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Analysis of factors influencing the efficiency of agricultural cold chain logistics enterprises based on intuitionistic Fuzzy-DEMATEL Method

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Abstract: In recent years, the No. 1 document of the Chinese Party Central Committee has repeatedly mentioned the need to strengthen the agricultural logistics industry and the rapid and healthy development of the cold chain logistics industry, and it is urgent to establish and cultivate some agricultural cold chain logistics enterprises with market competitiveness. In this paper, by considering the green development of enterprises and combining the connotation characteristics of agricultural cold chain logistics, the efficiency of Chinese agricultural cold chain logistics enterprises is evaluated by using a combination of intuitionistic fuzzy and DEMATEL methods, starting from five secondary indicators (financial, customer, green, cold chain operation and technological development) with 15 specific influencing factors, based on the research results showing: cold storage utilization rate, reefer truck utilization rate and total asset turnover rate are the three key factors affecting their development. Based on this, W listed enterprises are used as the example to propose corresponding countermeasures in terms of improving the efficiency of cold chain operations, strengthening green capabilities and attaching importance to the construction of intelligent logistics, to promote the sustainable development of China's agricultural cold chain logistics enterprises.

Keywords: Greening development; Agricultural cold chain logistics; Influencing factors; Intuitive fuzzy; DEMATEL method

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1. Introduction

In recent years, with the rapid development of the agricultural products logistics industry, the Party Central Committee and the State Council have attached more and more importance to it, and have put forward central documents to strengthen the development of the agricultural products logistics industry repeatedly. In the 19th Central Document No. 1 since the 21st century, "Opinions of the State Council of the Central Committee of the Communist Party of China on the Key Work of Comprehensively Promoting Rural Revitalization in 2022", it is pointed out clearly that the two bottom lines of guaranteeing national food security and not returning to poverty on a large scale need to be firmly held in 2022. Apparently, Promoting the high-quality development of the cold chain logistics industry is on the agenda while cultivating and establishing several agricultural cold chain logistics enterprises with strong market competitiveness has also become an extremely urgent topic at present.

Looking at the global development situation, it is not difficult to find: from production, processing, quality inspection, storage, distribution, sales, etc. as one of the food cold-chain system in Europe, the United Kingdom and other developed regions almost mature saturation, its cold chain logistics industry is moving towards the direction of scale and centralization, and will continue to combine big data, artificial intelligence, Internet of Things and other technologies, and has now achieved the application of satellite positioning system, remote control technology, the electronic data exchange, network tracking equipment and other advanced equipment and technologies. In China, due to the high cost of the cold chain logistics industry, the corresponding capital investment and resource construction are relatively insufficient, resulting in backward logistics facilities and equipment and difficulties in technology promotion, further leading to the lagging of the cold chain logistics industry. At the same time, the implementation of industry standards for cold chain logistics of agricultural products in China is not in place, and most enterprises are with self-regulatory capabilities and are unable to execute according to the prescribed standards, which puts the development of the logistics industry in a difficult situation. Therefore, as a carrier of agricultural products, the market demand for agricultural cold chain logistics will continue to increase, and as a large agricultural country, China urgently needs a scientific and reasonable evaluation of the efficiency of enterprises to help agricultural cold chain logistics enterprises to find their own shortcomings. By improving management, allocating resources and reorienting business in a targeted manner, it will not only meet the requirements of China's sustainable development policy, but also play an indispensable role in the development of the logistics industry and the road to agricultural modernization.

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Therefore, this paper firstly, by referring to the relevant literature on the performance evaluation of agricultural cold chain logistics enterprises as well as the industry policies and norms on the greening of some logistics enterprises, proposes to build a set of evaluation index system including three levels, examines the comprehensive performance of agricultural cold chain logistics enterprises with five dimensions (financial, customer, green, cold chain operation and technological development), and designs a set of 5 secondary indicators with 15 specific influencing factors. The vision and strategic objectives of the agricultural cold chain logistics enterprises are decomposed through the above five dimensions. Among them, the indicator of environmental self-monitoring program in the guideline level (green indicators) is the first time that scholars have developed and applied it to the evaluation of the performance of agricultural cold chain logistics enterprises.

Secondly, the research method DEMATEL is applied for the first time to an agricultural cold chain logistics enterprise. DEMATEL is used as a basis for constructing a model to determine the causal relationships between elements and the position of each element in the system. Particular emphasis is placed on the fact that the author has applied DEMATEL as a method to agricultural cold chain enterprises for the first time, which has the advantage of making full use of the experience and knowledge of experts to deal with complex social problems, especially for systems where the relationships between the elements are uncertain, by presenting this information in a fully visual way, as opposed to other decision-making tests or evaluation test methods. Finally, in python 3.7, combined with intuitionist fuzzy data processing and graphing, DEMATEL has the advantage over other decision-making or evaluation experiments of making full use of expert experience and knowledge to deal with complex social problems, especially for systems with uncertain elemental relationships, and to present this information visually.

2. Literature reviews

2.1 Cold Chain Logistics

With regard to the technical aspects of cold chain logistics for agricultural products, scholars such as Marija (2005) argue that production and logistics facilities in the supply chain should be located between the origin and the supply market, and that changes in the supply chain, including changes in time, distance or temperature, may lead to changes in the supply chain that affect the quality and quantity of the product to be maintained at an appropriate level for final delivery [1]; Ovca and Jevsnik (2008) investigate the customer's understanding of cold chain logistics in the

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framework of food safety and the related countermeasures for cold-chain logistics management [2]; Rohit (2011) and other scholars also construct a set of related systems to evaluate the performance indicators of cold chain logistics enterprises, use the system to identify the strengths and weaknesses of the enterprises themselves, and propose the right measures to promote the healthy development[3]. Boson et al. (2013) provide an overview of food traceability issues and point out that FTS is an integral part of logistics management, thereby leading to a new meaning of FTS [4]; David Bogataj (2017) points out that in the supply chain of fresh produce, the process from field to table can cause significant losses. By detecting the dynamic changes in the short shelf life of fresh produce in real time, including real-time calculations during transportation from one chain node to another, and using EMRP models can reduce losses during transportation [5]; Yantong Li (2020) and other scholars conducted a study on the food cold-chain path problem for frozen foods, which usually have a short shelf life, and based on a two-stage iterative method, fixed and optimization process and path-based optimization process such as linear planning and modeling ideas to solve the problem, and finally the scientific rationality of the solution was illustrated by numerous experiments and examples [6].

