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Research on Supply Chain Optimization and Economic Efficiency Improvement of Manufacturing Enterprises

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ABSTRACT

Supply chain optimization configuration contributes to the improvement and development of enterprise business application system. This paper takes the supply chain of manufacturing enterprises as the research object and analyzes the economic benefits of supply chain optimization of manufacturing enterprises. Aiming at the current development environment of enterprises, it puts forward the necessity of the development of enterprise supply chain flexibility, and establishes the overall supply chain flexibility model that contains the supply flexibility of the supply chain, the manufacturing flexibility and the distribution flexibility of the distributors. Simplify the total cost model of supply chain and establish the demand-driven supply chain optimization model. Analyze and validate the parameter settings of the improved particle swarm algorithm, and obtain the operating efficiency of the improved particle swarm algorithm with the changes of ordering cycle and inventory capacity. Combined with the sample enterprises, analyze the financial savings of each link after supply chain optimization. Further measurements show that after supply chain optimization of Company R, the saving percentage is 10.24%, and the annual saving amount is 562,807 yuan, with obvious economic benefits.

Keywords: improved particle swarm algorithm; flexibility model; demand-driven; economic efficiency; supply chain optimization

1. Introduction

With increasing global competition, users are becoming increasingly aware of the ability of manufacturers to respond quickly to product commitments (or the ability to produce such products), and in the near future users will expect such response time calculations to be compressed to near zero [1-2]. As a result, manufacturing companies want to properly address and fully resolve supply chain management issues in order to increase speed, efficiency, and product quality [3-5].

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On the other hand, there are already many enterprises have found that focusing on marketing can no longer create more value for the enterprise as well as the whole supply chain, thus enabling the enterprise to obtain additional advantages in competition, but technological innovation not only allows the enterprise to explore the blank part of the original field, obtain new patents, enter into completely new fields to produce new results, reduce production costs, and achieve the purpose of attracting more attention from consumers and manufacturers [6-8]. Moreover, R & D innovation investment can make manufacturing enterprises in product design or new service development, catering to consumer demand, and then exchange resources with consumers, draw new resources, and ultimately for the enterprise to save a lot of time costs and trial and error costs, for the enterprise, the supply chain to obtain value and to maintain their own competitive advantage has an important role [9-10]. As a core industry of the digital economy, digital product manufacturing drives the continuous transformation and upgrading of the national industrial structure [11]. As a technology-intensive digital product manufacturing industry, its high level of technology and R&D investment can gain the favor of consumers, therefore, the digital product manufacturing industry is always in urgent need of technological innovation. Technological innovation to enhance the role of such technology industry segments such as digital product manufacturing industry effect is more obvious, by reducing transaction costs and so on to enhance the level of industrial division of labor, to further enhance the output and efficiency of the manufacturing industry, and to accelerate the development of the country's economic high quality [12-13]. With the development of digital economy, the development of digital product manufacturing industry is crucial to economic development, how to improve the quality of technology-intensive products, improve production efficiency, and realize the value gain of the original industry, which is attracting more and more attention [14-15].

Literature [16] compared three models of traditional supply chain, centralized am supply chain and distributed am supply chain in terms of variable cost and carbon emission dimensions, and found that centralized am supply chain has better performance in terms of sustainable supply chain performance than traditional supply chain model. Literature [17] talks about the practice of an optimal control system in industrial production and supply chain management and combines the optimal control model, qualitative performance analysis strategy and computational methods of optimal control to optimize the solution of industrial production as well as supply chain management problems. Literature [18] assessed how supply chain performance affects organizational performance, and through the questionnaire method, it was learned that the rational adoption of DSC in business processes in manufacturing industry can help to improve supply chain performance and overall organizational performance. Literature [19] constructed a supply chain model based on the theory of demand to meet the analysis needs of manufacturers and retailers, and utilized this analytical model to carry out a relevant study on advertising rate, which confirms that the increase in advertising costs can bring corresponding value. Literature [20] studied how Industry 4.0 affects supply chain management based on supply chain theory innovation perspective, pointed out that SCI has positive significance for supply chain process efficiency improvement, but the SCI program has a certain degree of neglect for supply chain production-related technicians, and finally differentiated and discussed the SCI strategies for established enterprises and start-ups. Literature [21] aims to improve the practical performance of data science in supply chain management by proposing a new linear regression model based on sales data based on a data analysis perspective. Literature [22] builds a high demand and necessity production framework based on mathematical modeling strategies and analyzes numerical examples to confirm that the model guides production to cope with modifications of production schedules in demand and mid-supply scenarios, while guaranteeing a certain degree of profitability on manufacturing. Literature [23] clarifies that AI technology empowers enterprise production and operation, which can provide more economic benefits and reduce the cost of enterprise production and operation, and in the manufacturing supply chain production, it can realize the accurate prediction of customer demand and accurate marketing, and improve the competitiveness of enterprises. Literature [24] examined the performance of blockchain technology applied to additive manufacturing, and concluded that blockchain technology helps to improve the flexibility of additive manufacturing, and also improves the cost-effectiveness of additive manufacturing supply chain production, so it is necessary to vigorously promote the digitization and intelligence of supply chain production. Literature [25] emphasized the importance of supply chain inbound and outbound optimization for improving supply chain management, and investigated the optimal strategy for transaction execution systems based on a hybrid approach to propose a new supply chain inbound and outbound optimization scheme. Literature [26] explores the research prospect of the integration and development of AI and supply chain management, and synthesizes a number of actual cases to carry out in-depth analysis, explores the value creation possibilities of AI in supply chain management, and puts forward a specific AI technology in the supply chain business model of the practice program. Literature [27] conceived a decentralized model with blockchain technology and edge technology as the core logic to promote the development of new open manufacturing business models, and verified through practical feedback that the proposed model can ensure the security of the knowledge service sharing process in the manufacturing ecosystem.

This paper delineates the supply chain segments of manufacturing companies and simplifies the supply chain network structure of manufacturing companies. It explores the supply chain operation cost from three aspects: supplier cost, manufacturer cost and distributor cost. It proposes the development trend of supply chain flexibility, emphasizes the necessity of flexibility, and establishes a demand-driven supply chain flexibility model. Simplify the supply chain total cost model and set the supply chain objective function model. Select the improved particle swarm optimization algorithm to solve the model. Conduct parametric experiments to select the best algorithm parameters. Set the inventory capacity and explore the change of inventory capacity under different ordering cycles. Analyze the sample companies and analyze the percentage of savings and the annual amount of savings in the supply chain of the companies.

