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Optimization and system implementation of fuzzy integrated algorithm model for logistics supply chain under supply and demand uncertainty background

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Abstract

While improving the operational efficiency of the enterprise, the logistics supply chain directly or indirectly affects the performance of the enterprise because of its own and external uncertainty, resulting in tangible or intangible losses. In this era of rapid change and increasing competition, reducing the impact of uncertainty can reduce the risk and vulnerability of the entire logistics service supply chain, and can gain or maintain a competitive advantage. Therefore, based on the background of supply and demand uncertainty, this paper establishes the fuzzy integrated optimization model of logistics supply chain system by using LR fuzzy numbers. In order to solve this model, the study carried out deterministic processing and transformed it into a deterministic multi-objective linear programming model. At the same time, this study also designed a genetic algorithm to solve the model, in order to solve the choice of potential supply and demand uncertainty in the system, and achieve the global optimization of the network. Finally, the calculations are carried out by numerical examples. The results prove the effectiveness of the model and algorithm.

Keywords Supply and demand uncertainty · Logistics supply chain · Fuzzy integration algorithm · System model optimization

1 Introduction

As people's understanding of the logistics supply chain deepens and expands, the logistics supply chain extends from the inside of the enterprise to the outside of the enterprise. From the individual company, on the one hand, to the supplier and the supplier's supplier, on the other hand, to the customer and the customer's customer, to the final consumer. The structure of the supply chain extends from "single chain" to "net chain". Logistics supply chain can be understood as an organic logistics chain, which is formed by all the logistics activities involved in the economic activities within the time range from the market demand of products or services to meeting the demand. It is generally believed that the logistics supply chain consists of steps that directly or indirectly meet customer needs, including customers, retailers, distributors, manufacturers, and suppliers. Supply chain management usually involves the management of two-way information, funds, and material flows that occur in all processes of the supply chain to maximize the ultimate benefits of the supply chain. From the production of raw materials to the distribution of final products to the business processes of customers, the coordination and integration of supply chain members

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determines the complexity and dynamics of the supply chain. Therefore, this leads to uncertainty in the supply chain [1]. Uncertainty means that economic actors cannot accurately know the result of their own decision in advance. In the process of supply chain decision-making, uncertainty is an important factor affecting the overall performance of the supply chain, and it has the characteristics of '1 year' spread to the upstream and downstream of the supply chain. Changes in customer demand, delays in supplier delivery, failures in production equipment, etc., can lead to distortions in demand information, distortions, increased safety stocks, and reduced customer service levels. Following the classification methods of most scholars, we classify the sources of supply chain uncertainty into three levels. That is, the uncertainty of demand, the uncertainty of supply and the uncertainty of production [2].

Uncertainty in demand has become an important factor affecting supply chain performance as society progresses and develops. If the final product of the logistics supply chain can be a good link between the ideal and the reality of the customer, just hitting the customer's needs and inspiring the potential demand of the customer, it will bring huge market space to the product and win more profit [3]. With the rapid development of social economy and culture, the rapid development of science and technology, people's aesthetics and preferences tend to be more variability and diversity. The product cycle is getting shorter and shorter, the individualized demand is constantly being dig, and the customer's expectations for the product are getting higher and higher, which brings greater uncertainty to the demand of the supply chain. The reasons for supply uncertainty are manifold. The production delay caused by the failure of the supplier's production system, the supplier's own production technology conditions may cause uncertainty in the output period, the production delay caused by the delay of the supplier's raw material supply, the transportation delay caused by the accidental traffic accident, etc. In addition, changes in the production lead time, changes in the order quantity, etc., are also reasons for the uncertainty of supply. While improving the operational efficiency of the enterprise, the logistics supply chain directly or indirectly affects the performance of the enterprise because of its own and external uncertainty, resulting in tangible or intangible losses. In the process of logistics service supply chain management, the goodness of various uncertainties is the key factor for the stability and reliability of logistics service supply chain. Therefore, the identification of influencing factors of system reliability is the basis of reliability management. At the same time, the integrated optimization of logistics supply chain planning activities has an important contribution to enhancing the competitive advantage of enterprises [4, 5]. However, due to the complex structure of the logistics supply chain and the existence of a large number of uncertain factors, planning integration will create very complex decision problems [6, 7]. The more integrated planning activities, the more difficult it is to model and solve, so it is necessary to study the solution to this type of problem.

Therefore, based on the background of supply and demand uncertainty, this paper establishes the fuzzy integrated optimization model of logistics supply chain system by using LR fuzzy numbers. In order to solve the model, the research is deterministically transformed into a deterministic multi-objective linear programming model, and a genetic algorithm for solving the model is designed to solve the given potential supply and demand uncertainty in the system. Finally, the study is carried out by numerical examples, and the results demonstrate the effectiveness of the model and algorithm.

