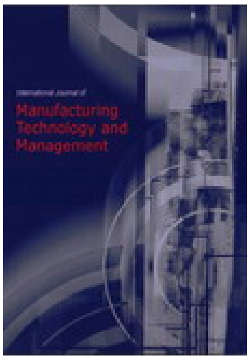

International Journal of Manufacturing Technology and Management

ISSN online: 1741-5195 - ISSN print: 1368-2148
https://www.inderscience.com/ijmtm

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DOI: 10.1504/IJMTM.2023.10056620

Article History:

Received:	28 December 2022
Last revised:	31 January 2023
Accepted:	21 March 2023
Published online:	28 January 2025

Service quality evaluation of agricultural cold chain logistics supply chain based on k-means clustering algorithm

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Abstract: In order to improve the reliability of the cold chain logistics supply chain and shorten the response time of the supply chain, a quality evaluation method of agricultural cold chain logistics supply chain based on k-means clustering algorithm was proposed. Firstly, build the quality evaluation system of agricultural cold chain logistics supply chain. Secondly, the root method is selected to check the consistency of the judgment matrix, and the weight vector of the logistics supply chain quality evaluation is calculated. Finally, the k-means clustering algorithm is used to evaluate the supply chain service quality. The experimental results show that the supply chain quality reliability of this method is 0.98, and the service response time is only six minutes; the service satisfaction rate can reach 99.6%.

Keywords: k-means clustering algorithm; weight vector; analytic hierarchy process; agriculture products; cold chain logistics; service quality assessment.

Reference to this paper should be made as follows: Zhang, Y. (2025) 'Service quality evaluation of agricultural cold chain logistics supply chain based on k-means clustering algorithm', *Int. J. Manufacturing Technology and Management*, Vol. 39, Nos. 1/2, pp.59–73.

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1 Introduction

Cold chain logistics transportation of agricultural products refers to a special supply chain system that ensures the quality and safety of agricultural products, prevents pollution and reduces losses to the greatest extent through processing, transportation, storage, distribution, retail and other links under the appropriate low temperature control environment after the fresh agricultural products such as vegetables, fruits, meat, poultry, fruits, eggs are collected from the origin. The rapid development of the cold chain logistics industry of agricultural products not only brings great convenience to our people, huge demand for the cold chain logistics industry, and smooth circulation channels for the circulation of agricultural products, but also brings greater demand and higher development and regulatory requirements (Han, 2020; Pang and Feng, 2021; Liu and Liao, 2022). The rapid development of data mining technology makes it deeply applied to the current research fields. Combining data mining technology with the evaluation system of agricultural cold chain logistics can provide a new idea for the construction of the evaluation system of agricultural cold chain logistics (Liu et al., 2020). In 2019, the cold chain logistics market in China far exceeded 300 billion yuan, with a year-on-year growth of more than 20%. The market scale is huge and the growth rate is obvious. With the rapid development of the industry and the continuous improvement of people's demand, the demand of the cold chain logistics market in China will continue to increase in the future (Sheng et al., 2020). The rapid development of e-commerce for fresh agricultural products also brings an important development opportunity to the cold chain logistics industry, but its existing service quality is also obvious (Yan, 2021). With the rapid development of social economy and the continuous improvement of people's living standards, the market requirements for the quality of fresh agricultural products are also rising. In the highly competitive market environment, the competitive advantage established solely by products has become less and more obvious, so many enterprises focus on logistics service quality. Therefore, studying an effective cold chain logistics supply chain service quality can help enterprises understand the situation of different logistics supply chains and provide a theoretical basis for improving the supply chain logistics service quality.

Shan and Yang (2020) proposed a service quality evaluation method for cold chain logistics of agricultural products based on cloud model and interval analytic hierarchy process (IAHP) technology, determined the service quality evaluation indicators, determined the impact of weight indicators through cloud drop sorting, built a cold chain logistics service quality evaluation model using cloud model, and obtained the evaluation results of cold chain logistics services of agricultural products using IAHP. This method can improve the reliability of service quality assessment results, but the service satisfaction is poor. Xu and Zhang (2022) proposed a product cold chain logistics service quality evaluation method based on fuzzy ANP-TOPSIS, collected the agricultural cold chain supply chain service data, obtained the agricultural cold chain supply chain service characteristic attributes through data mining, determined the service quality evaluation weight using network analysis method (ANP), and achieved the agricultural cold chain supply chain service quality evaluation through TOPSIS. This method can improve service satisfaction, however, the response time of the supply chain is too long and the response efficiency is poor. Geng and Gu (2020) proposed an evaluation method for cold chain logistics service quality of agricultural products based on evidence theory, obtained cold chain logistics service quality data through evidential reasoning, determined the membership function of cold chain logistics service quality evaluation by using cosine similarity function, modified weight data by using posterior distribution function, and evaluated cold chain logistics service quality by using fuzzy clustering method. This method can shorten the response time of the supply chain, Improve response efficiency, but the reliability of service evaluation is low.

