Research on Emergency Dispatch Optimization of E-commerce Logistics Based on Multi Objective Optimization Model

Honglin Hui [1, *, #], Hao Gong [2, #], Jiawen Gao [1], Wanqing Lu [2], Xiuye Hu [1]

[1]School of Intelligent Equipment College, Shandong University of Science and Technology, Taian, China, 271021

[2]School of Finance and Economics College, Shandong University of Science and Technology, Taian, China, 271021

* Corresponding Author Email: anshenyehuang@163.com

#These authors contributed equally.

Abstract. Logistics networks are closely related to daily life, and ensuring network circulation and responding to emergencies are crucial. This article delves into the logistics network adjustment strategy, aiming to improve the ability of the logistics network to respond to emergencies. The study begins by analysing the daily delivery volume and revealing the cyclical and trending characteristics of logistics demand. Subsequently, the ARIMA model and the BP neural network model were used to predict the transportation data, which could take into account the autocorrelation and nonlinear characteristics of the time series data, so as to improve the accuracy of the prediction. Further, this paper considers the impact of specific situations, such as DC5 shutdowns, on logistics networks. By constructing a linear programming model and applying a simulated annealing algorithm, this paper optimizes the cargo distribution strategy to ensure that the load rate of some routes reaches 100% without overloading, while the overall average load rate is only 5.29%. This optimization not only improves the efficiency of the logistics network, but also enhances its robustness in the face of unexpected events. Through these studies, this paper not only enriches the theoretical basis of logistics network adjustment, but also provides practical tools and methods for the management and optimization of actual logistics network, which has important theoretical significance and practical value.

Keywords: E-commerce Logistics Optimization Model, Cargo Volume Prediction Model, Linear Programming, Annealing Algorithm.

1. Introduction

With the booming development of the e-commerce industry, the role of e-commerce logistics networks is becoming increasingly prominent [1]. This network not only improves transportation efficiency, but also enables real-time tracking of cargo dynamics. Studying logistics networks is crucial for responding to holiday peaks or emergency situations, as it allows us to quickly adjust strategies to ensure timely delivery of goods. By predicting logistics data, we can plan and adjust cargo logistics in advance, optimizing routes. Therefore, building a predictive model to estimate the package volume of each logistics node and route, combined with the processing capacity of each node and the transportation capacity of the route, to make timely adjustments to the logistics network and ensure its efficient operation, is of great significance [2].

The optimization of e-commerce logistics networks has always been a research hotspot in the academic community, and in recent years, research on emergency transportation optimization has been discussed. He Zhilin proposed that genetic algorithm can be used as a multi-objective logistics path optimization method in cross-border e-commerce [3]; Taiji et al. proposed a typical case of cross-border e-commerce based on genetic algorithm in layout and integrated zone, and proposed corresponding optimization paths [4]; Yang Rongchuan proposed that the supply chain of cross-border e-commerce logistics services should take genetic algorithms as the main path and carry out corresponding measures [5]; Zhou Lin proposed that the ordering and transportation of fresh food in cross-border e-commerce can improve logistics transportation efficiency through genetic algorithms

[6]; Huang Jin proposed that the location of overseas warehouses for cross-border e-commerce exports can be accurately determined through genetic algorithms [7]. Although current research has proposed a variety of methods to optimize e-commerce logistics networks, such as the application of genetic algorithm in multi-objective logistics path optimizationand the optimization of fresh food distribution path based on genetic algorithm, but there are still some key issues and challenges. First of all, the existing research mostly focuses on the optimization of a single goal, such as cost minimization or service efficiency maximization, while the real-world logistics network optimization often needs to consider multiple goals at the same time, such as cost, efficiency, reliability, and environmental impact. Secondly, the existing research on how to quickly respond to market changes and emergencies in the optimization of logistics network in a dynamic environment is not sufficient. In addition, most of the research focuses on the development and testing of algorithms, and the scalability and practicability of algorithms in the actual complex logistics environment are relatively rarely discussed. In view of these problems, this paper considers the impact of emergencies on the logistics network, such as the shutdown of DC5, and constructs the corresponding optimization model to improve the robustness and flexibility of the logistics network. At the same time, this paper not only discusses theoretically, but also verifies the effectiveness and practicability of the proposed method through practical cases, which provides a new perspective and tool for the optimization of e-commerce logistics network.

