Research on Network Equilibrium Scheduling Method of Water Conservancy Green Product Supply Chain Based on Compound Ant Colony Algorithm

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Abstract. In order to improve the balanced scheduling performance of the water conservancy green product supply chain network, a research on the balanced scheduling method of the water conservancy green product supply chain network based on the composite ant colony algorithm is proposed. Build the logistics distribution model of water conservancy green product supply chain to obtain the competitive relationship between supply chains. By calculating the entropy value of the supply chain network scheduling task, the priority weight of the supply chain network scheduling is completed. Based on the composite ant colony algorithm for population fusion calculation, the balanced scheduling model of water conservancy green product supply chain network is constructed to realize the balanced scheduling of water conservancy green product supply chain network. The experimental results show that the proposed method has better performance in the supply chain balance, scheduling responsiveness and storage facility utilization of water conservancy green products.

Keywords: Compound Ant Colony Algorithm · Green Products; Balanced Scheduling · Supply Chain Network · Feature Extraction · Network Optimization

1 Introduction

At present, the constraints of resource and environmental issues on achieving sustainable development are increasingly prominent. Relying on the supply relationship between upstream and downstream enterprises, actively manufacturing and promoting green products is one of the effective ways to improve the green level of the entire supply chain [1]. However, when an enterprise carries out ecological transformation, it will often be accompanied by a large amount of cost input. These additional costs will be passed down the industrial chain level by level, and will eventually be transferred to customers. Whether customers are willing to pay enough premium to make up for additional costs is the key driving force to encourage manufacturing enterprises to take the

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initiative to adopt green strategies. Although green products can weaken the negative impact on the environment, the current green consumption awareness of customers has not been popularized. High manufacturing costs and product prices make it difficult for green products to gain competitive advantage in the market, which to a large extent also leads to the uncertainty of the income of each member in the green supply chain [2]. Therefore, how to balance the cost and profit of green products among members and improve the performance of green supply chain system is a problem that many managers and scholars have been concerned about.

In the domestic research, Tang Liang et al. Considering multiple different types of collaborative supply chain networks with interactive characteristics, the objective function of minimizing production cost, inventory cost, waiting cost and order backorder cost is constructed, and the decision variables of consolidation are designed to construct the start time constraint of similar orders in the same collaborative enterprise. In addition, the model considers two types of orders: deterministic order and stochastic order, and designs the arrival probability of stochastic order at discrete time points in interval time. In order to obtain the optimal production scheduling strategy of the collaborative supply chain network, four sub decision models are constructed based on the scenario of random order arrival or not, and further design the main decision model to judge the cost difference under different scheduling strategies of advance scheduling random order collaborative production and non advance scheduling random order collaborative production. The simulation results show that the merger decision brings production cost benefits, but also causes the delay of partial orders, and different types of collaborative supply chain networks have different anti-jamming capabilities to random orders. Gao Jibing et al. [4] believed that the operation interruption caused by the preventive maintenance of the network equipment in the coal supply chain would affect the total network traffic to a certain extent. In practice, effective scheduling was used to reduce the impact of network interruption. However, the current manual scheduling is not only inefficient, but also has limited time intervals to deal with. Therefore, based on the network flow characteristics of coal supply chain, combined with the characteristics of interruption scheduling, a mixed integer programming model is constructed. For the special network flow and scheduling structure of the problem, the CBD and BBC two Benders decomposition algorithms are used to solve the problem and make a comparative analysis. Finally, based on the BBC, the improved solutions are designed to integrate the advance of pre flow and add effective inequalities. The results of two groups of examples show that BBC has a better solution effect than CBD, and the solution efficiency of the improved algorithm based on BBC is significantly improved.

In foreign studies, Duan C et al. [5] studied the dynamic multi cycle supply chain network equilibrium problem considering marketing and corporate social responsibility in order to explore the optimal marketing and corporate social responsibility strategies in the dynamic multi cycle supply chain network system. Multi cycle CLSCN system includes manufacturers, retailers, recyclers and demand markets. Based on Nash non cooperative game theory and variational inequality, the optimal behavior and equilibrium conditions of members are designed. Then, a new multi cycle supply chain network equilibrium model is constructed. In this mode, marketing is the responsibility of manufacturers and retailers, and corporate social responsibility is the responsibility of manufacturers. Numerical examples verify the validity of the model, and analyze the impact of marketing and corporate social responsibility on the equilibrium results. Retailers are responsible for marketing, and manufacturers' corporate social responsibility activities are at a high level in the early stage, which is most conducive to the diversified supply chain network system and social welfare. Based on the research conclusion of this paper, the management enlightenment is proposed from the perspective of enterprises and government.

