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Research on Path Selection and Mathematical Modeling of Enterprise Logistics Cost Optimization in International Trade

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ABSTRACT

As the main link of international trade, logistics plays a pivotal role in the entire international trade transactions, and choosing the appropriate logistics path is conducive to cost savings for enterprises. This study combines the traditional logistics model with the actual situation of international trade to select the headway transportation, overseas warehouses and tail distribution as the main elements of enterprise logistics cost optimization in international trade. Based on the cost calculation of the main elements, we design the objective function and constraints of enterprise logistics cost optimization, build the optimization model, and obtain the optimal solution by iterative analysis using the fitness function and genetic operator in genetic algorithm. The empirical analysis shows that after applying the optimization model, the total logistics cost of enterprise D is reduced from US$99,373,500 to US$72,653,400, indicating that the model is effective in optimizing the logistics cost of enterprise D in international trade. This study provides an effective method for the optimization of cross-border enterprise logistics costs, which has a positive role in promoting the development of international trade.

Keywords: optimization model, genetic algorithm, fitness function, genetic operator, logistics cost optimization

1. Introduction

With the growth of global freight transportation and the continuous development of the logistics industry, logistics and distribution has become the core competitiveness of major enterprises. In order to improve the efficiency of logistics and distribution, reduce costs and provide better service quality, the application of mathematical modeling in logistics and distribution optimization becomes particularly important. The application of mathematical modeling in logistics and distribution optimization is conducive to improving the efficiency of logistics and distribution and service quality [1-2].

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Mathematical modeling of logistics distribution path optimization problem mainly involves two aspects: node selection and path generation. Firstly, node selection refers to selecting a part of the nodes as the start point, end point and passing intermediate nodes of the distribution path in a given set of customer nodes. Secondly, path generation refers to generating an optimal path that meets the requirements based on the selected nodes, so that the total cost and time of logistics and distribution can be minimized [3-5]. In terms of path selection, greedy algorithms or heuristic algorithms are commonly used. The idea of greedy algorithm is to select the optimal local solution as the global solution each time, and find the optimal path through continuous iteration. The heuristic algorithm, on the other hand, evaluates the goodness of the path by setting the fitness function, and then searches for the optimal solution by simulated annealing and other strategies [6-7].

Literature [8] used the nsga-all method to explore the problems related to cross-border logistics paths of inland cities along the “Belt and Road”, and the results pointed out that Chengdu and Xi'an should be constructed as China's airport-type logistics hubs. The optimization structure mentions that the logistics cost of cross-border air transport increases after joining the model, but the logistics time decreases significantly, which lays the foundation for the transition from cross-border water transport to air transport. Literature [9] proposed a hybrid optimization algorithm for the distribution route optimization problem by using two algorithms: fish swarm and ant colony, and introduced the concept of transfer coefficient to enhance the overall performance of the algorithm in response to the shortcomings of the ant colony algorithm. Solomon's problem R101 is used as an example data base to calculate and validate the artificial fish swarm-ant colony hybrid algorithm. It is shown through experiments that the hybrid artificial fish swarm-ant colony algorithm is better than other heuristic algorithms. Literature [10] constructed a multimodal route selection framework with the aim of optimizing cost, time and risk reduction for beverage transportation from Thailand to Cambodia. The results of the study show that the model serves as an effective guide for cost, practice and risk selection in multimodal transportation. Literature [11] examined the role of logistics and infrastructure design in facilitating international trade. Through a comprehensive analysis of relevant theories and practical impacts found that logistics and infrastructure can reduce transaction costs, promote market connectivity, etc. Based on this, the government formulated supportive policies, enterprises to strengthen the optimization of logistics, technological innovation and other recommendations. Literature [12] explored the application of mixed integer linear programming mathematical models in vehicle path problems, aiming to reduce transportation costs. The mathematical model of MILP mixed integer linear programming for case study is also introduced, and the related numerical study is launched.

Literature [13] created a statistical relationship between price and factors such as fuel, and introduced a logistics factor to ensure that costs remained constant. A system dynamics model was proposed to explore the impact of changes in these factors on product prices, which enabled firms to determine the in and out situations in the market. Literature [14] compares the system approach with the classical approach. Indicates that the entire supply chain is optimized when each part of logistics tracks costs and tries to minimize them. And systematically introduced logistics costs: the costs incurred by infrastructure, capacity or preparation to perform logistics activities or to do so over a period of time. Literature [15] demonstrates the integrated logistics problem for minimizing the total logistics cost and presents a model for optimizing the logistics network in the form of a mathematical planning model. It is presented that the integrated model of the logistics network applies heuristics and is able to determine the location of warehouses, frequency of transportation, etc., minimizing the distribution costs. Literature [16] presents a linear programming model for a door and window company with stores in different regions, aiming to find the minimum transportation costs. It was also implemented to optimize the transportation costs of the company's plants by means of the help of Evolver, IP-Solver and others. Literature [17] indicated that the logistics industry is also facing many challenges due to increasing transportation costs. The challenges and innovations in the logistics model are emphasized as important conditions for the sustainable development of logistics companies.

