Study on Influencing Factors of Cold Chain Logistics Supply Chain for Fresh Agricultural Products

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Abstract. Due to the perishable and fragile characteristics of agricultural products, cold chain logistics of agricultural products is more specific than general logistics activities. This paper proposes the combination of the interval gray number DEMATEL method, which solves the problem that the traditional DEMATEL method is too certain when scoring and ignores the differences of different enterprises. At the same time, the flexibility of interval gray number is used to solve the ambiguity of factor selection in evaluation. Deterministic, build a more flexible and realistic Grey-DEMATEL method decision model. Based on the interval gray number theory, the relationship matrix of the influencing factors for fresh agricultural products cold chain logistics supply chain is established. The comprehensive impact matrix of the cold chain logistics supply chain of fresh agricultural products was solved by MATLAB, and the cold chain logistics supply chain were quantitatively analyzed. The key influencing factors of the supply chain have laid the foundation for further optimizing the cold chain logistics supply chain of fresh produce.

Keywords: Cold chain logistics supply chain · Fresh agricultural products · Influencing factors

1 Introduction

Modern Industrial Engineering is the project which is gradually formed and developed on the basis of Production Manufacturing Management and System Engineering. It can be applied to services, manufacturing, food, medical, logistics etc. [1].

With the development of economy and the improvement of human living standard, increasingly attention has focused on the freshness and safety of food.

Low fresh food of loss rate is the foundation to ensure the freshness and quality safety of fresh food [2, 3]. However, the construction of fresh agricultural products cold chain logistics supply chain system has just started. It has faced the various problems like backward infrastructure, incomplete cold chain logistics supply chain system, low industry level, low marketization and different standards [4–6]. Although scholars have put forward many corresponding to the solutions, the lack of prioritization of these problems has greatly reduced the practical significance of lots of measures. Therefore,

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this paper combines DEMATEL (Decision making Trial and Evaluation Laboratory) method with interval grey number to construct Grey-DEMATEL model to analyze the influencing factors of cold chain logistics supply chain for fresh agricultural products.

Fang Kai and Zhong Chengbao [7] has used three-stage data envelopment analysis model to research the efficiency of China's cold chain logistics enterprises. Finally, they found that the main obstacle to their development was scale inefficiency. They put forward five related improvement suggestions based on that. Yuan Xueguo and Zou Ping [7] analyzed the development situation of China's cold chain logistics industry. The study shows that there are many problems in its development and then put forward corresponding countermeasures and suggestions according to the problems which need to be solved. The factors affected the development of a certain events from various aspects and the respective influencing factors are interrelated and interacted with each other. The status and influencing degree of the respective influencing factors are quite different among them. Therefore, from the point of view of System Engineering, this paper uses Grey-DEMATEL method model to analyze fresh agricultural products cold logistics chain supply chain and determine the hierarchical position and influencing relationship of the influencing factors on it.

2 Model Construction

A. *Construction of Key Influencing Factor Index System of Cold Chain Logistics Supply Chain for Fresh Agricultural Products*

This paper uses brainstorming method to analyze influencing factors of fresh agricultural products with cold chain logistics supply chain [9]. Screen 17 factors from five aspects which are vulnerability factors, personnel factors, management factors, facility factors and cost factors. Grey-DEMATEL method was used to establish the index system of key factors for fresh agricultural products cold chain logistics supply chain. There are 5 first-level indexes and 17 second-level index (the indexes are represented by $F_1, F_2, \cdots, F_{17}$.) in the index system. The key influencing factors index system fresh agricultural products cold chain logistics supply chain established in this paper is shown in Fig. 1.