In addition, in the process of the overall operation of the green supply chain, customer behavior is an important factor affecting the decision-making of members in each link. When water conservancy green products enter the consumer market, different customers often have different valuations or payment intentions. With the development and growth of online e-commerce platform, convenient and fast shopping channels and open and transparent product information make customers' behavior of purchasing products more complex and changeable. Before making the final purchase decision, customers will have a more comprehensive understanding and analysis of the product's performance, price, retailer's sales strategy, etc., often delaying the decision to purchase products in the current period, which will not only hurt the enthusiasm of green manufacturers for production, but also damage the interests of retailers. So for all members of the green supply chain, how to formulate a price and environmental protection level that can not only satisfy customers' consumption psychology but also ensure their own interests to maximize according to customers' purchase behavior in the actual market is one of the important problems faced at present.

With the worsening of resource and environment problems and the increasingly fierce market competition, more and more enterprises choose to produce green products and use effective marketing means, such as pre-sale strategy to stimulate customers' consumption demand, in order to comply with the trend of green development, improve their competitive strength, and obtain more revenue. Therefore, under the premise of green product pre-sale, aiming at the specific purchase behavior of customers in the actual market, building a green supply chain decision-making model and studying the decision-making situation of each member can enrich and expand the application of customer behavior theory and green supply chain management theory in the consumer market.

With the rapid development of e-commerce, the time and space constraints of the market have been broken. The increasingly transparent product information and increasingly fierce market competition make customers' consumption concepts diversified and personalized, and the purchase behavior presents a complex and dynamic trend. Affected by this, the core enterprises in the green supply chain are also facing unprecedented challenges when making decisions. Therefore, under the pre-sale mode, based on customer behavior, studying the optimal decision-making of green supply chain under different supply chain decision-making situations and contract mechanisms can effectively avoid the adverse impact of customer strategy waiting behavior on enterprises, create more revenue for enterprises, thus promoting green manufacturing and encouraging customers to consume green.

Based on the above research background, this paper applies the compound ant colony algorithm to the balanced scheduling of the water conservancy green product supply chain network, so as to ensure the stability of the water conservancy green product supply chain network.

2 Design of Network Equilibrium Scheduling Method for Water Conservancy Green Products Supply Chain

2.1 Build the Logistics Distribution Model of Water Conservancy Green Product Supply Chain

In practice, the logistics distribution center of water conservancy green product supply chain is multiple demand points, so the logistics distribution model of water conservancy green product supply chain is constructed. The logistics distribution process is as follows: the logistics distribution center of water conservancy green product supply chain has M special vehicles, of which the vehicle type and load capacity are the same; All vehicles to be distributed start from the same distribution center. All distribution vehicles need to pass through various distribution points and return to the distribution center after completing the task. The distribution center can obtain and update data information in real time, including the geographical location of all demand points that need services, and the number of water conservancy green products to be distributed. The water conservancy green products distributed are all regarded as one type, and the quality of these water conservancy green products will continue to decline with the increase of time; Q_i represents the demand for green water conservancy products at demand point i. Each demand point hopes to deliver green water conservancy products within its scheduled time. If the delivery arrival time has exceeded the specified time, the demand point can be rejected. The model is established to find the optimal distribution scheme under the condition that the cost is minimized, the maximum load capacity of each allocated vehicle is not exceeded, and the time range required by the demand point is not violated.

Put M vehicles (ants) into N demand points, and the actions of each vehicle (ant) in each step are: select the next demand point that it has not visited through certain criteria; And after completing a step, from one demand point to another, or a cycle, after completing the access to all N demand points, the pheromone concentration on all paths will be updated.

Assuming that there are N demand points in total, and the number of vehicles (ants) is M, there is formula 1:

$$M = \sum_{i=1}^{N} B_i(t) \tag{1}$$

Vehicles (ant number) located at demand point i at time t, and meeting $\Phi = \{\varepsilon_{ij}(t)\}$, Φ represents the concentration set of pheromones on the distribution path at time t, and $\varepsilon_{ij}(t)$ represents the concentration of pheromones on the distribution path at time t.