Aiming at the problems of low service reliability, long response time and low service satisfaction existing in the traditional evaluation methods mentioned above, an evaluation method of service quality of agricultural cold chain logistics supply chain based on k-means clustering algorithm is proposed. The overall research technical route of this method is as follows:

1 Determine the supply and demand status of agricultural cold chain logistics, determine the quality evaluation system of agricultural cold chain logistics supply chain, construct the evaluation and judgment matrix of agricultural cold chain logistics supply chain, and select the root method to check the consistency of the judgment matrix.

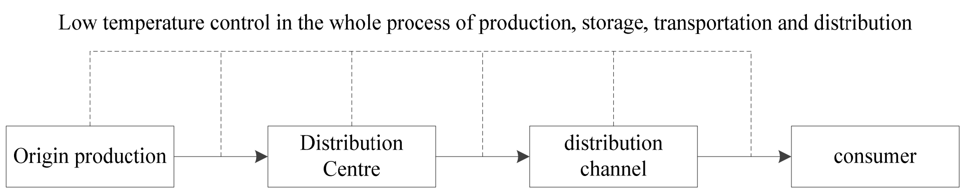
2 The weight vector of logistics supply chain quality evaluation is calculated, and the total ranking of supply chain quality evaluation levels is carried out by using k-means clustering algorithm. The quality evaluation of agricultural cold chain logistics supply chain is realised by using k-means clustering algorithm.

3 Take reliability, response time and service satisfaction as indicators for experimental verification, and draw conclusions.

2 Construction of cold chain logistics supply chain quality evaluation system for agricultural products

The cold chain is a low temperature system project, which not only needs to carry out the temperature control of the whole link, but also needs the coordination between the various entities in charge. In the whole cold chain process, any link breakage will lead to the inefficiency and destruction of the whole link. The quality of the cold chain depends on the control level of the weakest link (Zhou, 2021). See Figure 1 for the cold chain transportation process.

Figure 1 Typical flowchart of cold chain



According to the typical process of the cold chain, the cold chain is divided into these parts: the first part is the cold chain at the production end and the sales end, including the pre-cooling at the origin, and the production and sales are in a low temperature environment. In the second part, in the storage stage, setting the appropriate cold chain temperature level for the commodity and keeping it constant can create higher time value. The third part is to ensure that the quality of goods will not change due to spatial changes in the transportation and distribution links. In order to ensure the comprehensiveness and rationality of the evaluation indicators, the selected experimental indicators should cover all the above processes.

Through the consideration and analysis of the above 15 indicators, determine the secondary indicators of the agricultural cold chain logistics evaluation system. The two indicators of refrigeration conditions and refrigeration equipment are all around the refrigeration link in the cold chain logistics of agricultural products, so the refrigeration conditions and refrigeration equipment are combined into refrigeration conditions and equipment, which is turned into one indicator; among them, the cold transport conditions and cold transport equipment are both developed around the cold transport in the cold chain logistics of agricultural products. Therefore, the cold transport conditions and cold transport equipment are combined into cold transport conditions and equipment, which are turned into one indicator. Finally, 13 secondary indicators are determined in the indicator set of the agricultural cold chain logistics evaluation system produced in this graduation design, which are respectively cold transport conditions and equipment, cold transport conditions and equipment, and social contributions, Business scope, standards and specifications, rules and regulations, emergency response, industrial competitiveness, promotion of industrial development, favourable national policies, scientific research investment, cooperation between government and enterprises, and operational procedures (Yan and Chen, 2022). The above secondary indicators are then classified and summarised. According to the different perspectives of the indicators reflecting the enterprise's operating conditions or external conditions, the three indicators of favourable national policies, industrial development promotion and industrial competitiveness can be merged into a primary indicator of the enterprise's operating environment. The four indicators of business scope, rules and regulations, social contribution and emergency response can be merged into a primary indicator of the enterprise's operating conditions. Refrigeration equipment and conditions the four indicators of cold transport equipment and conditions, standards and specifications, and operating procedures are merged into a first-class indicator of cold chain logistics quality of agricultural products, and the two indicators of scientific research investment and government enterprise and enterprise cooperation are merged into a first-class indicator of scientific research cooperation.

