

Research on emergency logistics location-routing problem for public health emergencies

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Abstract: At present, the world's public health emergencies are becoming more and more frequent, bringing great threats to people's life and health safety and economic development. In the new crown pneumonia epidemic that affected the world in 2020, due to the shortage of medical resources and poor transportation of materials, the comprehensive control of the epidemic encountered great difficulties. In order to minimize the impact and loss caused by public health emergencies, it is necessary to study the location of emergency logistics centers and transportation route planning. This paper studies the positioning-routing problem in the emergency logistics system after public health emergencies, applies genetic algorithm and the Traveling Salesman Problem (TSP) to solve the positioning-routing problem in this paper, takes the current Wuhan map as an example, combines the p-center theory to take the location of each new coronary pneumonia directional receiving hospital as the basis for determining the material distribution center and transportation route, and uses actual cases to study the positioning-route problem.

Keywords: Public health emergencies; Location-routing problem; Genetic algorithms; Travel salesman problems; P-centric models.

1. Introduction

In recent years, public health emergencies have been unpredictable and difficult to control, and China's emergency logistics research has been carried out late and its implementation has lagged behind. Based on the sudden increase in demand for emergency logistics under the current novel coronavirus (COVID-19), this study aims to supplement the theory of emergency logistics through the analysis of the meaning and characteristics of emergency logistics, the analysis of emergency logistics capability points, and the construction of emergency logistics evaluation system and description ability, and provide pilot and theoretical support for the optimization of subsequent emergency logistics. Secondly, by constructing a mathematical model of emergency logistics capacity, discussing the changes and evolution laws of emergency logistics capacity, the emergency logistics capability is mathematically and physically, concretized and dynamic, and provides tools and approaches for the next step of emergency logistics key capability optimization research. Finally, by using the LRP multi-objective optimization model, the role of analysis positioning and transportation path provides new ideas and methods for solving practical problems, and makes the mathematical model have strong practical significance.

2. Literature review

2.1. Research on basic theory of emergency logistics

At present, a large number of scholars have studied the basic theories of emergency logistics, such as the connotation of emergency logistics, system construction, command, decision and plan, capability, reserve mode of emergency materials and resource management.

In the connotation of emergency logistics, Carter (1992) [1] believes that emergency logistics is the act of transporting the

right amount of rescue materials to the right destination at the right place and time in the right order. Cottrill (2002) [2] divided the emergency logistics into five stages, namely, planning, disaster reduction, early warning, response and recovery. Lee and Zbinden (2003) [3] further studied and improved on the basis of Cottrill's stage division theory, and divided the emergency logistics stage into preparation stage, processing stage and post-processing stage according to the status before, after and after the event. In terms of command and decision-making of emergency logistics, long (1997) [4] proposed that the establishment of a reliable information system is an important measure for the smooth implementation of emergency logistics. Özdamar et al. (2004) [5] designed and developed the emergency logistics decision support system (DSS) planning model to solve the dynamic time-dependent transportation problem. Chang et al. (2007) [6] established a logistics decision-making model with two stochastic programming models to determine rescue resource allocation rules, and provided a reference for government agencies to plan flood control emergency material allocation based on actual cases.

2.2. Research on location-path problem in emergency logistics system

After studying the basic connotation, system construction, capability analysis, network planning and other aspects of emergency logistics, scholars have further carried out a lot of research on facility location and vehicle routing in emergency logistics, and combined the two to carry out the research on Location-routing problem (LRP).

In terms of the location of emergency logistics facilities, Church and Re (1974) [7] studied the maximum coverage location problem, focusing on how to use relatively limited service facilities to provide services for more objects, among which the p-median model is an effective tool for facility location. Yi and Özdamar (2007) [8] proposed an integrated model and solution of facility location and distribution in a

deterministic environment for collaborative logistics support in post-disaster emergency response. Balcik et al. (2008) [9] considered the decision-making of facility positioning in the emergency logistics system in their research, and designed a logistics network for emergency logistics. Lu and Sheu (2013) [10] studied and designed a p-center model, and selected the optimal center as the emergency rescue distribution center from a certain number of candidate logistics centers according to the model. In terms of the emergency logistics vehicle routing problem, Knott (1988) [11] put forward a linear planning model for the transportation of rescue food earlier in order to improve the transportation efficiency ratio, minimize the transportation cost and maximize the quantity of food transportation after the disaster. Rathi (1992) [12] proposed to establish a linear programming model to establish the vehicle assignment optimization scheme in the emergency rescue transportation process after assuming that the transportation path and demand node transportation volume are known. Takeo (1996) [13] believes that the key of emergency transportation is the problem of solving the shortest transportation path.

