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Study on Influencing Factors of Grain Supply Chain Resilience Based on DEMATEL-ISM Method

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ABSTRACT

The essential requirement for the resilience and safety of the food industry supply chain is to achieve independent, controllable, safe, efficient, and sustainable development. Currently, and for a significant period in the future, the food industry supply chain faces several risks, primarily due to increased uncertainties. These risks manifest as the need for optimization in the layout of the food industry, prominent structural shortages, and a lack of full autonomy and control in key links of the industry chain. Such risks can potentially evolve into critical factors that restrict the resilience and security of the food industry supply chain. To effectively address these risks, this paper identifies 12 influencing factors based on four key capabilities of the food supply chain: forecasting ability, response-ability, adaptation ability, and recovery ability. An evaluation index system for the resilience of the food supply chain is constructed, integrating the Decision-Making Trial and Evaluation Laboratory (DEMATEL) and Interpretive Structural Modeling (ISM) methodologies. Analysis of the interactions between these factors reveals that three factors, including supply chain visibility, are fundamental, seven factors, including the level of agricultural mechanization, are intermediate, and dynamic logistics and flexibility are direct factors. Based on these conclusions, this paper proposes several targeted recommendations to enhance the development of the food supply chain. These recommendations aim to improve the supply chain's resilience and ability to withstand potential risks.

1. Introduction

In recent years, the global food supply has reached a delicate balance amid escalating challenges such as resource degradation, climate change, environmental deterioration, and frequent emergencies, posing threats to food security worldwide. Natural disasters like extreme weather affect food yield and quality and damage agricultural infrastructure and equipment, limiting food production's subsequent recovery and growth. The COVID-19 pandemic in early 2020 caused significant global food market disruptions, severely challenging domestic food distribution systems. Against this backdrop, China's food supply chain encountered operational irregularities and potential

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breakdowns, critically jeopardizing food security. Additionally, the sudden geopolitical shifts involving Russia and Ukraine in early 2022 intensified food price shocks and disrupted the agricultural trade patterns, further tightening the global food supply chain. Consequently, domestic food prices, fertilizers, and animal feed gradually rose[1]. Strengthening the resilience of the food supply chain has become imperative, emphasizing stable and secure operations to ensure food security. Efforts are focused on stabilizing grain production, securing vital agricultural product supplies, and enhancing the resilience of the grain supply chain to mitigate external uncertainties.

Enhancing food security resilience is urgent to comprehensively consolidate the foundation of food security and is crucial for achieving coordinated development and security at a higher level. It is a strategic imperative and essential guarantee for building a robust agricultural sector and achieving Chinese-style modernization. Accordingly, the 20th National Congress of the Party emphasized safeguarding food security, energy resources, critical industrial chains, and supply chains, recognizing that food issues are intricately tied to the national economy, livelihoods, and security. Ensuring the stable and safe supply of food and vital agricultural products is pivotal in advancing rural revitalization comprehensively. Food security governance is a top priority given the interconnected nature of food production, national transportation, and livelihoods.

This study aims to explore the factors influencing the resilience of the food supply chain. This study utilizes case studies and international examples within the realm of food supply chain management to pinpoint 12 crucial factors that impact the resilience of food supply chains, focusing on their forecasting, response, adaptation, and recovery capabilities. It proposes an evaluation index system for assessing food supply chain resilience. According to previous studies, DEMATEL-ISM is suitable for analyzing complex interactions and hierarchical relationships among supply chain elasticity factors due to its unique advantages. Therefore, we use the DEMATEL and ISM methods to establish a scientific evaluation system and accurately identify various influencing factors. This approach allows us to propose effective risk response strategies and ensure the stable and safe operation of the food supply chain.