This paper proposes the main elements of enterprise logistics cost optimization in international trade with reference to the existing research and various realistic factors in international trade. After designing the mathematical model of the cost of headway transportation, overseas warehouse and tail distribution in enterprise logistics, the objective function and constraints of enterprise logistics cost optimization model in international trade are proposed. Using the genetic algorithm in the fitness function iterative selection, crossover and other operations to screen the best individual fitness, and then using random traversal sampling genetic algorithm to obtain the optimal solution individual, to get the best path of enterprise logistics cost optimization. In this study, multinational trading enterprise D is selected as the subject, and the basic situation and problems of logistics cost management in enterprise D are analyzed. The logistics cost optimization model is applied to the logistics management system of the enterprise, and the changes in the total logistics cost, the main factor cost and the logistics cost in the main export trading countries before and after the application of the model are compared and analyzed to explore the effectiveness of the application of the logistics cost optimization model of the enterprise in international trade.

2. Method

2.1. Enterprise logistics cost elements and analysis

2.1.1. Main elements of logistics costs. In international trade, the enterprise logistics cost elements mainly include headway transportation, overseas warehouse, tail distribution 3 parts. Enterprises in international trade, there is a high cost of headway transportation, there is an urgent need to optimize the headway transportation routes. International trade enterprises are mainly based on overseas shared warehouses, but at present, each country only needs one overseas shared warehouse to be responsible for the main overseas warehousing services. Enterprises' tail-end distribution with different third-party logistics service providers to sign agreements, the main countries are divided into different distribution areas, distribution costs and distribution area price-related, the same area distribution costs are the same, the cost of cross-regional distribution is higher.

Unlike previous studies and combined with the reality of factors, in addition to the cost of logistics fees will be considered cost, distance, demand and other factors, this paper also makes improvements on the basis of the traditional logistics model, plus the consideration of the shared warehouse operating costs, freight rates between maritime shipping, the difference in warehousing costs between different regions, so that the logistics elements covered by the model of the logistics costs of enterprises in international trade is more comprehensive and more in line with the reality.

2.1.2. Calculation of the cost of each logistics element. Through the construction of international trade in the enterprise logistics cost model can be more comprehensive on the international trade in the logistics elements of the study, make full use of the optimization analysis of the relevant model to carry out international trade in the study of logistics costs, on the basis of the model targeted to the international trade in the logistics of the various aspects of the proposed optimization measures, so as to achieve the optimization of the enterprise international trade in the optimization and analysis of logistics costs.

1) Headway transportation cost. In this paper, for the convenience of the study, the headway transportation is set for shipping, according to the relevant enterprise internal headway transportation data show that the global headway transportation mode choice of shipping accounted for about 70% of the overall export transportation, the choice of shipping as the headway transportation method has a certain degree of representativeness and research.

The headway part of the enterprise logistics cost model in international trade is mainly established on the basis of supply node and demand node satisfaction, using the principles of route optimization and cost optimization to choose the optimized supply route and node layout, and on this basis to meet the product demand of all demand port nodes.

Headway Transportation Logistics Costs C_1:

$$C_1 = \sum_{s\in S}\sum_{g\in G} q_{sg} d_{sg}\, \theta z_{sg} + \sum_{g\in G}\sum_{s\in S}\sum_{v\in V} q_{sv} d_{sv}\, \theta z_{sv} \tag{1}$$

Formula (1) for the international trade in the enterprise logistics headway ocean freight logistics costs, the first part of the selected supply node and to the current headway logistics costs of overseas warehouses, the second part of the selected supply node to the overseas warehouses sub-store headway logistics costs. The decision variable of the formula is based on is the Chinese supply nodes and foreign overseas warehouses and overseas warehouses sub-warehouse will produce different transportation solutions, the choice of different impact on the results, different supply and demand nodes will produce different logistics solutions and costs.

2) Overseas warehouse cost. Enterprises in international trade logistics cost optimization model of the overseas warehouse part of the main existing overseas warehouse costs and sub-store optimization in the selection of overseas common warehouse costs [18], because the choice of the warehouse for the overseas shared warehouse, there is no construction costs. Overseas warehouse warehousing costs include warehousing costs and return costs, this paper studies the overseas warehouse and overseas warehouse warehousing logistics costs C_2 expression is shown below:

$$C_2 = \sum_{g\in G}\sum_{k\in K}(1+\beta) p_{g^{j}gk} + \sum_{v\in V}\sum_{k\in K}(1+\beta) m_v o_{vk} \tag{2}$$

Equation (2) represents the sum of the cost of overseas warehouse and the cost of sub-storage of overseas warehouse selected in the sub-storage optimization as well as the cost of return, the first part of which represents the cost of warehousing and return of overseas warehouse and the second part of which represents the cost of warehousing and return of sub-storage of overseas warehouse.

3) Tail-end distribution cost. Enterprises in international trade in the tail distribution and third-party companies signed outsourcing cooperation model, distribution cost model is mainly set up with the distribution area, in the same distribution area, the distribution cost is the same, do not need to take into account the distance of the demand point from the overseas warehouse, and there is no time penalty cost. When cross-regional distribution is carried out, certain transportation costs and time penalty costs will be incurred, so the basis for analyzing the cost of tail-end distribution.