After determining the distribution vehicles of the water conservancy green product supply chain, build a tabu list as shown in Formula 2:

$$P_{ij}^{k}(t) = \left\{ \begin{array}{cc} \frac{[\varepsilon_{ij}(t)]^{\alpha}[\gamma_{ij}(t)]^{\beta}}{\sum\limits_{s\in \text{ allowed}} [\varepsilon_{is}(t)]\alpha[\gamma_{is}(t)]\beta} & j \in \text{ allowed}_k \\ 0 & \text{else.} \end{array} \right\} \tag{2}$$

Among them, α represents the information heuristic factor, which is used to evaluate the relative importance of distribution routes, β represents the expected heuristic factor, which is used to evaluate the relative importance of visibility, allowed$_k$ represents all nodes that vehicle k can currently select, $\gamma_{ij}(t)$ represents the visibility at time t, , and represents the expected degree of vehicle (ant) transfer from node i to node j.

Through the tabu list, record each customer that has completed the task assigned by the ant, and keep updated throughout the search process [6]. After a period of time, the entire path search is completed. At this time, all taboo lists have been filled in. Then, calculate and compare the path length of each vehicle (ant) to obtain the best path. Save and record the best path, and update the pheromone on the path.

When the number of iterations reaches the upper limit, the final path obtained is the shortest path of vehicles (ants) in all paths. The rules for updating pheromones are Formula 3 and Formula 4:

$$\varepsilon_{ij}(t+N) = \phi \cdot \varepsilon_{ij}(t) + \Delta\varepsilon_{ij} \tag{3}$$

$$\Delta\varepsilon_{ij}(t+N) = \sum_{k=1}^{M} \Delta\varepsilon_{ij}^{k} \tag{4}$$

According to the logistics distribution process of the water conservancy green product supply chain, the distribution vehicles of the water conservancy green product supply chain are determined, and the logistics distribution model of the water conservancy green product supply chain is constructed by constructing the taboo list.

2.2 Obtain the Competitive Relationship Between Supply Chains

Assume that d_j represents the node set of the water conservancy green product supply chain network, s_g represents the node set of transportation, warehousing and manufacturing, b_i represents the water conservancy green product supply chain system composed of core suppliers, and s_h represents the uncertainty of water conservancy green product supply, then use Formula (5) to give the relationship between water conservancy green product storage and multi-level supply chain:

$$r_p = \frac{s_h * b_i}{s_g} + d_j \cdot \frac{\{l_p\} - m_o}{g_i \cdot \{p^*\}} + r_u \tag{5}$$

In the formula, $\{l_p\}$ represents the storage demand issued by the supplier according to the production progress, m_o represents the available facility resources for the i-th node of Class r_u water conservancy green products to execute t task in cycle p^*, and g_i represents the link of the storage facility node.

Suppose that e_h represents the inventory time of green water product d at the supply chain network node ph, and k_h represents the inventory area of green water product d at the supply chain network node ph, then use Formula (6) to calculate the demand status of green water product storage for each layer of the supply chain:

$$u_p = \frac{k_h \times e_h}{r_p - c_n}(d, ph) + \frac{p_y}{t^*} \tag{6}$$

where, c_n represents the transportation cost of water conservancy green product logistics storage, and p_y represents the state vector of water conservancy green product t^* being consumed.

Assume that I^* represents the set of logistics warehouses of green water products, J^* represents the set of suppliers of green water products, K_u represents the middleman, μ_e represents the supply and demand relationship of green water products, and E_I represents the service relationship of green water product logistics, then use Formula (7) to form a supply chain competition network of green water products:

$$G_K = \frac{E_I + K_u}{\mu_e} \times \left\{J^* \times I^*\right\} \tag{7}$$

Assume that τ_l represents the circulation status of green water products, l_p represents the service status of the warehouse, m_p represents the sales status of the middleman, the middleman places the water green products χ required by the market in the logistics warehouse, and ∂_j represents the types of water green products required by the market, and formula (8) is used to give the direct competition relationship among members in each node of the supply chain network:

$$b_g = \frac{\partial_j \times \tau_l}{m_p\{\chi \times l_p\}} \tag{8}$$

Assume that l_p^* represents the fixed inventory cost of the supply and demand goods in each market, and l_y^* represents the competition behavior between the warehouses or suppliers in each layer, then use Formula (9) to obtain the non cooperative competition relationship between the nodes of the supply chain in the same layer:

$$e_j = \frac{l_y^* + l_p^*}{P_o} \times \partial_l \tag{9}$$

where, P_o represents the maximum storage period of each water conservancy green product, and ∂_l represents the supply and demand capacity limit of various water conservancy green products.