2. Literature review

Domestic and foreign scholars have studied supply chain management in depth, focusing on the concept of resilience. Resilience emphasizes the ability of the supply chain system to predict unexpected risks, adapt when risks come, and quickly recover after risks. Vugrin et al.[2] built a comprehensive resilience assessment framework to analyze the petrochemical supply chain affected by hurricanes from absorption, adaptation, and recovery perspectives. However, Hao and Tan et al.[3] When measuring the resilience of China's supply chain, it was proposed that supply chain resilience refers to the ability of the supply chain to adjust to normal operations over time after experiencing disturbances. In recent years, more scholars have improved the stability of the supply chain by analyzing the factors affecting supply chain resilience (Sunmola et al.[4]Sorted visibility factors affecting supply chain resilience to deal with uncertain risks in the supply chain. Zhang et al.[5] Introduced the concepts of information factor and partnership factor to explore the resilience of the prefabricated building supply chain. To find the key factors affecting supply chain resilience more accurately, several scholars used the interpretive structure model to explore the logical relationship and hierarchical structure among the influencing factors and conducted classified research on numerous influencing factors. To sum up, the existing researches on supply chain resilience is gradually exploring its influencing factors in depth, but there is little research on the detailed classification and classification of influencing factors.

In previous studies, many methods have been used to study influencing factors of grain supply chain resilience, such as CRITIC-EWM, DEMATEL-ISM, and ORESTE. However, The DEMATEL-ISM method is the most popular among scholars. DEMATEL method focuses on using matrix theory and graph theory to evaluate the strength of influencing factors and conducts factor analysis of complex systems by measuring the cause degree of each influencing factor and other indicators[6]. ISM classifies the levels of influencing factors by establishing accessible matrices, etc., and transforms a complex system with complex relationships into a concise, clear, and intuitive multi-level hierarchical structural form **Error! Reference source not found.**. The DEMATEL method can identify the key influencing factors for complex systems. Still, it cannot analyze the factors' internal mechanism and hierarchical structure, while the ISM method can intuitively present the logical relationship between the factors. Both focus on factor analysis of complex systems, so combining the two methods based on this commonality can realize complementary advantages and provide strong support for quantitative analysis and scientific decision-making of complex systems. The food supply chain is a complex system involving many factors and complicated relationships. Therefore, compared with other methods, the DEMATEL-ISM method has more advantages in studying the resilience of the food supply chain.

Li et al. **Error! Reference source not found.**examine the correlation between various influential factors affecting the promotion of photovoltaic green roof retrofitting in existing buildings using a fuzzy DEMATEL-ISM-ANP research methodology. The improved DEMATEL-ISM integration approach proposed by Chen **Error! Reference source not found.** has two main components: threshold determination via the maximum mean de-entropy method and an additional transitivity check process. This methodology was applied to analyze the factors influencing the willingness of China’s rural-urban floating population to participate in social insurance as a case study. In this paper, DEMATEL and ISM methods are combined to deeply analyze the interrelationship between the influencing factors of the food supply chain, providing new ideas and scientific research methods for developing the food supply chain. Based on the DEMATEL -ISM model, the correlation and hierarchical relationship of risk factors are analyzed, key factors are identified, scenarios that may cause systemic risks are excavated, and risk prevention suggestions are given to provide references for the risk prevention and control of the food supply chain.

3. Construction of an index system of influencing factors of food supply chain resilience

After reviewing a substantial body of relevant literature and consulting expert opinions, combined with the key issues currently faced by China's grain supply chain, this research has identified 12 influencing factors under the four dimensions of forecasting ability, response-ability, adaptation ability, and recovery ability. These factors constitute the evaluation index system for the influencing factors of manufacturing supply chain resilience, as detailed in Table 1.

Table 1.
Evaluation index system of influencing factors of grain supply chain resilience

Primary index	Secondary index	Instructions	reference
Predictive power	Supply chain visibility	Based on the help of a visual information system, the entire supply chain operation process is comprehensively supervised and controlled	**Error! Reference source not found.**