Tailgate distribution cost C_3 is shown below:

$$\begin{aligned} C_3 = &\sum_{g\in G}\sum_{k\in K}(1+\beta) j_{gk} y_{gk} \\ &+\sum_{v\in V}\sum_{k\in K}(1+\beta) o_{vk} r_{vk} \\ &+\sum_{g\in G}\sum_{k\in K} c_{gk} T_{gk} j_{gk} \\ &+\sum_{g\in G}\sum_{v\in V} u_{gv} \gamma_{gv} E_{gv} \end{aligned} \tag{3}$$

The first part on the right side of the equal sign in equation (3) is the sum of tail delivery and return costs for overseas warehouses, the second part is the sum of tail delivery and return costs for sub-stores in overseas warehouses, and the third part on the right side of the equal sign is the time penalty cost of tail delivery. The fourth part is the tail-haul transit cost. The decision variables are whether the split-warehouse optimization model requires transshipment of goods, and how the split-warehouse can be carried out in the split-warehouse optimization model to achieve cost optimization.

2.2. Logistics cost optimization model construction

In summary, the objective function and constraints of enterprise logistics cost optimization model in international trade are:

$$\begin{aligned}\min C = &\sum_{s\in S}\sum_{g\in G} q_{sg} d_{sg}\theta z_{sg} + \sum_{g\in G}\sum_{s\in S}\sum_{v\in V} q_{sv} d_{sv}\theta z_{sv}\\ &+\sum_{g\in G}\sum_{k\in K}(1+\beta)p_g j_{gk} + \sum_{v\in V}\sum_{k\in K}(1+\beta)m_v o_{vk}\\ &+\sum_{g\in G}\sum_{k\in K}(1+\beta)j_{gk}y_{gk} + \sum_{v\in V}\sum_{k\in K}(1+\beta)o_{vk}r_{vk}\\ &+\sum_{g\in G}\sum_{k\in K}c_{gk}T_{gk}j_{gk} + \sum_{g\in G}\sum_{v\in V}u_{gv}\gamma_{gv}E_{gv}\end{aligned} \tag{4}$$

$$\sum_{g\in G}\sum_{k\in K} j_{gk} \le \sum_{s\in S}\sum_{g\in G} q_{sg}, \forall s\in S, \forall g\in G, \forall k\in K \tag{5}$$

$$\sum_{v\in V}\sum_{k\in K} y_{vk} \le \sum_{s\in S}\sum_{v\in V} q_{sv}, \forall s\in S, \forall v\in V, \forall k\in K \tag{6}$$

$$\sum_{k\in K} h_k = \sum_{g\in G}\sum_{k\in K} j_{gk} + \sum_{v\in V}\sum_{k\in K} y_{vk}, \forall v\in V, \forall g\in G, \forall k\in K \tag{7}$$

$$Z_{sg} \in \{0,1\}, \forall s\in S, \forall g\in G \tag{8}$$

$$Z_{sv} \in \{0,1\}, \forall s\in S, \forall v\in V \tag{9}$$

$$E_{gv} = \begin{cases}1, & u_{gv} > 0\\ 0, & u_{gv} = 0\end{cases} \quad \forall g\in G, \forall v\in V \tag{10}$$

$$T_{gk} = \begin{cases}b_{gk} - a_g, & b_{gk} > a_g\\ 0, & b_{gk} \le a_g\end{cases} \forall_g \in G, \forall k\in \mathrm{K} \tag{11}$$

$$q_{sg} = \begin{cases}j_{gk} + o_{vk}, & E_{gv} = 1\\ j_{gk}, & E_{gv} = 0\end{cases} \forall s\in S, \forall v\in V, \forall g\in G, \forall k\in K \tag{12}$$

Equation (4) is a model for optimizing the logistics cost of enterprises in international trade, where the first part of the headway transportation cost from the Chinese supply point to the current overseas warehouse. The second part of the Chinese supply point to the new overseas warehouse sub-store headway transportation costs. The third part is the storage and return cost of the overseas warehouse. The fourth part is the warehousing and return costs for the sub-stores of the overseas warehouse. The fifth part is the cost of final delivery to overseas warehouse and return and exchange. The sixth part is the cost of final delivery of overseas warehouse branches. The seventh part is the time penalty cost for the tail delivery of overseas warehouses. The eighth part is the optimized transshipment cost of sub-stores.

Equation (5) indicates that the total amount of goods sent from the supply point in China to the overseas warehouse is not less than the total amount of goods sent from the overseas warehouse to the demand region.

Equation (6) indicates that the total amount of commodities sent from the supply point in China to the sub-stores of overseas warehouses is not less than the total amount of commodities sent from the sub-stores of overseas warehouses to the demand region.

Equation (7) indicates that the total amount of commodities sent from overseas warehouses to the demand region and from overseas warehouses to the demand region is equal to the total demand in the demand region.