Suppose that q_k^l represents the non negative quantity of water conservancy green product l stored by warehouse k^*, u_p represents the storage vector of warehouse k^*, and Q_G represents the distance from storage facility k^{**} to the destination, then use formula (10) to obtain the operation cost of water conservancy green product logistics warehousing:

$$p_k = \frac{\{i^*, i^{**}\} + Q_G}{G_K\left(q_k^l \cdot u_p\right)} \pm e_j \mp b_g \tag{10}$$

In the process of balanced scheduling of the water conservancy green product supply chain network, the decision theory model is first integrated to form a water conservancy green product supply chain competition network [7], giving the direct competition relationship among the members of each network node, obtaining the non cooperative competition relationship between the supply chain nodes of the same layer, giving the warehousing cycle of each circulating water conservancy green product, and obtaining the logistics warehousing operation cost, It lays a foundation for the balanced scheduling of the supply chain network of green water products.

2.3 Prioritization Weight of Supply Chain Network Scheduling

In the process of balanced scheduling of water conservancy green product supply chain network, there are differences in scheduling demands among various network nodes, so the network scheduling priorities of the supply chain must be ranked according to plan to determine the optimal network scheduling configuration scheme.

Generally, priority weight ranking method is used, and subjective evaluation method and relatively objective AHP method are used for measurement. This method has a high degree of randomness and subjective color. Through in-depth analysis of the data, the information obtained is quite different from the actual situation. In view of the above problems, using the principles of informatics, taking the scheduling demand and the number of green water products as indicators, select each supply chain network with backup plans as the sample, take the optimal order of the supply chain network backup plans as the sample characteristics, and rank the weights according to the priority attribute values of the supply chain network backup plans [8]. The specific process is as follows:

Suppose that the observation value h_{ij} of the priority attribute d_j of the supply chain network scheduling of green water products belongs to category l, then the measure of d_j is Formula 11:

$$V = \left(v_{ij1}, v_{ij2}, \cdots, v_{ijl}\right) \tag{11}$$

When $0 \le v_{ijl} \le 1$, $\sum_{i=1}^{l} v_{ijl} = 1$. If the priority weight ranking of water conservancy green product supply chain network scheduling is regarded as the selection of samples, then the weight information of d_j to make emergency equipment sample h_i in l categories is $\frac{1}{l}$, which shows that attribute d_j does not play a decisive role in the priority ranking of supply chain network sample h_i. On the contrary, if there is only one 1 in v_{ijl} and the rest is 0, the entropy value of the supply chain network scheduling task is 0, indicating that the d_j attribute is important. Therefore, Formula 12 is obtained:

$$x_{ij} = 1 + \frac{1}{\lg l} \sum_{l=1}^{L} v_{ijl} \lg v_{ijl} \tag{12}$$

It can be seen that when $0 \leq x_{ij} \leq 1$ and x_{ij} are large, the entropy of supply chain network scheduling task is the minimum, and the two are closely related. When $x_{ij} = 1$, the weight value of d_j makes the entropy value of g in the l_1 class is 1, and the entropy value of g in other classes is 0, which shows that d_j has a great influence on the ranking of supply chain network scheduling priority h_i; When $x_{ij} = 0$ is set, $v_{ij} = \frac{1}{l}$ and d_j divide the supply chain network sample h_i into weight sorting. Redundancy attribute d_j needs to be removed. The more concentrated the value of v_{ij} is, the greater the effect of attribute d_j on h_{ij}'s priority sorting. Formula 13:

$$v_{ij} = \frac{x_{ij}}{\sum_{j=1}^{m} x_{ij}} \tag{13}$$

Then $0 \leq v_{ij} \leq 1$, $\sum_{j=1}^{m} x_{ij} = 1$, the greater v_{ij} is, the greater the influence of d_j on h_{ij}'s priority weight ranking. Therefore, the priority weight vector of supply chain network scheduling is Formula 14:

$$v_i = (v_{i1}, v_{i2}, \cdots, v_{im})^{\mathrm{T}} \tag{14}$$

On the basis of determining the priority attribute of supply chain network scheduling, the entropy value of supply chain network scheduling tasks is calculated, and the priority weight of supply chain network scheduling is sorted by combining the priority weight vector of supply chain network scheduling.