2. Manufacturing enterprise supply chain optimization method

2.1. *Analysis of supply chain network structure of manufacturing enterprises*

Manufacturing is a generic term for industries that process or reprocess raw materials and assemble parts and components produced by extractive industries and agriculture, i.e., industries that use products produced by human labor as objects of labor. It is also the industry that converts available resources and energy into industrial or consumer goods that can be used or utilized by people through the manufacturing process.

Supply chain is a complex network of various entities such as producers, logistics companies, and customers [28-29]. There are simultaneous flows of materials, work, money and information on the network. These entities include a number of management companies, manufacturing companies, transit warehouses, raw material and component suppliers, logistics companies, distribution centers, retail wholesalers, and end users.

The supply chain of a manufacturing company can usually be divided into three stages according to the logistics process:

1) Obtaining raw materials-supply.
2) Production of raw materials into products - manufacturing.
3) Distributing finished goods to retailers - distribution.

In this paper, we insist on dividing the supply chain into three traditional functions, supply, manufacturing and distribution, according to the main processes or functions of the supply chain. The corresponding models are categorized as integration within each function and between the two (supply-purchase, manufacturing-distribution, distribution-customer) as well as a comprehensive integration model of the three functions. The research done in this paper is to construct an integrated supply chain network simulation model that integrates supply, production and distribution.

In terms of topology, a supply chain is a network, i.e., a network of autonomous or semi-autonomous business entities. These business entities are jointly responsible for various activities related to one or more types of products, such as purchasing, producing, and finally delivering products to customers. From the point of view of the operation mechanism, the supply chain is a process, i.e., a process of moving an item through the supply of raw materials, storage, product production, and product delivery to the customer according to the customer's order. For the core enterprise in the chain, the supply chain is a web chain connecting its suppliers, suppliers of suppliers, and users, users. There are three different flows involved in the supply chain, namely material flow, information flow and financial flow.

The general configuration of the supply chain of a manufacturing enterprise is shown in Fig. 1, where manufacturers and assemblers are at the core of the chain, and they have decision-making and control functions, and the main business activities such as material acquisition, manufacturing and assembly as well as sales and distribution exist from upstream to downstream in sequence. At the same time, there is a bottom-up flow of information and capital and a top-down flow of materials. The goal is to increase the coordination, dynamics, transparency and consistency of the supply chain.

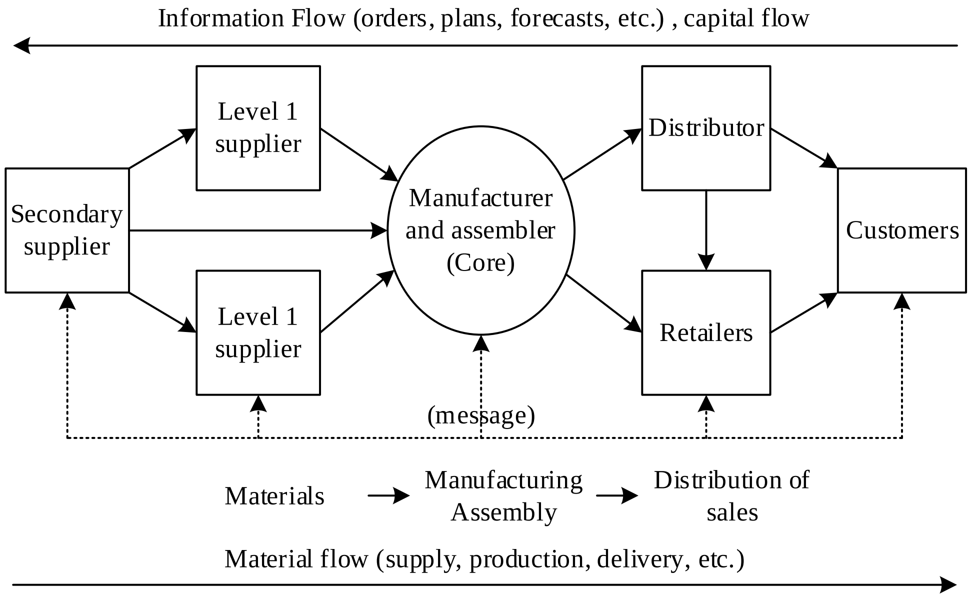

Fig. 1. Manufacturing enterprise supply chain network structure configuration

2.2. *Cost analysis of supply chain operations*

1) Supplier cost analysis. The costs incurred in the process of supplier operations are mainly, raw material storage costs, raw material processing costs and transportation costs. Assuming that manufacturing demand shortages can be delayed order, for the supplier's costs TC_1, where the cost of raw material production costs, $a*Z$. Transportation costs, t_i*X*T. Raw material inventory storage costs, h_1*L_1. Raw material delayed order penalty costs, $l_1*(I-p_1)*X*T$. Suppliers to obtain the supply capacity of ψ invested in the fixed costs, ψm_1. Then:

$$TC_1 = a*Z + t_1*X*T + h_1*l_1 + l_1*\times(1-p_1)*X*T + \psi m_1 \tag{1}$$

Where, a is the supplier's cost per unit of raw material produced. t is the supplier's transportation cost per unit of raw material to the manufacturer, p_t is the supplier's service level to the manufacturer. h_t is the supplier's cost of storage per unit of material, m_i is the fixed costs invested by the supplier to increase the supply capacity per unit. r is the raw material utilization rate (r units of raw material used to produce 1 unit of product), X is the number of products produced by the manufacturer. Z for the total production of raw materials, I_1 for the supplier's realistic inventory of raw materials, ψ represents the supplier's maximum supply capacity.