2.2 Evaluation of performance

With regard to research on the performance of logistics firms, in 2004, Knemeyer and Murphy suggested that 3PL firms, after undertaking outsourcing, shift their service focus to improving performance for their customers [7]. S-Bhaskaran et al. (2009) empirically analyzed the case of a small and medium-sized national distributor of cold-chain food products who improved their performance through a logistics alliance and concluded that common logistics could improve the efficiency of agricultural distribution [8]. Three perspectives constructed a food cold-chain logistics performance index system and applied DEA model to analyze the efficiency of food cold chain logistics services [9]; Joshia et al. proposed a performance evaluation index system framework for cold chain logistics service companies to analyze the strengths and weaknesses of cold chain logistics enterprises to help cold chain logistics enterprises to optimize and improve their business[10]; Ali et al. (2018) addressed the cold chain logistics lack of an integrated approach to risk management and resilience by building a model based on extensive empirical evidence to fill the gap in current research on cold chain logistics development [11].

2.3 Green Logistics

In terms of research on green logistics, Gungor and Gupta have studied product recycling and the promotion of environmental awareness in the manufacturing industry, analyzing

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product recycling from the perspective of environmental awareness, referring to the pressure from laws and regulations, as well as specific consumer evaluations and impressions, reinforcing the important role of green logistics in environmental protection and enabling the industry to significantly increase its environmental awareness [12]. Brito and Dekker suggest that there are three drivers of green logistics, namely economic and legal, as well as specific responsibilities that extend to both. Among these factors, the economy and the act of recycling are closely linked, and there is a direct or indirect link between the act of recycling and the company in terms of benefits. The use of recycling as a means of reducing costs, saving materials and increasing profits is an important factor in the development of green logistics, as well as a means of deterring new competitors from entering the market [13]. From the perspective of logistics firms, McKinnon, Browne, Whiteing et al. (2015)[14] summarized the research issues in logistics in the area of environmental sustainability and social responsibility, which include: corporate social responsibility disclosure[15], corporate best environmental practices from a stakeholder perspective[16], factors influencing the practice and development of corporate social responsibility, the influence of CSR on the choice of logistics service providers [17], the motivation of companies to engage in eco-innovation), the efficiency of vehicle movements in the transport of goods, the relationship between logistics service providers and shippers, and the position and role of the logistics service supply chain in a sustainable supply chain.

3. Construction of evaluation factors

3.1 Principles of indicator selection

In order to evaluate the performance of agricultural cold chain logistics enterprises effectively, it is necessary to rely on a reasonable and scientific performance evaluation method. In order to better achieve the objectives, this paper follows the following five principles in selecting indicators.

(1) Targeted principle

The ultimate goal of building a performance evaluation system for agricultural cold chain logistics enterprises is to improve the core competitiveness of the enterprise and increase the economic and social benefits of the enterprise. Therefore, in the process of performance evaluation, problems in the operation of logistics enterprises can be identified clearly, and the management of enterprises can analyze these problems in detail and find corresponding improvement measures.

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(2) Principle of Representation

The agricultural cold chain logistics system is a complex multi-stage, multi-factor process from production, storage and transport to the customer. The agricultural cold chain logistics process cannot be separated from the influence of each link, so it is needful to select a more comprehensive logistics link. Therefore, in the evaluation of the performance of agricultural cold chain logistics enterprises, it is necessary to conduct a representative evaluation on the aim of controlling the development points of the entire logistics chain.

（3）Principle of operability

Operability requires that the selected variable indicators can be obtained in quantitative or other forms, which is a very important principle. If the system of evaluation indicators is too complex or technically difficult, making it difficult or even impossible to operate, even if the selected evaluation indicators are systematic, scientific and comprehensive, they do not have research value and significance.

(4) Combination of qualitative and quantitative principles

A qualitative evaluation is usually a textual conclusion drawn by the evaluator based on previous literature or subjective ideas, which is ambiguous and subjective. Quantitative evaluation is a clearer and more objective result, as it is based on a large amount of actual data, even using quantitative formulas. Nevertheless, it is not easy to quantify qualitative indicators without absolute criteria, and if these factors are ignored, the integrity of the performance evaluation system is compromised.

(5) Combination of static and dynamic principles

The operational model of an agricultural cold chain logistics enterprise is not a static process, but a long-term, complex and dynamic process from the production to the distribution of fresh agricultural products. When evaluating the performance of such enterprises, it is significant to find a balance between the economic and long-term benefits of the enterprise and to find the best solution. Therefore, the indicators chosen should not be limited to short-term objectives but should reflect the long-term development trend of the agricultural cold chain logistics enterprise.

3.2 Selection of indicators

On the basis of following the principles of normality and scope of the index system construction ground, combined with the opinions of scholars and experts in related fields, the performance evaluation index system of agricultural cold chain logistics

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enterprises was finally formed [18]. In order to distinguish the basic structure of the whole index system, this paper identifies the first-level indicators as A, the second-level indicators as B_1... B_5, and the tertiary indicators are identified as C_1, C_2... C_{15}, as shown in Table 1.

Table 1
Factors influencing the efficiency of agricultural cold chain logistics enterprises

Target level	Code level	Indicator level
Factors influencing the evaluation of the efficiency of agricultural cold chain logistics enterprises（A）	Financial Dimension（B_1）	Total Asset Turnover Ratio（C_1）
		Increase Rate of Main Business Revenue（C_2）
		Total Assets Growth Rate（C_3）
	Customer Dimension（B_2）	Goodwill to Ratio（C_4）
		Customer-To-Customer Ratio（C_5）
		Customer Growth Rate（C_6）
	Green Dimension（B_3）	Environmental Management System Certification（C_7）
		Environmental Protection Related Information（C_8）
		Environmental Self-Monitoring Program（C_9）
	Cold Chain Operation Dimension（B_4）	Cold Storage Utilization Rate（C_{10}）
		Utilization Rate of Refrigerated Trucks（C_{11}）
		Cold chain food storage integrity（C_{12}）
	Technology Development Dimension（B_5）	Percentage of Technical Staff（C_{13}）
		Percentage of Highly Educated Personnel（C_{14}）
		R&D Investment Rate（C_{15}）

3.3 Specific evaluation indicators

3.3.1 Financial Indicators

Traditional financial accounting methods have mainly used the Wall weighting scale. At present, most financial evaluations mainly choose methods such as the balanced scorecard and economic value added for calculation. Based on these financial evaluation methods, this paper selects some relatively objective and actionable

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indicators, which mainly include the following three.

