Research on the Performance Evaluation Method of the Prefabricated Food Supply Chain Based on Fuzzy Theory

Lei Wang[1,2], Liangbo Zhao[1,*]

[1]School of Business Administration, Liaoning Technical University, Huludao, Liaoning, 125105, China
[2]Department of Basic Teaching, Liaoning Technical University, Huludao, Liaoning, 125105, China

E-mail:wllyq78@163.com; *1192545055@qq.com

Abstract. With the rapid development of the prefabricated food market, the complexity and uncertainty of its supply chain management have become increasingly prominent, putting forward higher requirements for supply chain performance evaluation. This paper aims to explore the performance evaluation method of the prefabricated food supply chain based on fuzzy theory to deal with the fuzziness and uncertainty in the evaluation process. By constructing a scientific and reasonable evaluation index system covering multiple dimensions such as delivery quality, cost efficiency, response speed, cooperation and coordination, and innovation ability, it comprehensively reflects the overall performance level of the supply chain. The fuzzy theory is used to deal with the fuzziness and uncertainty of the evaluation index. Data is collected through expert scoring or questionnaire surveys, a fuzzy relation matrix is established, and the weight distribution is determined by combining methods such as the analytic hierarchy process. Finally, the fuzzy synthesis operator is used for comprehensive evaluation calculation to obtain the membership vector of the prefabricated food supply chain at each evaluation level, providing an intuitive and scientific decision-making basis for supply chain managers. The research in this paper not only enriches the theoretical system of prefabricated food supply chain performance evaluation but also provides feasible methods and tools for practical operation, which is of great significance for improving the management level of the prefabricated food supply chain.

Keywords: Prefabricated food; Supply chain management; Fuzzy theory; Performance evaluation

1 Introduction

In today's fast-paced social life, prefabricated food, as a convenient and efficient catering solution, is gradually becoming the new favorite of consumers and the catering industry. With the continuous growth of market demand, the prefabricated food industry has ushered in unprecedented development opportunities. However, the complexity of the prefabricated food supply chain has also increased, involving multiple

A. Mallik et al. (eds.), *Proceedings of the 2025 6th International Conference on Management Science and Engineering Management (ICMSEM 2025)*, Atlantis Highlights in Economics, Business and Management 4,
https://doi.org/10.2991/978-94-6463-845-5_10

links such as raw material procurement, production and processing, logistics distribution, and sales, as well as numerous participants and stakeholders. Ma Lin et al. [1] analyzed the development status of the prefabricated food supply chain from the supply chain perspective. The main problems can be summarized as low standardization, low information transparency in the upstream, midstream, and downstream, high logistics costs, and insufficient customer stickiness and trust. They proposed using block chain technology to optimize the digital supply chain platform to achieve information sharing among the upstream, midstream, and downstream and improve the food traceability mechanism, providing a reference for the development of the prefabricated food supply chain. Jiang Ting [2] studied the challenges faced by prefabricated food supply chain management and analyzed its development opportunities. Liu Hui et al. [3] proposed the problems existing in the fresh food supply chain and gave research on solutions. How to effectively evaluate the performance of the prefabricated food supply chain has become the focus of attention inside and outside the industry.

Supply chain performance evaluation is an important part of supply chain management. It helps enterprises identify the advantages and disadvantages in the supply chain and provides a scientific basis for optimization decisions. However, traditional performance evaluation methods are often based on accurate data and clear evaluation criteria, making it difficult to deal with the fuzziness and uncertainty factors in the prefabricated food supply chain. For example, evaluation indicators such as customer satisfaction and response speed are often difficult to measure with precise numbers, and fuzzy theory provides an effective solution. Ding Baocheng et al. [4] established a performance evaluation index system for the agricultural product supply chain in the context of agricultural and commercial interconnection from four aspects: production, business process, logistics, and consumers. Han Qihao [5] analyzed the development status and main influencing factors of the cold chain logistics of fresh agricultural products in Henan Province and put forward suggestions for improving the development level of the cold chain logistics of fresh agricultural products in Henan Province. Li Xuefei et al. [6] analyzed the influencing factors of the development of the cold chain logistics of fresh agricultural products in Kaifeng City, Henan Province by using the questionnaire survey method and the analytic hierarchy process in the context of "rural revitalization".

