewards, invests the most to research and development, gets ISO9000 system certification in the earliest year, acquires the highest sales margins, owns the largest market share and meets customers' needs at the greatest degree. On the contrary, the worst enterprise presents an in-existent enterprise in the worst quality credit condition.

Step4: calculate the distance from the 8 enterprise to PIS and NIS by Eq.(4)

Step5: calculate the quality credit score of the 8 enterprises by Eq.(5)

The rounded quality credit scores of every enterprise are shown in the second last column of table 2. CWKM and RA are two indicators which reflect the willingness of an enterprise to maintain credit quality, but they don't seem fair for the 2 Japanese enterprises in China market, so the evaluation of the two Japanese enterprises is only from the remaining 5 indicators.

4.4. Results analysis

According to the score, the enterprises are classified into three grades. Grade A includes three good quality credit enterprises, which are all Chinese enterprises. Grade C includes two bad enterprises, which are also Chinese enterprises. The remaining one Chinese enterprise and the two Japanese enterprises are included in the grade B. According to the Chinese air-condition market analysis annual report 2010 published by State Information Center of China, three Chinese enterprises maintain the leading advantages in Chinese market. These three famous enterprises exactly accord with the enterprises in grade A in this paper. The brands of the three enterprises are also the only three appliance brands rated as the top 50 most valuable Chinese brands 2012 [17]. Last but not the least, the top 6 enterprises in grade A and grade B are evaluated as the global TOP 31 air-conditioning enterprises 2010 [18].

Japanese appliance enterprises are famous for their high technology and high product quality in the world, so it is interesting that the 2 Japanese enterprises are rated as grade B but not A. It is generally assumed that sales growth should be considered in the evaluation of quality credit. The sales growth of the 6 Chinese enterprises is all above 30% in 2010, however, that of J1 and J2 are respectively -17.55% and -6.6%. If we consider sales growth in this experiment, J1 and J2 will be rated as grade C, which is intuitively wrong. As a matter of fact, on one hand, sales growth of air conditioner is significantly affected by the Chinese policy of home appliance subsidies for rural areas while Japanese air conditioners are not on the subsidy list. On the other hand, China is not the major market of the 2 Japanese enterprises despite the fact that they have large market share in the world. According to the China air-condition market analysis annual report 2010, the China market share of foreign enterprises in 2010 has drastically decreased to half of that in 2005, from which we can conclude that the market share of two Japanese enterprises are shrinking. Their marketing strategy is to sell less but high priced air conditioners in the competition with Chinese enterprises to make more profits [19].

So adding sales growth into indicator system is not helpful for evaluating quality credit. On the contrary, it may even confound the evaluation. Above analysis reveals that indicators are closely related to industry environment, product characteristic, national policy and so on, so the selection of proper indicators is very important in quality credit evaluation. More studies in quality credit are urgently needed in the future.

At last, from table 2 we can see that C1 gets the highest score because it outperforms all other enterprises. It performs the best in 3 of the 7 evaluation indicators and the rest indicators are also close to the best. Besides, C5 and C6 attain the lowest score with almost all of their indicators the worst, reflecting that some problems may exist the quality credit of the enterprises. C5 and C6 are supposed to invest more fund into research and development, make effort to acquire high quality certification, promote its sales margins, market share and so on, so as to improve its quality credit. Other enterprises can also be analyzed in the same way. Some other indicators such as illegal results mentioned in section two are not included in this experiment owing to lack of data. Scoring result may slightly changes when add those indicators.

5. Conclusion

Quality credit evaluation is a relatively new research spot. In this paper, firstly the definition and evaluation indicators of quality credit are discussed. Three aspects, willingness, capacity and performance, are used to reflect the quality credit of an enterprise. Then the classical MCDM methods TOPSIS is used to evaluate the quality credit of 6 Chinese and 2 Japanese enterprises in Chinese market. The evaluation result reveals that some of the Chinese

enterprises behave very well in quality credit while two Japanese enterprises are slightly inferior. At last, the experiment result analysis proves the feasibility and effectiveness of TOPSIS in credit quality evaluation. Moreover, using TOPSIS to evaluate quality credit has two notable advantages. One is that it is easy to consider experts' or regulators' opinions based on TOPSIS, the other is that the evaluation result is easy to explain which makes it convenient to make suggestions to enterprises.

Some further studies are also needed. The results analysis in this paper reveals that quality credit evaluation indicators significantly affect the soundness of evaluation results, so the selection of proper indicators is very important and needs more studies. Besides, more effective mathematical models can be applied in quality credit evaluation.

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