2.4 Optimize the Supply Chain Network of Green Water Products

According to the priority weight ranking of supply chain network scheduling, the water conservancy green product supply chain network is optimized, and the optimal planning path of the water conservancy green product supply chain network is analyzed. The specific process is as follows:

Let Ω be the population size in the compound ant colony algorithm, distribute the population in the supply chain network optimization model, take the initial space of the population as the starting point [9], and obtain the initial optimization path element of the population as Formula 15:

$$\Delta b(j) = \exp\left(-h\left(u_j\right)\right) \tag{15}$$

Formula 16 is used to modify the initial optimization path elements of the population:

$$o = \xi o_{\max} - (o_{\max} - o_{\min})_{bet} \cdot \frac{k_{ter}}{k_{ter\max}} \tag{16}$$

where, ξ represents the interference degree parameter of the supply chain network, $o_{\max}$ and $o_{\min}$ represent the initial parameters of the supply chain network, $k_{ter\max}$ represents the optimization coefficient of the initial parameters in the supply chain network, and k_{ter} represents the number of iterations of the initial parameters in the supply chain network.

Using the fitness function of the supply chain network obtained above, the optimal logistics distribution path in the supply chain network model is obtained. This process can modify the initialization path of the population in the composite ant colony algorithm, as shown in Formula 17:

$$b(j) = \frac{\xi}{b(j)}(1 - \phi) + \Delta b(j) \tag{17}$$

where, ϕ represents the update interval of the population in the supply chain network.

By modifying the initialization path of the population in the compound ant colony algorithm, the network equilibrium mechanism of the water conservancy green product supply chain is obtained, as shown in Formula 18:

$$F_y = \frac{\lambda_p \times \omega_y}{s_p} + k_h \times (j_k) \tag{18}$$

Among them, λ_p represents the status of the supply chain network, ω_y represents the limiting factors of the supply chain network of green water products, s_p represents the equilibrium index of the supply chain network, k_h represents the minimum cost of the supply chain network optimization of green water products, and j_k represents the maximum goal of the supply chain network optimization.

The application of ant colony algorithm to the balanced scheduling of the water conservancy green product supply chain network requires the grid processing of the coverage area of the water conservancy green product supply chain network, and the corresponding cost value is set for each cell. The path search process of the ant colony algorithm is shown in Fig. 1.

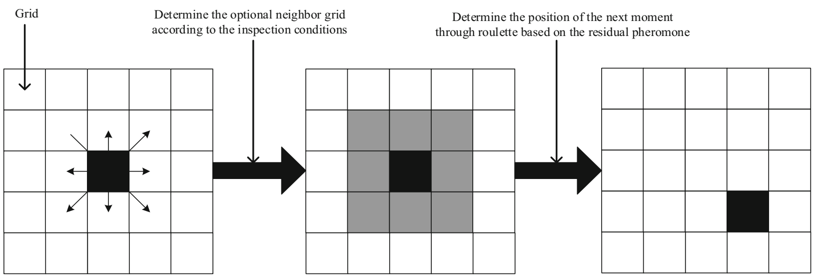

Fig. 1. Schematic diagram of ant colony algorithm search

In the ant colony path search diagram shown in Fig. 1, the black grid is the current position of the ant and can move to any method. Through the guidance of grid pheromone concentration, the ant colony moves towards the best direction. According to the above process, in the process of optimizing the water conservancy green product supply chain network, the composite ant colony algorithm is used to plan the ant optimal path. The specific steps are:

Step 1: Build the initial model of the water conservancy green product supply chain network, calculate the number and coverage area of the ant's optimal path and shortest path;

Step 2: Use the compound ant colony algorithm to initialize the supply chain network optimization model of green water products, set the initial model and basic information elements of the population, and set the iteration coefficient of the supply chain network processing of green water products;

Step 3: According to the status and actual time consumption of each ant's optimization path in the water conservancy green product supply chain network optimization model, complete the coding of each ant's optimization path and obtain the ant's location;

Step 4: Adjust the parameters of the composite ant colony algorithm according to the parameters of the interference degree of the water conservancy green product supply chain network. It can be seen from the calculation that the shortest path is the optimal path, and the path is optimal when the amount of information contained in the population is more;