Equation (8) indicates that Z_{sg} is a 0-1 variable. Equation (9) indicates that Z_{sv} is a 0-1 variable. Equation (10) denotes that in the binning optimization model, when the volume of transshipment is 0, then only the direct binning model is available and there is no transshipment cost, and when the volume of binned transportation is greater than 0, then the transshipment binning model is used and transshipment cost is incurred.

Eq. (11) represents the tailgate distribution delay time.

Eq. (12) indicates that when transshipment binning is required, the demand from supply point s to overseas warehouse g is equal to the sum of the demand from overseas warehouse g to demand region k and the demand from overseas warehouse bin v to demand region k; when transshipment binning is not required, the demand from supply point s to overseas warehouse g is equal to the demand from overseas warehouse g to demand region k only.

2.3. Logistics cost optimization path selection based on genetic algorithm

2.3.1. Adaptation function selection. The fitness function [19] is a function that measures the fitness of individuals in a population, and there are different values of fitness according to different problems of optimization, different demands or different constraints. The fitness function is always non-negative, in any case, we hope that its value is as large as possible, and its design mainly meets the conditions of single-valued, continuous, non-negative, maximization, reasonable, consistent, generality, and small amount of computation. The objective function may be positive or negative, i.e., sometimes seeking the maximum value, sometimes seeking the minimum value. The fitness function is changed from the objective function, from the population objective function $f(x)$ [20] to solve the fitness function $fit(f(x))$ as follows.

1) The population objective function $f(x)$ is directly operated positively and negatively as the fitness function $fit(f(x))$:

$$fit(f(x)) = \begin{cases} f(x), \\ \text{Solve the population objective function maximization problem} \\ -f(x), \\ \text{Solve the population objective function minimization problem} \end{cases} \tag{13}$$

2) Introduce a maximum or minimum constant term to use the population objective function $f(x)$ as the fitness function $fit(f(x))$:

$$fit(f(x)) = \begin{cases} C\max - f(x), \text{Constant } C\max \ge f(x), \\ \text{Solve the population objective function maximization problem} \\ C\min + f(x), \text{Constant } C\min \le f(x), \\ \text{Solve the population objective function minimization problem} \end{cases} \tag{14}$$

3) Adaptation function $fit(f(x))$ after taking the inverse of the population objective function $f(x)$ plus the objective function bounds valuation C:

$$fit(f(x)) = \begin{cases} \dfrac{1}{1+C-f(x)}, C - f(x) \ge 0, \\ \text{Solve the population objective function maximization problem} \\ \dfrac{1}{1+C+f(x)}, C + f(x) \ge 0, \\ \text{Solve the population objective function minimization problem} \end{cases} \tag{15}$$

The problem of deception of genetic algorithms may occur in the results of genetic algorithm calculations. One is that at the beginning of the evolution, there are individual outstanding genes in the initial population, and these genes can limit the selection process due to too much competition, which has some impact on the optimization performance of the algorithm. On the other hand, it is at a later stage of evolution, when all the individuals in the population become basically of similar fitness and are able to re-optimize less, to the extent that a locally optimal solution may be obtained. In order to avoid the two problems mentioned above, a relatively reasonable variation of the fitness function is required.

This paper applies:

$$Fit = e^{-1000\times\frac{1}{1+f(x)}} \tag{16}$$

Is the fitness function, and through 200 iterations constantly selecting, crossing, mutating, reversing and other operations on the entries with high fitness to screen out the individual with the best fitness, in order to study the best plan for the optimization path of the logistics cost of the enterprise in the international trade.

2.3.2. Genetic operators. The specific flow of the genetic algorithm is shown in Figure 1. It can be found that the genetic operator is the core part of the genetic algorithm [21], which simulates the genetic process of biological genes in nature, and its role is to survive the survival of the fittest by keeping the individual genes that conform to the individual genes, and eliminating the genes that are not adapted to the environment.