B. *Grey Number Research Method*

The grey number used in this paper is interval grey number [10, 11], which is recorded as $\otimes\lambda \in [\underline{\otimes}\lambda, \overline{\otimes}\lambda]$. The $\underline{\otimes}\lambda$ is lower limited of $\otimes\lambda$, $\overline{\otimes}\lambda$ is upper limited of $\otimes\lambda$. The detailed operation steps are as follows:

$$\otimes\boldsymbol{\lambda}_1 + \otimes\boldsymbol{\lambda}_2 = \left[\underline{\boldsymbol{\lambda}_1} + \underline{\boldsymbol{\lambda}_2}, \overline{\boldsymbol{\lambda}_1} + \overline{\boldsymbol{\lambda}_2}\right] \tag{1}$$

$$\otimes\boldsymbol{\lambda}_1 - \otimes\boldsymbol{\lambda}_2 = \left[\underline{\boldsymbol{\lambda}_1} - \overline{\boldsymbol{\lambda}_2}, \overline{\boldsymbol{\lambda}_1} - \underline{\boldsymbol{\lambda}_2}\right] \tag{2}$$

$$\begin{aligned} \otimes\lambda_1 \times \otimes\lambda_2 = [&min\left(\underline{\lambda_1\lambda_2}, \underline{\lambda_1}\overline{\lambda_2}, \overline{\lambda_1}\underline{\lambda_2}, \overline{\lambda_1\lambda_2}\right), \\ &max\left(\underline{\lambda_1\lambda_2}, \underline{\lambda_1}\overline{\lambda_2}, \overline{\lambda_1}\underline{\lambda_2}, \overline{\lambda_1\lambda_2}\right)] \end{aligned} \tag{3}$$

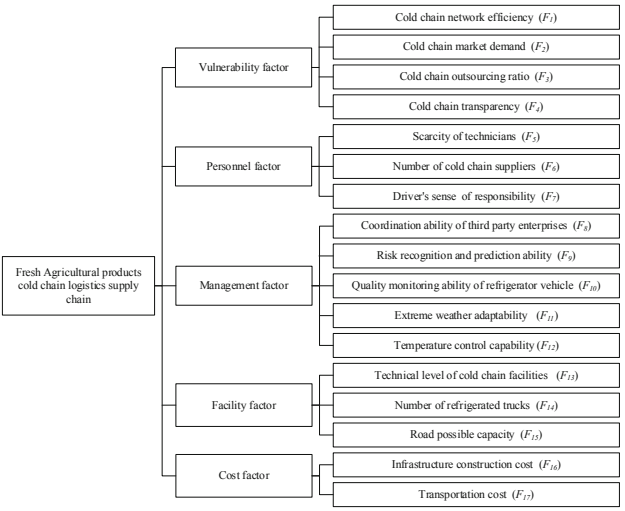

Fig. 1. Influencing factors index system of fresh agricultural products cold chain logistics supply chain

$$\otimes\lambda_1 \div \otimes\lambda_2 = \left[\underline{\lambda_1}, \overline{\lambda_1}\right] \times \left[\frac{1}{\underline{\lambda_2}}, \frac{1}{\overline{\lambda_2}}\right] \tag{4}$$

Considering that experts usually have a certain degree of fuzziness and uncertainty when they scored. The formula $\otimes\lambda_{ij}^k$ has been defined as the score of expert K for evaluating the influencing of influencing factor i on influencing factor j, and the $\otimes\lambda_{ij}^k \in \left[\underline{\otimes}\lambda_{ij}^k, \overline{\otimes}\lambda_{ij}^k\right]$. The clarificatory process for semantic evaluation variables for experts as follows:

(1) Standardize the upper and lower limit of grey number

$$\begin{aligned} \overline{\otimes}\tilde{\lambda}_{ij}^k &= \frac{\overline{\otimes}\lambda_{ij}^k - min\overline{\otimes}\lambda_{ij}^k}{\Delta_{min}^{max}} \\ \underline{\otimes}\tilde{\lambda}_{ij}^k &= \left(\underline{\otimes}\lambda_{ij}^k - min\underline{\otimes}\lambda_{ij}^k\right)/\Delta_{min}^{max} \\ \text{and, } \Delta_{min}^{max} &= max\overline{\otimes}\tilde{\lambda}_{ij}^k - min\underline{\otimes}\lambda_{ij}^k \end{aligned} \tag{5}$$