2) Manufacturer's Cost Analysis. The main costs incurred in the operation of a manufacturer are: the cost of purchasing raw materials, the cost of manufacturing products, the cost of storage (considering only the inventory of finished goods), and the cost of transportation. For the manufacturer's costs TC_2. The cost

of ordering raw materials, $\theta_1 * \frac{x*T}{Q_1}$. The fixed costs of production, $\theta_2 * \frac{X}{Q_2}$. The variable costs of production, $v*X$. The cost of storage of finished goods, $h_2 * \left(\frac{Q_2}{2} + n_2 * a_2\right)$. The cost of transportation of finished goods, $t_2 * Y$. The cost of delayed order penalties for finished goods, $I_2 * Y * (I - p_2)$. The fixed costs invested by the manufacturer in acquiring production capacity Φ, Φm_2. Then:

$$TC_2 = \theta_t * \frac{x*T}{Q_1} + \theta_2 * \frac{X}{Q_2} + v*X + h_2 * \left(\frac{Q_2}{2} + n_2 * a_2\right) + t_2 * Y + l_2 * Y * (I - p_2) + \Phi_{m_2} \tag{2}$$

Where, θ_t is the fixed cost incurred by the manufacturer each time he purchases raw materials. θ_2 is the fixed cost incurred by the manufacturer each time it produces. p_2 is the manufacturer's service level to the distributor, t_2 is the manufacturer's transportation cost per unit of finished goods to the distributor. h_2 is the manufacturer's storage cost per unit of finished goods, and l_2 is the manufacturer's penalty cost per unit of delayed orders. m_2 is the manufacturer's fixed cost of increasing production capacity per unit, and n_2 is the manufacturer's inventory safety factor for finished goods. σ_2 is the manufacturer's standard deviation of product demand between orders, and v is the manufacturer's variable cost of production per unit of product. Q_1 is the manufacturer's purchasing lot of raw materials, and Q_2 is the manufacturer's production lot. Y is the distributor's demand for the product, and ϕ represents the manufacturer's maximum production capacity.

3) Distributor cost analysis. The costs incurred by distributors in the course of their operations are ordering costs, storage costs (using an (s,S) inventory control strategy, i.e., continuously checking inventory. When it falls below the reorder point s, the distributor replenishes its inventory by stocking up to the maximum value S), Distribution costs. For distributors costs TC_3. Ordering costs $\theta_3 * \frac{D}{Q_{s^*}}$. Finished goods storage costs $h_3 \int_0^S (S-x) f(x) dx$, transportation costs $t_3 * D$, delayed ordering penalty costs $l_3 \int_S^{\infty} (x-S) f(x) dx$. The fixed cost Θm_3 invested by the distributor in acquiring distribution Θ capacity, then:

$$TC_3 = \theta_3 * \frac{D}{Q_3} + h_3 \int_0^s (S-x) f(x) dx + t_3 * D + l_3 \int_s^{\infty} (x-S) f(x) dx + \Theta m_3 \tag{3}$$

Where, θ_3 is the fixed cost incurred by the distributor for each order. l_3 is the distributor's penalty cost per unit of delayed ordering. h_3 is the distributor's storage cost per unit of product, and S is the number of products that the distributor needs to satisfy the market demand. Since the supply chain uses a delayed production strategy, the number of products required by the distributor is $S = \mu + n_3\sigma_3$, where μ is the mean of the market demand obeying a normal distribution. n_3 is the safety stock safety factor of the distributor's product, and σ_3 is the standard deviation of the demand for the product during the distributor's ordering interval. D is the customer's demand for the product, which is normally distributed, and Q_3 is the distributor's lot size.

2.3. Demand-driven supply chain flexibility model analysis

2.3.1. Necessity and possibility of the existence of flexibility:

1) Changing business environment. In the changing business environment, it is necessary to make enterprises and supply chains flexible, and flexible enterprises and supply chains have become a development trend.

Supply chain flexibility is divided into different levels, the lower level of flexibility is only passive to adapt to uncertainty, the higher level of flexibility can control or even reduce part of the uncertainty. For example, assuming that a supplier in the supply chain is on the verge of bankruptcy due to the breakage of the financial chain (the bankruptcy of the supplier is an uncertainty for the supply chain, which has a serious negative impact), if the supply chain as a whole, especially the core enterprise, can utilize its own ability (with high financial flexibility) to borrow from the supplier, etc. to save the supplier. In this process, supply chain flexibility reduces part of the uncertainty.

2) The development of flexible manufacturing technology and flexible management. With the development of the economy and the improvement of people's living standards, the traditional mass production has been unable to meet the increasingly personalized consumer demand. So all countries have invested a lot of human, material and financial resources to solve this contradiction. Under the flexible manufacturing technology and flexible management, the flexibility of enterprises and supply chains has the possibility of existence. After people's practical efforts, automatic control technology, flexible manufacturing technology, agile manufacturing and lean manufacturing and other production modes with flexibility came into being.

In addition to the hardware aspects such as flexible manufacturing, the soft factor of flexible management has also enabled organizations to gain a faster reaction time and respond to changes in customer demand in a timely manner. In the organization, through the formulation of flexible rules and regulations, the use of flexible incentives, the creation of a flexible organizational culture, and the construction of a highly flexible organizational structure and other ways to improve the flexibility of the organization, and thus improve its speed of response to meet the needs of consumers in a timely manner.

2.3.2. Supply chain flexibility model. In flexible supply chain management, the flexibility of the supply chain represents the surplus capacity of the overall operating resources of the supply chain, where the supply flexibility, production flexibility and distribution flexibility of the supply chain are mainly used to respond to the overall operational flexibility of the supply chain, which are expressed in the following three forms:

1) For supply flexibility of a supply chain, it is denoted by $W_l = \frac{\psi_{-Z}}{\psi}$, where ψ denotes the maximum supply capacity of the supplier and Z denotes the amount of raw materials produced by the supplier.

2) For the manufacturing flexibility of a supply chain, it is denoted by $W_2 = \frac{\Phi - X}{\Phi}$, where Φ denotes the maximum production capacity of the manufacturer and X denotes the amount of production by the manufacturer.

3) For the distribution flexibility of a distributor, it can be represented by $W_3 = \frac{\Theta - Y}{\Theta}$, where Θ denotes the maximum distribution capacity of the distributor, and Y denotes the distribution volume of the distributor.