	Demand forecasting	Prediction of future market demand based on sales, shortage rate, and inventory data	**Error! Reference source not found.**
	Risk awareness	Decision-makers ability to identify and avoid possible risks in supply chain operation	**Error! Reference source not found.Error! Reference source not found.**
Reactivity	Flexibility	Supply chain ability to respond quickly to environmental changes and uncertain events	**Error! Reference source not found.**
	Agility	The ability of the supply chain to respond quickly to unpredictable changes in demand or supply and to flexibly adjust direction or strategy in response to achieve rapid recovery or a better state	**Error! Reference source not found.-Error! Reference source not found., Error! Reference source not found.**
	Level of agricultural mechanization	The number of operations in agricultural production using machinery as a percentage of total operations	**Error! Reference source not found.**
Adaptability	Redundancy	Hold more inventory than is normally needed or have more capacity than is normally needed to cope with possible changes in demand or supply	**Error! Reference source not found.-Error! Reference source not found.**
	Dynamic logistics	Supply chain logistics ability can quickly adjust itself to meet the demand when the market demand changes	**Error! Reference source not found.**
	Grain output	Cope with different risks and different production fluctuations	**Error! Reference source not found.**
Resilience	Affected area	The amount of damage to the land where food is grown due to risks such as natural disasters	**Error! Reference source not found.**
	Environmental regulation	The intensity of regulation on various behaviors that pollute the environment	**Error! Reference source not found.**
	Supply chain complexity	Including the number of supply chain nodes, the length of the chain, the number of suppliers and dealers	**Error! Reference source not found.**

4. Data analysis

4.1 Analysis of influencing factors of food supply chain resilience based on DEMATEL

Based on the experience of experts and scholars, this paper uses the DEMATEL method to identify the core influencing factors of food supply chain resilience and explore the logical relationship between influencing factors more clearly. In this paper, experts in relevant supply chain fields and practitioners of food supply chain were invited to score the degree of mutual influence among the factors influencing supply chain resilience. The scoring method was 0-4 scale (where 0 means that factor a does not influence factor b, 1 means low influence, 2 means medium influence, 3 means high influence, and 4 means very high influence). The Initial direct influence matrix P of influencing factors of grain supply chain resilience is displayed in Table 2.

Table 2.

Initial direct influence matrix P of influencing factors of grain supply chain resilience

	C_{11}	C_{12}	C_{13}	C_{21}	C_{22}	C_{23}	C_{31}	C_{32}	C_{33}	C_{41}	C_{42}	C_{43}
C_{11}	0.00	3.71	1.41	1.10	0.63	2.27	3.68	0.39	2.29	1.63	1.66	0.46
C_{12}	1.05	0.00	3.54	1.90	3.49	1.85	1.71	3.02	1.73	1.02	0.93	2.37
C_{13}	0.61	1.27	0.00	3.63	1.24	1.34	1.24	3.61	1.22	0.59	0.46	2.00

C_{21}	0.54	0.88	1.49	0.00	1.46	0.85	0.83	2.12	0.80	0.51	0.44	1.37
C_{22}	0.54	1.17	2.05	3.59	0.00	1.20	1.29	3.68	1.32	0.56	0.49	2.02
C_{23}	0.88	1.93	3.24	1.68	2.20	0.00	1.90	1.12	1.88	0.90	0.95	3.37
C_{31}	0.98	1.83	2.34	1.44	3.51	1.76	0.00	1.78	1.78	1.00	0.98	3.56
C_{32}	0.85	1.15	1.39	2.10	1.41	1.37	1.29	0.00	1.61	0.90	1.00	1.44
C_{33}	1.20	1.80	3.29	0.95	2.17	1.73	1.61	1.32	0.00	1.12	1.15	3.54
C_{41}	2.59	3.27	1.27	0.78	0.78	3.59	1.22	0.41	3.68	0.00	1.64	0.44
C_{42}	1.68	2.24	0.44	0.93	1.07	3.78	3.71	0.49	2.22	1.56	0.00	0.54
C_{43}	0.51	1.15	1.98	3.78	1.34	1.12	1.07	3.71	1.10	0.61	0.66	0.00

4.1.1 Determine the comprehensive influence matrix

To reduce the subjective influence of the scorers on the experimental results, we calculate the average data of the recovered valid questionnaires, retain two decimal places, and finally obtain the initial direct influence matrix of the factors affecting the resilience of the food supply chain: $P = \left[p_{ij} \right]_{m \times n}$, As shown in Eq. (2). Where $\left[p_{ij} \right]$ represents the influence strength of the influencing factor i on the influencing factor j in the system.