Step 5: Collect the information of each network path in the water green product supply chain;

Step 6: the process of iterative calculation of Step 1 –Step 5, and then increase the number of iterations;

Step 7: According to the network fitness function of water conservancy green product supply chain obtained above, modify the planning results of ant optimization path information;

Step 8: Perform iterative calculation on the optimization path of each ant in the population. If it does not meet the requirements, return to Step 2. Finally, the optimal path information of the supply chain network optimization model is obtained. If the network information of the water conservancy green product supply chain is highly matched with the population, it indicates that the path is optimal. On the contrary, the path is long and time-consuming. In other words, the higher the fitness function value of the water conservancy green product supply chain network optimization model, the better the effect of the optimal path is, and the worse the effect is.

According to the above operation methods, based on the compound ant colony algorithm, the population fusion calculation is carried out on the water conservancy green product supply chain network optimization model. The optimal path information of the water conservancy green product supply chain network model is obtained through the fusion calculation results, and the water conservancy green product supply chain network optimization design is finally completed.

2.5 Construct the Network Equilibrium Scheduling Model of Water Conservancy Green Product Supply Chain

The process of establishing a two-level logistics service supply chain with water conservancy green product logistics service as the basic integrator under the joint action of multiple functional logistics services is called the description and assumption of the supply chain network equilibrium scheduling model.

Generally speaking, a logistics service integrator needs to face the service order demands of multiple scheduling customers at the same time, and each customer's logistics service order must contain multiple service process flows. Generally, these service processes can be divided into personalized service processes and large-scale service processes.

Because the customer order service has a strong similarity in transportation content, it can integrate the supply and demand of logistics services with a high similarity between one customer object and another, and establish a complete large-scale operation. Of course, independent personalized service countermeasures can also be set according to the actual scheduling needs of customer objects.

After receiving the logistics order of the customer object, the scheduling integrator can achieve optimal scheduling in the following ways:

- Analyze the service time and service link of these orders;
- Considering the uncertainty of service time of each provider, provide necessary time range conditions for the functional supply of services in each service link;
- ·Set the optimization target to be scheduled from many aspects such as scheduling cost and scheduling time, and determine the optimal scheduling plan.

When the logistics operation time of the supply chain provider is uncertain, the logistics service provider needs to comprehensively consider various application factors when conducting centralized logistics scheduling services.

In general, logistics integrators need to consider the following aspects:

The first point is the transportation cost factor. The lowest logistics cost of the supply chain is the primary goal of the integrator's scheduling service construction;

The second point is the time requirement factors related to transportation customers. The service integrator needs to comprehensively consider the requirements of all customers in terms of service order completion time, reasonably arrange the existing scheduling plan, and effectively control the supplier's delay time as far as possible, so as to achieve good scheduling services for logistics customers;

The third point is the logistics satisfaction factors related to suppliers. Integrators need to consider the application satisfaction of other suppliers and arrange the reasonable communication needs between adjacent logistics service processes.

Based on the above analysis, assuming that $L_1, L_2, \cdots, L_n$ represents n different supply chain logistics demand indicators, the cost minimization objective of the supply chain network equilibrium scheduling model can be defined as Formula 19:

$$R = \frac{\sum_{d_0}^{d_n} f \times (L_1 + L_2 + \cdots + L_n)}{n \times W_H^2} \tag{19}$$

where, d_0 represents the minimum logistics cost consumption condition, d_n represents the maximum logistics cost consumption condition, and f represents the transmission scheduling coefficient of goods in the supply chain.

In general, there are some hard constraints that must be observed in the supply chain network equilibrium scheduling model, including the time impact constraints and time correlation constraints of the supply chain customer demand, as well as the logistics transportation satisfaction constraints related to the supplier.

In order to make the scheduling solution method optimal and effective at the same time, so as to realize rapid adaptation to cargo transportation demand in actual operation, it is necessary to reasonably design various logistics expression parameters while studying the impact of scheduling parameters on supply chain scheduling performance.

Therefore, the more unified the planning form of supply chain logistics coordination objectives is, the more realistic the final scheduling application results will be [10], without changing the lead time decentralized control conditions. Suppose x_0 represents the minimum time constraint of customer demand in the supply chain, and x_n represents the maximum time constraint of customer demand in the supply chain. The goal planning form based on lead time decentralized control is defined as Formula 20:

$$Z = \frac{\sum_{x_0=0}^{x_n} R \times X_{\max}}{d_1 + \sum_{x_0}^{x_n} (n_2 - n_1)} \tag{20}$$

Among them, $X_{\max}$ represents the maximum expression value of logistics parameters, d_1 represents the satisfaction constraints of supply chain logistics transportation, and n_1 and n_2 represent the coordinated scheduling application indicators of two different logistics paths.