Fuzzy theory is a mathematical tool for dealing with uncertainty and fuzziness. It allows us to use concepts such as fuzzy sets and fuzzy relations to describe and handle things with fuzziness. In the performance evaluation of the prefabricated food supply chain, the introduction of fuzzy theory can more accurately reflect the fuzziness and uncertainty of the evaluation index and improve the accuracy and objectivity of the evaluation.

Therefore, this paper aims to explore the performance evaluation method of the prefabricated food supply chain based on fuzzy theory. By constructing a scientific and reasonable evaluation index system and combining the processing method of fuzzy theory, it provides a new idea and method for the performance evaluation of the prefabricated food supply chain. The research in this paper not only helps to enrich the theoretical system of prefabricated food supply chain performance evaluation but also provides feasible methods and tools for practical operation, which is of great

significance for improving the management level of the prefabricated food supply chain and promoting the healthy development of the industry.

2 Influencing Factors of Supply Chain Performance

The performance of the prefabricated food supply chain is the result of the joint action of multiple factors. By analyzing the influencing factors of the prefabricated food supply chain performance in combination with each link of the supply chain, the corresponding performance evaluation index system of the prefabricated food supply chain can be improved.

Customer Dimension

Customers are the final service objects of the supply chain, and their satisfaction and loyalty are important standards for measuring supply chain performance. From the customer dimension, the influencing factors of supply chain performance are mainly reflected in service quality, delivery punctuality, and customization ability. High-quality service can enhance the customer's shopping experience and improve their trust in the brand. Delivery punctuality is a key indicator for customers to evaluate the efficiency of the supply chain. Frequent late deliveries will seriously damage the corporate image. In addition, with the increasing diversification of consumer demands, the customization ability of the supply chain has become more and more important. Enterprises need to flexibly adjust the production plan according to the personalized needs of customers and provide products and services that meet their expectations. The demand of consumers for convenient, healthy, and delicious prefabricated food is constantly growing, especially among young people and busy office workers. Moreover, consumers pay more attention to food safety and require the prefabricated food supply chain to provide high-quality and traceable products. Regional dietary differences lead to diversified demands of consumers for the taste and variety of prefabricated food. Customer feedback is an important basis for improving products and services. The supply chain needs to establish an effective customer communication mechanism to collect and process customer opinions in a timely manner. Improving customer satisfaction and loyalty is helpful for the market expansion and word-of-mouth dissemination of prefabricated food brands[7].

Business Process Efficiency

In the prefabricated food supply chain, the business process covers multiple links such as raw material procurement, production and processing, warehouse management, and logistics distribution. The connection and coordination among these links are directly related to the overall operation efficiency of the supply chain. In order to improve the performance of the business process, the prefabricated food supply chain needs to adopt advanced logistics technology and information systems to achieve transparent, visual, and intelligent management of the supply chain. By optimizing the production process, improving the utilization rate of the warehouse, reducing logistics costs, and other measures, the prefabricated food supply chain can significantly improve the overall operation efficiency, reduce costs, and enhance competitiveness[8].

Financial Benefits

In the prefabricated food market, cost control and profitability are the keys to the sustainable development of the supply chain. The prefabricated food supply chain needs to pay close attention to key financial indicators such as raw material costs, production costs, and logistics costs. Through refined management and optimized resource allocation, effective cost control can be achieved. At the same time, the supply chain also needs to actively explore sales channels, enhance brand influence, and achieve continuous growth of sales revenue. By optimizing the financial structure and enhancing profitability, the prefabricated food supply chain can provide solid financial support for the long-term development of enterprises.