(2) Clear processing of standardized grey number

$$Y_{ij}^k = \frac{\left\{\underline{\otimes}\tilde{\lambda}_{ij}^k\left(1 - \underline{\otimes}\tilde{\lambda}_{ij}^k\right) + \left(\overline{\otimes}\lambda_{ij}^k \times \overline{\otimes}\lambda_{ij}^k\right)\right\}}{\left(1 - \underline{\otimes}\tilde{\lambda}_{ij}^k + \overline{\otimes}\lambda_{ij}^k\right)} \tag{6}$$

(3) Work out the clarity value

$$Z_{ij}^{k} = min \underline{\otimes} \lambda_{ij}^{k} + Y_{ij}^{k} \Delta_{min}^{max} \tag{7}$$

C. *DEMATEL Method*

This method is proposed by the Bottelle Institute of the United States to apply graph theory and matrix theory to effectively analyze the logical relationship between various factors. The specific operation steps are as follows:

(1) Construct influencing factor matrix. Use 0–5 to represent the relationships among the influencing factors. Detailed steps as follows:

$$a_{ij} = \begin{cases} 0 & \text{no influence between two} \\ 1 & \text{slight influence between two} \\ 2 & \text{low influence between two} \\ 3 & \text{obvious influence between two} \\ 4 & \text{great influence between two} \end{cases}$$

(2) Establish influencing factor matrix A. According to the expert's evaluation results to get directly influencing factor matrix A. Matrix A indicates the influencing degree of row factor i on column factor j.

$$A = (a_{ij})_{n \times n} = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ a_{n1} & a_{n2} & \dots & a_{nn} \end{bmatrix}$$

(3) Standardize matrix A. Sum of the rows of matrix A, *max* means the maximum of rows sum, let $X = A/max$.

(4) Calculate the comprehensive influencing matrix T. $T = X(I - X)^{-1}$

(5) Analyze influencing factors. According to the elements T_{ij} from the comprehensive influencing matrix to determine the relationships between the influencing factors. To get every element's influencing degree R_i, influenced degree D_j, centrality degree P_i and causality degree E_i [12, 13].

D. *Grey-DEMATEL Method*

In order to solve the uncertainty and fuzziness of factor selection in evaluation. This paper combines DEMATEL method with interval grey number to establish Grey-DETEMAL method decision model which is practical and flexible. Its operation steps are as follows:

(1) Establish fresh agricultural products cold chain logistics supply chain relationship matrix based on interval Grey Number Theory. The relationships between influencing factor i and influencing factor j are devided five kinds which are direct influence, weak influence, lower influence, obvious influence and great influence recoded as N, W, L, H and VH, the interval grey number in detail (see Table 1).

Table 1. Semantic variable of expert's evaluation

Semantic variable	Interval grey number
Direct influence (N)	[0, 0]
Weak influence (W)	[0, 0.25]
Lower influence (L)	[0.25, 0.5]
Obvious influence (H)	[0.5, 0.75]
Great influence (VH)	[0.75, 1]

The experts' evaluations would correspond change with experts' different attention on fresh agricultural products cold chain logistics supply chain. Therefore, the weight value is given the fuzziness characteristic of interval grey number (see Table 2).

Table 2. Semantic variable of expert's weight

Semantic variable	Interval grey number
Unimportant	[0, 0.3]
A little important	[0.3, 0.5]
Important	[0.4, 0.7]
More important	[0.5, 0.9]
Great important	[0.9,1]

(2) Establish the grey number matrix. Transformed the formed grey number matrix to get grey number matrix $\otimes\lambda$ according to Table 1.