(1) Total assets turnover ratio (C_1)

Operational capacity refers to the role of the enterprise in achieving financial objectives through the allocation of internal human resources, production materials and other combinations under the constraints of the external market environment. This important indicator is used by agricultural cold chain logistics enterprises to evaluate the efficiency of the overall use of assets, which reflects the ratio of business sales revenue to total assets in a certain period.

Total asset turnover = (net operating income ÷ average total assets) x 100%

(2) Operating income growth rate (C_2)

An important indicator of a company's ability to grow is its revenue growth rate, which includes the potential to increase its strength and scale in the future. In addition, the assessment of agricultural cold chain logistics companies includes their own operating conditions, market share and forecasts of future business trends.

Operating income growth rate = (increase in operating income ÷ total operating income in the previous year) x 100%

(3) Total assets growth rate (C_3)

The growth rate of total assets reflects the percentage of the growth rate of the total assets of the agricultural cold chain logistics enterprises at the end of the year over the growth rate of the total assets at the beginning of the year, which can not only be used to measure the ability of the enterprise to accumulate capital, but also to predict the future development of the enterprise.

Total assets growth rate = (Total assets at year end Total assets at beginning of year ÷ Total assets at beginning of year) x 100%

3.3.2 Client indicators

Evaluating customer satisfaction through post-event control is an important initiative for agricultural cold chain logistics enterprises to improve customer satisfaction rates. The specific content refers to the analysis of the gap between the current service and the expected service of customers based on the feedback results of important customers, and then take corresponding measures to make timely adjustments, so that the expectations of customers can be met to the maximum extent. The aim is to find the space expected by key customers and to bring long-term economic benefits to the company. The specific indicators selected include the following three.

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（1）Percentage of goodwill (C_4)

Goodwill, also known as commercial honor, is a relationship of trust between a customer and a businessman formed by a commercial entity (i.e. a business enterprise or merchant) in the course of frequent commodity transactions. It reflects the trust of customers in agricultural cold chain logistics companies and is usually expressed as a percentage of goodwill as a percentage of total assets at the end of the current period.

Goodwill to equity ratio = (current period end ÷ total assets) x 100%

(2) Customer Share Ratio (C_5)

The customer share ratio reflects the ratio of major customers (sales revenue). , Like the customer growth rate, the main purpose of the ratio of the total sales revenue of the main customers to the total operating revenue of the agricultural cold chain logistics enterprise for the period is to examine the level of satisfaction of the main customers of this agricultural cold chain logistics enterprise.

Customer share = (Total customer sales revenue ÷ Total business revenue of the enterprise) x 100%

(3) Customer growth rate (C_6)

Customer growth rate reflects the growth rate of major customers (sales amount). By comparing the change in sales value of major customers in the current and previous periods, it examines whether the agricultural cold chain logistics enterprise is able to retain its major customers. The assumption is that the customer is satisfied with the product or service of the business, then the customer will still choose this business to spend money with. The repurchase rate is equivalent to customer feedback and provides an objective indication of the level of customer satisfaction.

Customer growth rate = (total sales revenue of major customers for the period ÷ total operating revenue of agricultural cold chain logistics enterprises) x 100%

3.3.3 Green indicators

The evaluation of an enterprise's green responsibility is based on the basic principle of "reduce, reuse and recycle", with a focus on the use of energy and resources by agricultural cold chain logistics enterprises. From the perspective of the enterprise's sustainable development, the evaluation criteria of whether the enterprise is on the list of key emission units notified by the environmental protection department, whether it discloses information related to environmental protection and whether it has an environmental management system certification are represented by the number "2" for

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yes, "1" for no and "0" for not applicable.

(1) Availability of environmental management system certification (C_7)

Environmental management system certification is responsible for the development and implementation of environmental policies and the co-ordination of environmental factors within an organization's internal management system. This certification covers the planning activities, organizational structure, departmental responsibilities, practices, procedures, processes and resources required to develop, implement, review and maintain an environmental policy.

（2）Whether to disclose information related to environmental protection（C_8）

Information related to environmental protection refers to information on environmental management, environmental accounting, resource consumption and pollutant emissions. Access to environmental information and the regulation, inspection and supervision of the environment are the rights and obligations of all citizens, social legal persons and other organizations in accordance with the provisions of the law.

（3）Environmental self-monitoring programs（C_9）

The environmental self-monitoring program refers to the implementation of the Management Measures for Self-monitoring and Information Disclosure of State Key Monitoring Enterprises and the Management Measures for Supervision, Monitoring and Information Disclosure of State Key Monitoring Enterprises for enterprises. It is to strengthen the management of pollutant emission reduction of enterprises, fulfill the social responsibility of enterprises and disclose the self-monitoring situation of enterprises to the society.

3.3.4 Cold chain operational indicators

Each logistics link directly affects the operational performance of agricultural cold chain logistics enterprises. In comparison with other industrial logistics, the complexity of fresh agricultural products determines that they must always be in a cold environment in all aspects, which in turn requires a higher and more specific use of cold chain equipment, which can lead to a significant proportion of the total logistics costs occupied by refrigerated transport costs. The cold chain operational indicators selected for this paper include the following five.

（1）Cold chain stock quantity ratio（C_{10}）

Cold chain inventory quantity refers to the number of items kept by an agricultural cold chain logistics enterprise within a certain period of time. In this paper, we use the

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management capacity of the staff of the agricultural products cold chain logistics enterprise to express, that is, the number of people managed in the enterprise instead of the amount of inventory.

（2）Reefer utilization rate（C_{11}）

The use of refrigerated trucks is a key functional element essential to the operational aspects of agricultural cold chain logistics. It is specifically expressed as a proportion of the cost of refrigerated transport to the cost of sales, which can be expressed as the cost of refrigerated transport divided by the cost of sales.