Using λ_1, λ_2, and λ_3 to denote the utilization (using weights) of the total flexibility of the supply chain for supply flexibility, manufacturing flexibility, and distribution flexibility, respectively, where $\lambda_1 + \lambda_2 + \lambda_3 \leq I$, then the flexibility of the supply chain W can be expressed as:

$$W = \lambda_1 W_1 + \lambda_2 W_2 + \lambda_3 W_3 \tag{4}$$

Since the amount of raw materials available to the supplier cannot exceed the maximum supply capacity, the amount of product produced by the manufacturer cannot exceed the maximum production capacity, and the amount of product distributed by the distributor is not greater than its maximum distribution capacity, we obtain $\psi - Z \geq 0$, $\Phi - X \geq 0$, $\Theta - Y \geq 0$, and $\psi, \Phi, \Theta, X, Y, Z \geq 0$.

2.4. Establishment of supply chain optimization model

From the above cost analysis, the total cost model of the supply chain is $TC = TC_1 + TC_2 + TC_3$. Due to the intersection of the cost components of each node enterprise in the supply chain and the low correlation between some of the cost components and the final required results, such as transportation costs. Therefore, the total cost model of the supply chain is simplified. The simplified cost model for suppliers is:

$$TC_l = a * Z + h_t * I_l + l_l * (I - p_t) * X * T + \Psi m_I \tag{5}$$

For the manufacturer the simplified cost model is:

$$TC_2 = v * X + h_2 * \left(\frac{Q_2}{2} + n_2 * a_2\right) + l_2 * Y * (I - p_2) + \Phi m_2 \tag{6}$$

For distributors the simplified cost model is:

$$TC_3 = h_3 \int_0^S (S - x) f(x) dx + l_3 \int_S^\infty (x - S) f(x) dx + m_3 \tag{7}$$

$$n_i = \left(\frac{1}{2}\sqrt{\frac{\pi}{2}}\right) \ln\left(\frac{p_i}{1 - p_i}\right) \tag{8}$$

$$I_i = \frac{Q_i}{2} + n\sigma_i \tag{9}$$

$$S = X + n_3\sigma_3 \tag{10}$$

The goal of the supply chain is to maximize profit, that is, to satisfy a certain level of customer demand under the premise of making the total cost of the supply chain is minimized, the supply chain objective function model is:

$$\min TC = \min(TC_1 + TC_2 + TC_3) \tag{11}$$

2.5. Model optimization solution method

Particle swarm algorithm is a heuristic algorithm based on group intelligence, which has the excellent performance of less parameter setting, simple and easy programming implementation and fast convergence [30].

In standard particle swarm arithmetic, assuming a total of M particles in N-dimensional space, $x_i\,(i = 1, 2, \ldots, M)$ is used to denote the i th particle in M, where each particle represents a potentially feasible solution, and x_{ij} is used to denote the j th dimension $(j = 1, 2, \ldots, N)$ of particle x_i, notation:

$$X_i = (x_{i1}, x_{i2}, \ldots, x_{ij}, \ldots, x_{iN}) \quad \text{The current position of particle } x_i \tag{12}$$

$$V_i = (v_n, v_{i2}, \ldots, v_{ij}, \ldots, v_{iN}) \quad \text{The current velocity of particle } x_i \tag{13}$$

$$P_i = (p_{i1}, p_{i2}, \ldots, p_{ij}, \ldots, p_{iN}) \quad \text{The best position for particle } x_i \text{ to pass through} \tag{14}$$

$$P_g = (p_{g1}, p_{g2}, \ldots, p_{gj}, \ldots, p_{gN}) \quad \text{The best place for the whole group to pass} \tag{15}$$

Then the evolutionary equation for particle x_i in the evolutionary process is:

$$v_{ij}(t+1)=\omega v_{ij}(t)+c_1r_1\left(p_{ij}(t)-x_{ij}(t)\right)+c_2r_2\left(p_g(t)-x_{ij}(t)\right) \tag{16}$$

$$x_{ij}(t+1)=x_{ij}(t)+v_{ij}(t+1) \tag{17}$$

where t indicates that particle x_i is currently in the t rd evolutionary generation, ω is called the inertia weight, c_1 and c_2 are acceleration constants, and r_1 and r_2 are random numbers between $[0,1]$.

From the above equation, it can be seen that the velocity update of the particle is accomplished by three parts. The first part is "inertia", which comes from the velocity of the particle at the last moment, represented by ω in Eq. (16), and the larger ω is, the larger the inertia is, the less likely the particle will deviate from the previous trajectory. The second part is "cognition", which means that the particle will have a "cognition" of its own trajectory during its evolution, represented by c_1r_1 in the formula (16), and the particle intelligently adjusts the direction of its next movement by referring to the best position it has passed through, P_i. The third part is "cooperation", which is represented by c_2r_2 in Eq. (16), which means that each particle not only draws on its own historical experience, but also refers to the evolutionary experience of the whole group, and evolves towards the optimal position of the group P_g, which reflects the information sharing and cooperation of the group.

In this paper, we construct improved single objective particle swarm algorithm (F1-PSO) with adapted genetic technique based on particle swarm algorithm. In the standard particle swarm algorithm, the new position of the particle is determined by x_{old}, x_{pbest} and $gbest$ together, and considering the effects of x_{old}, x_{pbest} and $gbest$ respectively, there are three methods as follows.

1) Considering only the effect of x_{old} and $gbest$ on the fitness value of the new position of the particle, there are:

$$FI1.f(x_{new})=rf(gbest)+(1-r)f(x_{old}) \tag{18}$$

where $r=d_1/(d_1+d_2)$, $f(\ )$ are the fitness functions.

2) Considering only the effect of x_{pbest} and $gbest$ on the adaptation value of the new position of the particle, we have:

$$FI2.f(x_{new})=rf(gbest)+(1-r)f(x_{pbest}) \tag{19}$$

where $r=d_2/(d_2+d_3)$

3) Considering the combined effect of x_{old}, x_{pbest}, and $gbest$ on the value of the particle's new positional fitness, we have:

$$FI3.f(x_{new})=r_1f(x_{old})+r_2f(x_{pbest})+r_3f(gbest) \tag{20}$$

where $r_1=(d_1+d_2+d_3)/d_1$, $r_2=(d_1+d_2+d_3)/d_2$, and $r_3=(d_1+d_2+d_3)/d_3$.

The main idea of NLC is that the fitness value of the particle new position x_{new} is inherited in a way that draws on the evolutionary formulation of the particle in the PSO algorithm. The effect of parameter w_1c_1,c_2,r_1,r_2 is considered while inheriting the parent x_{old}, x_{pbest} and the gbest fitness value.

