

Dynamic Level Facility Location Problem under Major Epidemic

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Abstract

When dealing with COVID-19 (COVID-19) epidemic, patients with different infection degrees have different demands on medical services. Therefore, patients can be divided into mild and severe cases according to the degree of infection, while emergency medical facilities can carry out prevention and control isolation and hierarchical diagnosis and treatment for mild and severe cases. To optimize the overall efficiency of emergency medical care, the services needed by the people in the demand points are allocated to the corresponding emergency relief points, the patients with mild diseases are allocated to the general medical facilities and the patients with severe diseases to the advanced medical facilities. Different from other natural disasters, epidemic situation is characterized by dynamic changes, which leads to dynamic changes in demand. Therefore, the site selection of emergency medical facilities in this paper should be a continuous site selection decision.

Keywords

Epidemic response; Site-site-distribution.

1. Introduction

In recent years, there have been frequent outbreaks of infectious diseases worldwide. Influenza A (H1N1) in Mexico in 2009, poliomyelitis in Pakistan and other countries in 2014, Ebola in West Africa in 2014, Zika in 2015 and Ebola in the Democratic Republic of Congo in 2018. It has posed a great threat to the survival of human beings. Infectious diseases pose a huge threat to human health and development. When a large geographical area is affected by infectious diseases, it will cause a large number of casualties and economic property losses. For sudden spread of environment, a large-scale outbreak of infectious diseases, in particular, studies how the outbreak of the entire development cycle fast emergency medical facility layout, in order to satisfy the demands of patients with emergency medical resources dynamically and reduce their psychological cost, and to set up the classification and treatment level of medical facilities point network will largely control further spread of the epidemic. To improve the efficiency of emergency response to the epidemic and reduce the loss of human life and economic losses has its practical background and necessity.

Research on the site selection of emergency medical service facilities can be divided into site selection of emergency medical center [2], site selection of blood supply station [3], and site selection of ambulance station [4]. This paper mainly studies the location of emergency medical center. At present, there are relevant literatures at home and abroad to study the location of emergency hospital. Segall [5] adopts the method of quantitative analysis to determine the location and capacity of emergency hospital in the service area. Luo Q [6] et al. designed the location of emergency rescue centers and the number of ambulances assigned to each rescue center in order to provide rapid emergency rescue services under the condition of limited number of emergency workers. Chen Yingzhen [7] in determining medical center such as the quantity and the demand to medical center distance as small as possible under the premise of considering the shortage of medical supplies and some special groups of priority issues, a

double objective medical center location model is established, combined with the branch and bound algorithm and greedy algorithm of the ideal, the effectiveness of the algorithm is verified by numerical simulation. Albert [8] et al. studied the traffic infrastructure problem of the emergency management system and determined the location of emergency transportation service facilities by using integer programming and network partition methods. Considering the uncertain demand of each emergency medical service center, Peng Chun et al. [9] built a robust configuration model of emergency medical service center, solved it by branching and cutting algorithm, and carried out sensitivity analysis of the proportion of demand disturbance. Sun Huali et al. [10] studied the location, layout and capacity setting of the post-earthquake medical center to maximize the survival probability and minimize the psychological cost of the wounded. Chen Gang et al. [11] cited the uncertainty set of polyhedral to describe the uncertainty of the number of casualties, and at the same time took the classification of casualties and the classification of mobile hospitals into consideration to build a robust site selection model with the maximum survival probability of casualties. Taking the emergency medical rescue in Lushan, Sichuan Province as an example, they verified the feasibility and robustness of the model and solution method. The site selection of medical service facilities in the above literatures is a single-layer site selection model. However, in the actual rescue, hierarchical diagnosis and treatment are adopted for the medical facilities. The multi-level medical facilities are more in line with the actual situation, and the site selection of hierarchical facilities is more applicable.

2. Model

2.1. Problem Description

In this paper, a Dynamic Hierarch Facility Location Problem (DHFLP) model was established based on the comprehensive consideration of the Dynamic change of demand and the hierarchical diagnosis and treatment of patients, which is more in line with the practical needs. Will generate patients infected areas, according to the rate of severe outbreak, divided into patients with mild and severe patients, patients with mild to general health facilities, in severe cases sent to senior medical facilities, when patients with general medical facilities became seriously ill, and, to the advanced medical facilities, emergency medical facilities of hierarchical network structure. For each decision cycle, decision makers need to consider the following questions: 1) How many different levels (general and advanced) of emergency medical facilities should each medical facility be composed of? 2) What area of infection should each emergency medical facility be responsible for and where should each emergency medical facility be located? 3) The number of patients assigned to each medical facility in the infected area?

