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The Location Models and Algorithms for Emergency Shelter with Congestion

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Abstract

Aiming at the problem of road congestion during the evacuation process of disaster victims when sudden disasters occur, a two-objective evacuation site selection model with evacuation time and minimum construction cost is established. A characteristic of the model is designed by analyzing the characteristics of the model The simulated annealing algorithm with embedded algorithm. Finally, an industrial park is used as a specific example to provide a site selection plan for emergency refuges. The sensitivity analysis of parameters such as the number of emergency facilities and trade-off coefficients shows the proposed site selection model and algorithm. It can provide useful reference for realistic site selection decision.

Keywords

emergency management; congestion.

1. Introduction

China is one of the few countries with the most severe natural disasters in the world. There are many types of natural disasters in China, with high frequency and severe disasters. The most common disasters are meteorological disasters, earthquake disasters, and geological disasters. With the development of modern science and technology, industrial production activities are increasing, the use of hazardous chemicals is becoming more and more widespread, and hazardous chemical accidents are also emerging. Once an accident occurs, it will pose a great threat to the lives and property of surrounding people. For example, on June 5, 2017, a liquefied petroleum gas tanker transporting a petrol gas tanker in a loading and unloading area of a chemical company in Linyi City, Shandong Province, suffered an LPG leak, explosion, and fire during the unloading operation, causing 10 deaths and 9 injuries. On July 19, 2019, an explosion occurred at the Yima Gasification Plant of Henan Gas Group in Sanmenxia City, Henan Province, which killed 15 people and seriously injured 16 others. If the people affected by the accident can be evacuated to the emergency evacuation site in a timely manner so that the affected people can be rescued, this will greatly reduce the impact of the accident. How to choose an evacuation route? Both of these are key issues in the emergency system, and they are intrinsically related, that is, the location of the evacuation site largely determines the choice of the evacuation route, and the choice of the evacuation route also affects the facility location decision . Therefore, it needs to be integrated and optimized, which has important research significance for the design of the evacuation site layout and the evacuation route.

In 1909, German economist weber [1] first proposed the location of facilities. The research content was to determine the location of a warehouse in the industrial area so that the sum of the total distance to different customers was the smallest. Hakimi [2] proposed two in 1965. The classic location model: center point model (media problem) and median point model (median problem). The earliest research on the location of emergency facilities was in the 1970s. Roth [3] and Toregas et al. [4] determined the location of the facilities with the goal of establishing the total number of emergency facilities or the lowest cost, and proposed the collective coverage model (LSCP). Later, Churh et al. [5] proposed the maximum coverage model (MCLP). In addition, many scholars improved and extended the above basic model according to different constraints (cost, time, satisfaction, etc.) [6] [7]. More research on the location of emergency facilities can be found in the review literature [8].

In recent years, the location of emergency facilities for specific emergencies has attracted widespread attention from scholars. For example, Akella et al. [9] studied the location of road emergency signal base stations during the road transport of dangerous goods; Rawls et al. [10] Possible typhoon as the background, considering the possible impact of the typhoon, pre-selecting emergency rescue facilities; Iannoni et al. [11] studied the location of emergency medical stations on the highway, with average response time and each medical station The goal is to balance the workload, and the genetic algorithm is designed to solve this problem. Jia et al. [12] established a framework model for medical station location against the background of emergencies in multiple regions. Kongsomsaksakul et al. [13] established a two-level refuge site selection model with the minimum total evacuation time and the minimum evacuation time for each victim in the context of typhoon and flood disasters, taking into account the restrictions on traffic flow, and designed a solution for the model. Genetic algorithm. Yamada [14] abstracted the road network as an undirected graph, and used the minimum cost flow model to give the shortest path evacuation plan for the traffic flow evacuation allocation problem. The objective is to minimize the sum of the trips of the victims to the selected evacuation point.

The above research provides theoretical support for the location of evacuation sites and other emergency facilities, but there are some shortcomings. First, the above studies basically assume that "emergency costs are only related to distance." In fact, when the number of people exceeds the capacity of the path, the road will appear. Blockage, distance is not the only influential factor at this time. The parameter of path capacity is introduced in this paper, which can reflect the impact of emergency environment changes on the theoretical model. Secondly, most studies only focus on the optimization of the algorithm itself. However, there are few references to how the physical structure of the actual road network affects the evacuation site selection scheme, and the actual emergency environment has very obvious network structure characteristics. Finally, most of the previous studies on evacuation site selection have aimed at the minimum evacuation completion time, that is, the last person evacuation time, and emergency evacuation sites are important emergency public facilities, which should conform to the principles of "efficiency" and "fairness" That is, the requirements for residents to enjoy the evacuation service are basically fair, and the opportunity for rescue should be equal to everyone. Therefore, this article comprehensively considers the average evacuation time and the minimum completion time as the goal. Under the principle of nearest evacuation, the location of evacuation points on the general network diagram can maximize It reflects the realistic requirements of emergency management and provides a reference for emergency managers to make decisions.

2. Mathematical Model

2.1. Problem Description

In recent years, industrial parks have become the new focus of regional economic development. The number of industrial parks has been increasing and the scale has been expanding. Dangerous chemicals stored and produced in the parks are prone to accidents, and once they occur, they will cause serious consequences. In order to reduce the losses caused by the accident, it is necessary to evacuate the affected people to the evacuation site in a timely manner. The evacuation network diagram of the park is shown in Figure 1. During the evacuation process, the victims will usually choose the nearest refuge place to seek refuge, which is called the principle of nearest refuge. Gerrard et al. proposed the significance of the principle of proximity to the location of public facilities. Different from the location of urban evacuation sites, the location of the evacuation sites in the park must fully consider the distribution of dangerous sources, and it is necessary to establish an optimization decision model that takes into consideration multiple factors such as evacuation time and the risk of accidents from dangerous sources.