According to the above process, the calculation and processing of the application conditions of various coefficients are realized, and the construction of the network equilibrium scheduling model of the water conservancy green product supply chain is completed.

3 Comparative Analysis of Experiments

3.1 Build Supply Chain Logistics Network

In order to verify the application value of the method in this paper in the supply chain network balanced scheduling of water conservancy green products, the supply chain logistics network as shown in Fig. 2 is built as the cargo transport framework required for the experiment of the experimental group and the control group, and the Windows 10 operating system is loaded in the experimental host.

Figure 2 The supply chain logistics network includes n manufacturers and n recyclers. There is competition among members of the same kind, and there are transactions between members of the adjacent layer. Manufacturers use raw materials to produce new products, while using waste products for remanufacturing. New products and remanufactured products are low-carbon products with a certain degree of green, and the products are sold to various demand markets; The recycler's job is to simply dispose the waste products produced by consumers and then resell them to the manufacturer for use in the remanufacturing process.

Among them, the control host of the experimental group carries the method in the article, and the two control hosts of the control group carry the scheduling method considering consolidation decision and the scheduling method based on Benders decomposition respectively. In the experiment, the maximum cargo transportation volume is 10Mt, and there are 10 logistics transportation paths. Under the same experimental environment, analyze the specific changes of various experimental indicators.

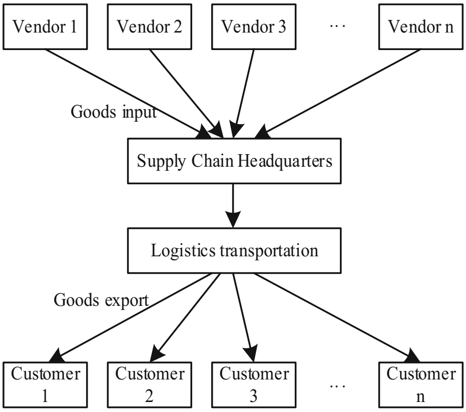

Fig. 2. Supply Chain Logistics Network

3.2 Setting Evaluation Indicators

In the experiment, in order to prove the feasibility of the proposed method, the experiment is first divided into two parts. The first part of the experiment specifies evaluation indicators to verify the performance of the proposed method. In the second part of the experiment, the scheduling method considering the merger decision and the scheduling method based on Benders decomposition are used as the comparison method for joint analysis and comparison, and the comprehensive effectiveness of different methods for the balanced scheduling of water conservancy green product supply chain network is verified from the aspects of scheduling responsiveness and storage facility utilization.

Suppose that r_g represents the maximum volume of goods supplied by intermediaries in the warehousing link, l_g represents the maximum volume of goods supplied by each layer of the supply chain to intermediaries, and r_h represents the volume of goods flowing from intermediaries to the market, then use Formula 21–23 to calculate the supply chain equilibrium r_g, scheduling response μ_o, and storage facility utilization μ_p of green water products:

$$r_g = \frac{w_d \times l_g}{r_h} \tag{21}$$

$$\mu_o = \frac{r_g \times l_g}{r_h} \pm w_d \tag{22}$$

$$\mu_p = \frac{\mu_o \times l_g}{r_h} \times 100\% \tag{23}$$

Among them, the higher the value of water conservancy green product supply chain equilibrium r_g, dispatching responsiveness μ_o, and storage facility utilization μ_p, the better the balanced dispatching effect of water conservancy green product supply chain network.

3.3 Result Analysis

When the network scheduling demand of water conservancy green product supply chain is 155, the supply chain balance, scheduling responsiveness and storage facility utilization rate in the scheduling process of the three methods are tested respectively. The supply chain equilibrium test results are shown in Fig. 3.