This article first analyzes the daily delivery volume to obtain a prediction model, and shuts down a certain center to simulate emergencies. Through heuristic algorithms, it optimizes the distribution of goods to ensure that other routes receive the distribution of goods at that station as normally as possible, while minimizing the number of changing routes and balancing the load. When the ideal situation cannot be met, it minimizes the number of packages that are not flowing normally. (Data Source: http://mathorcup.org/detail/2417)

2. Establishing a route cargo volume prediction model based on time series analysis and BP neural network algorithm

To ensure the accuracy of the predicted data, this article has decided to compare two methods, namely combining manual summarization of patterns with machine learning to obtain the final results.

2.1. Time series analysis model

In order to predict the daily cargo volume of each route, time series analysis methods [8] are used to analyze historical cargo volume data and make predictions based on it. Firstly, visual analysis is conducted on the historical cargo volume data to observe whether its trend follows seasonal or periodic patterns. Next, perform a stationarity test on the historical cargo volume data. If there is any non stationarity, it is necessary to use [score] or other methods to transform it into a stationary sequence. Subsequently, autocorrelation function (ACF) and partial autocorrelation function (PACF) analysis were performed on the stationary sequence to determine the appropriate parameters for the ARIMA model. Finally, based on historical data, the ARIMA model is used to predict the cargo volume and evaluate the accuracy and stability of the model's predictions.

2.2. BP neural network model

Using machine learning to predict cargo volume: Firstly, based on existing data and appropriate features, this paper selects time features (date, day of the week, holidays, etc.) as a reference for better predicting route cargo volume. Next, based on the predicted problem type, the data is divided into training set, validation set, and testing set to avoid model overfitting, and an appropriate model is selected for training [9]. Use the trained model to predict the data for the remaining time periods and present the prediction results.

This article uses MATLAB programming to enhance the fitting of data by increasing the value to 50, resulting in the results shown in Figure 1, Figure 2, and Figure 3.