Innovation Ability

Innovation and development are the sources of continuous improvement of the performance of the prefabricated food supply chain. In the prefabricated food market, enterprises need to continuously explore new business models, technologies, and products to meet the increasingly diversified needs of consumers. By introducing advanced production technologies, developing new dishes, optimizing sales channels, and other measures, the prefabricated food supply chain can continuously enhance its market competitiveness. At the same time, enterprises also need to pay attention to industry dynamics and changes in policies and regulations and adjust the strategic direction in a timely manner to ensure the stability and sustainable development of the supply chain.

3 Performance Evaluation Method of the Prefabricated Food Supply Chain Based on Fuzzy Theory

3.1 Design of the Performance Evaluation Index System of the Prefabricated Food Supply Chain

The performance evaluation index system of the prefabricated food supply chain should comprehensively cover all links and key elements of the supply chain. According to the practical experience and theoretical research results of supply chain management, a multi-dimensional evaluation index system including delivery quality, cost efficiency, response speed, cooperation and coordination, innovation ability, etc. can be constructed. These indexes can comprehensively reflect the overall performance level of the prefabricated food supply chain.

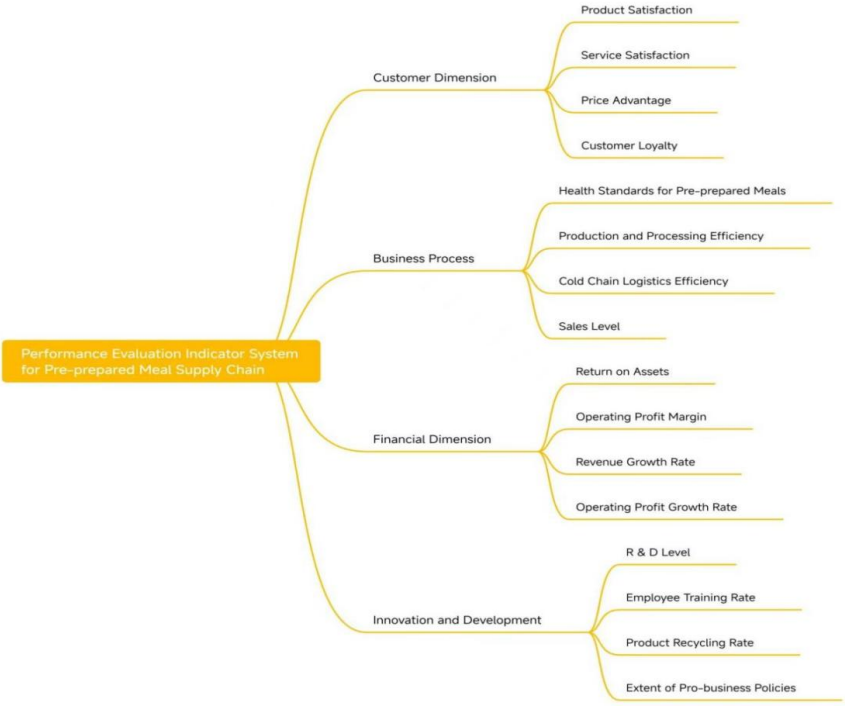

Fig. 1. Performance evaluation indicators for prefabricated food supply chain

3.2 Construction of the Performance Evaluation Model of the Prefabricated Food Supply Chain Based on Fuzzy Theory

3.2.1 Determine the Evaluation Factors and Evaluation Levels.

(1) Determine the evaluation factors

Set the evaluation factor set $U = \{u_1, u_2, u_3, \ldots, u_n\}$. In this factor set, there are evaluation factors acting on the evaluated object, and the specific value of is determined by the evaluation index system. Generally speaking, the evaluation index system contains multi-level goals. As shown in Figure 1, in the performance evaluation system of the prefabricated food supply chain in this paper, it is a two-level goal system. For example, $u_1 = \{u_{11}, u_{12}, u_{13}, \ldots u_{1k}\}$ and so on.

(2) Determine the evaluation levels

Set the evaluation level set $V = \{v_1, v_2, v_3, \ldots v_n\}$. In this set, represents the state of the characterized factor. Generally, there are 3 - 5 levels of state comments, such as {excellent, good, average, poor, bad}, etc., which vary in each specific evaluation system.