Through the above classification and analysis, four first level indicators of the indicator set in the agricultural cold chain logistics evaluation system designed and produced in this design are determined, which are respectively enterprise business environment, enterprise business situation, agricultural cold chain logistics quality and scientific research cooperation. Table 1 shows the specific situation of the first level indicators and the second level indicators of the agricultural cold chain logistics evaluation indicator set built in this graduation design.

Table 1 Evaluation index system of cold chain logistics of agricultural products

Evaluation index set of cold chain logistics of agricultural products	Macro environment of enterprise operation	Favourable national policies
		Industrial development promotion
		Industry competitiveness
	Enterprise operation	scope of business
		Rules and regulations
		Social contribution
		Emergency management
	Cold chain logistics quality of agricultural products	Refrigeration equipment and conditions
		Cold transport equipment and conditions
		standard specification
		Operation process
	Scientific research cooperation	Scientific research investment
		Cooperation between government and enterprises

The following is a detailed description and explanation of the four first level indicators and 13 second level indicators:

1 Enterprise business environment: Enterprise business environment is the external factor of enterprise operation. An enterprise's business environment is crucial for its foothold and development. Without good external environmental factors as support and consideration, an enterprise will lose its business foundation and foundation (Hu, 2021). The external factors facing the society are very complex. The favourable national policies, the promotion of industrial development and the competitiveness of the industry discussed in this graduation design are all part of the enterprise business environment. Favourable national policies refer to the influence and benefits of the major government of the country on the company. The support of national policies is the wind vane of the industry, which affects the direction and progress of the industry to a certain extent. Industrial development promotion is the development of cold chain logistics industry of agricultural products. Whether there is a development prospect or not, industrial development is the main environment for the company's operation and development, affecting the key decisions of the enterprise. Industry competitiveness is also a key factor for the survival of enterprises. The fierceness of competition affects the operation difficulty of enterprises. The focus of competition affects the core business and starting point of enterprises. Only enterprises with strong industry competitiveness have the ability to survive.

2 Enterprise operation: Enterprise operation is the internal conditions and conditions of enterprise operation. An enterprise can gain advantages in the industry only if its internal management is orderly and reasonable, and has certain value and significance to society and the country. There are also many indicators to evaluate the business situation of enterprises. The business scope, rules and regulations, social contributions, emergency response, etc. discussed in this graduation design are all business situations of enterprises (Wang et al., 2021). Business scope refers to the main businesses and specific situations covered by the enterprise, its position in the chain and its core businesses. Rules and regulations refer to various rules and relevant systems for internal management of enterprises, which determine the efficiency and standardisation of company management. Social contribution refers to the contribution of enterprise operation to the national and social development, which can make contributions to the key national tasks. Emergency response refers to the ability of an enterprise to deal with various risks and emergencies.

3 Cold chain logistics quality of agricultural products: The quality of cold chain logistics of agricultural products is the conditions that enterprises have when conducting cold chain logistics of agricultural products, so that this business can be carried out in an orderly and high-quality manner. The cold storage equipment and conditions, cold transport equipment and conditions, standards, specifications and operating procedures discussed in this graduation design are all related to the cold chain logistics quality of agricultural products. Refrigeration equipment and conditions refer to the hardware facilities that enterprises have for cold chain warehousing of agricultural products and the basic conditions for the normal operation of these facilities. Cold transport equipment and conditions refer to the hardware facilities that enterprises have for cold chain transport of agricultural products and the basic conditions for the normal operation of these facilities. Standards and specifications refer to whether the standards and specifications followed by enterprises in the process of cold chain logistics of agricultural products

meet the relevant requirements of the country or industry. Operation process refers to whether the specific operation process and link of cold chain logistics of agricultural products are complete, complete and reasonable to meet business needs.

