Research on the Risk Contagion Path and Prevention of Supply Chain Finance Based on DEMATEL-ISM Model

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Abstract. The financing risk of enterprises in the supply chain is easily transmitted in the supply chain system, leading to the overall supply chain in financial difficulties. Therefore, it is necessary to analyze the links and transmission paths of risk generation and control them in time. In this paper, 15 factors are extracted from three perspectives: supply chain environment, financing enterprise and core enterprise, and a risk assessment system for supply chain finance is established. Based on this, the coupling method of Decision-making Trial and Evaluation Laboratory-Interpretative Structural Modelling (DEMATEL-ISM) is used to investigate the influence relationship among the factors and the multi-level recursive structural analysis of supply chain risk transmission paths. The results show that the DEMATEL-ISM model can visualize the interactions among three levels of supply chain financial risks: supply chain environment, financing firms, and core firms, and identify five key influencing factors such as innovation capability of core firms in the process of financial risk generation and transmission. This paper investigates the factors affecting the generation of financial risks in the supply chain and the risk transmission paths, and provides guidance for effective control and prevention of supply chain financial risks.

Keywords: DEMATEL-ISM; Financial Risk; Supply Chain; Risk Contagion.

1. Introduction

Supply chain finance takes the product chain as the main body, and integrates the capital structure of enterprises and reduces operating costs by a model in which large enterprises or financial institutions control transactions and provide financing services to small and medium-sized enterprises in the supply chain [1]. Enterprises in the supply chain are interdependent, and the financial risk caused by one enterprise is easily transmitted through the supply chain network. Therefore, the study of financial risk transmission paths in supply chains helps to control the risks in a timely manner. In recent years, more and more studies have been conducted to analyze the risks of different financial systems, and the exploration of risks for supply chain systems can help the sustainable development of supply chain financial systems.

On the research dimension of supply chain financial risk transmission: Liu et al. [2] developed a variational disequilibrium model, which combines the equilibrium analysis of supply chain network with the financial situation of enterprises. The model can reflect the financial relationships between firms in the supply chain network and determine the impact of financial risk on the value of firms in the supply chain. zhao et al. [3] et al. established a supply chain financial network based on a scale-free network model and simulated the credit risk diffusion process in the financial network using a contagion model. The method plays an important role in the study of risk propagation paths in supply chain financial networks by simulating the contagion process of credit risk in supply chain financial networks. du et al. [4] compensated for the existing research on credit risk formation mechanism of SMEs in supply chain finance by using game model and enterprise return function, and the risk probability of decision interaction and corresponding behavior of enterprises and financial institutions in supply chain were analyzed. In the dimension of supply chain finance risk assessment, Wang et al. [5] constructed a new supply chain finance risk assessment system to measure the credit risk of financing from SMEs in the supply chain based on the improved hesitant fuzzy language PROMETHEE method. The method effectively controls the risk of financial institutions providing financing services to SMEs. liu et al. [6] established a risk monitoring model combining hierarchical

analysis and fuzzy comprehensive evaluation to quantitatively measure supply chain finance risk based on the inherent requirements of supply chain finance risk control. The method is used for risk prevention and control in the supply chain finance business of enterprises.

Existing studies provide enough experience and support for the analysis of supply chain financial risks, but they do not discuss in depth the different sources and formation mechanisms of financial risks in the overall link of the supply chain, and do not study the strength of the influence of multiple risk factors in the supply chain network and the interaction between them. In this paper, based on three dimensions of thinking, we construct a system about financial risk contagion from the constituent links of the supply chain, and then establish the factors affecting the financial risk of the supply chain, and then use the integrated Decision-making Trial and Evaluation Laboratory-Interpretative Structural Modelling (DEMATEL-ISM) method to calculate the importance of the impact of indicators on financial risk and derive a systemic hierarchy diagram of the financial risk of the supply chain, revealing the hierarchy of factors affecting the risk The systemic hierarchy of supply chain financial risks is calculated and the systemic hierarchy diagram of supply chain financial risks is derived. This paper contributes to the study of the role relationship between risk influencing factors in the supply chain financial system and further explores the operational path of financial risk transmission influenced by multiple factors in the existing supply chain.

