

A Review of Emergency Medical Rescue Network Optimization Problems

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Abstract: This paper mainly reviews the research on the optimization of emergency medical treatment network, which mainly includes the location of emergency medical facilities and the transportation of the wounded, as well as the integration of the two, and finds that although many scholars have paid attention to the research of related issues, they mainly focus on the optimization of emergency medical treatment network in the context of major natural disasters such as earthquakes and typhoons, and there are few related studies on the optimization of emergency medical treatment network under infectious health emergencies.

Keywords: Emergency medical rescue, Optimization, Transportation.

1. Introduction

Public health emergencies refer to major infectious disease epidemics, mass unexplained diseases, major food and occupational poisoning, and other events seriously affecting public health that occur suddenly, cause or may cause serious damage to public health. Throughout history, mankind has been often challenged by epidemic infectious diseases and various public health emergencies that endanger public health security. Since 2007, the World Health Organization (WHO) has declared six international public health emergencies (PHEICs): influenza A(H1N1) in 2009, wild poliovirus outbreak in 2014, Ebola virus outbreak in West Africa in 2014, Zika virus outbreak in 2015-2016, Ebola virus outbreak in Congo in 2018 and novel coronavirus outbreak in 2020. These major infectious health emergencies seriously threaten the life and safety of all mankind, and cause damage to the public environment, institutional norms, and even social order, profoundly affecting the economic and social development of countries around the world.

In the early days of the outbreak of the new crown pneumonia epidemic in Wuhan in 2019, many patients in urgent need of treatment emerged in a short period of time, far exceeding the medical service capacity of Wuhan, and there was a serious run-on medical resource. Since February 2020, to ensure centralized admission, Wuhan has implemented an emergency hospital project. Huo shen shan and Lei shen shan hospitals were quickly established to concentrate on the treatment of confirmed and critically ill patients. At the same time, large venues such as exhibition centers and gymnasiums will be transformed into large-space, multi-bed cabin hospitals to receive confirmed mild and suspected patients. and requisitioned hotels as centralized isolation points to isolate close contacts. At this point, the early medical run in Wuhan gradually subsided, forming a treatment system of "graded and classified admission, smooth transfer of light and heavy hospitals", and realized the "due collection and treatment of all should be treated" for confirmed and suspected cases. When large-scale infectious diseases break out, the number of infectious disease beds in existing hospitals will inevitably be unable to meet the surge in bed demand, and it is necessary to enhance the admission capacity through the rapid construction of emergency medical facilities, optimize the emergency treatment logistics network,

and provide guarantee for timely treatment of patients and effective control of the spread of the epidemic.

At present, most of the emergency response literature on infectious public health emergencies at home and abroad uses system dynamics models to study the development trend of the epidemic and put forward relevant epidemic prevention policy suggestions from the perspective of epidemic characterization, or uses the optimization model to study the distribution of medical materials from the perspective of operation research optimization, and some scholars have integrated the prediction of epidemic development trend and the distribution of emergency materials.

2. Literature Review

The optimization of emergency medical treatment network mainly includes the location of emergency medical facilities, the allocation of emergency medical resources (human and material resources) and the transportation of the wounded. Although many scholars have paid attention to the research of related issues, they mainly focus on the optimization of emergency medical treatment network in the context of major natural disasters such as earthquakes and typhoons, and the research paradigm is usually single-problem and ensemble problem research, while there are fewer related studies on emergency medical treatment network optimization under infectious health emergencies, and mainly focus on emergency medical material allocation research.

There are similarities and differences between the optimization of emergency medical treatment networks after infectious health emergencies and natural disasters. The biggest difference lies in the different characteristics of the research objects, the group differentiation of patients under infectious health emergencies, the dynamic changes of the number of diseases, etc. are in line with the obvious law of infectious disease transmission, and it is necessary to use infectious disease models and other depictions of their change characteristics, while the injured groups under natural disasters such as earthquakes Although there are differences and changes in injuries, they do not often cause mutual transmission of diseases, and the two change characteristics are completely different. However, whether it is an infectious health emergency or a major natural disaster, the optimization of the emergency medical rescue network is closely carried out around the needs of treatment, and it is necessary to select

or build emergency medical facilities to meet the relevant transportation, treatment, materials, and other needs of many injured patients in a timely manner. Therefore, the research on emergency medical rescue network in the context of natural disasters has certain reference significance for this study.