Reefer utilization rate = (Refrigerated transport costs ÷ Cost of sales) x 100%

（3）Cold chain food storage completeness rate（C_{12}）

The integrity rate of food storage, i.e., the integrity rate of agricultural products in the storage and custody process. It can be expressed as the average stock minus the total amount of goods with defects and deterioration divided by the average stock.

Food storage integrity rate = (average inventory - amount of damaged and deteriorated goods) / average inventory x 100%

3.3.5 Technology Development Indicators

From the perspective of the long-term development of agricultural products cold chain logistics enterprises, research and development, technical personnel and high-quality personnel are indispensable. On the one hand, the size of the investment in research and development reflects the importance that enterprises attach to the development of science and technology; on the other hand, highly qualified personnel and technicians together reflect the comprehensive strength of the enterprise staff.

（1）Percentage of technical staff（C_{13}）

Technicians are employees who have special professional skills and are mainly engaged in skilled social work, for which they receive relatively high remuneration. For agricultural cold chain logistics companies, technical personnel, especially professional technicians, are the basis for the growth of the company and are therefore valued by the company.

Percentage of technical staff = (number of technical staff ÷ total number of employees) x 100%

（2）Percentage of highly educated staff（C_{14}）

Educational qualifications are issued by public schools, public schools and other educational institutions that have been approved by the educational administration to implement education to upgrade qualifications and are authorized by the state to issue academic certificates. A highly qualified person is one who has received a high level of

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education, usually with a graduate degree of Bachelor, Master or even higher.

Percentage of highly educated staff = (number of highly educated personnel ÷ total number of employees) x 100%

（3）R&D investment rate（C_{15}）

To improve their competitiveness and growth, agricultural cold chain logistics enterprises must continuously innovate, develop and improve cold chain technology and equipment, so as to effectively save operational costs, gain more market share and maintain healthy development.

R&D investment rate = (technology and equipment investment cost ÷ total investment cost) x 100%

4. Model construction

DEMATEL, known as the Decision Making Test and Evaluation Test method, mainly uses matrix calculations and graph theory concepts. In the constructed matrix data, the logical relationships between the elements of the system and the direct influence matrix, the degree of influence of each element on the other elements and the degree of being influenced can be calculated, thus calculating the degree of cause and centrality of each element, which can be used as a basis for constructing a model to determine the inter-elements. This is used as the basis for the construction of the model, which determines the causal relationships between the elements and the position of each element in the system.

DEMATEL Model, the overall flow is shown in Figure 1.

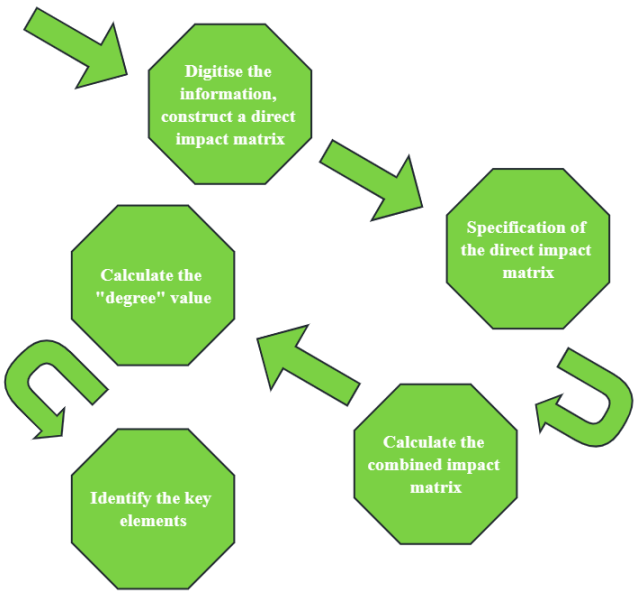

Fig. 1. DEMATEL flow chart

The specific steps are as follows.

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(a) Step 1: Digitize the information expressed by the indicators and construct a direct impact matrix.

The concept of intuitive ambiguity is as follows.

Definition 3.1: Let $F = (f_1, f_2, f_3, \cdots, f_n)$ be the set of options, and the decision maker compares n options between two and constructs a judgment matrix) $A = [a_{ij}]_{n\times n}$, $a_{ij} = (u_{ij}, v_{ij}, \pi_{ij}), i, j = 1,2,3, \cdots, n$.Where, u_{ij} and v_{ij} denote the decision maker's degree of preference for options f_i and f_j, respectively. f_i and f_j are compared. π_{ij} denotes the degree of hesitation of the decision maker towards the two options, $\mu_{ij}, v_{ij} \in [0,1]$, $\pi_{ij} = 1 - \mu_{ij} - v_{ij}$, at this point, the matrix A is called the intuitionistic fuzzy judgment matrix.

A risk preference factor $\eta \in [-1,1]$ is imported into the calculation and when $\eta < 0$, the decision maker is risk averse. When $\eta > 0$, the decision maker is risk neutral; when $\eta > 0$, the decision maker is risk chaser.

Definition 3.2: Suppose there exists an intuitionistic fuzzy number $\alpha = (\mu_\alpha, v_\alpha)$ with $\pi_\alpha = 1 - \mu_\alpha - v_\alpha$ as its hesitation, then its accuracy function is 0.