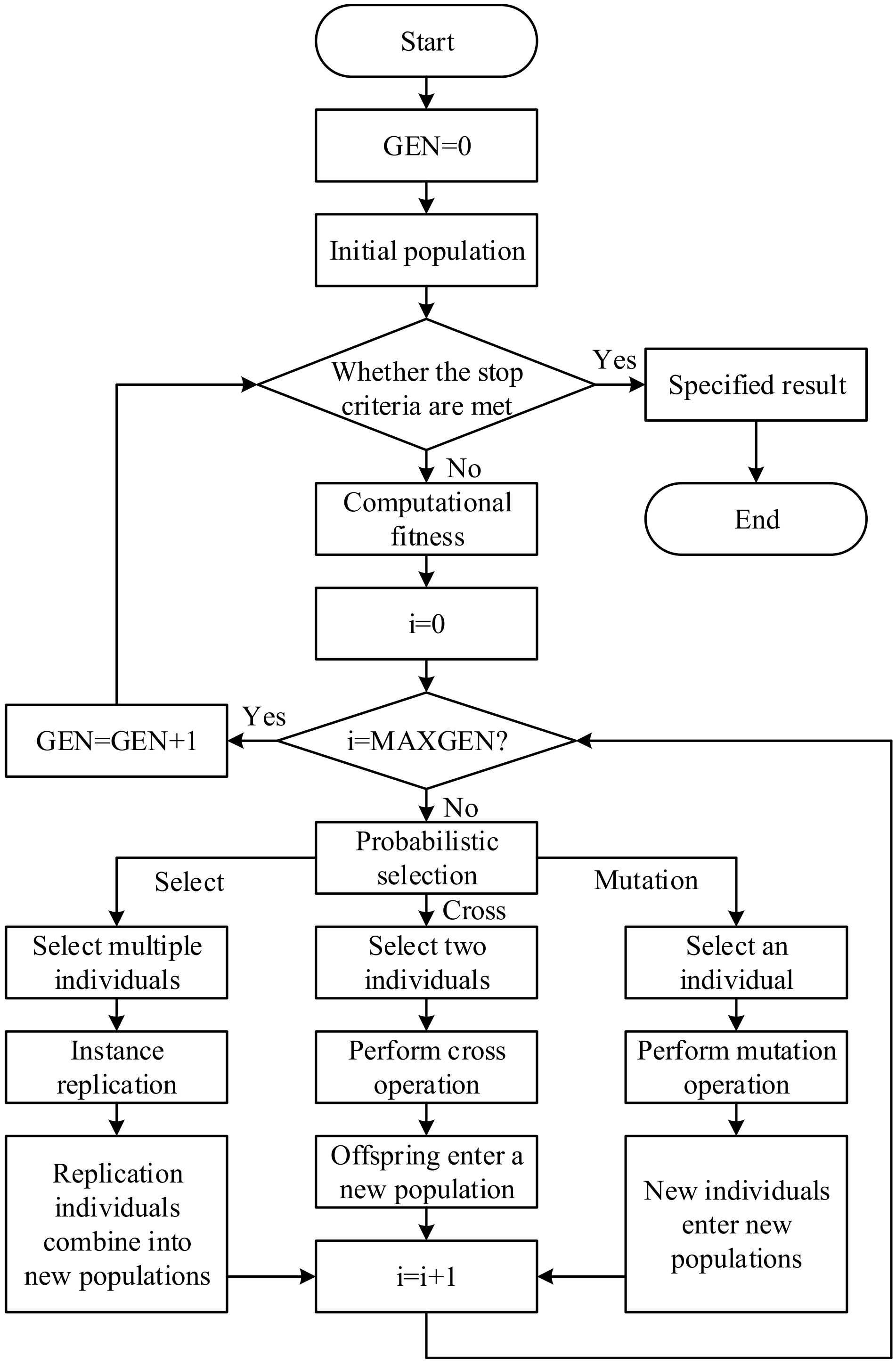

Fig. 1. Process of genetic algorithm

The selection operator chosen in this paper is random traversal sampling (SUS) [22], the random traversal sampling selection operator is formed by the improvement of roulette selection operator. This method is improved from roulette selection operator and improves the original complex form of repetitive sampling by following the marked pointer. The following parameters exist in random traversal sampling: the number of population values (Nind), the individual fitness matrix (FitnV), the index number of selected individuals (ChrIx), the number of selected individuals of the parental generation (Nsel), the total fitness is (F), the position of the randomly generated starting pointer (Start), the position of each pointer (Pointer), and the percentage of offspring selection (GGAP).

In random traversal sampling, the number of Nsel individuals needed is determined according to GGAP, which is generally 0.9, and Nsel individuals can be selected by generating Nsel equally spaced labeled pointer positions. Assuming that the number of individuals to be selected is Nsel, the steps of random traversal sampling are as follows: first, calculate the spacing between the pointers, then generate a random number between 0 and P of the starting pointer position, then calculate the position of each pointer, and finally select Nsel individuals according to the pointer position.

The random traversal sampling (SUS) selection operator applies the same initial population of 100 individuals as the roulette selection operator, and the selection operator by random convenience sampling has the following operations.

1) Calculate the total fitness value:

$$F = \sum_{k=0}^{n=Nind} FitnV_n, F \approx 0.0193 \tag{17}$$

2) Calculate the number of selected individuals in the parental generation:

$$Nsel = \lfloor Nind \times GGAP + 0.5 \rfloor_b\ Nsel = 90 \tag{18}$$

3) Calculate the pointer spacing:

$$P = F / Nsel, P \approx 0.00021 \tag{19}$$

4) Randomly generate the starting pointer position:

$$Start = 0.0001 \tag{20}$$

5) Calculate the position of each pointer:

$$Pointer = Start + i \times P, i = (0,1......., Nsel - 1) \tag{21}$$

6) Select the Nsel individuals to derive the index number of the selected individuals ChrIx.

7) Determine the selected individuals based on ChrIx to form a new population with NIND-Nsel individuals from the original population.

This paper applies the random traversal sampling (SUS) selection operator to achieve the fitness screening of the population individuals in each round, and after the MAXGEN number of times for the maximum iteration, the individual that obtains the optimal solution is used as the shortest path, i.e., the optimal path for the optimization of the logistics cost of the enterprise.

