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Risk of Chemical Dangerous Goods Supply Chain based on Grey Relational Model

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In the liquid chemicals supply chain, due to the dangerousness and multiple chemical properties of liquid chemicals, its supply-chain finance (SCF) has certain particularity. There still exist the problems such as storage safety, warehouse financing and delivery transportation etc. over the whole supply chain. In this paper, a subjective and objective structure entropy method is used according to the entropy theory. Then, the gray relational analysis is introduced to assess the credit risk of financing enterprises facing liquid chemical supply chain finance, which enhances the integrity of the assessment. The result of research shows that the method can shorten the supply chain of liquid chemicals effectively and reduce the possibility of leakage and pollution of liquid chemicals.

1. Introduction

1.1 Finance risk background of liquid chemicals supply-chain

To realize the resource integration of industry supply chain, the perfect supply-chain finance (SCF) should be no longer limited to single enterprise, but to link the information platform, the upstream and downstream enterprises, logistics transportation enterprise and financing institutes together (Fu, 2016; Yang et al., 2015). The continuous deepening of social production methods has intensified market competition. Different from the original single customer competition, the competition mode can be applied to the entire market supply chain transformation and internal supply chain interlocking. For businesses, the capital is the blood of business operations, and companies urgently need to improve the effectiveness of supply chain operations. Supply chain finance has brought financing convenience for SMEs, and the gradual realization of resource integration can largely reduce the moral risk of SMEs in accepting credit. In a complete supply chain finance chain, it will involve enterprises in different positions, and the industries between enterprises and the technical fields that are good at each other. But in the liquid chemicals supply chain, due to the dangerousness and multiple chemical properties of liquid chemicals, its SCF has certain particularity. There still exist the problems such as storage safety, warehouse financing and delivery transportation etc (Paydarnia et al., 2014). Over the whole supply chain. Therefore, this paper makes some brief analysis of these current problems with the liquid chemical supply chain finance. The SCF hasn't well-developed until in recent several years, and it has grown rapidly over a short period, esp (Leng and Peng, 2007). In the background "internet+" development, so it has presented new development features and mode. In 2015, the market size of Chinese supply chain market was about RMB 12 trillion; it is estimated statistically that in 2020, it might reach RMB 15 trillion. The reason for our positive attitude towards the SCF development is that it can provide the new development prospects for the middle and small-sized enterprise, bank, core enterprise and logistics enterprise.

1.2 New financial channel for middle and small-sized liquid chemical enterprise

Flow of goods generally means that the primary supplier transfers the goods to manufacturer, then transferred to the dealer, and finally flown to the consumer (Lei et al., 2012). The SCF can offer more convenience for middle and small-sized enterprise financing, relatively lowering the barrier of banks (Hu and Cheng, 2010). In the trend of internet+ rapid development, the big data can help the bank offer the more accurate and rapid service to the customers (Liu and Yu, 2007). These advantages of SCF mentioned above cannot be provided in off-line bank service, so the on-line SCF has attracted more middle and small-sized enterprises. Figure 1

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depicts the relationship between the enterprises in SCF. After selling goods, the supplier earns many receivables, and the bank mainly provides accounts receivable financing for supply enterprise; the dealer purchases goods from the core business, with the advance payment, and the bank mainly offers the advance payment financing; the overstock of suppliers can make inventory financing through logistics enterprise (Li et al., 2015).

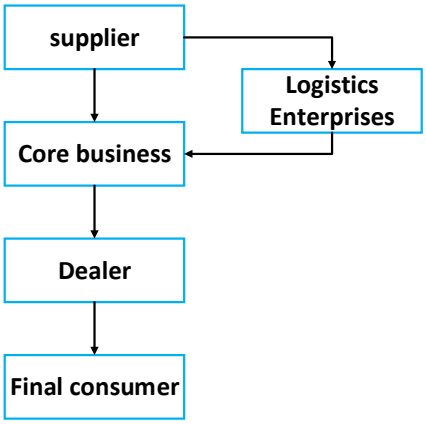

Figure 1: Supply Chain Finance in the enterprise diagram

1.3 Supply Chain financing in liquid chemical

In the operation process, the middle and small-sized liquid chemical enterprises can ensure the normal operation of their own capital chain by warehouse receipt pledge (Ahmadi et al., 2014; Zhu and Lu, 2010). Taking the Ningbo Commodity Exchange (NCE) for example, the warehouse receipt financing can be provided for the dealer. Despite the relatively higher technical requirement for liquid chemicals storage, the warehouse receipt pledge can still be made. Based on the cooperation between the NCE and the bank, the bank shall admit the registered warehouse receipt of the dealer in NCE, so as to make the receipt financing, which greatly reduces the stock and storage charge of dealer, and facilitate the capital flow. If the dealer becomes member of NCE, they can apply for bank financing through NCE.