It is accepted that a single master gives a fluffy assessment of the thing about markers based on their hazard inclinations, a two-by-two comparison is made between the markers, and after that the set of score capacities get to be an instinctive fluffy inclination choice, changing over the fluffy numbers into genuine numbers. At this organize, in arrange to meet the information necessities of the beginning framework of DEMATEL, the esteem of the corner to corner of the matrix is taken as 0, and after that after normalized distortion, the coordinate impact framework based on fluffy data is gotten S:

$$A[a_{ij}]_{n\times n} = \begin{bmatrix} (\mu_{11}, v_{11}, \pi_{11}) & (\mu_{12}, v_{12}, \pi_{12}) & \cdots & (\mu_{1n}, v_{1n}, \pi_{1n}) \\ (\mu_{21}, v_{21}, \pi_{21}) & (\mu_{22}, v_{22}, \pi_{22}) & \cdots & (\mu_{2n}, v_{2n}, \pi_{2n}) \\ \vdots & \vdots & \ddots & \vdots \\ (\mu_{n1}, v_{n1}, \pi_{n1}) & (\mu_{n2}, v_{n2}, \pi_{n2}) & \cdots & (\mu_{nn}, v_{nn}, \pi_{nn}) \end{bmatrix}$$

$$\xrightarrow{h^\eta(a_{ij})} H[h_{ij}]_{n\times n} = \begin{bmatrix} 0 & h_{12} & \cdots & h_{1n} \\ h_{21} & 0 & \cdots & h_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ h_{n1} & h_{n2} & \cdots & 0 \end{bmatrix}$$

Assuming that there are m experts in the expert team, denoted as $G = (g_1, g_2, g_3, \cdots, g_m)$, the evaluation of the experts needs to be synthesized and each expert is given the corresponding weight λ_k, $\lambda = (\lambda_1, \lambda_2, \lambda_3, \cdots, \lambda_m)$is the set of all decision experts$g_k(k = 1,2,3, \cdots, m)$,weights to obtain the integrated intuitionistic fuzzy preference decision matrix for the decision outcome of the expert team.

$$Y[y_{ij}]_{n\times n} = \sum_{k=1}^{m} \lambda_k H^{(k)}$$

Among other things, $y_{ij} = \sum_{k=1}^{m} \lambda_k h_{ij}^{(k)}, i, j = 1,2,3, \cdots, n$

(b) Step 2: Specification of the direct impact matrix N.

$$N = \left(\frac{y_{ij}}{\max\limits_{1\le i\le n}\left(\sum_j^n S_{ij}\right)}\right)_{n\times n}$$

(c) Step 3: Calculate the combined impact matrix T.

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$$T = N(I - N)^{-1}$$

Among other things,

I stand for a unit matrix, i.e., a matrix with a diagonal of 1 and other values of 0.

$(I - N)^{-1}$ is the inverse matrix of (I-N).

$T = [t_{ij}]_{n\times n}$ where t_{ij} indicates the extent to which indicator j is directly or indirectly influenced by indicator i.

(d) Step 4: Calculate the four "degree" values in the indicator.

Degree of influence. The degree of influence is the combined influence of the corresponding indicators in each row of the integrated influence matrix on the rest of the indicators, calculated as D, then $D = (D_1, D_2, D_3, \cdots, D_n)$, where $D_i = \sum_{j=1}^{n} t_{ij}, (i = 1,2,3, \cdots, n)$.

Influenced degree. The degree of influence is the combined influence of each column in the composite influence matrix on the rest of the indicators, measured as C, then $C = (C_1, C_2, C_3, \cdots, C_n)$, where$C_i = \sum_{j=1}^{n} t_{ji}, (i = 1,2,3, \cdots, n)$.

Centrality. Centrality reflects the importance of an indicator within the overall indicator and is measured as $M_i = D_i + C_i$

Degree of cause. The degree of cause indicates the degree of influence of the indicator on the remaining indicators in the overall indicator and is calculated as $R_i = D_i - C_i$.

Step 5: Identify the key elements that will influence its development.

Effective decision-making solutions are developed based on core factors and can effectively control and influence the outcome of decisions.

5. Empirical analysis

5.1 Intuitive fuzzy evaluation

Based on the indicator set $F = (F_1, F_2, F_3, \cdots, F_{15})$, five experts compared them two by two, and the experts' weights were equally distributed because of the uncertainty of their linguistic validity.

Drawing on Li Mei's work [19], the experts' languages {very unsatisfactory (0.05,0.95,0.00), unsatisfactory (0.25,0.65,0.10), average (0.50,0.40,0.10), satisfactory (0.75,0.15,0.10), and very satisfactory (0.95,0.05,0.00)} were data fuzzified to the intuitive fuzzy numbers were obtained [20], and the original matrix was constructed from them. All data calculations and graphical manipulations were processed in the Python 3.7 environment and are shown in Table 2.

Table 2
Expert team bias for risk indicators

U	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}
C_1	0	0.15	0.65	0.40	0.40	0.95	0.40	0.15	0.65	0.15	0.65	0.95	0.65	0.15	0.65
C_2	0.65	0	0.40	0.15	0.65	0.40	0.95	0.15	0.40	0.65	0.95	0.15	0.65	0.15	0.95
C_3	0.15	0.40	0	0.65	0.40	0.15	0.65	0.95	0.40	0.15	0.95	0.65	0.15	0.95	0.15
C_4	0.40	0.65	0.15	0	0.65	0.15	0.95	0.40	0.40	0.15	0.95	0.65	0.65	0.40	0.15
C_5	0.40	0.15	0.40	0.15	0	0.40	0.95	0.65	0.40	0.40	0.65	0.15	0.95	0.95	0.15

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C_6	0.05	0.40	0.65	0.65	0.40	0	0.40	0.15	0.95	0.65	0.15	0.40	0.95	0.65	0.15
C_7	0.40	0.05	0.15	0.05	0.05	0.40	0	0.40	0.15	0.40	0.95	0.15	0.65	0.15	0.95
C_8	0.65	0.65	0.05	0.40	0.15	0.65	0.40	0	0.40	0.95	0.15	0.65	0.65	0.95	0.40
C_9	0.15	0.40	0.40	0.40	0.40	0.05	0.65	0.40	0	0.40	0.95	0.65	0.15	0.40	0.15
C_{10}	0.65	0.15	0.65	0.65	0.40	0.15	0.40	0.05	0.40	0	0.95	0.40	0.65	0.15	0.95
C_{11}	0.15	0.05	0.05	0.05	0.15	0.65	0.05	0.65	0.05	0.05	0	0.65	0.95	0.40	0.15
C_{12}	0.05	0.65	0.15	0.15	0.65	0.40	0.65	0.15	0.15	0.40	0.15	0	0.40	0.65	0.95
C_{13}	0.15	0.15	0.65	0.15	0.05	0.05	0.15	0.15	0.65	0.15	0.05	0.40	0	0.65	0.40
C_{14}	0.65	0.65	0.05	0.40	0.05	0.15	0.65	0.05	0.40	0.65	0.40	0.15	0.15	0	0.15
C_{15}	0.15	0.05	0.65	0.65	0.65	0.65	0.05	0.40	0.65	0.05	0.65	0.05	0.40	0.65	0

5.2 Analysis of factors influencing the efficiency of agricultural cold chain logistics enterprises

The degree of impact, effeteness, centrality and causality were calculated for each pointer agreeing to the DEMATEL technique, as appeared in Table 3.