2 Related work progress researches

2.1 Supply chain and logistics network

The logistics supply chain is a complex dynamic system that requires an effective coordinated management approach. Supply chain management is based on understanding and mastering the internal laws and interconnections of all links in the supply chain. Rationalize the logistics, information flow, capital flow and business flow involved in each part of the production and distribution process by using the planning, organization, command, coordination, control and incentive functions of the management. Modern supply chain management theory provides an effective way to improve competitive advantage and reduce transaction cost. This way is to coordinate the relationship between members of the supply chain, strengthen the contact with partners, conduct transactions on the basis of coordinated cooperative relationship, and strive for the global optimization of the supply chain, so as to effectively reduce the overall transaction cost of the supply chain, make the interests of all parties in the supply chain increase synchronously. In order to achieve the best combination, maximize efficiency, and provide customers with the greatest added value at the lowest cost. It not only focuses on the internal resources and competitiveness of the enterprise, but also focuses on the resources and competitiveness outside the enterprise, emphasizing the integration of resources and competitiveness throughout the supply chain. In order for enterprises in the supply chain to obtain satisfactory results from cooperation, certain measures must be taken to avoid risks in the operation of the supply chain, such as improving information transparency and sharing, optimizing contract mode, establishing supervision and control mechanism, etc. In particular, various means must be adopted to implement incentives through the operation of incentive mechanism at all stages of enterprise cooperation. This is a new management idea and method and also a new competitive strategy for enterprises. The goal of supply chain logistics management is to minimize total cost, optimize customer service, minimize total inventory, and minimize total cycle time and to find the best balance between the objectives of logistics quality optimization, in order to maximize the performance of the supply chain, as shown in Fig. 1 [8].

2.2 Research progress at domestic and foreign

Tang and his groups [9] proposed a logistics planning model for multi-level supply chain based on various constraints such as production, inventory and transportation. Azadi and Tavana [10, 11] proposed the emergency supply chain reliability evaluation model and the multi-level multi-node decentralized control supply chain logistics planning model in the uncertain environment. Zhalechian and his groups [12] proposed a reliability supply chain network design problem considering node interruption and demand fluctuation. The hybrid intelligent algorithm is used to solve and prove that the reliability supply network is better than the network model. Balaman [13]designed a multi-objective logistics supply chain network model based on group intelligent agricultural products. A new improved binary particle swarm optimization algorithm with multiple algorithms is used to solve and verify the effectiveness and superiority of the algorithm. Liao [14] analyzed the logistics supply and demand balance problem of transportation system. Starting from the transportation system with logistics activity as the main body, the logistics demand supply model was established. The main line of supply chain management is information management. The basis of information management is to build an information platform, realize information sharing, and timely and accurately transmit the supply and demand information to all enterprises in the supply chain, so as to further realize the management of supply chain. Although the above paper does not analyze the imbalance of supply and demand of logistics from the perspective of supply chain, its research content and methods provide a way of thinking about the imbalance of supply and demand of logistics in the supply chain environment.

2.3 Analysis of the causes of unbalanced supply and demand of logistics under the environment of supply chain

In the supply chain environment, the mechanism of imbalance between supply and demand of logistics will affect the imbalance of supply and demand of logistics. The reasons mainly come down to five points: the complexity of the supply chain system, the insufficient

