

Evaluation on Risks of Manufacturing Enterprise Supply Chain based on BP Neural Networks

Yimiao Lv^{1,2,*}, Haibin Peng¹, Wenhao Li²

¹ Graduate University of Mongolia, Ulan Bator, 140201, Mongolia

² Guangzhou College of Technology and Business, Guangzhou, 528138, China

*Corresponding author: mml67899030@gmail.com

Abstract: In order to improve the evaluation and management of manufacturing enterprise supply chain risk and enhance the resilience of supply chain, this study evaluates enterprise supply chain risk from the perspective of sustainable development. Firstly, the risk factors that may exist in the supply chain are identified, and the supply chain risk evaluation index system is proposed. Then the risk evaluation model based on BP neural network is established, and the neural network model is trained, tested and evaluated by using the survey data. The survey and test results show that the overall risk of the enterprising is at a low level, and the risks of each link are different, among which, the financial risk, logistics risk and cooperation risk are at a high level, and the other risk factors are at a low level. The risk factors contributing the most to the enterprise supply chain risk were extracted. This paper theoretically enriches the supply chain risk evaluation methods, and puts forward feasible suggestions for enterprises to prevent supply chain risks and optimize and stabilize supply chain.

Keywords: Supply chain, BP neural network, Risk assessment.

1. Introduction

Affected by the new crown pneumonia epidemic, the world economy has been in deep recession and slow growth since 2020. U.S. GDP in 2020 fell 3.5%. Due to inflation, personal consumption recovery difficulties, the weak labor market, and other factors, the U.S. market economy in the short term is difficult to recover. In the European Union, the recurrence of the epidemic, the differences in fiscal policy, and the recovery fund make it difficult to start the disruption of the European Union's 2021 economy. Germany, Japan, Italy, Canada, and other countries are also facing enterprise investment willingness that is not strong, low consumption, and other difficulties, resulting in the global supply chain risk continuing to increase. In order to survive, enterprises must be able to adapt to the development trend of society, reasonably consider the risks in the economy, society, policy, and environment, and make business decisions. They must be able to quickly and effectively identify and assess the risks faced in the process of business management and formulate reasonable coping strategies and programs.

Supply chain risk management research began in the 1990s, and different scholars and experts each conducted a large number of valuable studies from different perspectives. Giannakis proposed that only when risks are effectively managed can a company develop [1]. Neiger believed that value engineering methods can be applied to assess supply chain risks from the perspective of the supply chain as a whole [2]. Chapman proposed a brainstorming method and a questionnaire survey method to identify risks in the construction engineering industry [3]. Humphrey, Fattahi, et al. Proposed a new method of SWOT analysis and risk identification based on hybrid multi-MOORA and AHP algorithms [4][5]. Reza et al. used the fuzzy TOPSIS method to evaluate suppliers from the perspectives of production, supply, demand, information, logistics, and environment [6], and Li Honghe et al. reduced procurement risk by defining the scope of project procurement [7].

The supply chain of manufacturing enterprises forms an organic network structure including procurement, storage, transportation, production, distribution, and other links due to the connection of raw material suppliers, manufacturers, distributors, retailers, and end customers, with a large number of node enterprises, coupled with the fact that outsourcing and globalization in recent years have increased the supply chain complexity dramatically, and it is highly susceptible to the effects of various types of endogenous and exogenous risks, which may lead to the disruption of production and operation. In this context, this paper adopts the theories of operations research, economics, and other mathematical methods to study the enterprise supply chain with the manufacturer as the core, how to identify the main supply chain risk factors, evaluate and analyze the various types of factors, and formulate the corresponding risk response strategy.