2. Construction of the Index System of Supply Chain Finance Risk Impact Factors

2.1. Supply Chain Environment

As a new way of enterprise financing, supply chain financial service closely connects the core enterprises and the upstream and downstream enterprises through the supply chain. And the supply chain environment is the overall assessment of the whole financial service risk environment. The supply chain environment is influenced by three dimensions: the inter-enterprise influence relationship, the general economic environment and the prospect development of the industry. The inter-firm influence relationship determines the process and intensity of risk contagion in the supply chain link. In the overall supply chain, if one enterprise has financial risks that lead to bankruptcy, it will affect the financial situation of the overall upstream and downstream cluster enterprises. Dense business relationships are prone to risk contagion, making business clusters vulnerable to simultaneous financial distress. Meanwhile, the downward situation of the overall economic environment will have a direct impact on the business conditions of enterprises and the financial decisions of financial institutions. The downward economic environment tends to cause a decline in the overall supply chain's financial adjustment ability and prevents timely control of financial risks. The development condition of the industry reflects the development prospect and profitability of the supply chain link enterprises. A sluggish industry development prospect will reduce the ability to cope with financial risks. In summary, in this paper, indicators are selected for the supply chain environment: unstable macroeconomic environment (S_1), low industrial development prospect (S_2), low information interoperability between enterprises (S_3), dense distribution of enterprises (S_4), and strong dependence of upstream and downstream enterprises on core enterprises (S_5).

2.2. Financing Enterprise

As the direct financing object of supply chain financial services, the financial risk of financing enterprises is the main source of overall supply chain financial risk. The risk of financing enterprises is directly influenced by three dimensions: financial status, security awareness and customer credit. The financial status of the financing enterprise determines its ability to cope with financial risks. The low-quality asset structure and profitability of a financing enterprise cannot meet the challenges posed by financial risks. At the same time, the sense of belonging of a company's employees is a guarantee of the company's growth potential prospects. If employee safety is not guaranteed, then employees

will lack a sense of belonging to the company and will reduce the overall business development efficiency. Finally, a lower level of customer credit represents a high risk of default, which directly causes financial distress for the enterprise. To sum up, in this paper, in terms of financing enterprises, indicators are selected: inadequate safety and security mechanisms for employees of financing enterprises (S_6), deformed capital structure of financing enterprises (S_7), lack of solvency of financing enterprises (S_8), poor credit status of customers of financing enterprises (S_9), and low timeliness and accuracy of delivery of financing enterprises (S_{10}).

2.3. Core Enterprise

Core enterprises are the guarantee of financing services provided by financial institutions to SMEs. The operating condition of core enterprises determines the financial institutions' assessment of enterprise financing risks. And the operating condition of core enterprises is directly influenced by three dimensions: competitive ability, environmental awareness and staff level. The competitive ability of core enterprises directly determines their performance in the market. Innovative enterprises have a stronger competitive advantage, can occupy more market share and have better development prospects. Competitive firms are better able to cope with financial risks. At the same time, the production of enterprises may cause pollution to the environment. Companies with a good sense of environmental protection have a stronger sense of social responsibility, which is conducive to the improvement of corporate goodwill. Finally, the level of employees in the core enterprise determines the business ability of the enterprise, and a high level of employees is conducive to the improvement of the enterprise's profitability. To sum up, in this paper, in terms of core enterprises, indicators are selected: low education level of employees in core enterprises (S_{11}), weak innovation ability of core enterprises (S_{12}), weak inventory management ability (S_{13}), fierce competition in the industry where core enterprises are located (S_{14}), and weak awareness of environmental protection in enterprises (S_{15}).

Combined with the previous 2.1~2.3, this paper constructs the table 1 to assess the risk contagion factors of supply chain finance.