2.2. Basic Facility Location Model

Establish a dynamic hierarchical facility location model:

$$\min(C_1 + C_2 + C_3 + C_4) \quad (1)$$

$$C_1 = \sum_{t=1}^T \sum_{p=1}^P F_p^c \text{fix} \left(\frac{x_{pt} - x_{p(t-1)} + 1}{2} \right) + \sum_{t=1}^T \sum_{h=1}^H F_h^c \text{fix} \left(\frac{x_{ht} - x_{h(t-1)} + 1}{2} \right) + \sum_{t=1}^T \sum_{p=1}^P f_p^c \text{fix} \left(\frac{x_{pt} - x_{p(t-1)} + 1}{2} \right) + \sum_{t=1}^T \sum_{h=1}^H f_h^c \text{fix} \left(\frac{x_{ht} - x_{h(t-1)} + 1}{2} \right) \quad (2)$$

$$C_2 = \sum_{k=1}^K \sum_{t=1}^T \sum_{p=1}^P cd_{kp} W_{kpt} Y_{kpt} + \sum_{k=1}^K \sum_{t=1}^T \sum_{h=1}^H cd_{kh} W_{kht} Y_{kht} + \sum_{k=1}^K \sum_{p=1}^P \sum_{t=1}^T \sum_{h=1}^H cd_{ph} W_{kp(t-2)} Y_{ph} \quad (3)$$

$$C_3 = \sum_{p=1}^P \sum_{t=1}^T X_{pt} o_p^c + \sum_{h=1}^H \sum_{t=1}^T X_{ht} o_h^c \quad (4)$$

Equation (1) is the objective function of total cost, that is, to minimize the total cost in the whole planning period. Where, the first term of the polynomial represents the construction cost or closure cost, the second term represents the transport cost of patients, the third term represents the treatment cost of the medical facility points, and the fourth term represents the operating cost of patients.

Equations (2) represent the expressions of each cost;

Equations (3) represent the constraint conditions of the model.

Equation (4) represents the number of mild cases in the infected area at each time period;

3. Example Solution and Result Analysis

3.1. Calculation Example Data Description

In order to further illustrate the effectiveness of the single-objective optimization model of hierarchical network proposed in this chapter, a numerical example will be given in this paper. According to the development state of the epidemic predicted above, it will be divided into 6 periods, i.e. There are 7 infected areas, i.e., according to the investigation, 8 areas are found to be suitable for rebuilding into general medical facilities, i.e. There are 5 alternative sites suitable for conversion to advanced medical facilities.

3.2. Example Results and Analysis

Table 1. Comparison of dynamic and static site selection results

	Dynamic site selection	static site selection
$t=1$	p_2, h_4	
$t=2$	$p_1, p_2, p_3, p_4, h_3, h_4$	
$t=3$	$p_1, p_2, p_3, p_4, p_5, p_7, h_2, h_3, h_4$	$p_1, p_2, p_3, p_4, p_5, p_7, h_2, h_3, h_4$
$t=4$	$p_2, p_3, p_4, p_5, p_7, h_2, h_3, h_4$	
$t=5$	p_3, p_4, h_2	
$t=6$	p_4, h_2	

Conclusion: At the number of medical staff set up the optional facilities provide service ability, in the case of deployment of all the staff, for the first time is can meet the demand, in the second period compared to the service ability enough cases, increasing the facilities of choice, general medical facilities points increased from 4 to 7, advanced medical facilities points increased from 2 to 4, In the third period, the demand for general medical facilities in the infected area is 1064, the number of advanced medical facilities is 170, the number of general medical facilities that need to be transferred to advanced medical facilities is 104, while the number of general medical facilities that can provide services is only 378, and the number of advanced medical

facilities is only 228. As a result, the number of beds in general and advanced medical facilities is insufficient. At the same time, in the actual situation, it is impossible to deploy all the medical staff to the epidemic relief. Therefore in the outbreak in real life rescue, emergency outbreak, the lack of medical resources (beds) in the short term, not only demand planning new medical facilities, more major is medical personnel, equipped with the relevant decision makers when making decisions, should not only consider the possible location to set capacity, also need to consider equipped with medical staff.

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