Some scholars believe that supply chain risk refers to the possible accidents and losses caused in the supply chain [8], while other scholars believe that supply chain risk refers to the various factors affecting the final goal of the supply chain, including risk factors, risky accidents, and outcomes [9]. However, for the manufacturing enterprise supply chain, because there are multiple node enterprises dispersed all over the world to form an organic supply chain network with dynamics and integration, the supply chain risk rises with the increase in the complexity of supply and demand, and the changes in the external environment, policy, economy, and society also exacerbate the supply chain risk. At this stage, most scholars have not done in-depth and targeted research on the supply chain of manufacturing enterprises, so supply chain risk management centered on manufacturing enterprises does not have a direct theoretical basis for risk management and practical guidance. According to various research results, the characteristics of supply chain risk for manufacturing enterprises can be summarized as follows:

(1) Objectivity: Whether it is caused by earthquakes, tsunamis, nuclear leaks, infectious diseases, or other man-

made causes of supply chain risk, is objective and does not transfer or disappear with the will of man [10].

(2) Episodic: Supply chain risk occurs at a time, place, and scope that is not fixed but is difficult to predict and accurately estimate. We cannot accurately grasp the occurrence of various types of risk; it can only be based on various types of information to improve the accuracy of prediction.

(3) Diversity: Supply chain risk is divided into endogenous risk, exogenous risk, management risk, operational risk, individual enterprise risk, overall risk, etc. Different risks affect each other and exist at the same time.

(4) Transmissibility: The risk of upstream enterprises can be passed along the supply chain to downstream enterprises and vice versa, and risk amplification or attenuation may also occur in the process of transmission.

2. Manufacturing Enterprise Supply Chain Risk Management System Construction

2.1. Risk identification program

(1) Risk screening: Due to the manufacturing enterprise supply chain links, which are numerous and face all kinds of internal risks, including production, procurement, transportation, warehousing, distribution, sales, etc., as well as external risks such as economic, political, environmental, social, etc., the enterprise needs to initially classify and recognize all kinds of risks and carry out the initial screening of risks.

(2) Risk monitoring: After the occurrence of risk, enterprise risk management personnel need to collect data—time, location, scope, degree of impact of risk occurrence records, analysis—to help managers better understand and deal with supply chain risk.

(3) Risk diagnosis: Managers need to judge and test the

reasons for the risk, the nature of the risk, the consequences, etc., to form a more comprehensive understanding of the supply chain risk.

2.2. Risk evaluation index system construction principles

(1) The principle of comprehensive and systematic, the evaluation indicators should be able to cover the risks in the supply chain, including both endogenous and external risks, especially those related to core enterprises and core businesses.

(2) The principle of concise and scientific, the indicators should have specific and clear meanings, reflect comparability, and also require concise and scientific features to facilitate evaluation.

(3) The principle of dynamic flexibility: because the environment faced by enterprises is not static and the supply chain risk will be different with environmental changes, the selected indicators should be able to be flexibly and dynamically adjusted according to the actual situation.

(4) The principle of combining qualitative and quantitative: in order to make a true and objective evaluation of all kinds of supply chain risks, it is necessary to consider combining some unquantifiable qualitative indicators with quantitative indicators so as to play a better evaluation-oriented role.

2.3. Analysis and description of indicators

Enterprise supply chain risk can be divided into two categories: endogenous risk and exogenous risk. Endogenous risks mainly include information communication risks, trust risks between enterprises, financial risks, and risks related to logistics; exogenous risks mainly refer to natural disaster risks, political risks, legal risks, technological risks, public health risks, economic cycle risks, etc. in the environment of the supply chain.

Table 1. Supply chain risk evaluation indicators

	Primary Indicator	Secondary Indicator	Attribute
Supply Chain Risk Indicators Evaluation System	Information Communication Risk S1	Communication effectiveness S11	Qualitative
		Information accuracy S12	Qualitative
		Smoothness of information channels S13	Qualitative
	Trust risk S2	Contract completeness S21	Qualitative
		Integrity mechanism soundness S22	Qualitative
		Supplier credibility S23	Qualitative
	Financial Risk S3	Total Asset Turnover Rate S31	Quantitative
		Return on total assets S32	Quantitative
		Total asset liability ratio S33	Quantitative
		Liquidity S34	Quantitative
	Logistics Risk S4	Delivery Risk S41	Quantitative
		Transportation risk S42	Quantitative
		Inventory risk S43	Quantitative
		Purchasing risk S44	Quantitative
		Distribution risk S45	Quantitative
External Environment Risk S5	Natural disaster risk S51	Qualitative	
	Political Risk S52	Qualitative	
	Legal Risk S53	Qualitative	
	Economic Risk S54	Qualitative	
	Technology risk S55	Qualitative	