Table 1. Assessment of risk contagion factors of supply chain finance

First-level Index	Second-level Index	Reference
Supply Chain Environment	unstable macroeconomic environment（S_1）	[7], [8]
	low industrial development prospect（S_2）	[7]
	low information interoperability between enterprises（S_3）	[9], [10]
	dense distribution of enterprises（S_4）	[7]
	strong dependence of upstream and downstream enterprises on core enterprises（S_5）	[9]
Financing Enterprise	inadequate safety and security mechanisms for employees of financing enterprises（S_6）	[8], [11], [12]
	deformed capital structure of financing enterprises（S_7）	[8], [13]
	lack of solvency of financing enterprises（S_8）	[14], [15]
	poor credit status of customers of financing enterprises（S_9）	[8]
	low timeliness and accuracy of delivery of financing enterprises（S_{10}）	[15], [8]
Core Enterprise	low education level of employees in core enterprises （S_{11}）	[8], [13], [11]
	weak innovation ability of core enterprises（S_{12}）	[14]
	weak inventory management ability（S_{13}）	[14], [15]
	fierce competition in the industry where core enterprises are located（S_{14}）	[7]
	Weak awareness of environmental protection in enterprises（S_{15}）	[8], [11], [12]

3. Dematel method

Decision-making Trial and Evaluation Laboratory (DEMATEL) is a method for solving system problems using graph theory and matrix tools. This paper based on expert experience, the elements of the study are established and the logical relationships between the elements are expressed quantitatively in the form of a matrix [16]. The influence relations between the elements and indicators such as centrality and causality are calculated. The specific steps are as follows.

Step1. Identify and quantify the logical relationships between the indicators and establish a direct impact matrix.The system is analyzed to determine the *n* elements that have an influence on the system, because the influence relationship between the elements in the system cannot be expressed quantitatively and is usually expressed qualitatively. In this paper, the influence relationships among the elements are expressed on a five-level scale from 0 to 4 (0 indicates no influence, 1 indicates weak influence, 2 indicates moderate influence, 3 indicates strong influence, and 4 indicates very strong influence). A comprehensive literature review and relevant expert experience are scored to indicate the influence relationships among the factors, and an initialized direct influence matrix of $n \times n$ is obtained.

Step2. The normalization directly affects the matrix calculation.Normalization process: the factors in the direct influence matrix *X* are divided by the maximum value of the sum of the influence factors of each row to obtain the normalized direct influence matrix. As shown in equation (1).

$$G = \frac{X}{max\sum_{j=1}^{n} x_{ij}} \tag{1}$$

Step3. Determine the comprehensive impact matrix. The normalized direct influence matrix is self-multiplied *n* times until the matrix value tends to zero (self-multiplication indicates the increased indirect influence between elements) The previous *n+1* matrices are summed to obtain the combined influence matrix, and the equations are given in (2)(3).

$$T = (G + G^2 + G^3 + ... + G^k) \tag{2}$$

$$T = G + (1 - G)^{-1} \tag{3}$$

Step4. Calculate the influence degree. influenced degree, cause degree and centrality degree.The influence degree refers to the sum of the values of each row in *T*, which indicates the combined influence value of each corresponding factor on all other factors, and the set is denoted as *D*, as shown in equation (4). The influenced degree refers to the sum of the values of each column of *T*, which indicates the combined influence value of each corresponding factor on all other factors, i.e., the influenced degree, and the set is denoted as *C*, as shown in equation (5).

$$D_i = \sum_{j=1}^{n} t_{ij} \tag{4}$$

$$C_i = \sum_{j=1}^{n} t_{ji} \tag{5}$$

The centrality of element *i (i=1,2, 3, n)* is the sum of the influence degree and the influenced degree of the element, and the centrality of the element is M_i. The centrality indicates the importance of the factor in the system. The cause degree is the subtraction of the influence degree and the influenced degree of element *i* to obtain the cause degree of the element, which is denoted as R_i. If the cause degree is greater than 0, it means that the factor has a great influence on other factors and is called the cause factor; on the contrary, it is called the result factor and is influenced by other factors.

$$M_i = D_i + C_i \tag{6}$$

$$R_i = D_i - C_i \tag{7}$$

4. ISM method

Interpretative Structural Modelling (ISM) is a method that enables the orderly arrangement of the influencing elements in a system by transforming the relationships between them, establishing a multi-level hierarchical model of the system structure, understanding the hierarchical relationships between the elements in a complex system through qualitative analysis, and clarifying the position of each influencing factor [17]. Finally, the system structure and internal element relationships are reflected by graphical methods to obtain a clear and intuitive system hierarchy diagram.