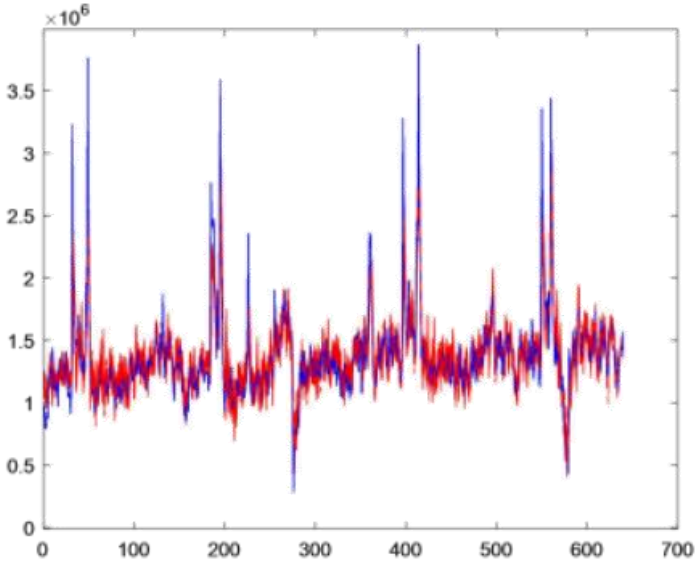

Figure 1. Test results of network training data

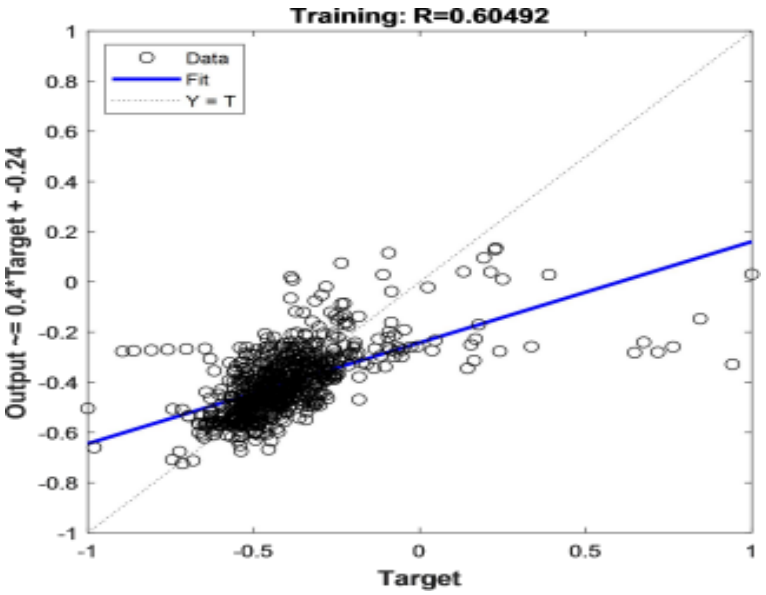

Figure 2. Fitting degree of neural network

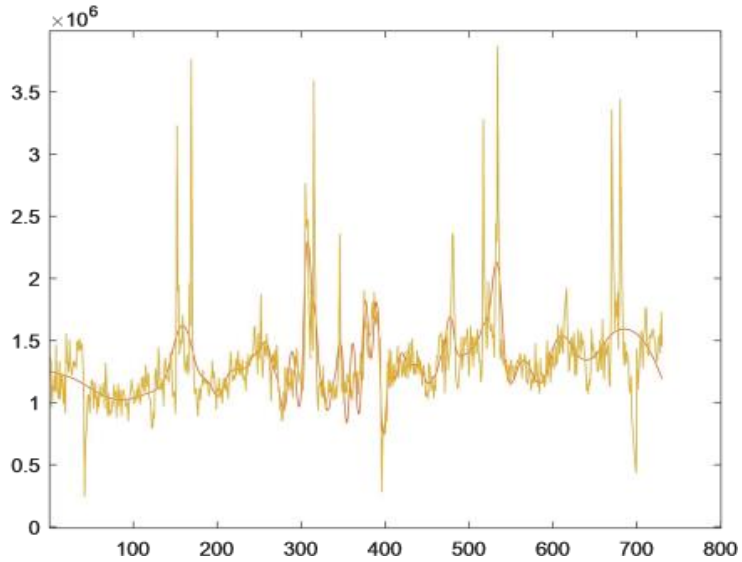

Figure 3. Comparison of True and Estimated Values of Neural Networks

After comparing the two schemes, the errors are within an acceptable range. Overall, a relatively accurate prediction result has been obtained. The following are the predicted results for lines DC14 → DC10, DC20 → DC35, and DC25 → DC62, as shown in Table 1.

Table 1. Prediction Results of Three Lines

2025-01-XX	DC14→DC10	DC20→DC35	DC25→DC62
01	27227	121	15441
02	26675	170	12998
……	……	……	……
30	58996	779	10584
31	57038	1017	11768

3. Optimization of Goods Allocation Model Based on Linear Programming and Annealing Algorithm

Firstly, based on the analysis above, predict the relevant data of CD5. Considering that CD5 has the dual identity of a receiving station for goods and a sending station for goods, it is necessary to predict the relevant stations and corresponding freight data from two perspectives. Note that when the transportation volume of other stations connected to DC5 is low and the connected stations can be connected through other additional stations, replacement can be done through this station, which has the least impact on other stations and meets the requirements of the question; On the contrary, when other stations connected to DC5 cannot find additional stations, it will cause the station to be unable to circulate goods normally. Visualize the logistics network related to DC5 as shown in Figure 4:

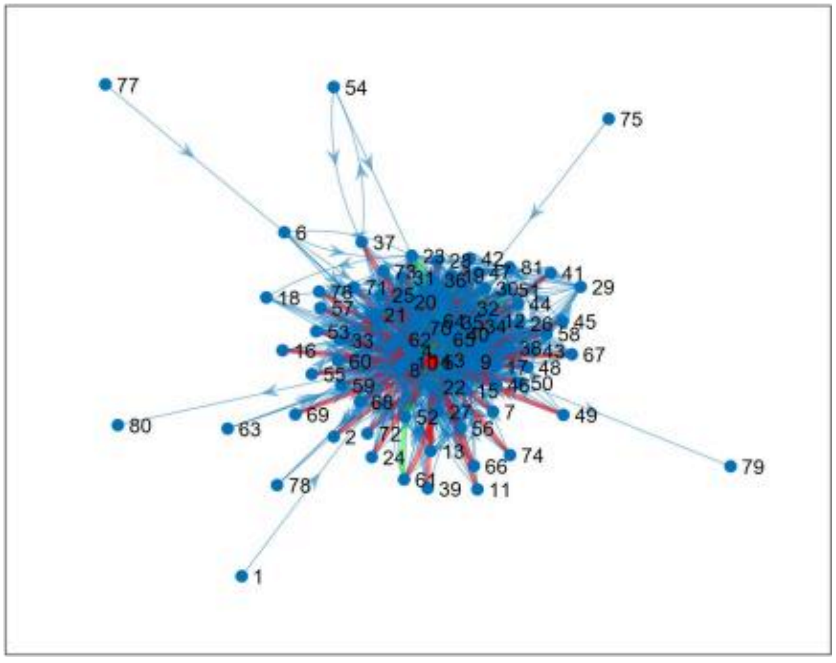

Figure 4. Visual analysis of DC5 related routes

3.1. Optimization of Goods Allocation Model Based on Linear Programming and Annealing Algorithm

For the above research, a linear programming model can be used to optimize the allocation of cargo volume, while using annealing algorithm for solving.

3.2. Linear Programming Allocation Model

(1) Establishment of decision variables [10]

The relevant lines of DC5 are $i = 1,2,\ldots,n, j = 1,2,\ldots,n$. Before the DC5 stop, the $i$freight volume from the line to j $j$wasx_{ij}^{a}, and after the shutdown, the freight volume $i$from the line to jx_{ij}^{b}. The $j$maximum freight volume from $i$to is c_{ij}expressed in.

(2) Establishment of objective function

According to the meaning of the question, the requirement is to solve the situation with the least impact, which is to minimize the change in total cargo flow and the difference before and after it. Then there are:

$$\sum_{j=1}^{n}\sum_{i=1}^{n}\left|x_{ij}^{a}-x_{ij}^{b}\right| \tag{1}$$

(3) Establishment of constraints

a. Each line should meet the maximum material flow limit

$$0 \le \sum_{j=1}^{n}\sum_{i=1}^{n} x_{ij}^{b} \le c_{ij} \tag{2}$$

b. If the allocation ratio of cargo volume after shutdown is p, the logistics volume of other routes should not exceed the maximum capacity

$$(1-p)\cdot x_{dc5}+x_{ij} \tag{3}$$

c. The freight volume within each time period m shall not exceed its capacity

$$\sum_{t=1}^{m}\sum_{j=1}^{n}\sum_{i=1}^{n} x_{i}^{b}(t) \le \sum_{t=1}^{m}\sum_{i=1}^{n}\sum_{j=1}^{n} c_{ij}(t), t=1,2,\ldots,m \tag{4}$$

d. The total allocation of DC5 goods should be equal to the quantity of goods on the relevant routes

$$\sum_{j=1}^{n}\sum_{i=1}^{n} x_{ij}^{a} = \sum_{j=1}^{n}\sum_{i=1}^{n} x_{ij}^{b} \tag{5}$$

e. Try to balance the freight volume of all routes as much as possible

$$\max_{i=1,2,\ldots,m}\left(x_{ij}^{b}-\frac{\sum_{i=1}^{n}\sum_{j=1}^{n}x_{ij}^{b}}{n}\right)-\min_{i=1,2,\ldots,m}\left(x_{ij}^{b}-\frac{\sum_{ij=1}^{n}\sum_{j=1}^{n}x_{ij}^{b}}{n}\right)\le\sigma \tag{6}$$

Among them, $\sigma$is the maximum allowable transportation deviation f. The quantity of goods should be greater than or equal to zero.

$$x_{ijt}^{b} \in Z \tag{7}$$

Among them, $x_{ijt}^{b}$is the $t$time, the $j$cargo carrying capacity from the $i$line to the line g. Minimize the abnormal circulation of goods as much as possible.

3.3. Simulated Annealing Algorithm Solution Model

This article sets the initial temperature $T_0 = 200$and temperature decay factor αbetween 0.5 and 0.99, and the problem size is determined by the number of iterations$L_i = 500$. When it is $L_i$small enough, that is, when $L_i \le 0.1$, "cooling ends" [11], the condition terminates.

The above is implemented through MATLAB programming. Firstly, the changes in cargo volume of some routes are shown in Figure 5:

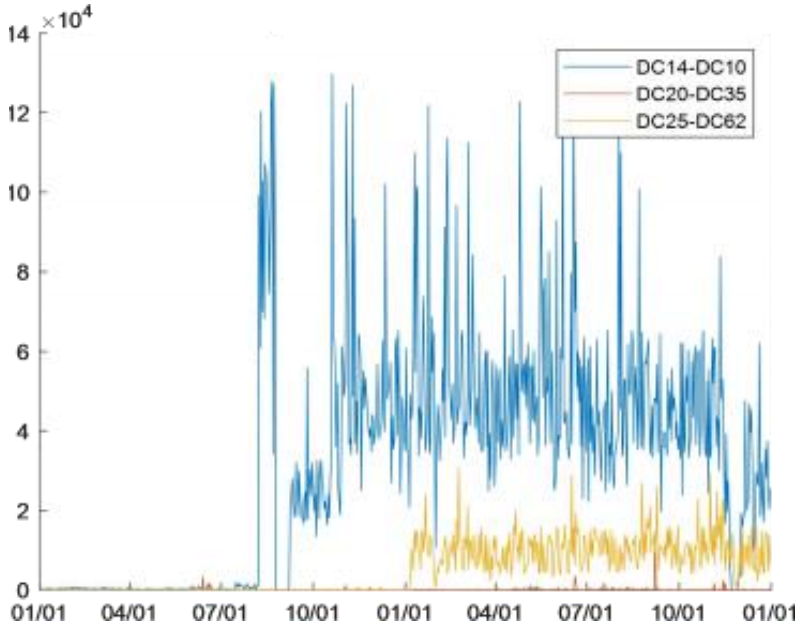

Figure 5. Line graph of changes in cargo volume for some routes

Taking January 1, 2025 as an example, after deleting the DC5 logistics location, a visual analysis of the directed graph of the remaining logistics locations is shown in Figure 6:

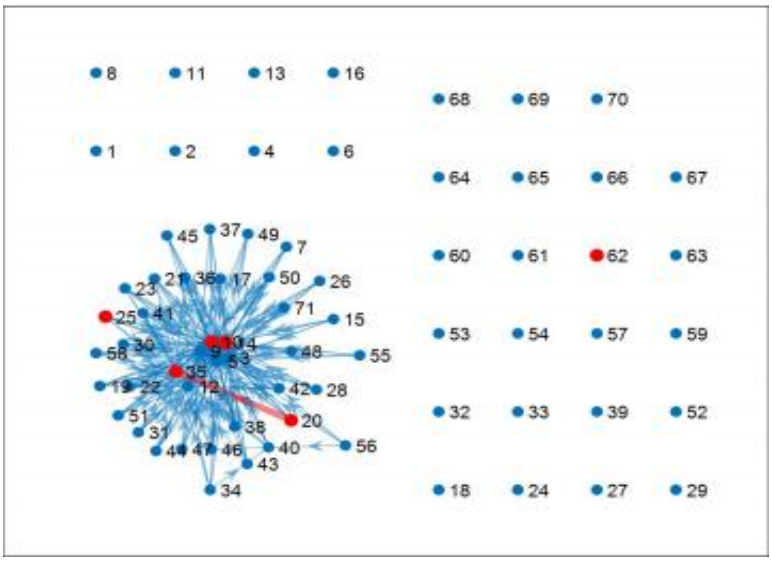

Figure 6. Directed graph of traffic at each node on January 1, 2025

Then calculate the workload, the formula is: workload (%) =monthly carrying capacity/maximum capacity, the calculation results are shown in Table.2.

Table 2. Quantity of goods in normal circulation and their workload

line	Remaining cargo quantity	Work load
69→8	0	100.00%
69→10	542.742	94.86%
23→32	254.258	57.90%
……	……	……
10→4	73903	42.91%

Among all the adjustment routes, there was no overload situation. Three routes had a load rate of 100%, namely: 69 → 8, 69 → 14, and 69 → 62. The load rates of the remaining routes were less than 100 or 0, with 66.49% of the routes having a load rate of 0 and an average load rate of 5.29%[12] .

4. Conclusion

This article explores the issue of emergency transportation in e-commerce logistics and proposes an optimization strategy that integrates ARIMA, BP neural network, linear programming, and simulated annealing algorithm. The research results indicate that:

(1) The goods allocation model can flexibly expand the network to meet growth demands.

(2) Simulated annealing algorithm has high efficiency and low dependency in solving complex problems.

(3) ARIMA and BP neural network 1 can effectively predict changes in logistics demand.

(4) In the context of logistics center, optimizing models and algorithms can ensure network efficiency.

(5) Visual analysis and evaluation have demonstrated the feasibility and efficiency of the proposed solution.

(6) The research provides a new perspective and practical technical support for the commercialization of e-commerce.

In summary, this study provides a comprehensive and in-depth optimization strategy for the emergency transportation of logistics for two companies, and its results not only have significant academic significance, but also have broad practical application value.

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