3. Results and discussion

3.1. Analysis of Logistics Cost Profile of Enterprise D

3.1.1. Basic Introduction of Enterprise D. D Enterprises is a multinational sports goods group of companies with products focusing on the mass sports market, a group with a full industrial chain from branding, design, R&D, manufacturing, logistics and retailing. Founded in 1976, the founder created the company with a new concept of self-service sports retailing. As a mass sports all-industry chain group, by the end of 2021 it was present in more than 60 countries on 6 continents, with nearly 2,500 stores, more than 3.6 million sports users, and 95,000 team members.At the end of 2021, global turnover exceeded 15.9 billion euros.The record performance in 2021 was thanks to 50% store sales and 50% e-commerce sales, which put the company 5.4% higher than the previous year. The company's production lines are located in 30 countries or regions around the world, of which 47.62% of the world's products originate in China. 64 logistics and warehousing centers are owned globally, of which 8 are in China, with more than 2,000 logistics employees in the Chinese region. Global exports in 2021 amounted to 13,264,400 teu (teu is a unit of 20-foot standard containers), and more than 1.3 billion pieces of products were transported.

3.1.2. Analysis of logistics costs in international trade. The logistics cost of enterprise D in international trade mainly contains the logistics cost caused by exporting in the exporting country, the international logistics and transportation cost (headway transportation, overseas warehouses and tail distribution), and the logistics cost caused by importing in the importing country. According to the financial statistics of the past years, the proportion of the cost of Enterprise D on these three to the total logistics cost of the whole segment is 18.4% of the logistics cost of the Chinese segment, 50% of the logistics cost of the international segment, and 30% of the logistics cost of the importing country.
1) Analysis of import and export freight index. Due to the change of the transportation mode and the price change of the shipping market, the logistics cost of international routes in international trade of enterprise D is very high. Whether it is by sea, air or railroad, the freight cost keeps changing every year, ranging from one month to one week. In the past two years, the outbreak of the new crown pneumonia, some shipping routes a day a price, and logistics cost budget, control and implementation of the difficulties. The changes in freight rates are due to adjustments made by shipping companies or airlines based on their own cargo loading, supply and demand, international fuel prices and other factors, so as to maximize their own interests. Shanghai shipping exchange CCFI statistics China container shipping price index analysis results as shown in figure 2, it can be seen that the price of each month will change, some months will be drastic changes, especially after the new crown epidemic around March 2020, the export shipping freight rate rose straight up, in December 2021 when the export freight rate index has reached 387.54. This gives the D enterprise this brings a great challenge to optimize the logistics cost of international segment in international trade.

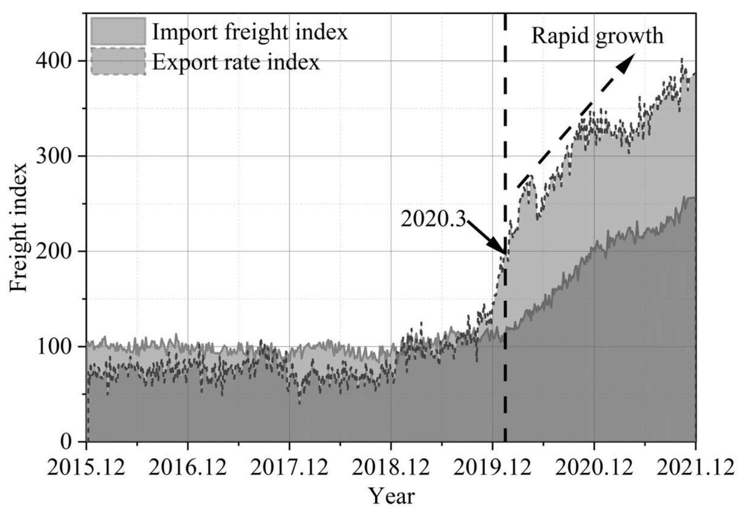

Fig. 2. The export container freight index in 2015-2021

2) Analysis of total logistics cost data of Enterprise D. As shown in Table 1, the analysis of the internal logistics cost data of enterprise D shows that from 2015 to 2021, especially after the outbreak of the new crown epidemic, the supply chain of the Chinese market has been stable, and the volume of sea and air cargo has continued to increase. Sea freight has always been the main export transportation mode of enterprise D, with sea cargo accounting for more than 90% of the cargo volume on average every year, and the sea cargo volume in 2021 is actually as low as 81.26%. In 2020, the new crown epidemic broke out in March and April, and air transportation was stopped during the peak shipping season, so the proportion of air freight was as low as possible to an unprecedented 0.36% that year, but in 2021, air freight continued to increase to 15.11%. There has been a slight decline in the freight volume of railways in the past three years, from 5.86% in 2015 to 3.63% in 2021. In terms of various transportation modes, the logistics cost of the international segment also increases with the increase in cargo volume, and the freight rates of international transportation continue to rise due to the impact of the epidemic. In 2015, the logistics cost of the international section of shipping, which accounted

for 93.78% of the shipments, was 46.0735 million US dollars, and in 2021, the logistics cost of the international section, which accounted for 81.26% of the shipping volume, was as high as 96.9506 million US dollars.