After the direct influence matrix P is obtained, it is normalized. First, calculate the sum of columns and rows in the direct influence matrix and find the maximum C . Second, divide each element of the matrix P by C to generate a new matrix, which is the normalization direct influence matrix D . The calculation formula is:

$$D = \frac{P}{C} \tag{1}$$

$$C = \max \left[\max_{1 \le j \le n} \sum_{i=1}^{m} p_{ij}, \max_{1 \le i \le n} \sum_{j=1}^{n} p_{ij} \right] \tag{2}$$

After the direct influence matrix is normalized, the comprehensive influence matrix Q can be constructed. The calculation formula of the comprehensive influence matrix is as follows:

$$Q = D(E - D)^{-1} \tag{3}$$

Where E is the identity matrix. The comprehensive influence matrix Q is shown in Table 3.

4.1.2 Determine the degree of centrality and reason

Table 3 shows the comprehensive influence matrix of factors influencing the elasticity of the food supply chain. The influence degree is the sum of the elements in a row i of the comprehensive influence matrix Q , which reflects the sum of the direct and indirect influences of the influencing factor i on other influencing factors. The affected degree H_i is the sum of the elements in the column i , which indicates the sum of the influence factor i by other influencing factors. The degree of centrality J_i represents the degree of influence factor i on the whole system. The greater J_i the degree of influence factor i is, the more important the position of influence factor is in the whole system. The degree of cause K_i indicates the strength of the influence of the influencing factor i . When $K_i > 0$ it means that the influencing factor i is the cause factor and has a strong influence on other influencing factors. When $K_i < 0$, it means that the influencing factor i is the resulting factor, which is strongly influenced by other factors, and the calculation method of K_i when is $G_i - H_i$. The calculation results are shown in Table 4.

Table 3

Comprehensive influence matrix Q of influencing factors of grain supply chain resilience

	C_{11}	C_{12}	C_{13}	C_{21}	C_{22}	C_{23}	C_{31}	C_{32}	C_{33}	C_{41}	C_{42}	C_{43}
C_{11}	0.17	0.45	0.44	0.42	0.36	0.40	0.44	0.40	0.39	0.23	0.23	0.39
C_{12}	0.22	0.31	0.53	0.50	0.48	0.39	0.37	0.54	0.37	0.21	0.21	0.48
C_{13}	0.16	0.28	0.29	0.45	0.30	0.28	0.27	0.45	0.27	0.15	0.14	0.36
C_{21}	0.11	0.20	0.26	0.22	0.24	0.20	0.19	0.30	0.19	0.11	0.11	0.25
C_{22}	0.16	0.28	0.38	0.46	0.26	0.29	0.28	0.47	0.28	0.15	0.15	0.37
C_{23}	0.20	0.36	0.49	0.45	0.40	0.28	0.35	0.43	0.35	0.19	0.19	0.48
C_{31}	0.21	0.36	0.47	0.46	0.46	0.37	0.28	0.48	0.36	0.20	0.20	0.50
C_{32}	0.16	0.26	0.32	0.36	0.29	0.27	0.25	0.28	0.27	0.15	0.15	0.32
C_{33}	0.21	0.35	0.49	0.42	0.40	0.36	0.34	0.44	0.28	0.20	0.20	0.49
C_{41}	0.28	0.44	0.45	0.41	0.37	0.46	0.35	0.40	0.45	0.17	0.23	0.40
C_{42}	0.24	0.39	0.39	0.40	0.37	0.45	0.43	0.39	0.38	0.22	0.16	0.39
C_{43}	0.15	0.27	0.36	0.45	0.30	0.27	0.26	0.45	0.26	0.15	0.15	0.28

Table 4
Centrality and causation of influencing factors of food supply chain resilience

	influence degree G_i	affected degree H_i	degree of centrality J_i	Centrality ranking	degree of cause K_i	Causation ranking
Supply chain visibility	4.33	2.26	6.59	10	2.06	3
Demand forecasting	4.60	2.93	8.53	1	0.67	4
Risk awareness	3.41	4.87	8.28	2	-1.47	10
Flexibility	2.37	4.98	7.35	9	-2.61	12
Agility	3.53	4.23	7.76	8	-0.70	8
Level of agricultural mechanization	4.17	3.99	8.16	3	0.18	7
Redundancy	4.34	3.80	8.14	4	0.53	5
Dynamic logistics	3.06	5.04	8.09	5	-1.98	11
Grain output	4.17	3.86	8.03	7	0.31	6
Affected area	4.42	2.14	6.55	11	2.28	1
Environmental regulation	4.20	2.11	6.32	12	2.09	2
Supply chain complexity	3.35	4.71	8.06	6	-1.37	9