3. Risk Assessment Model Based on BP Neural Network

3.1. BP neural network model construction and algorithm design

A BP neural network is a kind of back-propagation model whose structure includes an input layer, a hidden layer, and an output layer. Each layer is connected to the other, but the units

in the same layer are not connected to each other. Studies have shown that an increase in the number of hidden layers can enhance the ability of BP neural networks to solve nonlinear problems, but it will lead to a longer training time, and the experimental results are not easy to observe. In order to facilitate the observation of the results, this study proposes to use a three-layer network structure, and the topology of the neural network is schematized as follows:

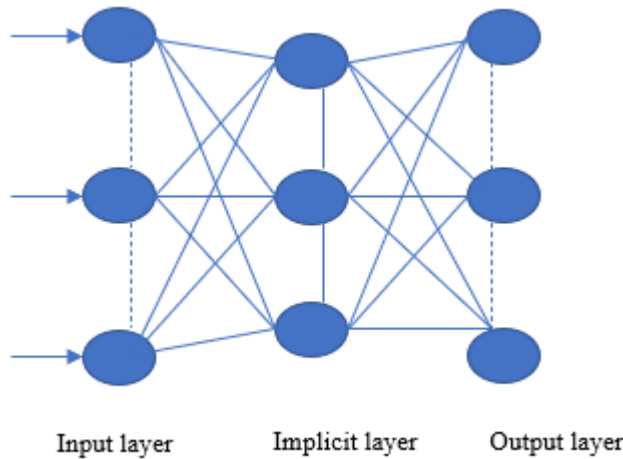


Figure 1. BP neural network topology

The number of input layer nodes refers to the number of factors that directly affect the evaluation results, and according to the number in the indicator system, the number of input nodes is determined to be 20.

The number of implied layer nodes is determined using the empirical formula $m = \sqrt{n + l} + a$, where n is the number of nodes in the input layer, l is the number of nodes in the output layer, and a is an integer between [10]. A smaller number of

nodes can be taken first for training and testing, and then increased to select the optimal number of implied layer nodes in turn, and the optimal number is 10.

The results of risk factor evaluation are used as the output layer, and the output node is determined to be 1.

In this study, the risk is scored from the two dimensions of the probability of occurrence of the risk and the loss caused, and the risk is classified according to the value of the risk. The evaluation criteria are as follows:

Table 2. Supply chain risk evaluation table

	Extremely low risk	Low risk	Medium risk	High risk	Extremely High risk
probability of occurrence (0-1)	0-0.19	0.2-0.39	0.4-0.59	0.6-0.79	0.8-1
Degree of damage (0-100)	0-5	6-25	26-45	46-75	76-100
Risk value (0-100)	0-0.95	0.96-9.75	9.76-26.55	26.56-59.25	59.26-100

Subsequently, the input data are initialized because the supply chain risk evaluation indicators are divided into 2 categories: qualitative and quantitative. Qualitative indicators are obtained through the expert scoring method to obtain the average of the indicator scores, and quantitative indicators need to be normalized by the formula $y = \frac{b - \min b}{\max b - \min b}$ normalization process. Where y is the standard value after normalization, b is the actual value of the indicator, \max indicates the upper limit of the value, and \min indicates the lower limit of the value.

The BP neural network learning process includes two steps of forward propagation and error-backward propagation, which can freely set the accuracy, approximate the continuous function, and better reflect the nonlinear function relationship between the input object and the output object. The main feature of its algorithm is that after the signal is input to the network, the neuron passes the processed signal to the intermediate layer, which completes the transformation, and

then passes the signal to the output layer to complete the learning and training process once. If the actual output does not match the expected value, the back propagation stage is initiated. The error is transmitted backward through the output layer, to the hidden layer, and to the input layer by layer, and the thresholds of each layer are corrected so that the correct rate is continuously improved.