2.1. Research on the location of emergency medical facilities

Emergency medical facilities in the context of natural disasters may include temporary medical clinics (usually stadiums or airports, etc.) or hospitals (collectively referred to as first-tier hospitals) that are close to the emergency, rear medical facilities (second-tier hospitals) and inter-provincial or nationwide medical facilities (third-tier hospitals). Infectious health emergencies also involve the location and establishment of emergency medical facilities, such as the establishment of more than ten cabin hospitals and Huoshenshan and Leishenshan hospitals during the Wuhan new crown pneumonia epidemic.

There are two main paradigms for current research on emergency medical facilities in the context of natural disasters: the construction or selection of emergency medical facilities at the planning level. It is mainly assumed that the casualty will move to the nearest casualty collection station to study the strategic location of emergency medical facilities, such as Drezner et al. [1] Comprehensively considering the multi-objective problem of P median, P center, two maximum coverage and minimum variance, and using the descent heuristic and taboo search method to solve the casualty collection point location problem. Jia et al.[2] Considering the uncertain demand and lack of medical resources, the site selection model of pre-disaster emergency medical facilities was established with the goal of maximum efficiency covering demand, and the genetic algorithm, positioning-allocation heuristic algorithm and Lagrangian relaxation method were used to solve it. Huang et al. [3] considers the possible failure of facilities and uses the p-centric method to construct a site selection model for emergency facilities with the goal of minimizing the maximum weighted distance between demand points and emergency facilities. Canbolat & Massow[4] aims to minimize the maximum straight-line distance from facilities to demand points, establishes a minimum risk emergency facility positioning model, and gives a simulation algorithm to solve it. Golabi et al. [5] Establishing a random mixed integer nonlinear programming facility siting model with the goal of minimizing total run time to achieve pre-disaster relief distribution center site selection.

From an operational perspective, select emergency medical facilities that meet rescue needs. Erkut et al.[6] Considering the trauma score index or survival rate of different injuries, and aiming at maximizing the survival probability of casualty, a site selection model of emergency medical facilities based on the survival function of service response time was constructed. Zhao & Chen [7] aims to maximize demand coverage and minimize the maximum distance and total weighted distance between demand points and the nearest emergency rescue facilities and establish a risk-based location model for emergency rescue facilities. Salman & Yücel [8] considered random road network damage to establish an emergency facility siting model that maximized the expected coverage needs. Chen & Yu [9] aimed at minimizing costs, established a site selection model for emergency medical facilities, and introduced the Lagrange relaxation method to

expand the scale of the problem.

There is less literature on the location of emergency medical facilities for infectious public health emergencies, some scholars focus on the supply of materials for demand determination, and some scholars consider the changes in demand brought about by the spread of the epidemic, such as Liu et al. [10] using the SEIHR-A model to characterize the spread of H1N1, and establishing a mixed integer nonlinear programming model to help decision makers determine the timing of opening and closing isolation wards and the allocation of emergency budgets.

2.2. Research on the transportation of patients or wounded

Public health emergencies and natural disasters are public emergencies, which also can generate many patients (wounded) who need to be transported for treatment in a short period of time and need to send patients (wounded) from multiple disaster points (epidemic areas) to emergency medical facilities with limited capacity (or treatment capacity) for treatment. Emergency medical rescue in the context of natural disasters (such as earthquakes, floods, typhoons, etc.) is more widely studied, and such problems mainly explore the specific plan of efficiently transporting many injured people from multiple emergency treatment sites to emergency medical facilities.