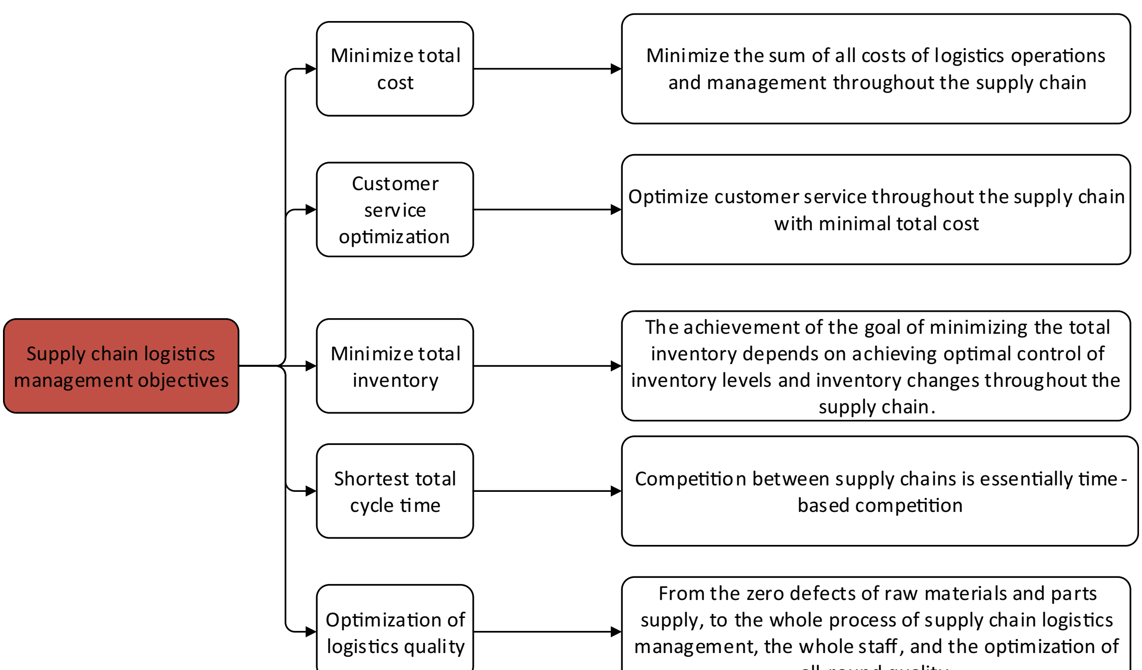

Fig. 1 Supply chain logistics management objectives

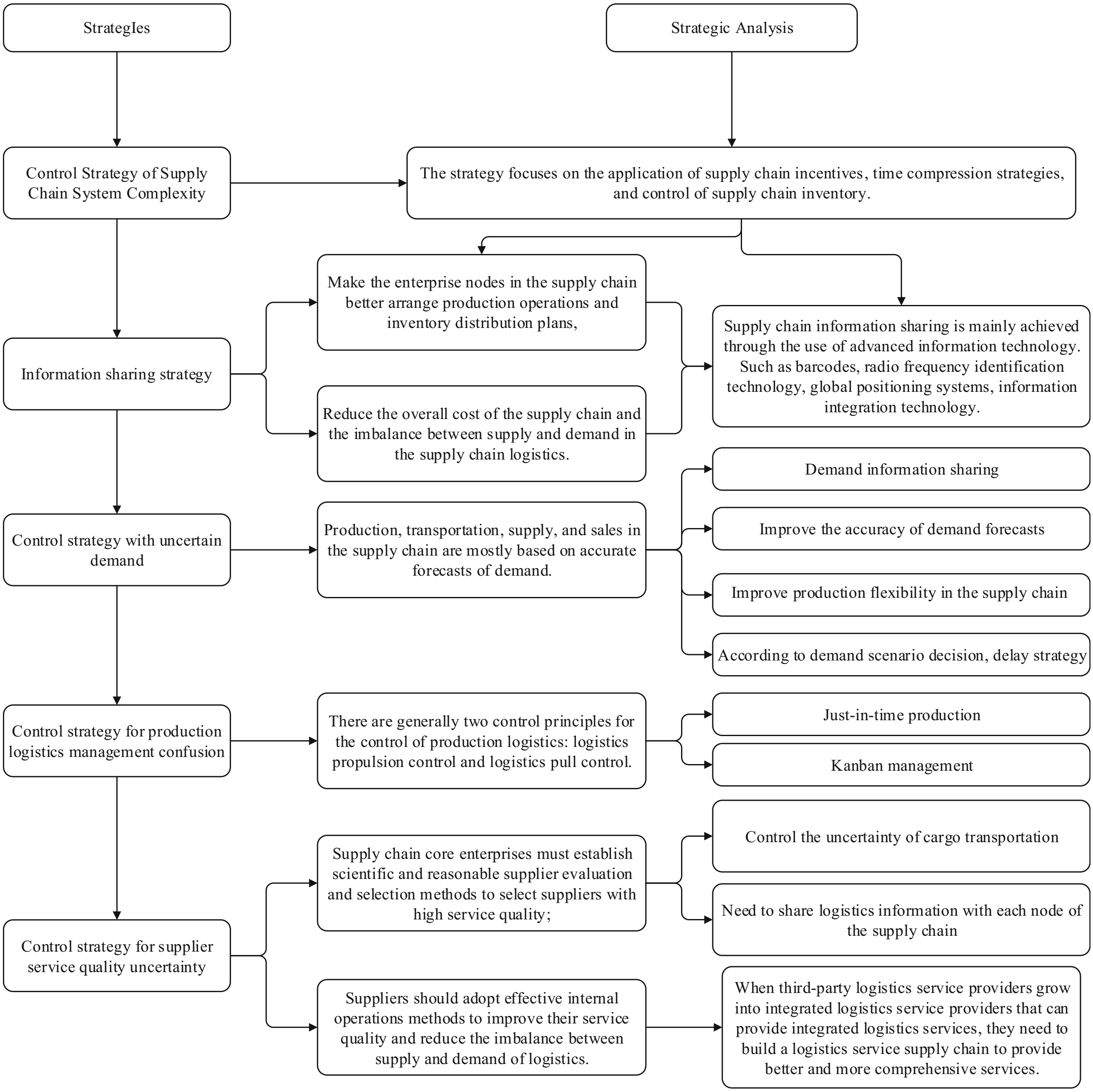

Fig. 2 Analysis of the reasons for the unbalanced supply and demand of logistics under the environment of supply chain

information sharing, the uncertainty of demand, the uncertainty of supplier service quality, and the confusion of production logistics management [15] (Fig. 2).

3 Fuzzy integration algorithm for logistics supply chain under the background of uncertainty of supply and demand

The complexity of logistics supply chain system is one of the main reasons for the imbalance between supply and demand of supply chain logistics. The structural complexity of the supply chain is manifested in two aspects. One is the complexity of the entity relationship of the supply chain. The second is the complexity of supply network form. Generally speaking, the supply chain presents a complex network structure, specifically chain, tree, two-way tree and star structures. For the actual supply network, the above structure is often complex. The foregoing summarizes the control strategies for the imbalance of supply and demand of logistics due to the complexity of the supply chain, mainly the application of supply chain incentive mechanism, time compression strategy, supply chain inventory control. The existence of multi-level inventory in the logistics supply chain is a direct manifestation of the imbalance of logistics supply and demand, but the certain amount of inventory maintenance is of great significance to ensure the continuity of production, avoid shortage of goods, and cope with the volatility of demand [16–18]. Therefore, in order to reduce the imbalance between supply and demand in the logistics supply chain, the control of inventory needs to be studied under the premise of guaranteeing a certain service level, which requires reducing the maintenance of inventory, reducing inventory costs, and increasing the flow rate of materials. The methods for supply chain inventory control mainly include: VMI, CPFR, JMI, multi-level inventory system optimization and control. This section will focus on the multi-level inventory and customer demand analysis system of the supply chain, using fuzzy integrated algorithm to study inventory control and customer demand strategy with uncertain demand, in order to achieve control of multi-level inventory system.