3.2. Sample data

The model obtains a total of 15 sets of data from literatures 11 and 12, with the first 12 sets of data as the training set samples of the neural network and the last 3 sets of data as the test samples. The trend of predicted risk and actual risk is basically consistent; only a few points of the predicted value and the real value of the deviation are large, which may be caused by a few suppliers understanding of the overall supply chain operation of the deviation.

3.3. Network training and validation

The first 12 sets of data are input into the BP network for

training, and the parameters are set as follows:

Table 3. BP neural network parameter settings

	Maximum number of iterations	Minimum error value	Learning factor
Numerical value	1000	0.0001	0.1

The training results are as follows (The red line is the actual value and the blue line represents the BP predicted value.):

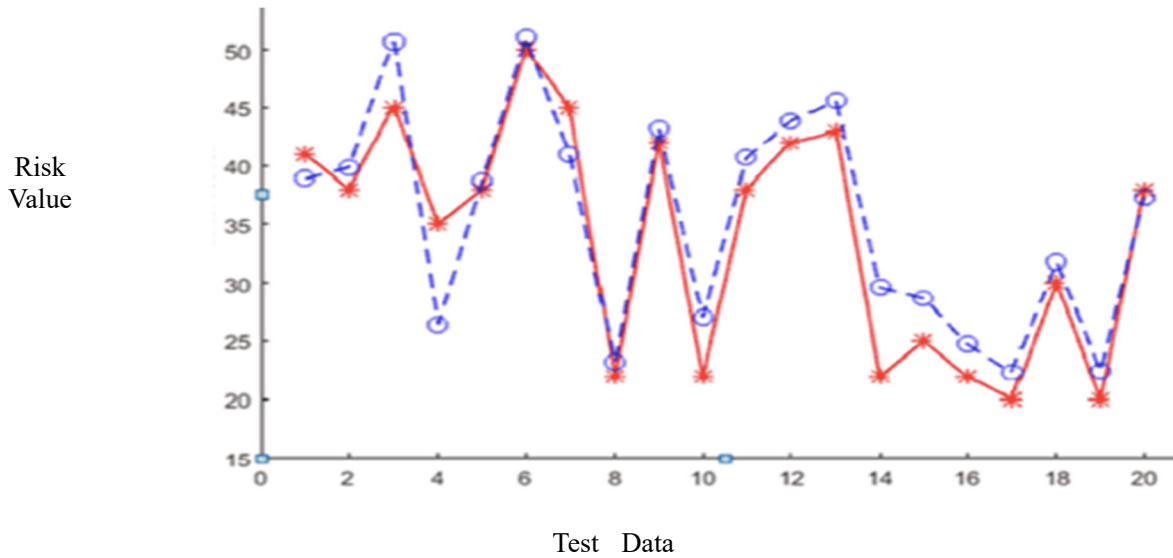


Figure 2. Training results

3.4. Analysis of results

The mean absolute error MAE, mean squared error MSE, mean squared error RMSE, and coefficient of determination R2 were used to verify the network error and validity.

$$MAE = \frac{1}{m} \sum_{i=1}^m |y_i - \hat{y}_i|$$

$$MSE = \frac{1}{m} \sum_{i=1}^m (y_i - \hat{y}_i)^2$$

$$RMSE = \sqrt{\frac{1}{m} \sum_{i=1}^m (y_i - \hat{y}_i)^2}$$

$$R2 = 1 - \frac{\sum_{i=1}^m (y_i - \bar{y})^2}{\sum_{i=1}^m (y_i - \hat{y}_i)^2}$$

Where y_i is the actual output value, \hat{y}_i is the predicted output value, and \bar{y} is the average value, the smaller the MAE, MSE, and RMSE, and the closer the R2 is to 1, the better the performance of the model.