Considering the effects of the factors of the evolutionary formula together, there are:

$$FI4.f(x_{new})=wf(x_{old})+c_1r_1f(x_{pbest})+c_2r_2f(gbest) \tag{21}$$

Neglecting the effect of the position x_{old} of the particle at the previous moment, there are:

$$FI5.f(x_{new})=c_1r_1f(x_{pbsas})+c_2r_2f(gbest) \tag{22}$$

Neglecting the effect of the particle's own historically optimal position x_{pbest}, there is:

$$FI6.f(x_{ner})=wf(x_{odd})+c_2r_2f(gbest) \tag{23}$$

where the value of parameter w_1, c_1, c_2, r_1, r_2 needs to be consistent with the particle evolution formula (16). In the PSO evolution formula, parameter w, c_1, c_2, r_1, r_2 has some limitations on the values, i.e., $w \in (0.1, 0.5)$, $c_1 r_1, c_2 r_2 \in (0.0, 2.0)$. Therefore, the three methods mentioned above can be further improved, then there are:

Considering all the factors together:

$$FI7. f(x_{new}) = \frac{w}{0.5} f(x_{old}) + \frac{c_1 r_1}{2.0} f(x_{pbost}) + \frac{c_2 r_2}{2.0} f(gbest) \tag{24}$$

Neglecting the effect of the position x_{old} of the particle at the previous moment, there are:

$$FI8. f(x_{new}) = \frac{c_1 r_1}{2.0} f(x_{pbets}) + \frac{c_2 r_2}{2.0} f(gbest) \tag{25}$$

Neglecting the effect of the particle's own historically optimal position x_{pbest}, there is:

$$FI9. f(x_{new}) = \frac{w}{0.5} f(x_{old}) + \frac{c_2 r_2}{2.0} f(gbest) \tag{26}$$

The genetic idea of LC is to introduce the linear idea of LCBD on the basis of NLC genetic method, and perform linear weighting operation on the fitness value of parental particles in the following ways:

Linear weighted inheritance based on all the influence factors of the evolutionary formula:

$$FI10. f(x_{new}) = \frac{w}{r} f(x_{old}) + \frac{c_1 r_1}{r} f(x_{pbest}) + \frac{c_2 r_2}{r} f(gbest) \tag{27}$$

Of these, $r = w + c_1 r_1 + c_2 r_2$.

Only x_{pbest} and $gbest$ and their associated evolutionary influences are considered:

$$FI11. f(x_{new}) = \frac{c_1 r_1}{r} f(x_{pasat}) + \frac{c_2 r_2}{r} f(gbest) \tag{28}$$

Of these, $r = c_1 r_1 + c_2 r_2$.

Only x_{old} and $gbest$ and their associated evolutionary influences are considered:

$$FI12. f(x_{new}) = \frac{w}{r} f(x_{old}) + \frac{c_2 r_2}{r} f(gbest) \tag{29}$$

Of these, $r = w + c_i r_2$.

3. Enterprise supply chain optimization method test

3.1. *Experiments on the parameters of the particle swarm algorithm*

3.1.1. Parameterization. The key parameters in the particle swarm optimization algorithm that affect the effectiveness of the algorithm are: maximum velocity v_{max}, inertia weights ω, and acceleration constants c_1 and c_2. The formulas for c_1 and c_2 are given below:

$$\begin{cases} c_1(t) = 4 * \dfrac{|f_a(t) - f_g(t)|}{f_a(t)} \\ c_2(t) = 4 - c_1(t) \end{cases} \tag{30}$$

Where, $f_a(t)$ is the average fitness of the particle's current generation $f_a(t) = \frac{1}{N} \sum_1^N f_i(t)$. $f_g(t)$ is the fitness of the particle swarm's current global optimal position $p_g(t)$.

The inertia weights of the particle swarm solving algorithm are designed as shown in the following equation:

$$\omega = 0.6 + \frac{Random}{2} \tag{31}$$

where $Random$ is a random number between 0 and 1. In this way, the inertia weights will vary randomly between 0.6 and 1, with a mean value of 0.8.

Meanwhile, by conducting a large number of experimental solutions, the maximum speed is designed to be 8 and the maximum number of iterations is 400 generations. The algorithm was run independently for 100 times.

3.1.2. Population size experiments. This experiment was designed with the hope of weighing the relationship with population size and run time to find an appropriate range of population sizes. The results of the experiment are shown in Figure 2.

When the population size is small, it may cause the algorithm to fall into the local best solution, resulting in premature convergence of the particle swarm algorithm and failure to search for the global best solution.

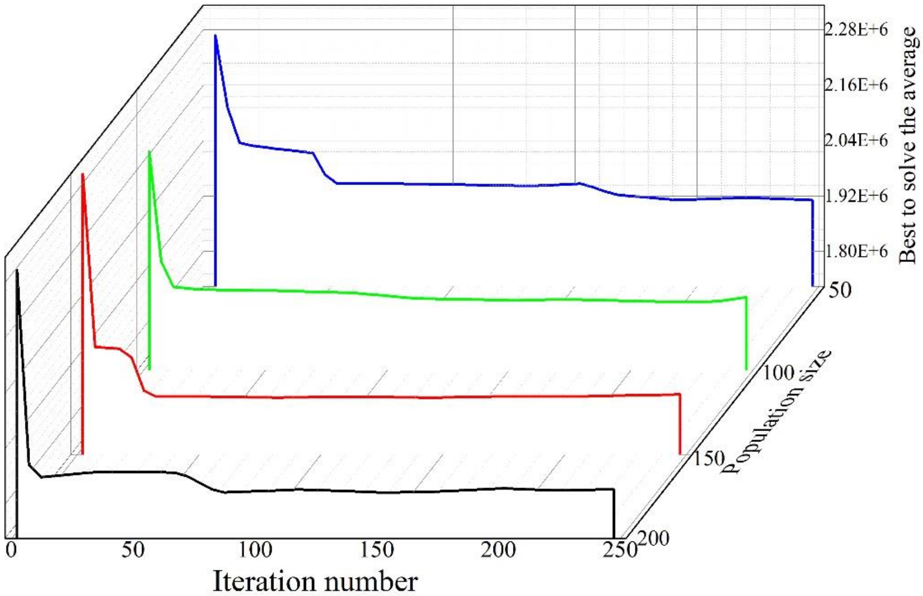

Fig. 2. The convergence curve of different population sizes

When the population is too large, it increases the running time of the program. Specific experimental data is shown in Table 1, through the above analysis of the particle swarm algorithm running speed there is a clear advantage. At the same time, along with the increase of the population the optimal value has obvious improvement. Therefore, the population size of particle swarm can be designed to be slightly larger, and the population size is set to be between 150 and 200 in this chapter.