3.1 Modelling

The competition in the twenty-first century is no longer the competition between enterprises, but the competition between supply chains. The logistics supply chain planning includes three basic issues: the application of the supply chain incentive mechanism, the time compression strategy, and the control of the supply chain inventory. The goal is to minimize the operating costs of the entire network from a global optimization perspective while meeting customer service levels. And assume:

a. The needs of each client area are known;
b. The transportation rate of the product, the operating cost of the collection center, the connection relationship and distance of each node are known;
c. In the network, the superior node and the lower node are one-to-many relationships;
d. The transportation cost is proportional to the distance and quantity, and the sorting cost is proportional to the quantity;
e. Stock center stock is zero;
f. The entire network information is transparent, and the lower level decision is the basis for the superior decision.

The fuzzy integrated optimization model of the logistics supply chain network is given below:

S.T.

$$\sum_{P=1}^{p}\sum_{g=1}^{G}\tilde{N}(n)=\sum_{d=1}^{D}\tilde{M}(m) \tag{1}$$

$$\tilde{M}(m)=\sqrt{\frac{2\sum_{r=1}^{R}b_{\tilde{m}m}(t)\times q_{\tilde{n}n}(t)\times q_{\tilde{m}m}(t)}{q_{\tilde{n}o}(t)\times e_{\tilde{n}on}(t)}},r= \\ =1,2,\ldots,R \tag{2}$$

$$\sum_{g=1}^{G}e_{\tilde{n}on}(t)\geq 1,\sum_{d=1}^{D}q_{\tilde{n}o}(t)\geq 1 \tag{3}$$

$$\sum_{g=1}^{G}e_{\tilde{n}on}(t)<\sum_{d=1}^{D}S_{\tilde{m}m}(t) \tag{4}$$

$$\sum_{p=1}^{P}I_{\tilde{n}o}(t)=1,\ p=1,2,\ldots,P \tag{5}$$

$$\sum_{d=1}^{D}I_{\tilde{m}m}(t)=1,\ d=1{,}2,\ldots,D \tag{6}$$

$$\sum_{r=1}^{R}v_{\tilde{m}n}(t)=1,\ d=1{,}2,\ldots R \tag{7}$$

$$x_{\tilde{m}n}=0,1,\ g=1,2,\ldots,G \\ x_{\tilde{m}m}=0,1,\ m=1,2,\ldots,M \tag{8}$$

$$\partial_{\tilde{m}\tilde{n}}=0,1,\ p=1,2,\ldots,P,\ r=1,2,\ldots,R \tag{9}$$

$$P_{\tilde{n}n}=0,1,\ n=1,2,\ldots,N,\ g=1,2,\ldots,G \tag{10}$$

$$\tilde{d}_{\tilde{n}on}=0,1,\ g=1,2,\ldots,G,\ d=1,2,\ldots,D \tag{11}$$

$$q_{\tilde{n}o}(t)\geq 0,\tilde{M}(m)\geq 0,AB_{\tilde{m}om}(t) \\ \geq 0,\ p=1,2,\ldots P,\ r=1,2,\ldots,R,\ d=1,2,\ldots,D \tag{12}$$

There are two types of symbols in this model, namely model parameters and decision variables.

(1) The model parameters are as follows:

$\tilde{N}(n)$ refers to a collection of product types produced by the manufacturer n;

$\tilde{M}(m)$ refers to a collection of raw materials provided by supplier m;

J refers to the total number of enterprises in each node that constitute the supply chain;

M refers to supplier collection;

O refers to customer collection;

N refers to manufacturer collection;

T refers to the planning period divided into several periods $t = 1, 2, \cdots, T$;

$b_{\tilde{n}n}(t)$ refers to t the maximum production capacity of the manufacturer n product $\tilde{n}$;

$b_{\tilde{m}m}(t)$ refers to t period supplier m raw material $\tilde{m}$ maximum capacity;

$q_{\tilde{n}n}(t)$ refers to the maximum inventory capacity of the manufacturer $\tilde{n}$ and product n during the t period;

$q_{\tilde{m}m}(t)$ refers to t time supplier $\tilde{m}$ m raw material maximum inventory capacity;

$q_{\tilde{n}o}(t)$ refers to the maximum inventory capacity of the customer o product $\tilde{n}$ during t period;

$e_{\tilde{m}nm}(t)$ refers to t time period manufacturer n's maximum transport capacity to supplier m raw material $\tilde{n}$;

$e_{\tilde{n}on}(t)$ refers to t the maximum transport capacity of the customer o to the manufacturer's n product;

$S_{\tilde{n}n}(t)$ refers to t time period when the manufacturer n produces $\tilde{n}$ the product;

$S_{\tilde{m}m}(t)$ refers to t time supplier m produces raw material $\tilde{m}$ equipment costs.

$P_{\tilde{m}m}(t)$ refers to t time period unit product $\tilde{m}$ variable production cost at manufacturer m (including manufacturing costs and other direct costs).

$P_{\tilde{n}n}(t)$ refers t time unit product $\tilde{n}$ variable production cost at manufacturer n (including manufacturing costs and other direct costs).

$I_{\tilde{n}n}(t)$-t time period unit product $\tilde{n}$ inventory cost at manufacturer n.

$I_{\tilde{m}m}(t)$-t-time unit product inventory cost at manufacturer m.

$I_{\tilde{n}o}(t)$-t-time unit product $\tilde{m}$ inventory cost at manufacturer o.