2. Credit risk assessment based on grey correlation analysis

2.1 Weight measuring method based on grey correlation analysis

Based on Entropy Theory, the weight determination method combining the subject and objective approaches is proposed in this paper. In this method, both the Delphi expert investigation method and fuzzy analysis method are integrated to form the typical sequencing, according to entropy decision formula the entropy value calculation and void analysis are made, and then the potential deviation data is processed (Wang et al., 2009); so the final weight can be determined in the weighted average method of subjective and objective results which maintains the accountability of subjective approach as well as emphasize on the logic importance of mathematical approach. The structure entropy weight method is applied in this paper to determine the weight:

2.1.1 Expert opinions collection and ranking matrix

Firstly, members of the expert panel were selected. Each expert was issued with a feedback form of weight measurement in the index system, and sort the importance of each index according to the rules and procedures in Delphi method (Chen et al., 2014), 1-N for degree of importance. Given that N experts make ranking of importance, a11 means the importance ranking of the first index by the first expert, and the number (1-m) indicates gradually declining of importance degree from small to large; similarly, am1 is the importance ranking of the mth index by the first expert; a_{mn} is the importance ranking of the mth index by the nth expert; finally, the typical ranking matrix A is formed.

2.1.2 Correction of deviation degree

Considering each expert in different research fields (Zhong et al., 2015) with different cognition of each index, certain deviation must be generated in the collected data; to lower the deviation degree and uncertainty, the correction of deviation degree should be made for the data above. The ranking matrix in the last section has been converted, and the membership function to define the conversion is given as formula (1):

$$F(a_{mn}) = -\eta p_n(a_{mn}) \ln p_n(a_{mn}) \tag{1}$$

where

$$p_n(a_{mn}) = \frac{t - a_{mn}}{t-1} \tag{2}$$

let

$$\eta = \frac{1}{\ln(t-1)} \tag{3}$$

and then substitute the formula (4) and formula (5) into the formula

$$p_n(a_{mn}) = \frac{t - a_{mn}}{t-1} \tag{4}$$

$$\eta = \frac{1}{\ln(t-1)} \tag{5}$$

θ_{mn} is the corresponding membership function of a_{mn}; let t=m+2, when the maximum number of index is 4, t=6; θ_{mn} is the membership of expert ranking number, and B_{mn} is membership matrix.
Suppose that n experts have same discourse for the k index (k=1,2,…m), i.e. the "consensus" for the k index by n experts is taken as average cognition degree, denoted by B_k; the deviation of the kth index by the experts in terms of cognition is taken as "cognitive deviation degree", denoted by C_k. Let B_k and C_k as following:

$$\begin{aligned} B_k &= \frac{(\theta_{k1} + \theta_{k2} + \cdots + \theta_{kn})}{n}, \\ C_k &= \left| \frac{\left[\max(\theta_{k1} + \theta_{k2} + \cdots + \theta_{kn}) - B_k\right] + \left[\min(\theta_{k1} + \theta_{k2} + \cdots + \theta_{kn}) - B_k\right]}{2} \right| \end{aligned} \tag{6}$$

To define the overall cognition of the kth index by n expert R_k.

$$R_k = B_k(1 - C_k) \tag{7}$$

Then the vector R of overall cognition degree for m indexes by n experts can be shown in the matrix R.

$$R = [R_1, R_2, ..., R_m] \tag{8}$$

2.1.3 Normalization processing

To derive the weight ω_k of the k index, it is necessary to make normalization processing formula (8) for formula (9), and obviously, the derived ω_k is the weight of the k index.

$$\omega_k = \frac{R_k}{\sum_k R_k} \tag{9}$$

$$R_k = B_k(1 - C_k) \tag{10}$$

2.2 Risk assessment process

In grey theory, the grey correlation analysis (GCA) is the method to analyze the correlation or similarity between all elements of the system; its basic idea is to make ranking of the assessed target in terms of correlation degree. The GCA is to analyze the trend of things development, without any strict rule for sampling quantity or obedience to certain mathematical distribution for the samples.

2.2.1 Expert rating

Every expert makes assessment for the selected target according to the evaluation index options. Given the assessment grade 1, 2, 3, 4 and 5, the grade number means the performance of one certain index for this assessed target; the higher number indicates better performance. Given number of assessment index as m, and number of selected experts as k (suppose that the selected experts are at the same level of knowledge and experience), then one m×k rating matrix A is formulated for each assessed target on the basis of experts scores.