(3) Clear processing of the grey number matrix according to formula (5), (6), (7), and used the formula (8) to calculate the weighted weight matrix Z. Z_{ij} represents the element which lies in column j and row i of the weight matrix.

$$Z_{ij} = \omega_1 Z_{ij}^1 + \omega_2 Z_{ij}^2 + \ldots + \omega_n Z_{ij}^n$$

ω_n represents the weight proportion of element Z_{ij}

$$\sum_{i=1}^{n} \omega_i = 1 \tag{8}$$

(4) Gain the standardized matrix M according to formula (9), (10) to standardized Z. Then used formular (11) to calculate comprehensive influencing matrix T ($T = \left[t_{ij}\right]_{n\times n}$).

$$M = S \cdot Z \tag{9}$$

$$\mathrm{S} = \frac{1}{\max\limits_{1 \le i \le n} \sum_{j=1}^{n} Z_{ij}} \quad i,j = 1,2,\cdots n. \tag{10}$$

(5) Calculate the comprehensive influencing matrix.

$$T = M(I - M)^{-1} \tag{11}$$

(6) Calculate influencing degree R_i, influenced degree D_j, centrality degree P_i and causality degree E_i

$$R_i = \sum_{i=1}^{n} t_{ij} \quad (i = 1, 2, \cdots, \mathrm{n}); \tag{12}$$

$$D_j = \sum_{j=1}^{n} t_{ij} \quad (j = 1, 2, \cdots, \mathrm{n}); \tag{13}$$

$$P_i = R_i + D_j | i = j; \tag{14}$$

$$E_i = R_i - D_j | i = j \tag{15}$$

Through the above calculation, the influencing degree of each influencing factor on fresh agricultural products cold chain logistics supply chain could be judged by the influence degree and influenced degree. The importance of each index could be determined in the agricultural cold chain logistics' influencing factors index system by the centrality degree. It could further analyze the relationships between each index by the causality degree [12, 13]

3 Example Analysis

In order to better use Grey-DEMATEL method to analyze the key influencing factors of fresh agricultural products cold chain logistics supply chain, this paper carried out an example analysis of fresh agricultural cold chain logistics in M enterprise. Firstly, the questionnaire was distributed to seven experts who knew about the cold chain logistics supply chain of agricultural products or had been engaged in the cold chain logistics of fresh agricultural products for a long time to fill in, then recycled and analyzed. According to the results of investigation and interview, seven experts were given different weights which are processed by interval grey number method (see Table 3).

According to the above formulas and the analysis of the results of questionnaires, the Grey-DEMATEL method is used to construct a direct influencing matrix A.

The direct influencing matrix A is converted into grey number matrix X according to Table 3. Formula (5)–(7) are used to clarify the grey number matrix X. Finally, a comprehensive influencing table (see Table 4) is obtained. The influencing degree R_i, influenced degree D_j, centrality degree P_i and causality degree E_i of each factor are be worked out (see Table 5).

According to the cause index of each factor, the influencing factors of fresh agricultural products cold chain logistics supply chain are divided into two categories.

(1) Cause factors. The rank of cause factors ($E_i > 0$) by their size is: $F_1 > F_6 > F_9 > F_4 > F_2 > F_{14} > F_5 > F_{11} > F_3 > F_7$. These factors are positive factors to promote the development of cold chain logistics supply chain

Table 3. Expert weight values

Category of experts	Expert weight
Head of cold chain logistics project of M company	[0.3, 0.7]
Head of cold chain logistics development planning department of M company	[0.5, 0.8]
Cold chain logistics supply chain expert 1	[0.3, 0.6]
Cold chain logistics Supply chain expert 2	[0.3, 0.5]
Cold chain logistics supply chain expert 3	[0.4, 0.7]
Cold chain logistics supply chain expert 4	[0.6, 0.9]
Cold chain logistics supply chain expert 5	[0.7, 1]

due to they have a direct influencing on it. These factors should be strengthened. Advanced logistics equipment and technology such as GPS technology, RFID and wireless handheld terminal can be applied to realize the information management of all operation links for vehicle logistics and improve the efficiency of cold chain network. What's more, the strength of leading enterprises, changes in market supply and demand, construction of marketing channel and regional economic development should be paid attention to promote the circulation of the whole chain.