3.2.2 Establish the Judgment Matrix and Determine the Weights.

Data is collected through expert scoring, questionnaire surveys, etc., and then the collected data is transformed into a fuzzy relation matrix by using the fuzzy mathematics method. The construction of the fuzzy relation matrix needs to consider the fuzziness and uncertainty factors of the evaluation index.

Methods such as the analytic hierarchy process (AHP) and the entropy weight method are used for weight calculation. These methods can comprehensively consider the subjective judgment of experts and the objective information of data and obtain a relatively reasonable weight distribution result.

3.2.3 Conduct Fuzzy Comprehensive Evaluation.

After constructing the fuzzy relation matrix and determining the weight distribution, the fuzzy synthesis operator can be used for fuzzy comprehensive evaluation calculation. The fuzzy synthesis operator can synthesize the fuzzy relation matrix and the weight vector to obtain the membership vector of the evaluated object at each evaluation level. Finally, according to the membership vector, the evaluation level of the evaluated object can be judged or a comprehensive evaluation score can be obtained.

4 Empirical Analysis of the Performance Evaluation of the Prefabricated Food Supply Chain Based on Fuzzy Theory

Based on the above performance evaluation system and model construction, this paper investigates and collects relevant data from a large logistics enterprise that has actually started implementation and uses the fuzzy comprehensive evaluation method to conduct a comprehensive performance evaluation analysis of the logistics enterprise.

4.1 Determine the Evaluation Object

According to the evaluation system and calculation model construction in the third part of this paper, the evaluation index system of the logistics enterprise is divided into two levels: the first level, the total goal factor $u = \{u_1, u_2, u_3, u_4\}$; the second level, the sub-goal factor set, where $u_1 = \{u_{11}, u_{12}, u_{13}, u_{14}\}$, $u_2 = \{u_{21}, u_{22}, u_{23}, u_{24}\}$, $u_3 = \{u_{31}, u_{32}, u_{33}, u_{34}\}$, $u_4 = \{u_{41}, u_{42}, u_{43}, u_{44}\}$. In determining the index weight values of the factor set, this paper uses the analytic hierarchy process to calculate the index weights. First, a questionnaire survey is conducted among the evaluation panel to evaluate the weights of the indicators at all levels. Second, through widely solicit the opinions of the members of the judging group, the judgment matrix of pairwise comparisons is determined. Table 1 shows the

judgment matrix of pairwise comparisons of the first-level indicators. The final evaluation results after comparing, counting, and sorting the first-level and second-level indicators are shown in Table 2.

Table 1. $u_1 \sim u_4$ Compare the judgment matrix and the weight

u	u1	u2	U3	U4	weight
u1	1	2.2222	1.5002	2.9994	0.4069
U2	0.45	1	0.7502	1.5002	0.1931
U3	0.6666	1.333	1	2.2222	0.2713
U4	0.3334	0.6666	0.45	1	0.1287

Table 2. Meaning and weight of evaluation indicators

Level 1 indicators	weight	Secondary indicators	weight	order of evaluation			
				excellent	good	general	poor
Customer dimensionu11	0.4069	Product satisfaction	0.41	0.20	0.40	0.30	0.10
		Service satisfaction	0.19	0.30	0.40	0.20	0.10
		Price advantage	0.27	0.30	0.40	0.30	0.00
		Customer loyalty	0.13	0.30	0.20	0.25	0.25
operation flow；work flow u21	0.1931	Healthy prepared dishes reach the standard level	0.40	0.3	0.3	0.2	0.2
		Production and processing efficiency	0.08	0.25	0.35	0.2	0.2
		Cold chain circulation efficiency	0.23	0.15	0.3	0.3	0.25
		Sales level	0.29	0.3	0.35	0.2	0.15
Financial dimensionu31	0.2713	Return on assets	0.17	0.2	0.3	0.25	0.25
		Operating profit margin	0.38	0.55	0.25	0.15	0.05
		Revenue growth rate	0.11	0.4	0.3	0.25	0.05
		Operating profit growth rate	0.34	0.3	0.35	0.2	0.15
Innovation and developmentu41	0.1287	Research and development level	0.27	0.25	0.3	0.2	0.25
		Employee training rate	0.19	0.3	0.25	0.25	0.2
		Product recovery rate	0.41	0.1	0.5	0.15	0.25
		Policy benefits enterprises	0.13	0.2	0.25	0.25	0.3