4 Scientific research cooperation: Scientific research cooperation means that enterprises carry out relevant research and development work and carry out cooperation and exchange in the course of operation. Continuous scientific research cooperation is the sustainable driving force of a company's sustainable operation. The scientific research input discussed in this graduation design and the cooperation between government and enterprises are all scientific research cooperation. Scientific research investment refers to the investment of enterprises in R&D and talent training. Government enterprise and enterprise cooperation refers to the cooperation between enterprises and the government, universities, research institutes and enterprises in the upstream, downstream and industry to jointly promote the competitiveness of enterprises and the process of industry development.

In this regard, the evaluation index system of cold chain logistics of agricultural products is constructed.

3 Quality evaluation of agricultural cold chain logistics supply chain based on k-means clustering algorithm

3.1 Construction of judgment matrix for quality evaluation of agricultural cold chain logistics supply chain

Let the judgment matrix be $A = (a_{ij})m * n$ and m to represent the target number of agricultural cold chain logistics supply chain.

Secondly, in the judgment matrix, when element a_{ij} is determined, there are $a_{ij} = 1/a_{ji}$, $a_{ii} = 1$ and $a_{ik} * a_{ki} = 1$, and the judgment matrix is basically constructed.

In the first level indicator layer, the evaluation indicators are the enterprise business environment, the enterprise business situation, the quality of agricultural cold chain logistics and scientific research cooperation. This level is the evaluation factor under the criteria of the agricultural cold chain logistics evaluation system, so the judgment matrix of this level for the agricultural cold chain logistics evaluation system is set as A_1. The corresponding values of each indicator are a_{12}, a_{13}, a_{14}, a_{23}, a_{24} and a_{34}, which form the judgment matrix:

$$A_1 = \begin{bmatrix} a_{11} & \dots & a_{14} \\ \vdots & \ddots & \vdots \\ a_{41} & \dots & a_{44} \end{bmatrix} \tag{1}$$

Similarly, in the indicator layer, there are different evaluation indicators under each criterion. In the enterprise business environment, there are three secondary evaluation indicators: favourable national policies, promotion of industrial development, and industrial competitiveness. Therefore, the judgment matrix for the criterion of enterprise business environment is set as B_1. Wherein, the corresponding value of each index is b_{12}, b_{12}, b_{13}, b_{23}, forming the judgment matrix:

$$B_1 = \begin{bmatrix} b_{11} & \dots & b_{13} \\ \vdots & \ddots & \vdots \\ b_{13} & \dots & b_{33} \end{bmatrix} \tag{2}$$

In the case of enterprise operation, there are four secondary evaluation indicators: business scope, rules and regulations, social contribution and emergency response. Therefore, the judgment matrix for the criterion of enterprise operation is set as C_1, where the corresponding value between each indicator is c_{12}, c_{13}, c_{14}, c_{23}, c_{24} c_{34}, forming the judgment matrix:

$$C_1 = \begin{bmatrix} c_{11} & \dots & c_{14} \\ \vdots & \ddots & \vdots \\ c_{41} & \dots & c_{44} \end{bmatrix} \tag{3}$$

Under the cold chain logistics quality of agricultural products, there are four secondary evaluation indicators: logistics quality refrigeration equipment and conditions, cold transport equipment and conditions, standards and specifications, and operating procedures. Therefore, the judgment matrix for the criterion of cold chain logistics quality of agricultural products is set as D_1, where the corresponding values between each indicator are d_{12}, d_{13}, d_{14}, d_{23}, d_{24}, and d_{34}, forming the judgment matrix:

$$D_1 = \begin{bmatrix} d_{11} & \dots & d_{14} \\ \vdots & \ddots & \vdots \\ d_{41} & \dots & d_{44} \end{bmatrix} \tag{4}$$

Under scientific research cooperation, there are two secondary evaluation indicators, namely scientific research investment and government enterprise and enterprise cooperation, so the judgment matrix for scientific research cooperation is set as E_1, where the corresponding value between each indicator is e_{12}, forming the judgment matrix:

$$E_1 = \begin{bmatrix} e_{11} & e_{12} \\ e_{21} & e_{22} \end{bmatrix} \tag{5}$$

Therefore, all judgment matrices of this model are constructed.