$C_{\tilde{n}on}(t)$-t-time unit product $\tilde{n}$ transportation cost from manufacturer n to customer o;

$C_{\tilde{m}nm}(t)$-t time unit raw material $\tilde{m}$ transportation cost from supplier m to manufacturing n;

$D_{\tilde{m}nm}(t)$-t time unit raw material n from supplier m to manufacturing $\tilde{m}$ transportation cost;

$\tilde{D}_{\tilde{m}nm}(t)$-$t$ the total amount of raw materials $\tilde{m}$ that the supplier m promises to deliver to the manufacturer n;

$d_{\tilde{n}on}(t)$ -t the total amount of raw materials that the manufacturer n promised to deliver to the customer o.

$\tilde{d}_{\tilde{n}on}(t)$-$t$ time customer's $\tilde{n}$ total demand for manufacturer n products.

$\partial_{\tilde{m}\tilde{n}}$-structural factor between unit product and raw material $\tilde{m}$.

$P_{\tilde{n}n}(t)$ -t time period manufacturer n pair price $\tilde{n}$.

$w_{\tilde{n}o}(t)$-t-time customer o demand for products $\tilde{n}$.

$v_{\tilde{m}n}(t)$-t time the price at which the manufacturer n purchases raw materials $\tilde{m}$.

(2) The decision variables are as follows:

$x_{\tilde{m}n}(t)$ refers to t time product $\tilde{n}$ in the manufacturer's planned production batch;

$x_{\tilde{m}m}(t)$ refers to t time raw materials $\tilde{m}$ in the planned production batch of supplier m;

$y_{\tilde{n}n}(t)$ refers to the amount of inventory $\tilde{n}$ at the end of the period at the manufacturer n;

$y_{\tilde{m}n}(t)$ refers to the amount of raw materials $\tilde{m}$ at the end of the period at the supplier m;

$y_{\tilde{n}o}(t)$ refers to the amount of inventory at the end of production $\tilde{n}$ the period at the customer o;

$z_{\tilde{n}on}(t)$ refers to t time period product $\tilde{n}$ shipment volume from manufacturer n to customer o;

$AB_{\tilde{m}om}(t)$ refers to t time raw materials $\tilde{m}$ transportation volume from upstream enterprise to enterprise n;

$$u_{\tilde{n}n}(t) = \begin{cases} 1 & t - \text{time manufacturer } n \text{ produces products } \tilde{n} \\ 0 & \text{Others} \end{cases} \tag{13}$$

$$\mathrm{u}_{\tilde{m}m}(\mathrm{t}) = \begin{cases} 1 & t \text{ period supplier } m \text{ production raw materials} \\ 0 & \text{Others} \end{cases} \tag{14}$$

$$\mathrm{u}_{\tilde{n}o}(\mathrm{t}) = \begin{cases} 1 & t \text{ time customer } o \text{ order product } \tilde{n} \\ 0 & \text{Others} \end{cases} \tag{15}$$

Constraints (2) and (3) ensure the conservation of the entire logistics supply chain products; Constraint (4) uses the economic order quantity (EOQ) according to the customer area demand to determine the optimal order quantity of the distribution center; according to the problem description and parameter definition, aim at maximizing the expected profit. At the same time, a random expectation value model of the supply chain logistics plan in the planning period T is established. In the objective function, X represents all the decision vectors in the model. The objective formula (1) indicates that the model goal is to maximize the expected profit; the constraints of the model are based on Eqs. (2–16).

3.2 Determination of fuzzy integrated algorithm model

This study uses LR-type fuzzy numbers, ie $M_i = (k_i, a_1, b_i)_{LR}$.

Then it is also a $\sum M_i = (k_i, a_1, b_i)_{LR}$ type fuzzy number, and there is

$$\sum M_i l_i f(x) = \left(\sum_{i=1}^{kk} l_i f(x), \sum_{i=1}^{mm} a_i f(x), \sum_{i=1}^{mm} b_i f(x) \right) \quad (16)$$

$$\text{Min} \sum M_i l_i f(x) = \text{Min} \left(\sum_{i=1}^{kk} l_i f(x), \sum_{i=1}^{mm} a_i f(x), \sum_{i=1}^{mm} b_i f(x) \right)_{LR} \quad (17)$$

where $f(x)$ is an n-ary non-negative function on i; x is the decision variable.

Let $C = (a, v, m), B = (b, y, z) \in^{o}_{iLR}$,Then define $C \leq B_L \Leftrightarrow a < b, a - v < b - y, a + m < b + z$.

Obviously $\leq L$ is the partial order relationship on $^{o}_{iLR}$.According to this partial order relationship, the above formula can be converted to:

$$\begin{aligned} \text{Min } B^L &= \sum_{i \in k^+} (m_i - a_j) f_j(x) \\ Z &= \sum_{i \in k^+} (v_i + b_j) f_j(x) \\ Z^R &= \sum_{i \in k^+} (y_i + z_j) f_j(x) \end{aligned} \quad (18)$$

$$S.T\ m \in M \in i^n \quad (19)$$

X represents the feasible domain of the decision variable in the model. So this fuzzy integrated optimization model can be converted to:

$$\begin{aligned} Min\, Z^R = &\sum_{i=2}^{G} (a_i - b_i) x_i + \sum_{k=2}^{D} (a_k - b_k) x_k \\ &+ \cdots + \sum_{i=2}^{G} \sum_{r=1}^{R} (cc - by) D_{dr} n_r x_d^r \end{aligned} \quad (20)$$

$$Z = \sum_{i=2}^{G} a_i x_i + b_g + \sum_{i=2}^{G} c_d x_i + \sum_{i=2}^{G} \sum_{r=1}^{R} cc D_{dr} n_r \quad (21)$$

$$S.T\ (xg, xd, xpg, xgd, npg, Q_d) \in (X_G, X_D, X_{PG}, X_{DD}) \quad (22)$$

where

$$\overset{0}{M} = (\overset{\circ}{c}, a, b)_{LR};\ ''\circ'' = [p, g, m];\ \overset{\circ}{K} = (y^{\circ\circ}, a^{\circ\circ}, z^{\circ} \quad (23)$$