Based on the existing research results, this paper first studies the importance, characteristics, existing problems and suggestions of emergency logistics in public health emergencies. Then it explains the losses and impacts of the COVID-19 in 2020. Finally, the location-path problem in emergency logistics is studied, and the actual map of wuhan is used as an example. the p-center theory and genetic algorithm are applied to solve the example using python.

3. Problem description

This paper determines the location of emergency materials distribution center after an emergency, and plans the vehicle path from each distribution center to each demand point to minimize the total transportation time of emergency materials.

3.1. P-center location model

The p-center model refers to selecting p locations from among n candidate logistics distribution centers, and matching corresponding distribution centers for each demand point. The ultimate goal is to minimize the total transportation cost or total transportation time from each distribution center to each demand point.

The basic assumptions of this model are:

- ① Each demand point and each distribution center are treated as points in geometry.
- ② The distance and path from each demand point to the distribution center are calculated based on a linear distance.
- ③ The transportation time from each demand point to the distribution center is proportional to the distance.
- ④ The demand of each demand point can be satisfied by the corresponding distribution center.

Equation (1) is an objective function that minimizes the distance from the demand point to the distribution center under the weight of the demand point. I is the set of demand points, $I = \{1,2,3, \dots, n\}$; J is the set of alternative distribution centers, $J = \{1,2,3, \dots, m\}$; w_i is the weight of the i th demand point; p is the actual number of distribution centers established, and $p < m$; Equation (2) indicates that each demand point can only match one distribution center; Equation (3) indicates that the number of distribution centers ultimately established is p , where x_j means 1 when the distribution center is established at point j , otherwise 0;

Equation (4) indicates that the guaranteed demand point is matched to the selected distribution center, where y_{ij} means that when the demand point i is satisfied at the distribution center j , it is 1, otherwise it is 0.

Location model:

$$\min f = \sum_{i \in I} \sum_{j \in J} w_i \sqrt{(x - x_j)^2 + (y - y_j)^2} \quad (1)$$

$$s.t. \sum_{j \in J} y_{ij} = 1, \forall j \in I \quad (2)$$

$$\sum_{j \in J} x_j = p \quad (3)$$

$$y_{ij} \leq x_j, \forall i \in I, \forall j \in J \quad (4)$$

$$y_{ij} \in \{0,1\}, \forall i \in I, \forall j \in J \quad (5)$$

$$x_i \in \{0,1\}, \forall j \in J \quad (6)$$

3.2. TSP routing model

The path planning of emergency supplies distribution in Wuhan can be summed up as a traveling salesman problem. In the sense of graph theory, the traveling salesman problem (TSP) is often referred to as the minimum Hamiltonian cycle problem, and its model is constructed as follows:

$$\min Z = \sum_{i=1}^n \sum_{j=1}^n d_{ij} x_{ij} \quad (7)$$

$$\left\{ \begin{array}{l} \sum_{j=1}^n x_{ij} = 1, i \in V \end{array} \right. \quad (8)$$

$$s.t. \left\{ \begin{array}{l} \sum_{i=1}^n x_{ij} = 1, j \in V \end{array} \right. \quad (9)$$

$$\sum_{i \in S} \sum_{j \in S} x_{ij} \leq |S| - 1, \forall S \subset V, 2 \leq |S| \leq n - 1 \quad (10)$$

$$x_{ij} \in \{0,1\} \quad (11)$$

Equation (7) indicates that the objective function of the model is to minimize the total path; Constraints (8) and (9) indicate that each point in the graph has only one edge in and one edge out; Constraint (10) indicates that the constraint does not have any sub loop solutions, and the solutions satisfying constraints (8), (9), and (10) constitute a Hamiltonian loop.

4. Case study

Table 1. Location coordinates of distribution center

Number	District	DC coordinates	Sum of distance
1	Caidian	114.101;30.533	11096.874
2	Hanyang	114.2325;30.5225	6432.68
3	Jiangan	114.29;30.61	4791.066
4	Jiangnan	114.27;30.61	6392.775
5	Jiangxia	114.31;30.38	10003.87
6	Qiaokou	114.24;30.57	4044.048
7	Qingshan	114.42;30.61	5984.63
8	Wuchang	114.33;30.54	15702.37

This case applies the TSP problem to the case, and uses genetic algorithms to solve the vehicle routing problem

between distribution centers and demand points in various regions of Wuhan using Python. The location and distance of distribution centers in each district are shown in Table 1.

5. Conclusion

This paper studies the location routing problem in emergency logistics after public health emergencies from two aspects: theoretical model and practical examples. The latest hot issue, COVID-19, which has a serious impact on Wuhan, is taken as an actual case for analysis.

The significance of this study is to apply the urgently needed public health emergencies as the research content, providing a reference theoretical basis for solving practical problems.

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