Table 4. BP neural network prediction error

MAE	MSE	RMSE	R2
3.006	15.845	3.98	0.845

The error between the output of the test sample and the target value is within the permissible range, and the model can be used to evaluate the supply chain risk. The trained network has accumulated experience in predicting the risk value of the evaluation indicators and can predict the comprehensive score of supply chain risk. It only needs to rank the score situation, compare the evaluation criteria, screen out different levels of risk according to the needs of the enterprise, and select one or more risks to focus on control.

Table 5. Evaluation results of first-level risk indicators

Risk Evaluation Indicators	Predicted value	Risk Level
Information Communication Risk	18.25	Medium
Trust risk	26.756	High
Financial Risk	38.852	High
Logistics Risk	59.28	High
External Environment Risk	9.86	Low

4. Conclusion

The supply chain of manufacturing enterprises has a complex network structure that is susceptible to different types of risks, causing operational disruption and bringing great losses to the enterprise supply chain. In this paper, by classifying and identifying the supply chain risk indicators, constructing the risk evaluation index system, and then using BP neural network to predict and evaluate different types of risks, and predicting the overall risk value of the supply chain risk indicators, this paper can help enterprises to grasp the degree of impact of different risks, better formulate the risk management and control decisions, and reduce or avoid major losses.

Acknowledgment

This paper was supported by Guangzhou Philosophy and Social Science 14th Five-Year Plan Project: "Research on industrial upgrading of high-end equipment manufacturing industry in Guangzhou based on dual value chain perspective", NO:2022 GZGJ79 and and Foshan Social Science Planning Project in 2023: Research on the Influence

Mechanism and Path Optimization of Breakthrough Technological Innovation in Foshan Robotics Industry from the Perspective of International Competitiveness, NO:2023-QN11.

References

- [1] Giannakis M, Louis M. A multi-agent based framework for supply chain risk management[J]. *Journal of Purchasing & Supply Management*, 2011, 17: 23-31.
- [2] Neiger D, Rotaru K. Supply Chain risk identification with Value-focused Process engineerin [J]. *Journal of Operations Management*, 2009, 27: 154–168.
- [3] Chapman R J. The controlling influences on effective risk identification and assessment for construction design management [J]. *International Journal of Project Management*, 2001 (3): 147- 160.
- [4] Humphrey A.SWOT analysis for management consulting [J]. *SRI Alumn Newsletter*, 2005,1:7-8.
- [5] Fattahi R, Khalilzadeh M. Risk evaluation using a novel hybrid method based on FMEA, extended MULTI-MOORA,and AHP methods under fuzzy environment [J]. *Safety science*, 2018, 102:290-300.
- [6] Reza Kiani Mavia, Mark Gohb,Neda Kiani Mavi. Supplier selection with Shannon entropy and fuzzy TOPSIS in the context of supply chain risk management[J]. *Procedia-Social and Behavioral Sciences*, 2016, 235: 216 -225.
- [7] Li Honghe, Zhang Jianguo, Research on Management Mode of Partial Scattered Procurement in Construction Projects[J]. *Construction Economy*,2015(12):29-32.
- [8] Mohammed C. Iqbal, Shalij P.R. Supply Chain Risk Assessment in the Ornamental Fish Supply Chain[J]. *International Journal of System Dynamics Applications*, 2019, 8, 36-50.
- [9] Sirish Kumar Guoda, Haritha Saranga. Sustainable supply chains for supply chain sustainability: impact of sustainability efforts on supply chain risk [J]. *International Journal of Production Research*, 2018,56:5830-5835.
- [10] Li Hui,Supply Chain Risk Management in Manufacturing Enterprises[D].Lanzhou University of Technology, 2011.
- [11] Meiyuan Hou,Research on Supply Chain Risk Evaluation Method Based on BP Neural Network[D]. Liaoning Normal University, 2013.
- [12] Liu Hongsheng, Lu Huiqing. Research on lean supply chain collaboration risk evaluation of manufacturing enterprises based on BP neural network[J].*Logistics Technology*, 2011:103-106.