$\overset{0}{M} = (\overset{\circ}{c}, a, b)_{LR}$; "∘" = $[p, g, m]$; $K^\circ = (\overset{\circ\circ}{y}, \overset{\circ\circ}{a}, \overset{\circ}{z})$; $[pg, ds, dt]$; $\overset{0}{S}_g(s_{cg}, s_a, s_\beta)_{LR}$ represents the feasible domain of the decision variable, and the problem has been transformed into a typical multi-objective programming model. For multi-objective programming problems, the objective function is usually transformed into a compromise model by weighted summation. For this purpose, set:

$$\chi_1 + \chi_2 + \chi_3 = 2,\ \chi_{1,2,3} > 0 \quad (24)$$

Therefore we got

$$\text{Min}\ (xg, xd, xpg, xgd, npg, Q_d) = \chi_1 Z^k + \chi_2 Z + \chi_3 Z^R \quad (25)$$

$$S.T\ (xg, xd, xpg, xgd, npg, Q_d) \in (X_G, X_D, X_{PG}, X_{DD}) \quad (26)$$

3.3 Interactive ε constraint algorithm

This paper studies a multi-objective fuzzy programming model. At present, the commonly used multi-objective problem solving methods mainly include three types: a priori, interactive and posterior methods. In contrast, interactive methods are characterized by high efficiency and flexibility, allowing for interactive and incremental measurement and adjustment of the level of satisfaction of each objective function in accordance with the preferences of the decision maker, thereby ensuring that the optimal solution obtained can better meet the preferences of decision makers. To this end, this study proposes an interactive ε constraint algorithm. This facilitates the convergence of the guided search to the decision maker's preferred solution, thereby helping the decision maker to select the Pareto optimal solution that best fits his or her preference.

This interactive method has the following advantages:

a. In each iteration, the decision maker can choose multiple Pareto optimal solutions;
b. The decison maker selects the way of narrowing the search space by adding an upper bound constraint to the objective function of the solution;
c. Without limiting the number of iterations of the algorithm, the decision maker determines the termination of the algorithm based on the satisfaction of the solution obtained.

The specific steps of the interactive ε constraint method are as follows:

Step 1 Optimize each objective function with lexicographic order to get the payment matrix of the objective function. The execution steps of the lexicographic optimization method are as follows:

a. Optimize the first objective function (with the highest priority) to get $\min Z_1 = Z_1^*$;
b. Optimize the second objective $Z_1 = Z_1^*$ function by adding constraints to obtain $\min Z_2 = Z_{21}^*$;
c. Optimize the second objective function as a single target to obtain $\min Z_2 = Z_2^*$, and the corresponding first objective function value is Z_1'. Then the payment matrix is $\begin{bmatrix} Z_1^* & Z_{21}^* \\ Z_1' & Z_2^* \end{bmatrix}$.

Step 2 Calculate the variation range $r = Z_{21}^* - Z_2^*$ of the second objective function according to the payment matrix.
Step 3 Based on the range of variation of the second objective function, set the number of grid points to g.
Step 4 Use the second objective function as a constraint. For each grid point, solve the following problem:

$$\begin{aligned} &s.t\ \min Z_1(X) - \rho s/c \\ &X \in S,\ Z_2(X) + s = \varepsilon \end{aligned} \tag{27}$$

where: $\varepsilon = Z_2^* + (i \times r)/g, i$ is an iterative counter, ρ is a positive minimum (value is 10^{-6}–10^{-3}), X is the solution vector, and S is the feasible domain of the solution.
Step 5 The decision maker chooses the Pareto optimal solution according to his preference. If the decision maker is satisfied with the selected solution, then the current solution is selected as the optimal solution, and the calculation stops. Otherwise, the decision maker chooses the n preferred solutions and increases the upper bound constraint of the second objective function to reduce the search space. Calculate the upper bound constraint $i+1$ of the eighth iteration $KB^{(i+1)} = \max[Z_j^{(i)} + a^j(Z^{\min} - Z_j^{(i)})]$.Go to *step 2*.

3.4 Genetic algorithm

This study uses genetic algorithm to solve by segmentation hybrid coding and breakpoint intersection.

(1) Encoding of the solution.
This study uses corresponding position coding. The basic structure is:

$$[I_1, I_2, \ldots, I_G | II_1, II_2, II_D] | III_1, III_2, III_3, \ldots III_D] \tag{28}$$

(2) Selection of initial population.
Due to the complexity of chromosome coding, an initial population is generated by randomly assigning relational nodes.

(3) Fitness.
Fitness is an indicator for evaluating the pros and cons of chromosome performance. The higher the fitness value, the greater the chance of survival during evolution. For chromosome.
$k : \text{fitness}_k = [M - f_m(x_g, x_d, x_{pg}, x_{dr})]^2$,where $\{M - \max m_k f_k(x_g, x_d, x_{pg}, x_{dr})\} \to 0$.