Table 1. Analysis of the results of the population size experiment

Population size	Convergence algebra	Optimal value	Running time
50	241	2105364	58s
100	179	1963811	63s
150	152	1845096	75s
200	126	1801240	80s

3.1.3. Impact of stockpile capacity constraints. The relevant parameters of the model are designed as:

Liquidity: the liquidity limit for each cycle is 700,000 Yuan.

Discount type: total amount discount is used.

Inventory capacity: Independent repeated experiments for inventory capacity of 60000 m^2, 80000 m^2 and 100000 m^2 respectively.

1) Inventory capacity of 60000 m² when the model of the relevant parameter analysis. Inventory capacity of 60000 m² related cost trends shown in Figure 3, where the vertical axis cost unit is yuan. It shows the trend of procurement cost, inventory cost, and ordering cost in four ordering cycles when the inventory capacity is 60000 m². At the third ordering cycle, the purchasing cost shows the maximum value.

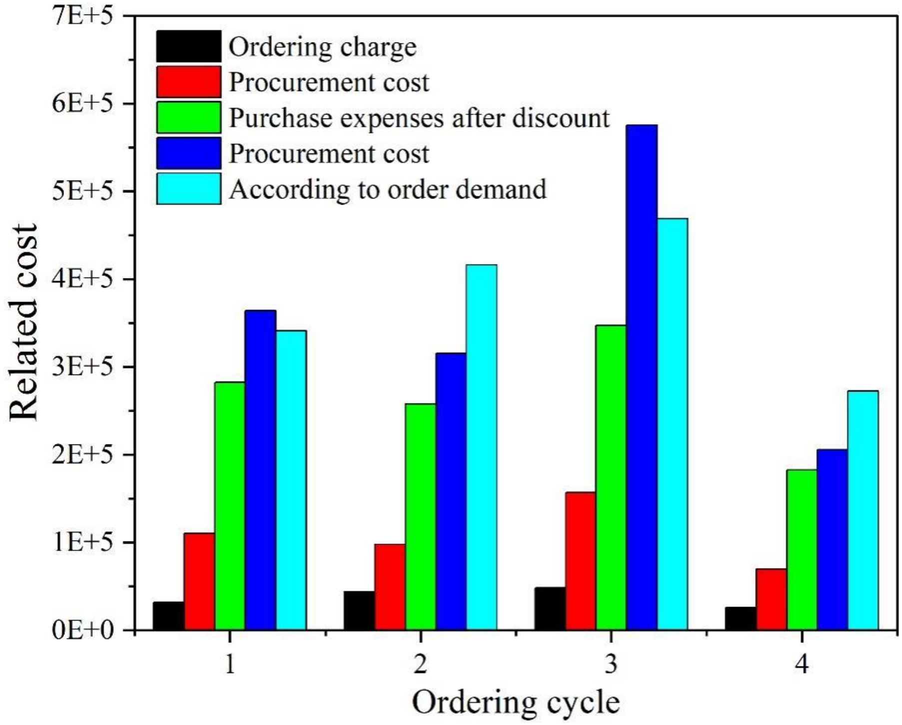

Fig. 3. The inventory capacity is 60000 m2 related expenses

Inventory capacity 60,000 m² the inventory capacity (in m²) for each cycle is shown in Table 2.

A comprehensive analysis of the graphs and tables leads to the following conclusions:

At ordering cycle 1, the marketing firm meets the inventory capacity constraints while wanting to get the highest possible purchase discounts due to the initial inventory and its own inventory capacity constraints. Inventory costs are higher in this cycle.

In ordering cycle 2, there are sufficient items in stock at the beginning of the ordering cycle. Therefore, order quantities from this week onwards only need to be replenished for some of the out-of-stock orders in this cycle.

At ordering cycle 3, the marketing firm's inventory level drops sharply with the delivery of orders in cycles 1 and 2, while being affected by the demand for larger orders in ordering cycle 1.

At ordering cycle 4, the inventory is replenished this cycle for only some of the out-of-stock items, based on the sufficient order quantity in cycle. As a result, the purchase amount for this weekly cycle is smaller, and inventory costs are reduced accordingly. However, due to the presence of customized items, the ordering costs are not significantly reduced.

Table 2. Inventory capacity of 60000 cycles

	The first order period	The second order cycle	Order 3	The order period of the fourth order
Actual inventory	68124.21	63425.19	53127.79	26866.04

2) Analysis of the relevant parameters of the model when the inventory capacity is 80,000 m². The trend of costs associated with an inventory capacity of 80,000 m² is shown in Figure 4, which shows the trend

graphs of purchasing costs, inventory costs, and ordering costs at four ordering cycles respectively when the inventory capacity of 80,000 m² is.