Step1. Calculate the overall influence matrix. The combined influence matrix T in DEMATEL reflects the relationship and degree of interaction between different factors, but it does not consider the influence of factors on themselves. Since the factors are in one-to-one correspondence with themselves, they can be represented relationally by the unit matrix I. The matrix H combines the two and reflects the overall influence relationship of the system factors. It is shown in equation (8).

$$H = T + I \tag{8}$$

Step2. Calculate the reachability matrix.λ is the threshold value, and in this paper, we take λ=0.5. The reachability matrix K can be calculated from the overall impact matrix H by using a Boolean algebraic algorithm, see equation (9).

$$k_{ij} = \begin{cases} 1, & h_{ij} > \lambda \\ 0, & h_{ij} < \lambda \end{cases} \tag{9}$$

The number 1 in the reachable matrix represents the existence of an influence path between two elements. Conversely, there is no path.

Step3. Determine the factor set and perform the initial classification. By determining the reachable set R (see equation (10)) and the prior set S (see equation (11)) the impact indicators $x_i(i = 1,2, \dots n)$ can be graded separately, and the reachable set R and the prior S set are expressed as follows:

$$R_i = \{x_j | x_j \subseteq X, k_{ij} = 1\} \tag{10}$$

$$S_j = \{x_i | x_i \subseteq X, k_{ij} = 1\} \tag{11}$$

$$R_i = R_i \cap S_i \tag{12}$$

For the element x_i that satisfies Equation (12), it is classified as the bottom set of elements of the impact indicator and the rows and columns corresponding to that element are removed in the reachable matrix K. The above process is repeated. After removing, the initial chart is available.

Step4. Construct a multi-level recursive structure model based on the hierarchical structure summary.

The relationship between the factors is determined by the accessibility matrix. Based on the multi-level recursive structure, we can clearly understand the supply chain risk transmission path and propose corresponding measures to control the risk in time.

5. Case Study

5.1. Direct impact matrix construction

In this paper, we invited five experts (two bank experts, one government official, one core supply chain entrepreneur, and one professor of university management) with rich research background in the field of financial risk and supply chain enterprise management, and the experts have studied supply chain enterprise risk management for more than five years. We collected experts' opinions by anonymously, and established a five-level division for scoring the strength of inter-influence relationships among indicators, with a 0-4 scale system (0 means no influence, 1 means very weak influence, 2 means moderate influence, 3 means strong influence, and 4 means very strong influence). Finally, we statistically processed and summarized the experts' opinions. This survey first assigns

subjective weights to the degree of influence of indicators in the field of supply chain finance risk based on the experts' experience, and then processes the weighted average based on the experts' ratings of the inter-influence relationship between indicators. After summarizing the scores, the initial matrix was obtained as shown in Table 2:

Table 2. Direct impact matrix

	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	S_{11}	S_{12}	S_{13}	S_{14}	S_{15}
S_1	0	2	0	0	0	2	0	0	0	0	0	0	0	0	0
S_2	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
S_3	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0
S_4	0	0	0	0	4	0	0	0	0	1	0	0	0	0	0
S_5	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
S_6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S_7	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0
S_8	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0
S_9	0	0	0	0	0	0	1	2	0	0	0	0	0	0	0
S_{10}	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0
S_{11}	0	0	0	0	0	0	0	0	0	0	0	3	2	0	2
S_{12}	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
S_{13}	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0
S_{14}	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
S_{15}	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0

5.1.1 Data Analysis

Based on the data in the direct influence matrix in Table 2, the indicators of centrality and causality are calculated, and the centrality M_i is the horizontal coordinate and the causality R_i is the vertical coordinate, and the results of the causes of supply chain financial risk factors are plotted, as shown in Figure 1.