(4) Select operator.
The higher the fitness, the higher the probability that the chromosome is selected, and the probability of selection is $pk = \frac{\text{fitness}_k}{\sum_{k=1}^{K} \text{fitness}_k}$, where K is the population size.

(5) Cross.
Due to the particularly complex structure of the chromosomes, an infeasible solution may occur after the crossover. The objective function of this study is more complicated, and using this method will greatly increase the complexity of the algorithm. Solve using the interactive ε constraint algorithm described above to ensure that each chromosome is a feasible solution.

(6) Variation.

(7) Chromosome adjustment.

The above cross-variation method ensures that each chromosome corresponds to a feasible network structure. However, due to the complex chromosome structure, many problems may still occur after crossover and mutation:

4 Optimization of fuzzy integrated algorithm for logistics supply chain under the background of supply and demand uncertainty

4.1 Optimization model

The design and clustering algorithm of the multi-level logistics supply chain optimization model based on customer requirements under different product conditions can well explore the customer's individualized needs and supplier matching. According to the analysis of the customer's relevance to the product's demand score data, Apriori algorithm can well explore the relationship between the potential decision-making factors affecting the customer and the product. Based on the above characteristics, this paper uses the Apriori algorithm of data mining and the combination of clustering algorithm and genetic algorithm to solve the model. Genetic algorithm has good global search ability and can quickly search all solutions in the solution space without falling into the trap of rapid descent of local optimal solutions. It is a global optimization algorithm. The general iterative method is easy to fall into the trap of local minima and appear the phenomenon of dead cycle so that the iteration cannot be carried out. Genetic algorithm overcomes this shortcoming and is a global optimization algorithm. Enter in a single product situation, use Apriori algorithm to calculate, enter Step1, multi-product scenario directly into Step2, and the algorithm execution process is as follows:

Step1 Enter the customer score and search for items that meet the minimum support α and the minimum confidence β. Find the frequent item set σ_1, use σ_1 to find the frequent item set σ_2, and know to find the k frequent item set and input the set Ω, the initial $\Omega = \mathbb{C}$.Go to Step2.

Step2 Enter the demand score value of the customer m, and use the score of this user m as the initial clustering center. Enter the score of the i-th supplier kib of the k-th layer, and calculate the similarity to select the kib input set $m = 1, m = m + 1$.Let the initial $k = 2, k = k + 1, i = 1, 2, 3, \ldots S_k$, initial S_k, and Ω be the number of nodes in the kth layer. Loop to find all the solution sets that satisfy the condition. Go to Step3.

Step3 Enter the solution set Ω and optimize the entire solution space according to the model's inventory capability constraints and transport capacity constraints $\sum^{M} x_{ki}^{m} \le h_{ki}, x_{kij} \le d_{ki}$ to get the initial solution $\Omega_{(0)}$. Determine the initial population size as R, the crossover probability as P_J, the mutation probability as P_b and the termination evolution criterion, and set the evolution algebra counter $t \leftarrow 0$.

Step 4 Calculate the fitness of the individual, this paper studies the minimum value of the objective function, so the objective function is taken as the fitness value of the individual.

Step5 Population evolution: Select and use $N/2$ selection operator from $\Omega_{(t)}$ to select to the parent $N \ge M$. Rate P_j performs crossover to form N intermediate individuals. N intermediate individuals are independently independent, and mutations are performed according to probability P_b to form N candidate individuals. From the candidate individuals selected above, R individuals are selected to form a new generation population $\Omega_{(t+1)}$ according to individual fitness.

Step6 Terminate the test. If the set termination condition has been met, the $\Omega_{(t+1)}$ individual is output as the optimal solution, and the calculation is terminated. Otherwise set $t \leftarrow t + 1$ and go to step 4 to continue.

4.2 Simulation examples and results analysis

In the cost structure of supply chain, inventory cost is the most important cost, and it is also difficult for brands, distributors and retailers to judge. With the online, digital and intelligent supply chain information, the flow, sharing and decision support of information are expected to greatly optimize the inventory and make the correct amount of inventory appear at the right time and place. Optimize the supply and demand of the entire logistics supply chain through the forecast of customer demand and supplier inventory. The simulation results are based on data mining to predict the customer demand and the supplier's inventory. According to the prediction results and simulation examples, the results of logistics supply chain optimization are obtained.

(1) Analysis of forecast results of customer demand.

In order to ensure the quality of data analysis, the selected data are authoritative and objective. The data selected in this experiment are the data set of a brand car of Yiche.com in September 2018. According to statistics, the total number of customer clicks is 11,882,596, the number of browsing times that meet the conditions is 951,487, and the number of sales is 59,421. Calculating that the number of clicks and browsing time are both 84,716, we can know that the frequency of simultaneous occurrences is the number of sales. According to the correlation analysis, the customer's click volume and browsing time are 91% related to the customer's demand, which indicates that the customer's click volume and browsing time have a strong ability to interpret the customer's demand. Thus, future sales can be predicted based on the effective clicks of the next period. The predicted correlation results are combined with the customer's demand data into the model.

(2) Analysis of the results of logistics service provider inventory.