Table 3

Degree of influence, degree of being influenced, degree of centrality and degree of cause of factors influencing the efficiency of agri-food cold chain logistics enterprises

Factors influence	Degree of impact D	Degree of being influenced C	Centrality M	Degree of cause R
C_1	55.81	57.07	112.88	-1.2648
C_2	57.31	57.31	114.62	0.0002
C_3	57.30	57.31	114.61	-0.0034
C_4	57.09	57.09	114.17	0.0001
C_5	57.30	57.30	114.60	0.0036
C_6	57.29	57.29	114.58	-0.0072
C_7	58.22	57.75	115.97	0.4676
C_8	57.30	57.29	114.59	0.0070
C_9	57.08	57.08	114.16	-0.0035
C_{10}	57.30	56.05	113.36	1.2539
C_{11}	58.19	58.65	116.84	-0.4536
C_{12}	57.07	57.07	114.14	-0.0070
C_{13}	57.30	57.31	114.61	-0.0035
C_{14}	57.30	57.30	114.59	0.0001
C_{15}	57.53	57.51	115.04	0.0105

As centrality reflects the significance of each pointer, encourage significance bends influencing the effectiveness of agrarian cold chain coordination endeavors are plotted based on their values, as appeared in Figure 2.

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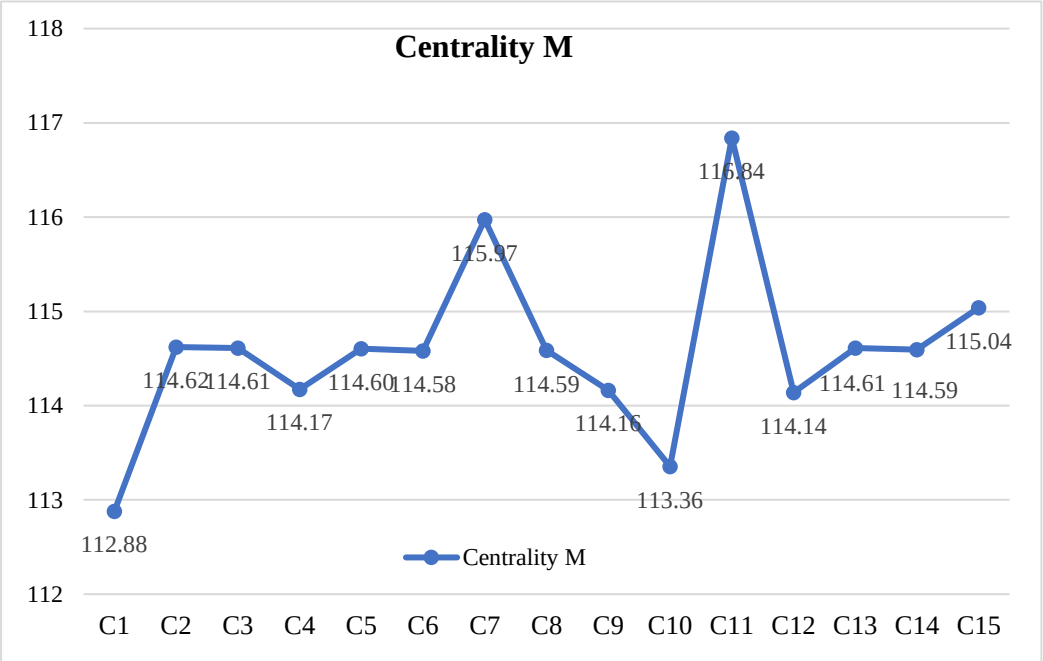

Fig. 2. Importance of factors influencing the efficiency of agricultural cold chain logistics enterprises

After arranging the centrality of the indicators in Figure 2 in descending order and dividing them according to key factors, central factors and important factors, it can be seen as follows.

(a) The three indicators of utilization rate of refrigerated trucks C_{11}, environmental management system certification C_7 and R&D investment rate C_{15} are the key factors affecting the efficiency of agricultural cold chain logistics enterprises, indicating that utilization rate of refrigerated trucks and environmental management system certification as well as investment in developing new products are the key factors determining the efficiency of agricultural cold chain logistics enterprises.

(b) Business revenue growth rate C_2, technical staff ratio C_{13}, total assets growth rate C_3, customer share ratio C_5, highly educated staff ratio C_{14} These five indicators are the central factors affecting the efficiency of agricultural cold chain logistics enterprises, indicating that business revenue growth rate and total assets growth rate are the financial guarantee for enterprises to obtain economic benefits, customer share ratio is an important performance to meet customer demand, while the share of technical staff and highly educated staff reflects the scientific and technological support needed for the long-term development of enterprises.

(c) The seven indicators of environmental protection-related information, customer growth rate, environmental self-monitoring program, food storage integrity rate, cold storage utilization rate and total asset turnover rate are important factors affecting the efficiency of agricultural cold chain logistics enterprises, i.e. environmental protection-related information and environmental self-monitoring program inform the long-term green development of enterprises, customer growth rate and goodwill ratio reflect the service quality of enterprises, food storage integrity rate and cold storage utilization rate reflect the safety of cold chain transportation process and the degree of cold storage utilization, while total asset turnover rate is an important factor affecting the financial aspect of enterprises.

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Based on the positive and negative values of the cause degree they were divided into cause-and-effect factors and further obtained a cause-effect diagram of the efficiency of agricultural cold chain logistics enterprises, as shown in Figure 3.