3.2 Consistency test of judgement matrix

The judgment matrix has been constructed. On this basis, calculate the weight of each evaluation index. Assume that the constructed judgment matrix is

$$A = \left(a_{ij}\right) m * m \tag{6}$$

Here we need to solve the judgment matrix in this model, and we choose the root method to approximate calculation (Zeng et al., 2020). First, multiply the elements in each line of A to the power of m to obtain the corresponding vector, as shown in formula (6):

$$W^* = \left(w_1^*, w_2^*, \dots, w_m^*\right)^T \tag{7}$$

wherein $w_i^* = \sqrt[m]{\prod_{j=1}^{m} a_{ij}}$, then normalise the vector W^*, that is, let $w_i = w_i^* \Big/ \sum_{i=1}^{m} w_i^*$ get the weight vector as shown in formula (7):

$$W = \left(w_1, w_2, \ldots, w_m\right)^T \tag{8}$$

Sum each column of elements in A to get $s_j = \sum_{i=1}^{m} a_{ij}$ of vector $S = s_1, s_2, \ldots, s_m$, and finally calculate the value of $\lambda_{\max}$ as formula (8):

$$\lambda_{\max} = \sum_{i=1}^{m} s_i w_i = SW = \frac{1}{m}\sum_{i=1}^{m} \frac{(AW)_i}{w_i} \tag{9}$$

Because of the randomness and contingency of objective affairs in the logistics field, our analysis and processing may lack objectivity and be one-sided, so it is almost impossible to require that the processing standards of each comparison judgment matrix are identical. Therefore, when we construct the judgment matrix, we do not require each analysis to be completely consistent.

In the evaluation model, we do not require different judgments to be consistent, but a confused comparison matrix that cannot pass scientific verification may lead to errors in judgment and processing. Therefore, we will conduct consistency inspection on the judgment matrix generated by various factors to determine whether it meets the model requirements (Dong, 2022).

Therefore, consistency must be checked when single factor analysis and ranking of each factor in the model are conducted.

In order to conduct consistency test, it is necessary to define several concepts, namely consistency index CI, random index RI, and consistency ratio CR:

$$CI = \frac{\lambda_{\max} - m}{m - 1} \tag{10}$$

$$CR = CI / RI \tag{11}$$

According to the corresponding CI calculation $\lambda'_{\max}$, judge whether the consistency of comparison judgment is acceptable.

3.3 Quality evaluation of agricultural cold chain logistics supply chain based on k-means algorithm

This design will comprehensively evaluate the cold chain logistics business of agricultural products operated by enterprises through k-means clustering algorithm. K-means clustering algorithm is a qualitative analysis method, which is characterised by abstracting the structure of real things, combining expert judgment, and comparing the same layer to judge the importance of each element. Then use some special calculation methods to calculate the weight value of each element, and finally calculate the weight of each sub level element to the highest goal and rank it (Li et al., 2021). K-means algorithm is a kind of algorithm that divides N data points in I-dimensional space into ke categories. Each cluster can be parameterised by their mean vector $m^{(k)}$. Data points are represented by set $\{x^{(n)}\}$, where $n = 1, 2, \ldots, N$. Each vector x has I components x_i. We assume that x

exists in a real number space, and there is a metric for defining the distance between points, as shown in formula (12).

$$d(x, y) = \frac{1}{2}\sum_{i=1}^{N}\left(x_i - y_i\right)^2 \tag{12}$$

Before the k-means algorithm starts, it is necessary to initialise k-mean value, namely: $2\{m^{(k)}\}$, in some way, such as random initialisation. Then a two-step algorithm is used for iterative calculation. In the allocation step, each data point n is allocated to the nearest mean value. In the update step, the mean value needs to be adjusted to match the sample mean value of the data point in charge. Repeat the allocation and update steps until the allocation is no longer changed.

According to the calculation rules of k-means algorithm, the relative weight vector of the four evaluation indicators of the first level indicator layer to the target layer is shown in formula (13):

$$W^{(1)} = \left(w_1^{(1)}, w_2^{(1)}, \ldots, w_m^{(1)}\right)^T \tag{13}$$

Each evaluation indicator corresponds to multiple secondary evaluation indicators in the target layer. For the single criterion weight vector of the corresponding element *j* of the upper layer, these evaluation indicators are shown in formula (14):

$$W^{(1)} = \left(p_1^{(2)}, p_2^{(2)}, \ldots, p_m^{(2)}\right)^T W^{(1)} \tag{14}$$

After determining the weight of supply chain quality evaluation index, this paper uses k-means clustering algorithm to calculate the comprehensive evaluation value.