There are 8 functions in the enterprise's three-level logistics service supply chain to provide distributors, and the customer price sensitivity coefficient is set to 1. a is 85%, $T(A \cap B)$ is 7, and then the number of customers m is 9. The sensitive parameters of the service level are 0.9, 0.9, 0.7, 0.7, 1, 0.7, 0.65, 0.85, 0.85, 0.7. The logistics service cost coefficient γ is 0.85. The minimum profit A of the function provider's participation in the service is 112, 101 114, 108, 105, 100, 95, 100. Based on the genetic algorithm, the parameters are selected as S_i, the population size is 60, the crossover rate is 0.6, and the number of iterations is 150. The maximum service volume X_i of the function provider is 60, 50, 50, 60, 65, 60, 60, 60 in order. The penalty factor π is 0.002, and the price of the product C_i is 100. Different function providers have different service levels for different tasks. The data of the customer and function provider are shown in Tables 1, 2 and 3.

Based on the above data, the simulation operation is used to determine the size of the function supplier's inventory and the size of the customer's attractiveness and function to provide the logistics service cost of the distributor. The calculation error accuracy is 0.01, and the operation results are shown in Tables 4 and 5.

The task of calculating the selected function provider for service is that the function provider 3 serves the customers 1, 2, respectively. The function provider 6 serves the customers 3, 4, 6, 7, 8, 9 and the function provider 7 serves the customers 5, 9. Compared with the actual inventory quantity t, the inventory of function providers 3 and 7 meet the conditions. Finally, the result of the logistics service

Table 1 Service provider service level table

	Clients								
	1	2	3	4	5	6	7	8	9
5.26 Suppliers									
1	4.54	4.78	4.89	4.69	4.82	4.91	4.27	4.76	4.66
2	4.57	4.71	4.85	4.99	4.75	4.65	4.82	7.51	4.60
3	5.23	5.31	5.33	5.29	5.31	5.34	5.04	5.06	5.06
4	4.98	4.51	4.51	4.59	4.51	4.94	4.59	4.87	4.92
5	4.45	4.30	4.31	4.31	4.28	4.60	4.68	4.39	4.40
6	4.29	4.95	4.89	4.49	4.59	4.81	4.62	4.68	4.60
7	4.65	5.18	5.49	5.51	5.97	5.67	5.49	5.41	5.61

Table 2 Supplier inventory and customer demand

	Clients								
	1	2	3	4	5	6	7	8	9
Suppliers									
1	159	158	167	165	149	169	157	169	159
2	171	181	182	187	169	157	167	161	165
3	198	187	157	191	167	159	153	158	157
4	159	141	157	154	157	167	161	163	169
5	157	157	153	179	188	187	154	134	179
6	168	168	154	174	164	169	197	177	157
7	157	192	184	179	155	175	167	172	168

Table 3 Expected values of the service level of the function provider and the situation of the supplier's inventory

	Clients								
	1	2	3	4	5	6	7	8	9
Q_j	5	5	4.6	4.9	4	3	4.2	5	3
P_j	191	186	175	170	186	169	179	185	190

cost is 653.14 yuan (calculation error accuracy is 0.01). Under the fuzzy integrated algorithm model, it mainly analyzes the customer behavior law based on the fuzzy algorithm analysis technology and predicts the supplier's inventory and customer's demand. Based on the prediction results, the customer's attractive decision variables are constructed, and the task allocation optimization model of the logistics supply chain is constructed. Its optimization goal is to minimize the service cost of logistics service integrators, and to select the most attractive suppliers to provide services to customers, improve customer satisfaction and corporate competitiveness.

Table 4 Features provide the distributor's attractiveness to the customer

	Clients								
	1	2	3	4	5	6	7	8	9
Suppliers									
1	4.51	4.76	4.84	4.66	4.80	4.93	4.24	4.73	4.64
2	4.56	4.73	4.83	4.98	4.77	4.64	4.80	7.52	4.59
3	5.25	5.28	5.30	5.27	5.33	5.36	5.03	5.04	5.32
4	5.00	4.53	4.50	4.55	4.54	4.95	4.61	4.87	4.71
5	4.46	4.28	4.36	4.33	4.21	4.59	4.71	4.35	4.54
6	4.26	4.94	4.89	4.45	4.62	4.83	4.65	4.68	4.61
7	4.63	5.19	5.49	5.49	6.00	5.70	5.46	5.45	5.59

Table 5 Functions provide the size of the logistics service cost of the distributor

	Clients								
	1	2	3	4	5	6	7	8	9
Suppliers									
1	155	156	166	164	158	163	159	170	161
2	170	180	180	189	166	160	165	165	162
3	200	185	161	181	169	159	158	153	161
4	155	151	161	161	160	160	160	169	165
5	159	159	158	181	185	191	150	141	178
6	169	167	154	182	169	160	201	178	159
7	159	190	182	176	156	177	172	170	171

5 Conclusion

The optimization of the fuzzy integration algorithm of the logistics supply chain under the uncertainty of supply and demand is studied. The ultimate goal is to apply the theoretical research results to practice. This is really helping to improve supply chain performance and bring social benefits. Therefore, based on the research work of domestic and foreign scholars, this paper expounds the uncertain factors affecting the operation of supply chain, and discusses the theory and method of supply chain optimization under uncertain environment. Based on the fuzzy algorithm theory of complex systems, aiming at supply chain optimization under uncertain conditions, designing a supply chain network with strategic layer integration, establishing a fuzzy integrated algorithm optimization model, and designing a model solving algorithm. The performance of the algorithm and the applicability of the model are tested by examples. Finally, the prototype system is developed by simulation example and result analysis, and the running examples are given, which fully verifies the rationality and effectiveness of the theory and method proposed in this paper.

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Declarations

Conflict of interest The authors declared that they have no conflict of interest to this work. We declare that we do not have any commercial or associative interest that represents a conflict of interest in connection with the work submitted.

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