(2) Result factors. The rank of result factors ($E_i < 0$) by result factors' absolute value is: $F_{17} > F_{10} > F_{13} > F_8 > F_{12} > F_{15} > F_{16}$. The quality control capability and transportation cost are the factors which are easily changed by other results. Therefore, the relevant rules of fresh agricultural products cold chain logistics supply chain should be standardized. The organization and coordination of all links should be strengthened. Improve transport efficiency and reduce cost. The assessment and training of refrigerated vehicle drivers and professionals should be strengthened gradually.

According to the centrality degree ($P_i > 0$) index of each factor, the rank of fresh agricultural products cold chain logistics supply chain's influencing factors is: $F_8 > F_{12} > F_{17} > F_{11} > F_5 > F_{13} > F_{14} > F_{10} > F_2 > F_4 > F_3 > F_{15} > F_9 > F_{16} > F_6 > F_1 > F_7$. It shows that temperature control capability, coordination ability of third party enterprises and extreme weather adaptability would make enterprises actively face the problems caused by it and reduce can losses in maximum. Therefore, enterprises should constantly debug in the application process of information platform to determine the application environment and optimal technical parameters of each technology. And give full play to the role of information platform.

Table 4. Comprehensive influencing table

Factor	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	F_{11}	F_{12}	F_{13}	F_{14}	F_{15}	F_{16}	F_{17}
F_1	0.0242	0.1776	0.1180	0.0873	0.2170	0.0492	0.1913	0.3419	0.1570	0.2814	0.1630	0.2424	0.2886	0.1022	0.2575	0.1404	0.3425
F_2	0.0166	0.0462	0.1787	0.0645	0.1771	0.0354	0.0760	0.2559	0.0331	0.1315	0.0959	0.1658	0.2237	0.0559	0.2015	0.0932	0.2616
F_3	0.0352	0.1024	0.1346	0.1009	0.2199	0.0624	0.1083	0.3633	0.1630	0.2256	0.2679	0.3515	0.2945	0.2097	0.1774	0.2519	0.3728
F_4	0.0340	0.1812	0.1200	0.0967	0.1302	0.0520	0.0938	0.3427	0.0610	0.2984	0.2590	0.3405	0.2836	0.2128	0.2525	0.2526	0.2698
F_5	0.0360	0.1867	0.2318	0.1059	0.1497	0.1472	0.2125	0.3802	0.1640	0.2231	0.1801	0.3597	0.3191	0.1203	0.2763	0.1645	0.3817
F_6	0.0216	0.0295	0.0649	0.0514	0.0547	0.0222	0.0472	0.2145	0.0182	0.1915	0.0943	0.2163	0.0834	0.0541	0.1615	0.0688	0.2214
F_7	0.0238	0.0534	0.0714	0.0591	0.1632	0.0328	0.0527	0.1535	0.0428	0.1148	0.0819	0.2385	0.1992	0.1543	0.1030	0.1719	0.1571
F_8	0.1199	0.0846	0.2115	0.1701	0.1317	0.0658	0.1085	0.3193	0.0585	0.2024	0.2369	0.1986	0.1826	0.1835	0.1360	0.1400	0.3355
F_9	0.0328	0.0782	0.2209	0.1867	0.1382	0.0614	0.1967	0.2576	0.0409	0.3044	0.2564	0.3278	0.2819	0.0986	0.2501	0.2389	0.3680
F_{10}	0.0273	0.1037	0.2333	0.0987	0.2406	0.1543	0.2224	0.3923	0.1721	0.3320	0.1765	0.2735	0.3212	0.1948	0.1953	0.1567	0.3927
F_{11}	0.0291	0.0553	0.1130	0.0838	0.1843	0.0432	0.1814	0.3094	0.0380	0.2569	0.1352	0.2909	0.2375	0.0682	0.1340	0.1937	0.3182
F_{12}	0.0243	0.0490	0.0777	0.1608	0.0784	0.0385	0.0591	0.2512	0.0255	0.2232	0.1212	0.2427	0.1139	0.0651	0.1887	0.0939	0.2599
F_{13}	0.0367	0.1844	0.1278	0.1030	0.2180	0.0544	0.0993	0.3697	0.1614	0.3077	0.1865	0.3673	0.2929	0.1203	0.2671	0.2520	0.3720
F_{14}	0.0264	0.1946	0.1283	0.0936	0.2376	0.1627	0.1191	0.3667	0.0731	0.3171	0.2694	0.2640	0.3053	0.1099	0.2719	0.2508	0.3846
F_{15}	0.0263	0.1910	0.2191	0.0856	0.2413	0.1514	0.2089	0.2901	0.0800	0.3134	0.1612	0.2634	0.3024	0.1901	0.1789	0.2396	0.3884
F_{16}	0.0199	0.0393	0.0724	0.0492	0.0568	0.0310	0.0571	0.2074	0.0199	0.1012	0.1838	0.1989	0.0852	0.0525	0.0628	0.0687	0.2223
F_{17}	0.0199	0.0393	0.0724	0.0492	0.0568	0.0310	0.0571	0.2074	0.0199	0.1012	0.1838	0.1989	0.0852	0.0525	0.0628	0.0687	0.2223