4.1.3 Analysis of influence results based on DEMATEL

First, the degree of centrality is analyzed. Table 4 shows that the top three factors in terms of centrality score values are demand forecast, risk awareness, and agricultural mechanization level. These three factors significantly influence other factors and are also moderately influenced by some factors themselves, making them key core elements in the entire supply chain resilience system. Among them, demand forecasting is the most central factor and should be the primary focus for improving supply chain resilience. In the unstable environment of the real economy, end demand changes rapidly and fluctuates greatly, food producers can achieve cost reduction and efficiency improvements only by conducting an in-depth market analysis, exploring demand patterns, and making scientific predictions about future demand.

Second, the reason degree is analyzed. Among all the factors affecting the resilience of the food supply chain, there are seven cause factors and five effect factors. The three factors with the highest cause degree are the disaster area, environmental regulation, and supply chain visibility, which have the greatest impact on other factors and are crucial in determining the strength of supply chain resilience. Ignoring these three factors would restrict the influence of other factors to a certain extent. Therefore, to ensure the long-term smooth operation of the food supply chain, it is essential to prioritize these three factors.

4.2 Analysis of influencing factors of grain supply chain resilience based on ISM
4.2.1 Establish the reachability matrix

According to the research methodology, the established comprehensive impact matrix Q is first subjected to a threshold μ to eliminate indicators with minor influence, thus simplifying the matrix to obtain the relationship matrix A. The relationship matrix A is then added to the identity matrix E , and Boolean operations are performed iteratively until the matrix no longer changes, ultimately resulting in the reachability matrix K . It is noteworthy that introducing different thresholds expresses different logical relationships. Typically, selecting the threshold μ based solely on expert experience lacks objectivity. This study adopts the sum of the mean and standard deviation in the statistical distribution as the μ value, a method that effectively reduces subjective influence**Error! Reference source not found.**. The formulas for calculating the threshold μ and the reachability matrix K are as follows:

$$\mu=\alpha+\beta,\mu\hat{\mathrm{I}}\ \left[0,1\right] \tag{4}$$

$$A_{ij}=\begin{cases}1,q_{ij}\geq\mu\\0,q_{ij}<\mu\end{cases} \tag{5}$$

Among them, α and β represent the mean and standard deviation, respectively, of all elements in the comprehensive impact matrix Q . q_{ij} denotes the element in the i row and j column of the comprehensive impact matrix Q .

Using MATLAB software, the mean ($\alpha=0.32$) and standard deviation ($\beta=0.11$) of all elements in the comprehensive impact matrix Q can be calculated. According to Eq (4), the threshold u is computed as $u=0.32+0.11=0.43$. The final reachability matrix K is obtained, as shown in Table 5.

Table 5
Reachable matrix

	C_{11}	C_{12}	C_{13}	C_{21}	C_{22}	C_{23}	C_{31}	C_{32}	C_{33}	C_{41}	C_{42}	C_{43}
C_{11}	1	1	1	0	0	0	1	0	0	0	0	0
C_{12}	0	0	1	1	1	0	0	1	0	0	0	1
C_{13}	0	0	0	1	0	0	0	1	0	0	0	0
C_{21}	0	0	0	0	0	0	0	0	0	0	0	0
C_{22}	0	0	0	1	0	0	0	1	0	0	0	0
C_{23}	0	0	1	1	0	0	0	1	0	0	0	1
C_{31}	0	0	1	1	1	0	0	1	0	0	0	1
C_{32}	0	0	0	0	0	0	0	0	0	0	0	0
C_{33}	0	0	1	0	0	0	0	1	0	0	0	1
C_{41}	0	1	1	0	0	1	0	0	1	0	0	0
C_{42}	0	0	0	0	0	1	1	0	0	0	0	0
C_{43}	0	0	0	1	0	0	0	1	0	0	0	0