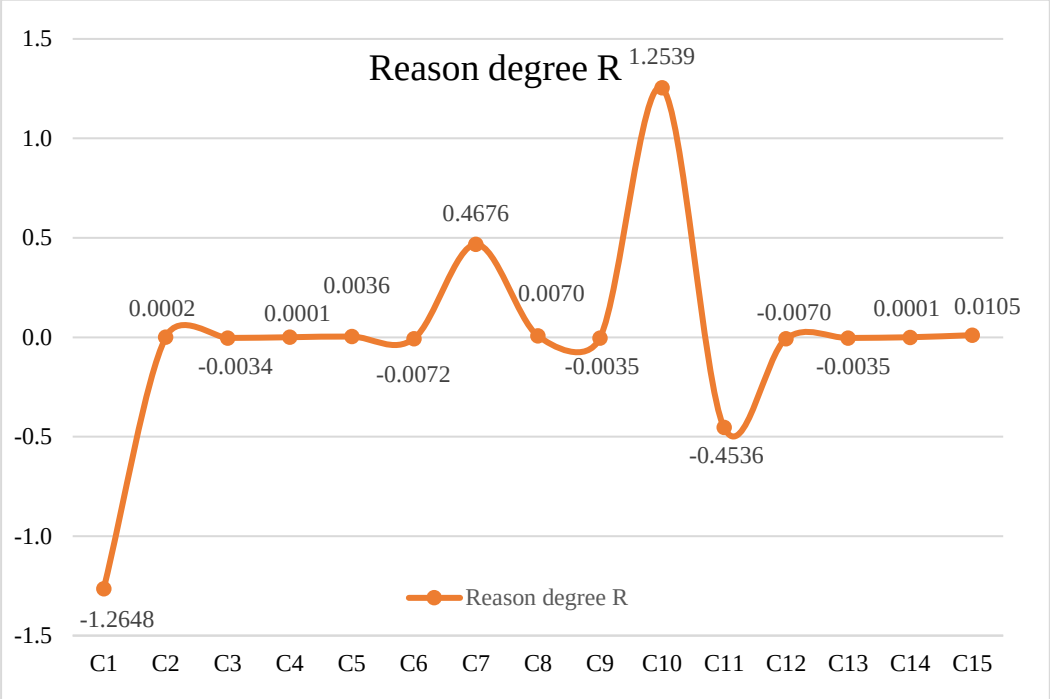

Fig.3. Cause-and-effect diagram of factors influencing the efficiency of agricultural cold chain logistics enterprises.

According to the content of Figure 3, the positive reasons are arranged in descending order, and the results are: cold storage utilization rate, environmental management system certification, R&D investment rate, environmental protection-related information, customer share, business income growth rate, goodwill share, and the share of highly educated personnel, which indicate that in the whole index system, these factors accelerate or promote the improvement of the efficiency of agricultural cold chain logistics enterprises in a positive way; the negative reasons are degree in descending order, the results of which are: total asset turnover rate, refrigerated truck utilization rate, customer growth rate, food storage integrity rate, technical staff ratio, environmental self-monitoring program, total asset growth rate of these 7 indicators, indicating that these factors are first under the influence of the above factors, and then have other effects on the efficiency of agricultural products cold chain logistics enterprises.

The cause factor is a direct factor for the efficiency improvement of agricultural cold chain logistics enterprises, which can not only promote the efficiency improvement of agricultural cold chain logistics enterprises from the positive side, but also influence the improvement of enterprise efficiency evaluation system from the side. Therefore, the later development should pay more attention to the cause factor - by improving the cause factor to influence the result factor and further improve the efficiency of agricultural cold chain logistics enterprises. For example, by optimizing the organizational structure and business processes, fully integrating the internal resources of the enterprise, strengthening the coordination between various departments, improving the efficiency

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of the enterprise and building the core competitiveness of the enterprise; improving the quality control of the market and green environmental protection norms, improving the quality production of cold chain food, and incorporating the basic industry standards of the agricultural cold chain into the food market access system to ensure the quality and safety of cold chain food; actively strengthening internal talent training We are also concerned about the introduction of external talents and are focusing on training, attracting and retaining talents.

5.3 Case-based empirical evidence - the example of a W-listed company

5.3.1 Selection of evaluation subjects

(a) Current development of W-listed companies

Relying on its location as a transportation hub in the Central Lu region and the many customers with cold chain transportation needs in the Central Lu region, the W-listed company has maintained long-term cooperative relationships with some of its well-known customers to provide quality third-party cold chain logistics transportation, warehousing, sorting and general logistics services. The company mainly serves fresh food, seasonal vegetables, other production and processing plants, as well as large supermarkets, fresh food retailers and restaurant chains. The company's services are sold on a "direct sales" basis to generate revenue, profit and cash flow. The company is currently developing its supply chain business by focusing on the cold chain business and capturing the core points of the cold chain industry to create a diversified industry.

(b) Determining the selection of listed company W

The sample objects selected for evaluation in this paper were obtained from CSMAR and CNINF, then the publicly disclosed "annual report" information of logistics enterprises was obtained and data queries as well as data collation were conducted, and finally listed company W were selected as the research objects.

By analyzing the data of listed agricultural cold chain logistics enterprises in the last three years (2019-2021) of listed company W, quantitative three-level indicators (C_1-C_{15}) were used to evaluate agricultural cold chain logistics enterprises on the basis of establishing a performance evaluation system for agricultural cold chain logistics enterprises, as shown in Table 4.

Table 4
W Raw values of evaluation indicators for listed companies in the last 3 years

Indicators	Influence Factors	Year		
		2019	2020	2021
C_1	Total Asset Turnover Ratio	16.10%	18.28%	5.91%
C_2	Operating income growth rate	31.34%	19.50%	-21.78%
C_3	Total Assets Growth Rate	50.97%	74.10%	140.39%
C_4	Goodwill Ratio	0.00%	0.00%	0.00%
C_5	Customer Ratio	52.94%	51.88%	50.46%
C_6	Customer growth rate	122.31%	17.09%	-23.91%
C_7	Environmental Management System	1.00%	1.00%	1.00%

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	Certification			
C_8	Environmental Protection Related Information	1.00%	1.00%	2.00%
C_9	Environmental self-monitoring programmed	1.00%	1.00%	1.00%
C_{10}	Cold Storage Utilization Rate	16.13%	16.00%	7.69%
C_{11}	Utilization rate of refrigerated trucks	-15.65%	7.84%	7.01%
C_{12}	Food storage integrity rate	-2.33%	1.42%	-15.67%
C_{13}	Percentage of technical staff	12.90%	8.00%	3.85%
C_{14}	Percentage of highly educated personnel	12.90%	16%	15.38%
C_{15}	R&D investment rate	0.00%	0.00%	0.00%

5.3.2 Dimension lessness of indicators

(a) step 1: the data are dimensionless. For the positive indicator X_{ij}, it can be processed according to the following formula.

$$X'_{ij} = \frac{X_{ij} - m_j}{M_j - m_j} \qquad \text{…（5- 1）}$$

Where M_j is the maximum value of X_{ij} and m_j is the minimum value of X_{ij}.