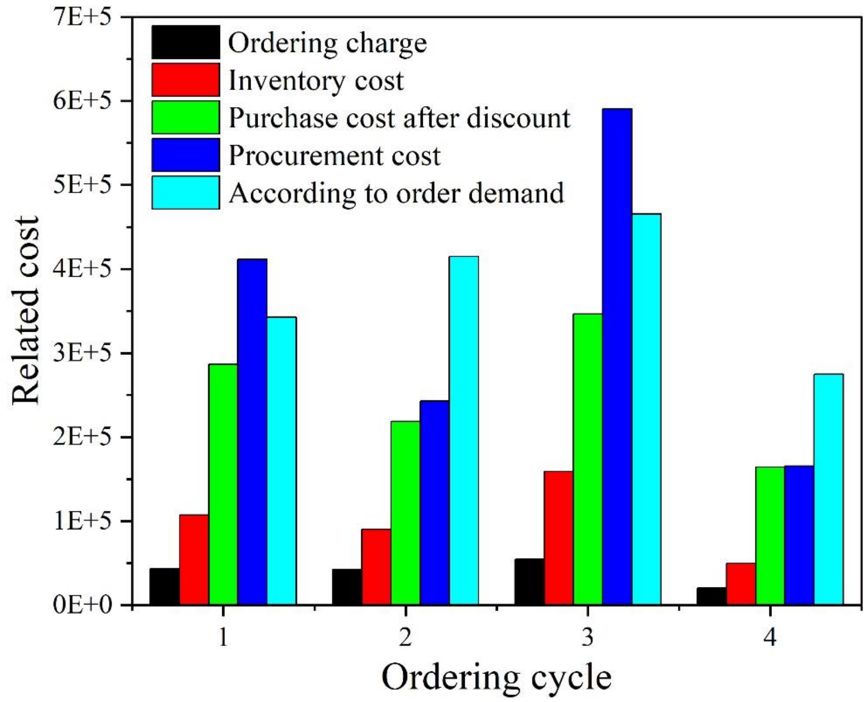

Fig. 4. The inventory capacity is 80000 m2 related cost trends

Inventory capacity 60,000 m² the inventory capacity (in m²) for each cycle is shown in Table 3.

A combined analysis of the graph and table leads to the following conclusions:

At ordering cycle 1, along with the increase in inventory capacity from increasing 60,000 m² to 80,000 m², the purchase cost increases from 36,897.66 Yuan to 42,157.41 Yuan. Therefore, in ordering cycle 1 the firm wants to get higher purchase discounts within the inventory capacity allowed, and the ordering cost and inventory cost increase accordingly.

In ordering cycle 2, due to the increase in ordering volume in cycle 1, the purchasing cost and inventory in cycle 2 decreases accordingly due to the impact of inventory capacity. The decrease in ordering costs is not significant due to the impact of customized products.

The purchasing amount in ordering cycle 3 and ordering cycle 4 follows a similar trend as when the inventory capacity is 100,000 mln and when the inventory capacity is 100,000 mln.

And when the inventory capacity is 100,000 m², the purchase amount for each ordering cycle is basically the same as when the inventory capacity is 80,000 m² because the purchase lot does not increase endlessly due to the limitation of liquidity for each cycle.

Table 3. The inventory capacity of each period of the inventory capacity of 80000 m2

	The first order period	The second order cycle	Order 3	The order period of the fourth order
Actual inventory	73562.12	66879.56	75413.55	36593.59

3.2. *Measurement of supply chain economic benefits*

3.2.1. Introduction of enterprises. R Group is a renowned manufacturing company with a wide range of businesses that encompasses a number of business modules including apparel, textile, fabric processing, property development and management consultancy. Since its establishment in 1979, the company has expanded and matured its business, and has become a target for manufacturing companies to learn from.

Since 2011, R Group has accelerated its supply chain integration efforts, and has made new breakthroughs in its business by integrating excellent supply chains and cultivating high value-added supply chain enterprises.

As of now, the Group's basic industrial products such as shirts and suits have become the company's business cards. In recent years, while Group R is striving to seek breakthroughs in its supply chain, many other manufacturing enterprises hope to learn from the experience of Group R's vigorous integration, and hope to seek continuous breakthroughs in their business development.

1) Global Supply Chain Front-end Network Expansion. For apparel companies, fabric and texture have always been the key to success for apparel companies. Similarly, R Group needs to increase control and research and development in fabric quality and material quality. Conventional view, R Group as a clothing manufacturer, had to carry out fabric procurement, reserves and other links, so the procurement process can greatly affect the product production program, affecting the development of the R Group's planning. In view of this, Group R decisively chose the upstream means to strengthen control.

2) Horizontal Network Integration of Global Supply Chain. After the integration of raw materials, textile fabrics and other production resources, on the one hand, Group R has accelerated the pace of horizontal integration. On the other hand, R Group's horizontal integration is also reflected in horizontal alliances, first of all, from the real estate presence since 1992, which can be reflected in R Group's attention to the development of other industries, through horizontal alliances to realize the group's business diversification.

3) Global supply chain downstream network control. Group R has privatized many of its early stores and bought a large number of stores, thus controlling the marketing channels in its own hands. Therefore, while the enterprise faces downstream competition, Group R is able to maintain its own channel system, which means that Group R does not need to worry about the uncertainty of channel construction, and is more conducive to the integration of enterprise resources. On the other hand, by cooperating with famous foreign brands, R Group has positioned itself as a high-end production base, and in principle, it does not make low-priced products or process low-grade products. R Group's control over its downstream partners also stems from R Group's segmentation of the foreign market, and R Group has set up a branch office in Japan, which not only serves as a sales company, but also as a window to publicize R Group's brand and culture. The branch is not only a sales company, but also a window to publicize the R Group brand and culture. Group R also has offices in the United States and Hong Kong, all of which emphasize Group R's focus on global channel development.

3.2.2. Supply chain optimization benefit analysis:

1) Current operating costs. The operation volume is shown as the annual operation volume of 541,236.63 tons and the average monthly operation volume of 32,579.02 tons.

The cost situation is shown in Table 4. Through the operation volume and the data in the table, it can be seen that the operation cost of Company R will be reduced after the optimization of production logistics.

According to the data of Company R, the annual operating volume (including raw material storage, finished product shipment) operation action. At present, there are two pieces of equipment, traveling stacker and conveyor belt, in Area B of Company R. The depreciation life is 67 months for both of them.

Table 4. Cost condition

Name	Stacker	Conveyor belt
Purchase cost (yuan)	895441.10	63521.84
Years of depreciation (month)	67	67
Monthly maintenance cost (yuan/month)	2896.24	3017.35
Monthly operating cost (yuan/month)	18753.98	4015.74
Operating cost per ton (month)	0.61	0.18

2) Annual operation data. Company R's full year operation data before optimization is shown in Figure 5, which shows the expected annual value of Company R's full year operation data. The total cost of packaging in the west zone is 425558.6*12=5106703.2 yuan, the cost of loading and unloading 398733.33*12=4784799.96 yuan, and the subtotal of loading and unloading 500068.43*12=6000821.16 yuan.