4.2.2 Construct a multi-level hierarchical structure model

Based on the reachability matrix, the reachability set, antecedent set, and intersection set can be calculated, thereby facilitating the hierarchical division. The reachability set $R(C_i)$ refers to the set of elements in a row of the reachability matrix that contains 1. The antecedent set $S(C_i)$ refers to the set of elements in a column of the reachability matrix that contains 1. The intersection set $T(C_i)$ is the intersection of $R(C_i)$ and $S(C_i)$. The collection of influencing factors in the reachability matrix is shown in Table 5. Using $R(C_i)=T(C_i)$ as the basis for hierarchical division, the factors at the first level are selected. After determining the first-level factors, these factors are removed, and the same principle of $R(C_i)=T(C_i)$ is applied to identify the second-level factors. This process is repeated until the ISM structural model of the manufacturing supply chain resilience factors is obtained. Sets of influencing factors of the reachable matrix in Table 7. Finally, a hierarchical table of the influencing factors of grain supply chain resilience is constructed (see Table 6), and the ISM model diagram is drawn (see Figure 1).

Table 6
Hierarchical decomposition

hierarchy	element
First floor (top floor)	C_{21}; C_{32}
Second floor	C_{13}; C_{22}; C_{43}
Third floor	C_{12}; C_{23}; C_{31}; C_{33}
Fourth floor (bottom floor)	C_{11}; C_{41}; C_{42}

Table 7
Sets of influencing factors of the reachable matrix

	Reachable set $R(C_i)$	Precedence set $S(C_i)$	Common set $T(C_i)$
C_{11}	C_{11}; C_{12}; C_{13}; C_{21}; C_{22}; C_{31}; C_{32}; C_{43}	C_{11}	C_{11}
C_{12}	C_{12}; C_{13}; C_{21}; C_{22}; C_{32}; C_{43}	C_{11}; C_{12}; C_{41}	C_{12}
C_{13}	C_{13}; C_{21}; C_{32}	C_{11}; C_{12}; C_{13}; C_{23}; C_{31}; C_{33}; C_{41}; C_{42}	C_{13}
C_{21}	C_{21}	C_{11}; C_{12}; C_{13}; C_{21}; C_{22}; C_{23}; C_{31}; C_{33}; C_{41}; C_{42}; C_{43}	C_{21}
C_{22}	C_{21}; C_{22}; C_{32}	C_{11}; C_{12}; C_{22}; C_{31}; C_{41}; C_{42}	C_{22}
C_{23}	C_{13}; C_{21}; C_{23}; C_{32}; C_{43}	C_{23}; C_{41}; C_{42}	C_{23}
C_{31}	C_{13}; C_{21}; C_{22}; C_{31}; C_{32}; C_{43}	C_{11}; C_{31}; C_{42}	C_{31}
C_{32}	C_{32}	C_{11}; C_{12}; C_{13}; C_{22}; C_{23}; C_{31}; C_{32}; C_{33}; C_{41}; C_{42}; C_{43}	C_{32}
C_{33}	C_{13}; C_{21}; C_{32}; C_{33}; C_{43}	C_{33}; C_{41}	C_{33}
C_{41}	C_{12}; C_{13}; C_{21}; C_{22}; C_{23}; C_{32}; C_{33}; C_{41}; C_{43}	C_{41}	C_{41}
C_{42}	C_{13}; C_{21}; C_{22}; C_{23}; C_{31}; C_{32}; C_{42}; C_{43}	C_{42}	C_{42}
C_{43}	C_{31}; C_{32}; C_{43}	C_{11}; C_{12}; C_{23}; C_{31}; C_{33}; C_{41}; C_{42}; C_{43}	C_{43}