2.2.2 Establishment of comparison matrix

The primary condition for grey correlation analysis is the selection of one standard data array. Given the optimal assessment index set corresponding to the assessed results as follow:

$$F^* = \left[f_1^*, f_2^*, ..., f_m^* \right] \tag{11}$$

Where f_k^* is the optimal value of the k index, $k = 1, 2, ..., m$;

$$f_m^n = \frac{a_{m1} + a_{m2} + \cdots + a_{mk}}{k} \tag{12}$$

f_m^n is the average assessment value of the m index in the nth enterprise; then one new matrix was established by combining the optimal index set and comparison matrix (Table 1).

Table1: Indicator set weight analysis

Index	f1	f2	f3	f4	f5	f6	f7
Weights	0.109	0.099	0.014	0.188	0.254	0.084	0.123

2.2.3 Normative processing of index value

Generally, there are different dimensions and dimensionless in the assessment indexes, so the direct comparison cannot be made; to ensure the results reliability, these indexes above should be processed normatively. Given the variation interval of the k index as$[f_{k1}, f_{k2}]$, where f_{k1} is the minimum value of the k index among all assessed enterprises, and f_{k2} is the maximum value, then the formula (13) can be adopted to convert these index values into dimensionless quantity .

$$C_k^i = \frac{j_k^i - j_{k1}}{j_{k2} - j_k^i} \qquad C_k^i \in (0,1) \tag{13}$$

Where *i*=1,2,…,*n*; *k*=1,2,…,*m*, so the matrix D' is converted into matrix C.

$$D' = \begin{bmatrix} f_1^1 & f_2^1 & \cdots & f_m^1 \\ f_1^2 & f_2^2 & \cdots & f_m^2 \\ \cdots & \cdots & \cdots & \cdots \\ f_1^n & f_2^n & \cdots & f_m^n \end{bmatrix} \tag{14}$$

$$C = \begin{bmatrix} C_1^* & C_2^* & \cdots & C_m^* \\ C_1^1 & C_2^1 & \cdots & C_1^1 \\ \cdots & \cdots & \cdots & \cdots \\ C_1^n & C_2^n & \cdots & C_m^n \end{bmatrix} \tag{15}$$

2.2.4 Calculation of comprehensive assessment results

In grey system theory, (16) is the standard sequence of numbers, and (17) is the optimal contrastive sequence.

$$C^* = \left[C_1^*, C_2^*, ..., C_m^* \right] \tag{16}$$

$$C = \left[C_1^i, C_2^i, ..., C_m^i \right] \tag{17}$$

The correlation coefficient $\varepsilon_i(k)$ of the kth index and the kth optimal index of the ith enterprise by the GCA method is given as:

$$\varepsilon_i(k) = \frac{\min \left| C_k^* - C_k^i \right| + \rho \max \left| C_k^* - C_k^i \right|}{\left| C_k^* - C_k^i \right| + \rho \max \left| C_k^* - C_k^i \right|} \tag{18}$$

Where ρ is resolution ratio, taking 0.5 generally, and $\rho \in (0,1)$. In the correlation calculation method, the correlation matrix E is given as:

$$E = \begin{bmatrix} \varepsilon_1(1) & \varepsilon_1(2) & \cdots & \varepsilon_1(m) \\ \varepsilon_2(1) & \varepsilon_2(2) & \cdots & \varepsilon_2(m) \\ \cdots & \cdots & \cdots & \cdots \\ \varepsilon_n(1) & \varepsilon_n(2) & \cdots & \varepsilon_n(m) \end{bmatrix} \tag{19}$$

where $R = [r_1, r_2, \ldots, r_n]^T$ is the vector of synthetic judgment results of n assessed enterprises, and $W = [w_1, w_2, \ldots, w_m]^T$ is the weight allocation vector of m assessment indexes.
Thus, the comprehensive evaluation result is as following:

$$R = E \times W \tag{20}$$

Table2: Performance analysis

Supplier name	Correlation	Ranking
Haier	0.963	1
Hisense Electric	0.675	4
Tsingtao	0.864	3
Double star	0.902	2
Aucma	0.405	5

Table 2 lists the performance analysis results: with higher correlation r_i, it means that C_i is closest to the optimal index C^*_i, i.e. the ith enterprise is superior to other enterprises. Hereby, on one hand, the correlation ranking adaptive to the receivables, advance money or stock pledge of financing enterprises in the supply chain financing mode can be made, i.e. the more the correlation degree is, the less the credit risk of financing enterprise will be; on the other hand, it reflects the correlation of receivables, advance money or stock pledge for one certain financing enterprise, which can be one of the assessment indexes in the commercial bank, providing guidance of supply chain finance mode adaptability for the financing enterprises.