According to the constructed agricultural product quality risk evaluation index system, the factor set is determined to be expressed as $U = (u_1, u_2, \ldots, u_n)$, and then the fuzzy evaluation vector $V = (v_1, v_2, \ldots, v_n)$, namely the comment set, is established.

Secondly, determine the weight set of each risk factor, and construct the risk evaluation index weight set $W = (w_1, w_2, \ldots, w_m)$.

Then, according to the evaluation judgment matrix obtained in the previous section, determine the membership of the comment set:

$$R = \sum_{i=1}^{N}\frac{A}{g_i} \tag{15}$$

In the formula, g_i represents the degree of membership of the evaluation index to the comments.

Finally, comprehensive evaluation calculation.

Evaluation calculation formula determined by evaluation matrix *R* and weight vector *W*:

$$Z = W \cdot R \tag{16}$$

Through k-means clustering algorithm evaluation calculation, the final calculation result can be the quality result of agricultural cold chain logistics supply chain. Therefore, the quality evaluation of agricultural cold chain logistics supply chain based on k-means algorithm is realised.

4 Experimental verification

4.1 Experimental data

The data of this experiment comes from five fresh agricultural products cold chain logistics supply chain service enterprises in this city. At present, one fresh enterprise wants to choose one enterprise with good service quality as the cooperative object from these five service enterprises in order to expand its scale and increase its market competitiveness. Therefore, the above enterprises meet the requirements of this experiment. In order to effectively evaluate the service quality of agricultural products cold chain logistics supply chain enterprises of different enterprises, collect the supply chain service quality data of five different enterprises. The data types mainly include storage temperature control data, timeliness data, food packaging safety data, and traceability data. The total data volume reaches 5 GB.

4.2 Experimental scheme and indicators

Based on the experimental data collected above, the experimental scheme is set as follows: the method in this paper is compared with the method in Shan and Yang (2020) and the method in Xu and Zhang (2022), with the service reliability, response time and satisfaction level of the cold chain logistics supply chain as indicators.

- Service reliability of cold chain logistics supply chain: The ability of cold chain logistics suppliers of agricultural products to meet their service commitments to customers can be evaluated by quantitative analysis, including inventory accuracy rate A_k, shipment accuracy rate A_f, and arrival punctuality rate A_t.

$$A_k = \frac{K_n}{T_n} \times 100\% \tag{17}$$

  Among them, K_n represents the number of matching items in the inventory, and T_n represents the total number of items stored.

$$A_f = \frac{L_N}{Z_s} \times 100\% \tag{18}$$

  Among them, L_N represents the order processing quantity with correct shipment, and Z_s represents the total number of orders.

$$A_t = \frac{z_N}{Z_s} \times 100\% \tag{19}$$

  Among them, z_N represents the number of orders completed on time.

- Response time consuming: The responsiveness of cold chain logistics suppliers of agricultural products is mainly reflected in the ability of service personnel to respond to customer service, mainly including the ability to quickly respond to customer needs, the quality of customer service communication, and the service awareness of distribution personnel. Qualitative analysis can be used to analyse the degree of cold chain service standardisation, the ability to respond quickly to customer needs, the level of value-added services, the quality of customer service communication, and the service awareness of distribution personnel. The judgment of these indicators is based on the score of the customer's senior management according to the actual situation.

- Service satisfaction level: The satisfaction level of cold chain logistics services for agricultural products is mainly assessed from the perspective of customer perception, mainly including service price satisfaction, customer complaint rate, contract renewal rate, and willingness to recommend other customers. The customer complaint rate T_{sr} is shown in formula (20):