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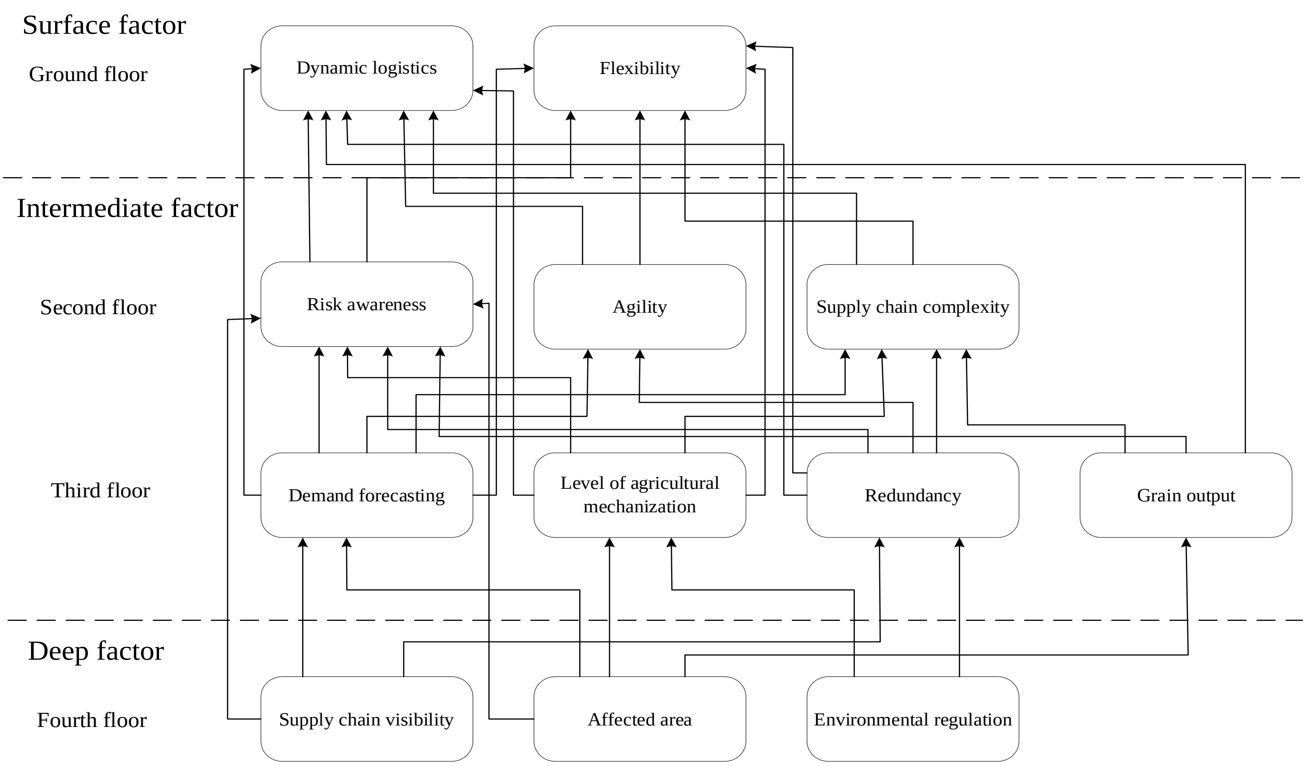

Fig.1. ISM model

4.2.3 Analysis of impact results based on ISM

As seen in Figure 1, influencing factors can be categorized into three hierarchical layers: surface factors, middle factors, and deep factors. Dynamic logistics and flexibility are classified as surface factors, which constitute the first layer of the system. These surface factors exhibit limited proactivity and are significantly impacted by other factors. Directly intervening in surface factors has a substantial effect on supply chain resilience. For instance, enhancing supply chain flexibility improves its responsiveness, helping to avoid unexpected risks. Similarly, rapidly adjusting logistics levels enables the supply chain to respond promptly to changes in market demand. The fourth layer, or deep factors, are the fundamental elements affecting the resilience of the food supply chain. Deep factors indirectly affect supply chain resilience by transmitting their influence layer by layer. If deep factors encounter issues, the middle and surface factors will also be constrained. Therefore, deep factors should be the primary focus when addressing the resilience of the food supply chain. Among the three deep factors, the disaster area and supply chain visibility share a similar mechanism of action on supply chain resilience. Both aim to transfer more information from upstream and downstream of the supply chain to its members, ensuring rational resource utilization and timely identification of potential risks. Information and visualization of the supply chain form the basis for its efficient operation.