Table 1. The company's export logistics data in 2015-2021 (USD)

Cargo quantity	Marine cargo	Air cargo	Rail cargo
2015	1543161	2232453	99114
2016	1614429	1924614	79985
2017	1752557	1765435	83755
2018	1753417	1452265	73142
2019	1961946	738231	62611
2020	1979574	651385	92249
2021	2405081	514105	67312
Proportion of cargo	Marine cargo	Air cargo	Rail cargo
2015	93.78%	0.36%	5.86%
2016	93.81%	0.91%	5.28%
2017	90.08%	4.82%	5.10%
2018	90.57%	5.37%	4.06%
2019	90.50%	8.43%	2.07%
2020	95.25%	0.36%	4.39%
2021	81.26%	15.11%	3.63%
International logistics	Marine cargo	Air cargo	Rail cargo
2015	46073595.75	4705990.69	5686735.72
2016	59149566	8295393.25	6557624.21
2017	67230014.07	5334551.56	7946646.91
2018	77916031.78	2328087.69	8126459.97
2019	88908527.76	2171762.61	8293174.5
2020	91031012.34	4468321.79	17263897.26
2021	96950567.36	7675230.23	19045394.27

3) Analysis of logistics costing problems. At present, Enterprise D does not attach much importance to the transportation cost, but cares more about the production and sales cost of the products, thus it will cause serious problems in the accounting and management of logistics cost. The breakdown of logistics costs for an order to Canada in 2021 is shown in Table 2, and the logistics costs for another order to Mexico are shown in Table 3. The weight of the goods to the port of Vancouver, Canada, is 24,826KG, and the volume is 65CBM, so it is delivered in a 40HQ container, and the customer service personnel of enterprise D asked for quotations and booked with the senior forwarder who cooperated with the company more at that time. After the goods arrived at the port of shipment, the goods packaging needs to be checked before shipment, safely sent to the destination port, the customer received the bill of lading. An order for 6 pieces of palletized cargo from Shanghai airport to Mexico City International Airport, signed CIF terms. The weight of the goods is 6235KG, the volume is 8.5CBM, and all the above charges are collected by the international freight forwarding company, and then docked with the airlines. From the above two cost details, we can see that the cost of packaging the goods in the factory is not listed separately, which is due to the cost is counted by the production department, the international department of the staff do not quite understand it. The relevant personnel of the international department of enterprise D will be reported to the Ministry of Finance as the logistics costs of the contract, and ignored the case of the above communication costs and other hidden costs. If all kinds of hidden costs are ignored in the statistics, it will easily lead to a large error in costing.

Table 2. Breakdown of logistics costs to Vancouver, Canada (USD)

Number	Project	Cost	Number	Project	Cost
1	Shipping cost	14826.20	6	File fee	542.63
2	Booking charge	326.41	7	Customs charges	98.65
3	Dock charge	1125.63	8	Charging fee	524.21
4	Lead charge	104.26	9	Suitcase charge	121.32
5	towage	3592.52	——	——	——

Table 3. Breakdown of Logistics Costs to Mexico (USD)

Number	Project	Cost	Number	Project	Cost
1	Shipping cost	326145.26	5	Customs charges	215.65
2	Booking charge	3256.41	6	Inland charge	1524.63
3	Airport packing charge	9882.6	7	Inland charge	199.86
4	Appraisal fee	321.03	——	——	——

3.2. Logistics cost optimization effect analysis

Based on the above analysis of the logistics cost of Enterprise D, this paper takes Enterprise D as a pilot to implement the logistics cost optimization model proposed in this paper, and applies the model to the current logistics system of the enterprise to construct a new type of logistics system in December 2021. After more than two years of application, the various problems in logistics management described earlier in this paper have been initially solved, achieving a significant reduction in the complexity of logistics operations, optimizing the key factors affecting logistics costs, and the optimization of these key factors has brought about a significant reduction in the logistics costs of Enterprise D.

After applying the logistics cost optimization model in the logistics management system, the changes in the cost of first-leg transportation, overseas warehouses and last-mile distribution elements are shown in Figure 3. In this study, the model is analyzed using the data of the first three years and the next three years, and compared with the beginning of 2019, the logistics cost of enterprise D's international trade in September 2024 has been significantly optimized. The total logistics cost decreased from 99.3735 million US dollars to 72.6534 million US dollars. In September 2024, the cost rate of overseas warehouses decreased by 39.31% compared with 2019, and the expenses decreased from US$25.6432 million to US$15.5634 million, a decrease of US$10.0798 million. There are two main reasons: first, according to the requirements of the optimal logistics cost optimization scheme obtained by genetic algorithm analysis, the address of overseas warehouses has been re-optimized, and some warehouses with unreasonable layout have been merged. The storage area has decreased from 556,900 square meters to 382,400 square meters, and the storage area has decreased significantly. Second, the implementation of the logistics cost optimization model at the end of 2021 led to a significant decline in finished goods inventories and the cancellation of some redundant warehouses, both of which led to a decrease in overseas warehouse expenses. In terms of last-mile distribution costs, compared with 2019, although the rate will only decrease by 5.91% in 2024, the cost amount will also be reduced by 2.2514 million US dollars, indicating that the application of the enterprise logistics cost optimization model has promoted the reduction of the logistics cost of enterprise D. The logistics cost optimization model proposed in this paper can save costs for enterprises in terms of logistics, and there is a possibility of continuous optimization in the future, and it is foreseeable that the logistics cost of enterprise D will be further reduced in the future. In addition, the model will also make a positive contribution to the profit growth of enterprise D, the total cost of logistics decreased by 26.7201 million US dollars, accounting for 3.26% of the total profit of the year, and the logistics cost optimization model has achieved initial results in the optimization of logistics costs in the international trade of enterprise D.