(b) step 2: the effect of zeros and negative values is eliminated and the whole is panned.

In order to obtain meaningful results, the zeros and negative numbers should be removed from the data, and the dimensionless data should be shifted wholly by using the formula $X_{ij} = X_{ij} + \alpha$. The smallest value of α should be the closest to X_{ij} to ensure that the value of α is sufficiently small, as the value of α is too large to destroy the intrinsic pattern of the original data. Considering that the logarithm must be more than 0, this paper takes α= 0.0001, meaning an overall translation to the right of 0.0001 units.

$$X_{ij} = X_{ij} + 0.0001 \qquad \text{...（5- 2）}$$

(c) Step 3: Results of dimensionless metrics processing for W-listed companies

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Table 5

Numerator evaluation values for the last 3 years for W-listed companies

Indicator factors	Year			Average	Rank
	2019	2020	2021		
C_1	0.8239	1.0001	0.0001	0.6080	3
C_2	1.0001	0.7772	0.0001	0.5925	6
C_3	0.0001	0.2588	1.0001	0.4197	10
C_4	0.0001	0.0001	0.0001	0.0001	12
C_5	1.0001	0.5727	0.0001	0.5243	7
C_6	1.0001	0.2805	0.0001	0.4269	9
C_7	0.0001	0.0001	0.0001	0.0001	12
C_8	0.0001	0.0001	1.0001	0.3334	11
C_9	0.0001	0.0001	0.0001	0.0001	12
C_{10}	1.0001	0.9847	0.0001	0.6616	1
C_{11}	0.0001	1.0001	0.9648	0.6550	2
C_{12}	0.7807	1.0001	0.0001	0.5936	5
C_{13}	1.0001	0.4587	0.0001	0.4863	8
C_{14}	0.0001	1.0001	0.8001	0.6001	4
C_{15}	0.0001	0.0001	0.0001	0.0001	12

Table 5 shows the results of the dimensionless treatment of the evaluation indicators of W-listed companies for the last three years (2019-2021). The quantitative indicators are not comparable as they are measured in different units. Therefore, after the actual values of the indicators are determined, the dimensionless treatment of the indicators must be carried out in order to solve the problem of comprehensibility among the indicators.

Firstly, based on the ranking of the mean values of C_1, C_2...C_{15} indicators, it can be seen that: C_{10} ranks first, C_{11} ranks second and C_1 ranks third, and these three indicators belong to the key factor indicators; secondly, according to the text content of section 3.2 of this paper, the three key indicators are C_{14}, C_{12} and C_2 in descending order of centrality; finally, the remaining 5 indicators, C_5, C_{13}, C_6, C_3 and C_8, are the central factors affecting the efficiency of agricultural cold chain logistics enterprises. To sum up, C_{10}, C_{11} and C_{12} are also classified as cold chain operation indicators, while C_1, C_2 and C_3 are also financial indicators.

Conclusions

This paper takes W listed enterprises as an example, through the average ranking of the dimensionless indicators in the past 3 years (2019-2021) can be obtained: C_{10} (cold storage utilization rate) ranked first, C_{11} (refrigerated truck utilization rate) ranked second, C_1 (total asset turnover rate) ranked third, the above 3 are the key factors; secondly, C_{14} (proportion of highly educated personnel) ranked fourth, C_{12} (cold chain food storage completion rate) ranked fifth, C_2 (operating income growth rate) ranked sixth, C_5 (customer share ratio) ranked seventh, C_{13} (technical staff share) ranked eighth these five indicators, the above five are the central factors;

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finally, C_5, C_{13}, C_6, C_3, C_8, C_4, C_7, C_9 and C_{15} are important factors.

(1) Cross-sectional analysis: Among the C_1-C_3 factor indicators, C_1 has the largest value of total asset turnover, indicating that it is the core factor in financial indicators; among C_4-C_6, C_5 has the largest value of customer share, indicating that it is the core factor in customer indicators; among C_7-C_9 factor indicators, C_8 has the largest value of environmental protection-related information, indicating that it is the core factor in green environmental protection; while among C_{10}-C_{12} factor indicators, C_{10} and C_{11} have the largest value, indicating that it is the core factor in technology development indicators. C_{12} factor indicators, C_{10} and C_{11} are the most critical factors, and among the C_{13}-C_{15} factor indicators, C14 has the largest value, indicating that it is the core factor in science and technology development indicators.

(2) Vertical analysis: C_{10}, C_{11} and C_{12} belong to the cold chain operation indicator layer, while C_1, C_2 and C_3 belong to the financial indicator layer.

(3) Comprehensive analysis: In terms of the centrality and causality of the factors influencing the efficiency of Chinese agricultural cold chain logistics enterprises, taking W listed enterprises as an example is in line with the logic of this paper's research. In other words, the research process and research results based on intuitionistic fuzzy evaluation and DEMATEL method to calculate the centrality and cause degree of each indicator are desirable.

Although the research method used in this paper can identify the key factors that will identify the efficiency of agricultural cold chain logistics enterprises to a certain extent, the research scope is limited to agricultural cold chain enterprises, and the accuracy of its research results needs to be further verified and improved. At the same time, in the experimental results, the more important factors of both enterprises belong to the green indicator layer and the financial indicator layer, which shows that environment and finance are extremely important for the sustainable development of enterprises. Therefore, the focus of future research will be extended to energy, environmental protection, finance and other related areas. In terms of the evaluation index system, as the internal and external environment of the enterprise keeps changing, the corresponding enterprise performance evaluation indexes will also change, so the evaluation index system can be dynamically analyzed based on the time dimension for the sake of finding more suitable indicators, so as to better evaluate the development level of the agricultural cold chain logistics industry.

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