5. Research conclusions and suggestions

5.1. Research Conclusion

Based on an extensive analysis of the literature, this paper identifies and screens the influencing factors of grain supply chain resilience. It constructs a DEMATEL model to explore the effect of each factor on supply chain toughness and an ISM model to stratify and classify each factor. Comprehensive research reveals that demand forecasting is the most crucial core factor. Disaster area, supply chain visibility, and environmental regulation have the greatest impact on other factors, making them the most fundamental influencing factors. Flexible and dynamic logistics are the most affected by other factors and serve as direct influencing factors of supply chain resilience. By understanding the interaction relationships and hierarchical structures among these factors, the analysis becomes more intuitive. This allows for more targeted recommendations to be made for enterprises to enhance their supply chain resilience.

5.2. Countermeasures and Suggestions

Based on the analysis of influencing factors outlined in Figure 1 and the results from the DEMATEL-ISM model, the following recommendations are proposed to enhance the resilience of the food supply chain:

First, improve supply chain visibility and enhance information communication. The DEMATEL-ISM analysis identifies supply chain visibility and disaster areas as deep factors that significantly influence the system. These deep factors impact the resilience of the supply chain either directly or indirectly through intermediary layers. Enhanced visibility provides supply chain members with comprehensive and timely information, which facilitates a real-time understanding of operational conditions and supports prompt responses to disruptions. Therefore, digitizing supply chain processes, utilizing advanced information analytics, and aligning production planning with market demand are essential strategies to enhance visibility. This approach ensures that all members have access to critical information, enabling them to manage and mitigate risks effectively.

Second, maintain optimal inventory levels and establish stable cooperative relationships across all sectors. The disruptions observed in the global commodity market, which has resulted in increased logistics costs and raw material prices, underscore the importance of managing inventory levels strategically. The DEMATEL-ISM model highlights redundancy as an intermediate factor within the third layer of the system. By maintaining moderate inventory redundancy for raw materials and finished products, the food supply chain can better accommodate emergency demands and buffer against market fluctuations. Furthermore, outsourcing procurement, processing, and sales functions to Original Equipment Manufacturers (OEMs) can enhance supply chain efficiency and mitigate the adverse effects of market volatility. Strengthening this intermediate factor of redundancy positively influences the surface factors, such as dynamic logistics and flexibility, thus reinforcing overall supply chain resilience.

5.3 Limitations and Future Research Directions:

Limitations:

Handling of Uncertainty: The proposed method falls short in addressing the complexities associated with uncertain information. Improved techniques for managing uncertainty and incorporating probabilistic approaches could enhance the robustness of the analysis.

Integration of Expert Opinions: The study does not utilize more sophisticated methods for integrating diverse expert inputs. Advanced techniques, such as Bayesian methods or consensus-based approaches, could provide a more comprehensive aggregation of expert knowledge and reduce potential biases.

Lack of Novel Models: The research relies on established models without introducing innovative approaches. Future work could benefit from exploring and developing new models that incorporate recent advancements in data analysis and decision-making frameworks.

Research Directions:

Incorporate Advanced Uncertainty Models: Future studies should consider incorporating advanced uncertainty modeling techniques, such as fuzzy logic or probabilistic graphical models, to better handle the variability in data and expert opinions.

Enhance Expert Integration Methods: Investigating more effective methods for aggregating expert opinions, such as multi-criteria decision analysis (MCDA) or Delphi techniques, could improve the accuracy and reliability of the results.

Develop and Test Novel Models: Exploring new theoretical frameworks or hybrid models that combine elements of existing methodologies with innovative approaches could provide deeper insights into the factors affecting supply chain resilience.

By addressing these limitations and pursuing these research directions, future studies can contribute to a more nuanced understanding of supply chain dynamics and enhance the practical applications of resilience strategies.

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Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.” Authors must identify and declare any personal circumstances or interest that may be perceived as inappropriately influencing the representation or interpretation of reported research results. Any role of the funders in the design of the study; in the collection, analyses or interpretation of data; in the writing of the manuscript, or in the decision to publish the results must be declared in this section. If there is no role, please state “The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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