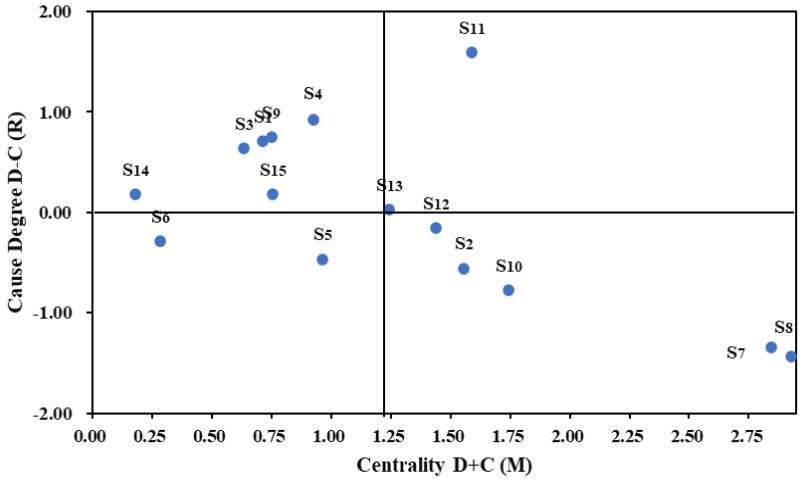

Fig. 1 Cause – effect diagram

5.1.2 Causal degree analysis

In Figure 1, its vertical coordinate cause degree represents the influence of risk indicator i on all other factors. If the cause degree is positive, it means that the indicator has a large influence on other factors and belongs to the cause factor; if it is negative, it means that the indicator is greatly influenced by other factors and belongs to the result factor. As shown in Figure 2, there are 8 factors with values greater than 0 in the risk system of supply chain finance, which are: unstable macroeconomic environment (S_1), low information interoperability between enterprises (S_3), dense distribution of enterprises (S_4), poor credit status of customers of financing enterprises (S_9), low education level of

employees of core enterprises (S_{11}), weak inventory management ability (S_{13}), intense competition in the industry where core enterprises are located (S_{14}), Weak awareness of enterprise environmental protection (S_{15}), which is a cause factor, is easy to influence other factors in the supply chain financial system. When controlling financial risks, we need to focus on cutting off the transmission process between these causal factors and other factors; there are 7 factors with values less than 0: low prospects for industrial development (S_2), strong dependence of upstream and downstream enterprises on core enterprises (S_5), inadequate safety and security mechanisms for employees of financing enterprises (S6), deformed capital structure of financing enterprises (S_7), lack of solvency of financing enterprises (S8), delivery of financing enterprises The timeliness and accuracy of the financing enterprise is low (S10), the week innovation ability of the core enterprise (S_{12}). These factors are outcome factors, indicating that these factors are vulnerable to the influence of other factors. When controlling the financial risk of the supply chain system, it is necessary to prevent it from being disturbed by other factors leading to the increase of systemic risk.

5.1.3 Centrality Analysis

As shown in Figure 1, the centrality of the horizontal coordinate indicates the degree of influence of factor *i* in the supply chain financial system by other factors or the degree of influence of other factors. The larger the centrality value is, the greater the degree that the index *i* is influenced by other factors or influences other factors, i.e. the more critical the factor *i* is. As can be seen from Figure 2, the top 5 influencing factors with the greatest centrality are, in order, the low prospect of industrial development (S_2) the deformed capital structure of financing enterprises (S_7) the lack of solvency of financing enterprises (S_8) the low timeliness and accuracy of delivery of financing enterprises (S_{10}) the weak innovation ability of core enterprises (S_{12}), so these two factors are selected as the key influencing factors. Supply chain enterprises should give more attention to these five influencing factors in the work of supply chain financial risk control.

5.2. Construct a progressive hierarchy of financial risk influencing factors

This paper analyzes the causal relationship and the corresponding importance of each element in the supply chain financial system through the DEMATEL model. To further confirm the logical hierarchy among the influencing indicators, it is necessary to construct a recursive hierarchy of influencing factors according to the ISM model. According to the repeated division step in the ISM model construction method, five basic levels are selected.