For example, with the goal of minimizing the transportation time, for example, Sacco et al. [11] established a linear programming model for casualty classification and transport with the goal of maximizing survival rate. Argon et al. [12] conducted a study with the goal of minimizing casualty mortality, considering the change in casualty care priorities over time. For research aimed at maximizing the number of survivors, Dean & Nair [13] established a mixed integer programming model to maximize the number of expected survivors, considering medical resources and the probability of survival of the casualty. Kamali et al. [14] established a casualty transport model with the goal of maximizing the number of expected survivors considering the classification of casualty examinations and the priority of casualty care. Mills et al. [15] considers the survival rate and service time of casualty of different trauma types, and aims to maximize the number of expected survivors, and establishes a Markov decision-making model for casualty allocation. Wilson et al. [16] established a casualty classification transport model to minimize five objective functions including the expected number of deaths and the total idle time of responders. Kilic et al. [17] considered the change in casualty care priorities over time with the goal of minimizing the difference between the number of rescuers and the number of casualties and the cost of treatment.

Aiming at the problem of patient transportation in infectious public health emergencies, Sitek & Wikarek [18] proposed a decision-making model to support patient transportation and distribution during the epidemic, which not only considers the number of beds in the hospital, but also considers the types of available beds, the number of available healthcare staff with specific qualifications, the availability of specific types of medical transportation and other constraints, and proposes an iterative algorithm to solve the model.

2.3. Research on the integration of site selection of emergency medical facilities and transportation of the patients or wounded

The problem of site selection of emergency medical facilities - casualty transportation is the selection of appropriate emergency medical facilities for casualty patients after on-site examination and classification, and the appropriate transportation method is used to transport them to emergency medical facilities for treatment, and few scholars have studied such problems. Salman & Gül [19] studied multi-stage facility siting – casualty transport with the goal of minimizing the total casualty transport journey, waiting time, and total cost weighting of new facilities. Caunhye et al. [20] In the context of catastrophic radiation events, considering the classification of injuries to set the priority weight of treatment to minimize the total transportation time of the casualty, the post-disaster medical facility location-casualty transport model was established considering the classification of the casualty and medical facilities. Yi & Özdamarb [21] based on the changes of the casualty's demand for emergency medical resources in different time periods, established a dynamic model of emergency facility site selection-casualty transportation-resource allocation with priority and capacity constraints, aiming to minimize the unmet demand and the total waiting time of the casualty. Haghi et al. [22] integrated the site-delivery route of materials to disaster areas and the transportation of wounded to emergency medical facilities, considering the uncertainty of demand, supply and cost parameters, the risks of material distribution centers, medical institutions, and supply points, and using a robust random planning method to maximize the fairness of relief material distribution, maximize the level of medical response of the wounded and minimize the cost of response. The method of simulated annealing combinatorial genetic algorithm based on ϵ constraint is used to solve the problem. The study assumes that the number of vehicles is unlimited and that supplies, and wounded share the same type of transport vehicle, while in actual rescue vehicles are limited and the casualty (complex injuries) rarely share the same type of vehicle with many material transports. Based on the cholera outbreak in Haiti in 2010, Anparasan & Lejeune [23] proposed an infectious disease response model to determine the establishment of medical service settings, the allocation of ambulances, and the transportation scheme of seriously ill patients, and proposed an algorithm using hierarchical constraints and effective inequalities to solve them.

3. Conclusion

The existing research results provide a theoretical reference for follow-up research to a certain extent, but in general, the research on the integration and optimization of emergency medical treatment network under infectious health emergencies needs to be comprehensively and deeply carried out, as follows:

There are few existing literatures on the site selection and patient transportation of emergency medical facilities under infectious health emergencies and patient transportation studies that combine infectious disease models to characterize the change characteristics of the number of patients. However, there are certain intrinsic transformation laws between different patient groups under the background of infectious diseases and considering the dynamic changes of the number

of patients in the optimization study of emergency medical treatment network can better ensure the rationality of the site selection and construction of emergency medical facilities and the admission of patients.

Most studies did not consider the dynamic siting of emergency medical facilities. However, infectious public health emergencies are persistent and diffuse, and the number of patients in various patient groups will change dynamically during the development of the epidemic, and their dynamic changes will lead to continuous changes in the need for hospital admission capacity. Therefore, considering the dynamic location of emergency medical facilities based on the changing characteristics of the number of patients is conducive to maximizing the utilization rate of emergency medical facilities and reducing unnecessary waste under the condition of limited resources.

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