$$T_{sr} = \frac{S_{ts}}{Z_s} \times 100\% \tag{20}$$

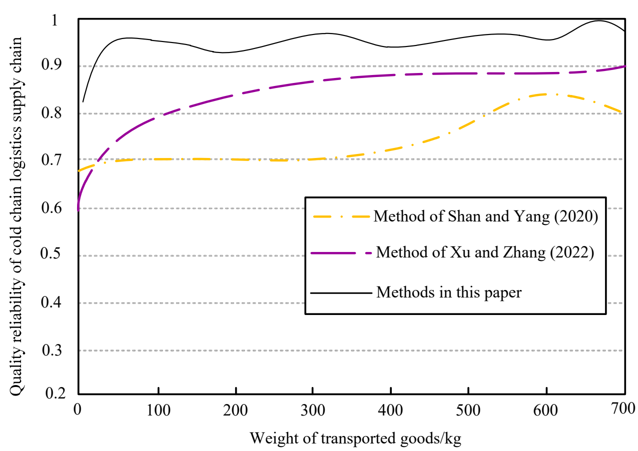
Among them, S_{ts} represents the number of orders involved in valid complaints. Qualitative indicators include service price satisfaction, contract renewal rate and willingness to recommend other customers. The customer representative expert is used to judge the score according to the actual situation.

4.3 *Experimental result*

4.3.1 *Reliability comparison of cold chain logistics supply chain*

In order to verify the reliability of the quality of cold chain logistics supply chain of agricultural products under the method of this paper, the reliability analysis of the quality of cold chain logistics supply chain of agricultural products is conducted using the methods of Shan and Yang (2020), Xu and Zhang (2022) and this paper. The results are shown in Figure 2.

Figure 2 Reliability of cold chain logistics supply chain (see online version for colours)

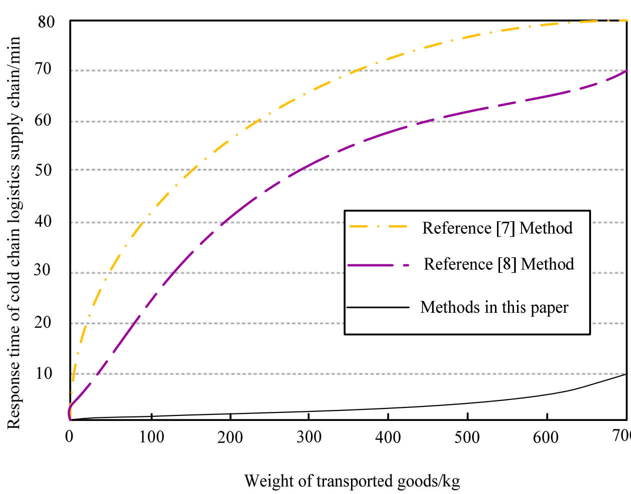


It can be seen from the analysis of Figure 2 that when the transportation weight of cold chain goods of agricultural products is 200 kg, the quality reliability of cold chain logistics supply chain of agricultural products in Shan and Yang (2020) method is 0.70, the quality reliability of cold chain logistics supply chain of agricultural products in Xu and Zhang (2022) method is 0.83, and the quality reliability of cold chain logistics supply chain of agricultural products in this method is 0.92; when the transportation weight of cold chain goods of agricultural products is 400 kg, the quality reliability of cold chain logistics supply chain of agricultural products in Shan and Yang (2020) method is 0.72, the reliability of cold chain logistics supply chain of agricultural products in Xu and Zhang (2022) method is 0.88, and the quality reliability of cold chain logistics supply chain of agricultural products in this method is 0.94; when the transportation weight of cold chain goods of agricultural products is 600 kg, the quality reliability of cold chain logistics supply chain of agricultural products in Shan and Yang (2020) method is 0.85, the quality reliability of cold chain logistics supply chain of agricultural products in Xu and Zhang (2022) method is 0.89, and the quality reliability of cold chain logistics supply chain of agricultural products in this method is 0.98; the reliability of cold chain logistics supply chain under this method is always higher than that of other traditional methods, which shows that this method has a certain effect on improving the reliability of cold chain logistics supply chain. This is because the method in this paper can accurately evaluate the service quality of the logistics supply chain. In case of unreliable supply chain, the transportation service will be terminated, thus improving the service quality of the supply chain.

4.3.2 Comparison of service response time of cold chain logistics supply chain

In order to verify the service response efficiency of the agricultural cold chain logistics supply chain under the method of this paper, the method of Shan and Yang (2020), the method of Xu and Zhang (2022) and the method of this paper are used to conduct the response time of the agricultural cold chain logistics supply chain, and the results are shown in Figure 3.