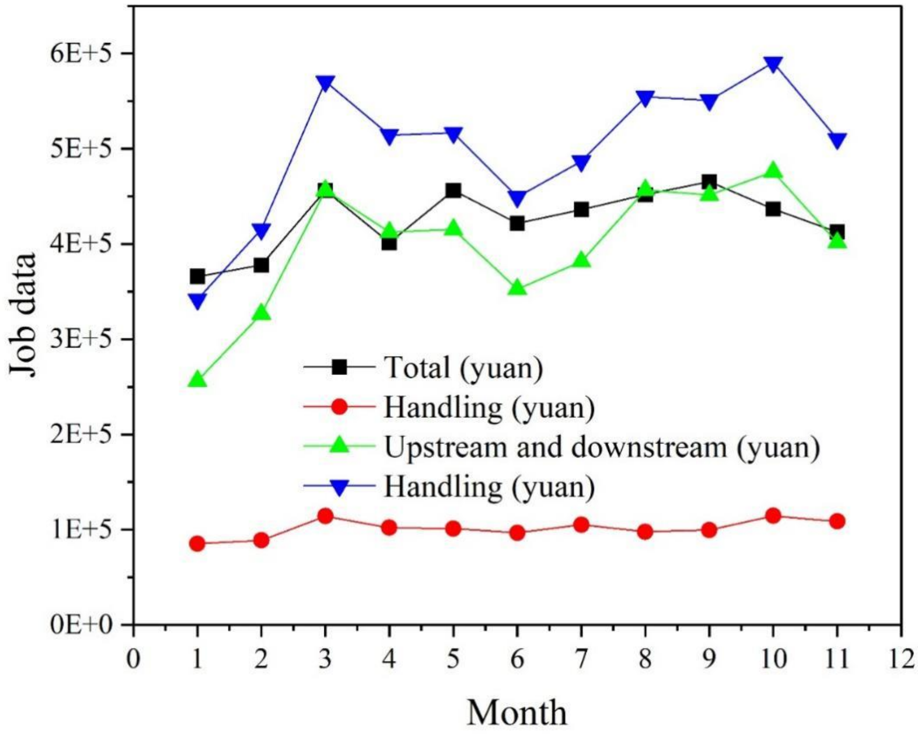

Fig. 5. Annual operating data

3) Equipment investment and staffing. The equipment investment and staffing of Company R before optimization are shown in Table 5, with a total monthly purchase amount of 6,740,000 yuan and a monthly depreciation cost of 157,494.5 yuan.

Table 5. Equipment investment and personnel allocation

Device name	Quantity	Purchase price (yuan)	Purchase amount (yuan)	Depreciation month	Monthly depreciation cost (yuan)
Stacking arm	3	500000	1500000	65	23076.92
Fork lift truck	8	100000	800000	65	12307.69
The fork truck automatically decouped the arm	3	10000	30000	65	461.54
Lift wheel	3	100000	300000	65	4615.38
Pedal bridge	2	15000	30000	65	461.54
Plastic tray	18000	200	3600000	35	102857.14
Mesh bag	8000	60	480000	35	13714.29
Total (month)			6740000		157494.5

The labor cost of Company R before optimization is shown in Table 6, with a total monthly labor cost and operating cost of 165,000 yuan.

Table 6. Labor cost and operating cost

Post setting	Quantity	Single month cost (yuan)	Monthly cost (yuan)	Remark
Field supervisor	1	8000	8000	
Forklift	12	7500	90000	
Hook man	3	5000	15000	
Stevedore	8	6500	52000	Only used for raw material unloading car
Total (month)	24	27000	165000	

4) Operating variable costs. The operating variable costs realized by Company R before and after operation are shown in Table 7, with a total operating variable cost of 96,467.9 yuan.

Table 7. Operating cost

Project	Quantity	Unit price (yuan)	Monthly cost (yuan)	Remark
Warehousing - forklift oil consumption	8210	0.6	4926	The amount of raw materials per month
Raw material transfer - oil consumption of forklift	8210	0.6	4926	The amount of raw materials per month
Oil consumption of finished product	26341	0.6	15804.6	The total transit quantity of finished products
Finished loading car - oil consumption	26341	0.5	13170.5	The total transit quantity of finished products
Warehousing - forklift maintenance	8210	0.4	3284	
Raw material transport-forklift maintenance	8210	0.4	3284	
Finished product transport-forklift maintenance	26341	0.4	10536.4	
Finished loading car - repair of forklift	26341	0.4	10536.4	
Other equipment maintenance	1	20000	20000	Mechanical arm, ejector etc
Other unforeseen operating costs	1	10000	10000	Unpacking
Total (month)			96467.9	

5) Calculation of the amount of savings. On the basis of the above data, the amount of savings saved by Company R after optimization is further calculated, and the calculation results are shown in Table 8, with a total savings ratio of 10.24% and an annual savings of 562807 yuan.

Table 8. Savings measurement

Serial number	Subject		Amount (yuan)
1	Monthly depreciation cost		145751
2	Monthly labor cost		165000
3	Monthly operating cost		96467.9
4	Investment monthly cost	Fixed total investment	6740000
5	Investment monthly cost	Annual cost	725514
6	Investment monthly cost	Monthly cost	67400
7	The project profit is calculated by 10%		42123
8	Fixed assets deduct taxes		15703
9	The monthly price of the tax is not combined		452196
10	Tax cost 6%		28708
11	Total monthly income quotation		456231
12	Project original monthly payment cost (including partial packing charges)		501271
13	The cost of the original tax deduction (the original 3% invoice)		445635
14	Economy ratio		10.24%
15	Annual amount		562807

4. Conclusion

This paper analyzes the necessity of supply chain flexibility in manufacturing enterprises, establishes a demand-driven supply chain flexibility model, and utilizes the improved particle swarm algorithm to solve the model. Suitable cases are selected for research to measure the economic benefits of supply chain optimization in manufacturing enterprises.

The key parameters affecting the particle swarm optimization algorithm are set separately, and the convergence curves under different iteration times are compared, and the operation speed of the improved particle swarm algorithm is significantly improved when the population size is set to 150~200. And when the ordering cycle of the supply chain is 4 and the inventory capacity is 100000 m^2, the purchase amount of each ordering cycle is basically the same as that of the inventory capacity of 80000 m^2, because the purchasing batch will not increase endlessly due to the limitation of liquidity of each cycle. The sample company's annual operating data, operating costs, equipment investment and staffing, and operating variable costs were statistically compiled, and the combined savings percentage for optimized Company R was further measured to be 10.24%, with an annual savings amount of 562,807 Yuan. The saving ratio is significant, and the supply chain optimization utilizes the enterprise to further manage and upgrade.

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