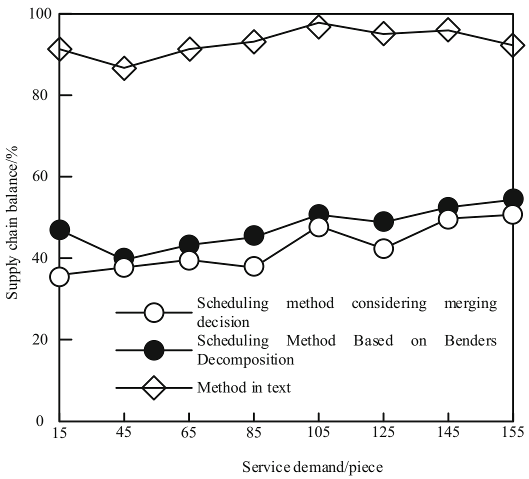

Fig. 3. Supply Chain Equilibrium Test Results

It can be seen from the experimental results in Fig. 3 that, with the increasing demand for services, the proposed method for network equilibrium scheduling of water conservancy green product supply chain can promote all suppliers in the water conservancy green product supply chain to reach the optimal stable equilibrium state, thus ensuring the effective utilization of water conservancy green products.

The dispatching responsiveness test results are shown in Fig. 4.

The results in Fig. 4 show that, compared with the scheduling method considering merger decision and the scheduling method based on Benders decomposition, the method in this paper is more responsive in the network balanced scheduling of water conservancy green product supply chain, which can significantly reduce the logistics cost, improve the economic benefits of logistics, and achieve the overall balance of the supply chain of water conservancy green products for logistics warehousing.

The storage facility utilization test results are shown in Fig. 5.

According to the results in Fig. 5, when the scheduling method considering consolidation decision and the scheduling method based on Benders decomposition are adopted, the utilization rate of storage facilities is low, below 70%. However, when the method in the paper is adopted, the utilization rate of storage facilities can be increased to more than 80%, which improves the layout of logistics and warehousing, and greatly improves the economic and social benefits of logistics.

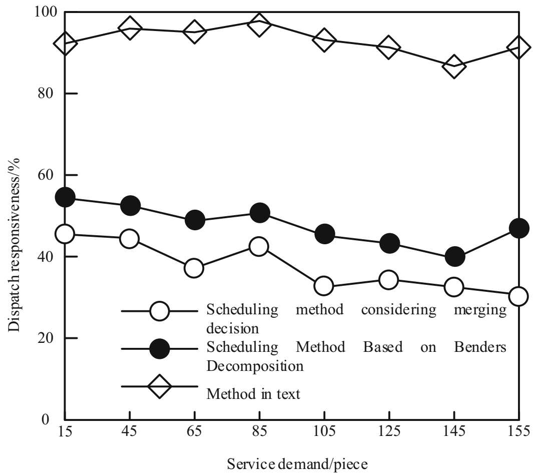

Fig. 4. Dispatch Responsiveness Test Results

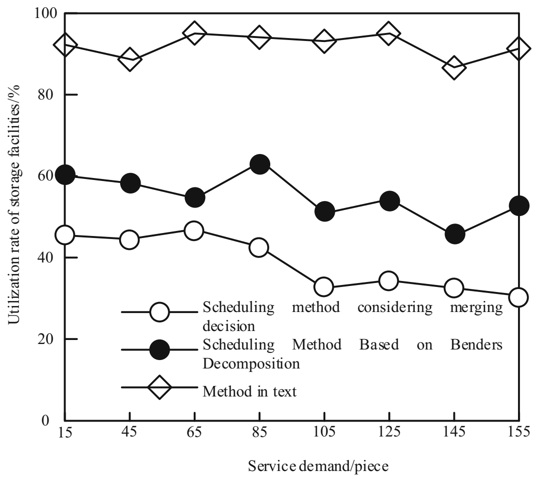

Fig. 5. Storage Facility Utilization Test Results

4 Conclusion

This paper proposes a research on the network equilibrium scheduling method of water conservancy green product supply chain based on the compound ant colony algorithm. Based on the logistics distribution model of water conservancy green product supply chain, this paper obtains the competitive relationship between supply chains. Based on the priority weight ranking of supply chain network scheduling, the population fusion calculation is carried out based on the composite ant colony algorithm to realize the balanced scheduling of water conservancy green product supply chain network. The results show that the method has better performance in the network equilibrium scheduling of water conservancy green product supply chain. However, there are still many deficiencies in this research. In the future research, we hope to introduce particle swarm optimization algorithm to optimize the compound ant colony algorithm, and further improve the network equilibrium scheduling performance of water conservancy green product supply chain.

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