4.2 Determine the Evaluation Level

The comments of this model are divided into four levels, and the specific comments set is $v=(v_1,v_2,v_3,v_4)=\{\text{Excellent、 Good、 general、 poor}\}$

4.3 Establish a Judgment Matrix

$$B_1=A_1\cdot R_1=[0.41\quad 0.19\quad 0.27\quad 0.13]\cdot\begin{bmatrix}0.2 & 0.4 & 0.3 & 0.1\\ 0.3 & 0.4 & 0.2 & 0.1\\ 0.3 & 0.4 & 0.3 & 0.0\\ 0.3 & 0.2 & 0.25 & 0.25\end{bmatrix}=[0.259\quad 0.374\quad 0.2745\quad 0.0925]$$

$$B_2=A_2\cdot R_2=[0.4\quad 0.08\quad 0.23\quad 0.29]\cdot\begin{bmatrix}0.3 & 0.3 & 0.2 & 0.2\\ 0.25 & 0.35 & 0.2 & 0.2\\ 0.15 & 0.3 & 0.3 & 0.25\\ 0.3 & 0.35 & 0.2 & 0.15\end{bmatrix}=[0.2615\quad 0.3185\quad 0.223\quad 0.197]$$

$$B_3=A_3\cdot R_3=[0.17\quad 0.38\quad 0.11\quad 0.34]\cdot\begin{bmatrix}0.2 & 0.3 & 0.25 & 0.25\\ 0.55 & 0.25 & 0.15 & 0.05\\ 0.4 & 0.3 & 0.25 & 0.05\\ 0.3 & 0.35 & 0.2 & 0.15\end{bmatrix}=[0.389\quad 0.298\quad 0.195\quad 0.118]$$

$$B_4=A_4\cdot R_4=[0.27\quad 0.19\quad 0.41\quad 0.13]\cdot\begin{bmatrix}0.25 & 0.3 & 0.2 & 0.25\\ 0.3 & 0.25 & 0.25 & 0.2\\ 0.1 & 0.5 & 0.15 & 0.25\\ 0.2 & 0.25 & 0.25 & 0.3\end{bmatrix}=[0.1915\quad 0.366\quad 0.1955\quad 0.247]$$

The comprehensive evaluation set of the second-level indicators is:

$$R=[B_1+B_2+B_3+B_4]^T=\begin{bmatrix}0.2590 & 0.3740 & 0.2745 & 0.0925\\ 0.2615 & 0.3185 & 0.2230 & 0.1970\\ 0.3890 & 0.2980 & 0.1950 & 0.1180\\ 0.1915 & 0.3660 & 0.1955 & 0.2470\end{bmatrix}$$

The comprehensive evaluation set of the second-level indicators is follows:

$$B=A\cdot R=[0.286\quad 0.3416\quad 0.2328\quad 0.1395]$$

4.4 Results Analysis and Recommendations

According to the principle of maximum membership, we found that the "product satisfaction" and "service satisfaction" indicators in the "customer dimension" performed the best, which reflects that the prefabricated vegetable supply chain has achieved remarkable results in ensuring the freshness of food ingredients and improving service quality. At the same time, it can also be observed from the weight of evaluation indicators in Table 2 that the weight of

"customer dimension" is relatively high, which emphasizes the importance of customer experience in the performance evaluation of prefabricated vegetable supply chain. However, it is worth noting that despite the outstanding performance of the "customer dimension", certain indicators in the "financial dimension", such as "return on assets" and "revenue growth rate", may be under weighted or generally performed. This may mean that, in the pursuit of customer satisfaction and service quality, the prefabricated vegetable supply chain is facing certain financial pressure, or has not achieved a significant increase in financial income in the short term. The reasons for this phenomenon may include fierce market competition, increased difficulty in cost control, long investment return cycle and other factors.