As shown in Figure 2, the risk system of supply chain finance can be divided into 3 causative levels, which contain 5 basic levels in total. The basic level L_1 is the direct cause, which is the most direct influence factor leading to the occurrence of financial risk, including the inadequate safety and security mechanism of employees of financing enterprises (S_6), the deformed capital structure of financing enterprises (S_7), and the lack of solvency of financing enterprises (S_8).

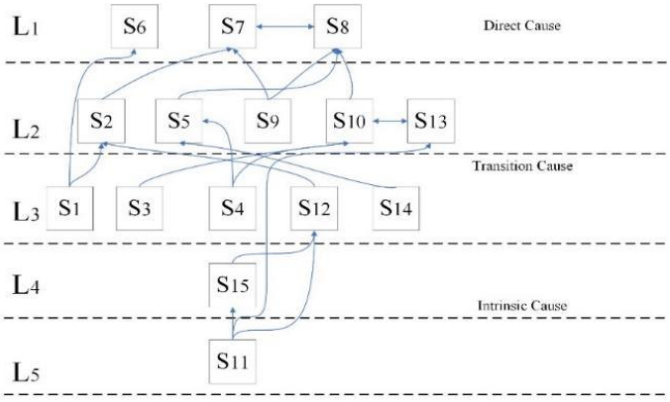

Fig. 2 Progressive hierarchy of risk influencing factors in supply chain finance

The basic level L_2~L_3 in Figure 2 is the transitional causative factor, in which it plays the role of carrying forward and backward, including the unstable macroeconomic environment (S_1), Low

industrial development prospect (S_2), Low information interoperability among enterprises (S_3), Dense distribution of enterprises (S_4), Strong dependence of upstream and downstream enterprises on core enterprises (S_5), Poor credit status of customers of financing enterprises (S_9), Low timeliness and accuracy of delivery of financing enterprises (S_{10}), Weak innovation ability of core enterprises (S_{12}), Weak inventory management ability (S_{13}), Intense competition in the industry where core enterprises are located (S_{14}). Although these factors cannot directly lead to the occurrence of supply chain finance risk, their complex influence relationship will lead to the lack of overall stability of the supply chain system, which is in a state prone to breeding risks. Among them, factors such as low industrial development prospect (S_2), low timeliness and accuracy of delivery of financing enterprises (S_{10}), and weak innovation ability of core enterprises (S_{12}) have relatively complex influence relationships with other factors and are key factors, which play a critical role in the influence system of supply chain finance risk and need more attention.

The basic level L_4~L_5 are the essential causes, including the low education level of core enterprises' employees (S_{11}) and the weak awareness of environmental protection (S_{15}), which can help reduce the risk of financial risks in the supply chain.

6. Conclusions and Suggestions

(1) The DEMATEL method was applied to analyze the inter-influence relationships among factors, calculate the causality and centrality of 15 risk-influencing factors, determine the causal attributes of supply chain financial risk-influencing factors, and establish 5 key supply chain financial risk-influencing factors such as weak innovation ability of core enterprises (S_{12}) based on the centrality and other indicators.

(2) Based on the DEMATEL model, the ISM method is used to establish a progressive hierarchical model of supply chain financial risk influencing factors, which divides the financial risk influencing factors in the supply chain system into three causal levels, including direct causal factors, transitional causal factors and essential causal factors, including five levels. The model can visually represent the intrinsic correlation and risk transmission paths among risk influencing factors.

On this basis, this paper proposes the following three recommendations.

(a) Respond to financial risks by improving innovation capabilities. Innovation is fundamental to the survival of enterprises. Consciously recruit and train highly educated talents with professional ability to develop the enterprise innovation track to fundamentally solve the profitability problem of enterprises.

(b) Real-time understanding of the financial situation of financing enterprises and effective assessment of the possibility of their falling into financial risks. Risk avoidance for financing enterprises that may fall into financial risks in a timely manner to avoid the contagion of financial risks in the supply chain.

The risk contagion factor assessment system of supply chain finance constructed in this paper needs to be improved. There are some shortcomings in the study of the trade flow process of the supply chain. In addition, there are some inaccuracies in the expert scores, which may reduce the accuracy of the model. Also, the comprehensiveness of the factor assessment system can be enriched. Future research on the risk contagion mechanism in supply chain financial networks can be conducted.

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