Figure 3 Time consuming of cold chain logistics supply chain response of agricultural products (see online version for colours)



It can be seen from the analysis of Figure 3 that when the transportation weight of cold chain goods of agricultural products is 100 kg, the response time of the cold chain logistics supply chain of agricultural products in Shan and Yang (2020) method is 44 mins, the response time of the cold chain logistics supply chain of agricultural products in Xu and Zhang (2022) method is 26 mins, and the response time of the cold chain logistics supply chain of agricultural products in this method is 2 mins; when the transportation weight of cold chain goods of agricultural products is 300 kg, the response time of cold chain logistics supply chain of agricultural products in Shan and Yang (2020) method is 67 mins, the response time of cold chain logistics supply chain of agricultural products in Xu and Zhang (2022) method is 53 mins, and the response time of cold chain logistics supply chain of agricultural products in this method is 3 mins; when the transportation weight of cold chain goods of agricultural products is 600 kg, the response time of cold chain logistics supply chain of agricultural products in Shan and Yang (2020) method is 79 mins, the response time of cold chain logistics supply chain of agricultural products in Xu and Zhang (2022) method is 66 mins, and the response time of cold chain logistics supply chain of agricultural products in this method is 6 mins; when the method in this paper always has a low supply chain response application, it shows that the method in this paper has a high logistics supply chain response efficiency. The reason why this method has fast evaluation efficiency is that this method directly constructs the supply chain service quality evaluation system. After the calculation of the evaluation weight vector, it directly ranks the supply chain quality evaluation through the k-means clustering algorithm, so as to quickly obtain the evaluation results.

4.3.3 Comparison of service quality satisfaction of cold chain logistics supply chain

In order to verify the service quality satisfaction of agricultural cold chain logistics supply chain under this method, the method of Shan and Yang (2020), the method of Xu and Zhang (2022) and this method are used to conduct the service quality satisfaction rate of agricultural cold chain logistics supply chain. The results are shown in Table 2.

Table 2 Satisfaction rate of service quality of cold chain logistics supply chain of agricultural products

Cold chain cargo transportation weight of agricultural products/kg	*Satisfaction rate of supply chain service quality/%*		
	Shan and Yang (2020) method	*Xu and Zhang (2022) method*	*Methods in this paper*
100	78.2	80.2	98.2
200	80.3	73.9	99.6
300	83.9	72.6	99.5
400	76.3	82.0	98.3
500	79.1	83.6	98.0

Table 2 shows that when the transportation weight of agricultural products in the cold chain is 200 kg, the satisfaction rate of supply chain service in the Shan and Yang (2020) method is 80.3%, the satisfaction rate of supply chain service in the Xu and Zhang (2022) method is 73.9%, and the satisfaction rate of supply chain service in this method is 99.6%; when the cold chain cargo transportation weight of agricultural products is 300 kg, the supply chain service satisfaction rate of Shan and Yang (2020) method is 83.9%, the supply chain service satisfaction rate of Xu and Zhang (2022) method is 72.6%, and the supply chain service satisfaction rate of this method is 99.5%; when the cold chain cargo transportation weight of agricultural products is 500 kg, the supply chain service satisfaction rate of Shan and Yang (2020) method is 79.1%, the supply chain service satisfaction rate of Xu and Zhang (2022) method is 83.6%, and the supply chain service satisfaction rate of this method is 98.0%; this method always has a high supply chain service satisfaction rate, which shows that this method can improve the supply chain service quality. Satisfaction is the embodiment of the comprehensive performance of the supply chain. The method in this paper improves the reliability and efficiency of the supply chain, and thus has higher user satisfaction.

5 Conclusions

In order to improve the reliability of the traditional supply chain quality evaluation, shorten the response time of the supply chain, and improve the service satisfaction of the logistics supply chain, this paper proposes a quality evaluation method of agricultural cold chain logistics supply chain based on k-means clustering algorithm. Determine the quality evaluation system of agricultural cold chain logistics supply chain; construct the judgment matrix, calculate the weight vector of logistics supply chain quality evaluation, and realise the quality evaluation of agricultural cold chain logistics supply chain through k-means clustering algorithm. The experimental results show that:

1 The quality reliability of agricultural products cold chain logistics supply chain in this method is 0.98; it shows that this method has a certain effect on improving the reliability of cold chain logistics supply chain.

2 The response time of agricultural products cold chain logistics supply chain of this method is only 6 minutes when this method is always applied with low supply chain response; it shows that this method has higher response efficiency of logistics supply chain.

3 This method always has a high supply chain service satisfaction rate, which can reach 99.6%; it shows that this method can improve the supply chain service quality.

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