Table 5. Causality degree and centrality degree of influencing factor

Index	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	F_{11}	F_{12}	F_{13}	F_{14}	F_{15}	F_{16}	F_{17}
R_i	3.6874	3.4413	2.6721	3.5751	3.6388	3.1815	2.1126	3.3395	3.2808	1.5284	3.5311	2.8854	2.0731	3.5205	1.8734	1.6155	1.5284
D_i	0.5540	1.7964	2.3958	1.6465	2.6955	1.1949	2.0914	5.0231	1.3284	3.9258	3.0530	4.5407	3.9002	2.0448	3.1773	2.8463	3.9258
P_i	4.2414	5.2377	5.0679	5.2216	6.3343	4.3764	4.2040	8.3626	4.6092	5.4542	6.5841	7.4261	5.9733	5.5653	5.0507	4.4618	5.4542
E_i	3.1334	1.6449	0.2763	1.9286	0.9433	1.9866	0.0212	−1.6836	1.9524	−2.3974	0.4781	−1.6553	−1.8271	1.4757	−1.3039	−1.2308	−2.3974

4 Conclusion

In this paper, the brainstorming method was used to find out the key factors which influenced fresh agricultural products cold chain logistics supply chain. Due to the complex relationships between influencing factors of fresh agricultural products clod chain logistics supply chain, an index system was established for its influencing factors. Through the analysis of the relationships among the influencing factors of it, the grey number matrix was used to describe quantitatively. In view of the fuzziness and uncertainty when experts scored for influencing factors, the interval grey number from grey number theory was used to clarify it. Then Grey-DEMATEL model was established. The validity and operability of fresh agricultural products cold chain logistics supply chain's influencing factors model based on Grey-DEMATEL have been verificated by the case. The conclusion could better fit the actual situation of enterprises, reflect the problems existed in cold chain logistics supply chain and provide reference measures for enterprises to improve.

Clarification. The reason of anonymous is that all the experts involved in the scoring work in the enterprise, involving some private information of the enterprise, so anonymous words are used to score.

The Authenticity of the questionnaire, the questionnaire was scored by colleagues and leaders of the internship department at that time, and was analyzed against the background of the internship company.

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