In view of the problems found in the performance evaluation of prefabricated vegetable supply chain, we can make the following suggestions:

(1) Continuous optimization of customer experience: Although the "customer dimension" performs well, supply chain managers still need to continue to pay attention to changes in customer needs and constantly optimize products and services to consolidate and expand market share. For example, customer satisfaction and loyalty can be further enhanced by adding diversified sales channels, increasing prefabricated dishes, and improving the efficiency of cold chain logistics.

(2) Strengthen financial management and cost control: In view of the indicators with low weight or general performance of "financial dimension", supply chain managers should strengthen the monitoring and management of financial situation, and improve cost control and financial benefits by optimizing the procurement process, reducing logistics costs and improving production efficiency. At the same time, actively seek new profit opportunities, such as developing value-added services, expand the international market, etc.

(3) Focus on innovation and coordinated development: In the performance evaluation of prefabricated vegetable supply chain, "innovation ability" is also an important index. Supply chain enterprises should increase investment in research and development to improve product quality and richness to meet the increasingly diverse needs of consumers. At the same time, strengthen the cooperation with upstream and downstream enterprises, form a close linkage between the upstream and downstream of the industrial chain, and jointly promote the healthy development of the prefabricated vegetable industry.

(4) Government policy support and guidance: The government can encourage prefabricated vegetable supply chain enterprises to increase investment in green logistics and environmental protection packaging by formulating reasonable tax policies and green subsidies, so as to promote the development of the industry to a more environmentally friendly and sustainable direction. At the same time, we will strengthen supervision and guidance over the prefabricated vegetable industry to promote fair competition and market order.

5 Conclusion

The performance evaluation method of prefabricated vegetable supply chain based on the fuzzy theory can effectively deal with the ambiguity and uncertainty factors in the evaluation process, and improve the accuracy and objectivity of the evaluation. The future research can further expand the breadth and depth of the evaluation index system, introduce more advanced fuzzy mathematical tools and methods, improve the intelligence and automation level, and provide more scientific and comprehensive decision support for the prefabricated supply chain managers.

Reference

1. Ma Lin, Zhou Fengjie. Problems and Countermeasure Suggestions of the Pre - made Food Supply Chain[J]. Grain Processing, 2023, 48(05): 83 - 86.
2. Jiang Ting. Analysis of Challenges and Opportunities in the Supply Chain Management of Pre - made Food[J]. Logistics Sci - Tech, 2024, 47(04): 141 - 143.
3. Liu Hui, Song Chunhao, Hong Heng, et al. Research on the Problems and Solutions in the Fresh Food Ingredients Supply Chain - Taking the Pre - made Food as the Background[J]. Hebei Enterprises, 2022,(05): 21 - 23.
4. Ding Baocheng, Kong Lingfeng. Performance Evaluation of the Agricultural Product Supply Chain under the Background of Rural - Commercial Interconnection[J]. Manufacturing Automation, 2023, 45(01): 85 - 90.
5. Han Qihao. Comprehensive Evaluation of the Cold Chain Logistics of Agricultural Products in Henan Province Based on the Fuzzy Analytic Hierarchy Process[J]. Modern Food, 2020(17): 19 - 21 + 31.
6. Li Xuefei, Zhao Rui. Analysis of the Influencing Factors of the Development of the Cold Chain Logistics of Agricultural Products in Kaifeng City Based on the Analytic Hierarchy Process[J]. Logistics & Material Handling, 2021, 26(52): 82 - 85.
7. Ma Yilong. Analysis of the Current Situation and Development Countermeasures of the Cold Chain Logistics of Fresh Agricultural Products in China[J]. Modern Food, 2023, 29(14): 29 - 31.
8. Zhao Song. Research on the Current Situation and Problems of the Pre - made Food Industry[J]. Modern Food, 2023, 29(04): 22 - 24.