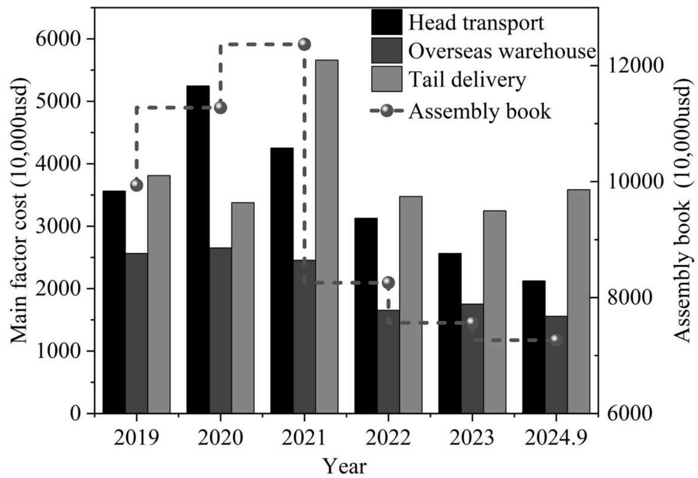

Fig. 3. 2019-2024 logistics cost analysis

Subsequently, this study analyzes the changes in the logistics cost of enterprise D in the main exporting countries of international trade (the United States, the United Kingdom, Russia, Japan, and India), and further explores the application effect of the logistics cost path optimization model proposed based on genetic algorithm. Table 4 shows the detailed comparison results of logistics costs in major exporting countries before and after the implementation of the logistics optimization model. In 2020, the total logistics cost of enterprise D in the United States was 1.8829 million US dollars, accounting for 1.67% of the total logistics cost of enterprise D that year. After the implementation of the logistics optimization model in the enterprise logistics management system, the total logistics cost in the United States will decrease by 726,200 US dollars in 2023, and the rate will decrease by 38.57% year-on-year, indicating that the implementation of the logistics cost optimization model has promoted the reduction of the total logistics cost in the main exporting countries of enterprise D. The logistics cost optimization rate in other exporting countries is also between 8.90% and 18.82%. In addition, customer satisfaction has also improved significantly in various countries, from 65.01%-77.12% before optimization to 92.17%-96.52%, which indicates that the logistics cost optimization model not only has a positive effect on cost optimization, but also has an optimization effect on customer satisfaction.

Table 4. The cost optimization of the logistics of each exporter (10,000USD)

Index		Country				
		United States	UK	Russia	Japan	India
Before (2020)	Logistics cost	188.29	103.86	65.35	61.37	54.28
	Customer satisfaction (%)	70.99%	72.55%	77.12%	67.06%	65.01%
After (2023)	Logistics cost	115.67	94.62	56.42	49.82	45.62
	Customer satisfaction (%)	95.45%	95.93%	92.3%	92.17%	96.52%
Cost difference		72.62	9.24	8.93	11.55	8.66
Cost optimization rate (%)		38.57%	8.90%	13.66%	18.82%	15.95%

4. Conclusion

This paper establishes the objective function and constraints of enterprise logistics cost optimization in international trade, constructs the optimization model and solves it by using genetic algorithm, and conducts empirical investigation on the practical effect of the method.

Due to the change of transportation mode and the price change of the shipping market, the logistics cost of international routes in international trade is very high. And the company has serious problems in logistics cost accounting. In 2021, the logistics cost optimization model proposed in this paper was applied to the logistics system of the enterprise, and it was found that the logistics cost of enterprise D in international trade was significantly optimized. The total cost of logistics was reduced from 99.3735 million US dollars to 72.6534 million US dollars, and the total cost decreased by 26.7201 million US dollars, accounting for 3.26% of the total profit of the year. In addition, after the implementation of the logistics optimization model, the total logistics cost in the United States will decrease by 726,200 US dollars in 2023, and the rate will decrease by 38.57% year-on-year. The results show that the implementation of the logistics cost optimization model has promoted the reduction of the total logistics cost in the main exporting countries of enterprise D.

Therefore, the enterprise logistics cost optimization model can select different optimization paths for the enterprise logistics situation, which can achieve more effective cost optimization. Future research can consider covering the tariff factors in international trade logistics as well as country-specific costs, which will make the logistics cost optimization model more mature and comprehensive.

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