3. Conclusions

The liquid chemical industry originally expands in line with the growth of investment in fixed assets, but such an approach to development is hard to sustain in an era of rapid informationization. However, liquid chemicals naturally have the genes of supply chain finance, and the space for market development is huge. The integration of "information + logistics + capital" has become the standard model of modern supply chain finance. The traditional liquid chemical trading process is complicated and the upstream of production is highly concentrated. However, most midstream and downstream enterprises in the industry are SMEs, and they are in a weak position with strong financing needs. We should actively accelerate the development of the liquid chemical supply chain finance, integrate the abundant upstream and downstream resources, establish a complete warehousing and logistics system in the country, improve bank credit and other services, and create a complete ecosystem of liquid chemicals supply chain. Supply chain credit risk assessment is a very complex systematic project, and the existing decision-making model often cannot take into account the subjective and

objective at the same time. In this paper, for such problems, a subjective and objective structure entropy method is used according to the entropy theory. Then, the gray relational analysis is introduced to assess the credit risk of financing enterprises facing liquid chemical supply chain finance, which enhances the integrity of the assessment.

References

Ahmadi M.A., Ahmadi M.R., Hosseini S.M., Ebadi M., 2014, Connectionist model predicts the porosity and permeability of petroleum reservoirs by means of petro-physical logs: application of artificial intelligence, Journal of Petroleum Science & Engineering, 123, 183-200.

Chen J., Wang C., Wu X., 2014, Evaluation method of steering column switches operating performance based on the gray correlation degree, Advanced Research and Technology in Industry Applications (WARTIA), 2014 IEEE Workshop on, 2014(23), 853-856, DOI: 10.1109/WARTIA.2014.6976407

Fu Y., 2016, Coupling Degree between Industrial Clusters and Supply Chains based on the Gray Correlation Model, Revista de la Facultad de Ingeniería, 31(8), 14-26, DOI: 10.21311/002.31.8.25

Hu F., Cheng L.S., 2010, Based on gray correlation analysis of the government investment in public works project performance evaluation model, Fuzzy Systems and Knowledge Discovery (FSKD), 2010 Seventh International Conference on, 3, 1217-1223, DOI: 10.1109/FSKD.2010.5569137

Lei J.S., Bao L., Wen L., 2012, Application of Improved Gray Correlation Analysis Model to the Estimation of Country Rock Stability, Advanced Materials Research, Trans Tech Publications, 594(3), 28-32, DOI: 10.4028/www.scientific.net/AMR.594-597.28

Leng Z.H., Peng S., 2007, The Application of Improved Gray Correlative Analysis in Evaluating of Financial Risks of Enterprise, Management Science and Engineering, ICMSE 2007, International Conference on, IEEE, 28(5), 1900-1904, DOI: 10.1109/ICMSE.2007.4422117

Li J., Li X., Lv N., Yang Y., Xi B., Li M., 2015, Quantitative assessment of groundwater pollution intensity on typical contaminated sites in china using grey relational analysis and numerical simulation, Environmental Earth Sciences, 74(5), 3955-3968.

Liu G., Yu J., 2007, Gray correlation analysis and prediction models of living refuse generation in Shanghai city, Waste Management, 27(3), 345-351, DOI: 10.1016/j.wasman.2006.03.010

Paydarnia H., Hajiaghasi S., Abbaszadeh K., 2014, Improved structure of pnn using pca in transformer fault diagnostic, Arabian Journal for Science & Engineering, 39(6), 4845-4851.

Wang J., Xue H., Tao Y., 2009, Study on the Gray Correlation Degree of Economy-Environment-Society System Based on Entropy Weighted, Computer Network and Multimedia Technology, International Symposium on, 9(6), 1-4, DOI: 10.1109/CNMT.2009.5374651

Yang Z., Liu L., Li X., 2015, Application of the gray correlation model in fault diagnosis of high voltage circuit breakers, Power System Technology, 39(6), 1731-1735, DOI: 10.13335/j.1000-3673.pst.2015.06.042

Zhong L., Wen L., Ning L., 2015, The uncertainty entropy of low-rate speech quality evaluation and the analyses of the gray correlation, IEICE Electronics Express, 12(3), 20141019-20141019, DOI: 10.1587/elex.12.20141019

Zhu X., Lu X., 2010, Research on Technological Innovative Evaluation of Regional Enterprises Based on Entropy and Gray Correlation, Management and Service Science (MASS), 2010 International Conference on, 65(3), 1-4, DOI: 10.1109/ICMSS.2010.557703