According to the actual background, the model in this paper is based on the following assumptions:

(1) The candidate evacuation points, hazard sources, and points to be evacuated are all known and discrete, and the candidate evacuation points have no capacity limit. (2) After an accident with a dangerous source, it only affects people in the accident area, and it will not be affected outside the area. (3) To avoid organizational chaos during evacuation, it is assumed that the people at a certain evacuation site are going to the same evacuation site. (4) The passage of people to be evacuated in the evacuation route meets the FIFO principle

The purpose of the location model is to select q evacuation points from S to serve the evacuation points in K.

$$\min \sum_{i \in I} \{ \mu_1 \lambda_1 p_i \alpha_i + \mu_1 \lambda_2 p_i \beta_i \} + \sum_{j \in J} \mu_2 y_j c_j \quad (1)$$

$$\lambda_1 + \lambda_2 = 1 \quad (2)$$

$$\sum_{j \in J} x_{kj} y_j = 1,\ k \in K; \quad (3)$$

$$x_{kj} - y_j \le 0,\ k \in K, j \in J; \quad (4)$$

$$\sum_{j \in J} y_j c_j \le C \quad (5)$$

$$x_{kj}, y_j, \in \{0,1\}, k \in K, j \in J \quad (6)$$

In the model, equation (1) is the objective function, which minimizes evacuation time, accident risk, and cost; equation (2), the weight of the two evacuation times is 1, and equation (3) indicates that each evacuation point can only have one evacuation point Responsible for service; Equation (4) indicates that only the candidate evacuation points can be selected to serve the evacuation points; Equation (5) indicates that the construction cost of the shelters does not exceed the total budget limit; Equation (6) indicates the 0-1 variable constraint.

3. Algorithm Design

The location model in this paper is a difficult problem, and the solution complexity increases sharply as the value increases. The simulated annealing algorithm is a local search heuristic algorithm, which simulates the physical annealing process. It is a random optimization algorithm based on Monte-Carlo iterative solution strategy. The model is solved by using the simulated annealing algorithm of the embedded algorithm.

4. Example Analysis

This article uses a certain industrial park as the background to carry out an example analysis. There are 11 hazardous sources in the park. There are also office, residential and other gathering points in the park, according to the park's floor plan and population distribution, as shown in Figure 1. There are 48 people gathering points potentially affected by dangerous sources, 16 candidate evacuation points, and 11 dangerous sources. In the event of an accident at a hazardous source, in order to provide emergency services to the affected people in a timely manner and prevent them from being exposed to dangerous areas for too long, the park management department decided to establish a fixed refuge point. How to establish an evacuation site selection plan to maximize the timeliness of emergency services for personnel.

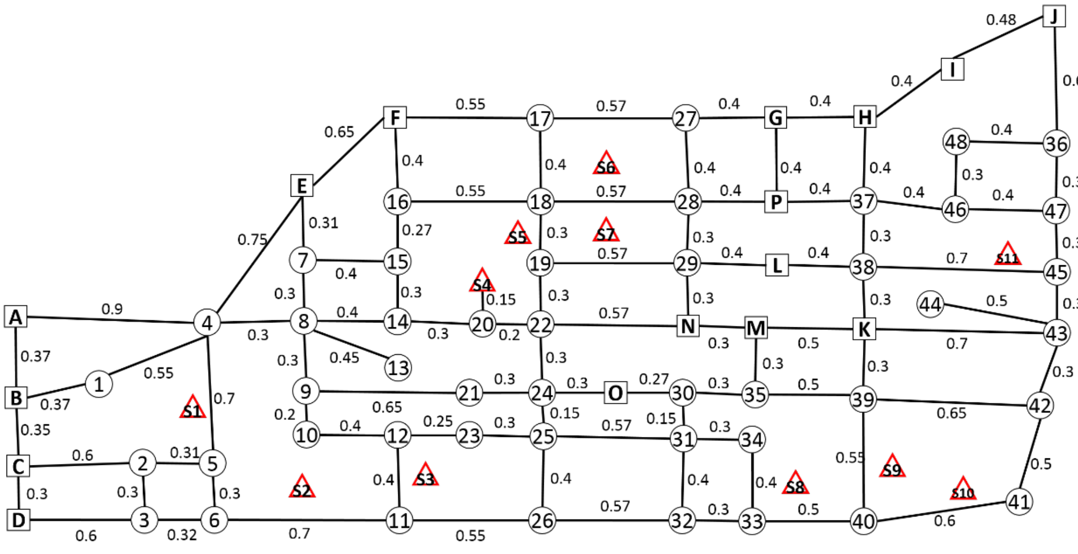

Fig. 1 Industrial Park Network Diagram

According to the algorithm designed in this paper, the above examples are calculated by MATLAB programming. The target value of the function is 332540.

4.1. Impact of Total Facilities q on Site Selection Scheme

(1) The two goals of evacuation site construction cost and evacuation time are contradictory. When there are a large number of evacuation site constructions, the cost is higher, the evacuation time is lower, and the emergency efficiency is higher. At this time, if the emergency efficiency is slightly reduced, it can be large. The total cost will be reduced significantly; when the number of evacuation sites is small, reducing the total cost will cause a significant reduction in emergency efficiency. (2) When calculating the number of different locations, the evacuation points D, E, K, O, and B that are selected more often can be regarded as key evacuation areas. Temporary evacuation points can be planned around the area. Rescue vehicles should be available at the evacuation site. When disaster victims arrive, vehicles and other means of transportation can be used to quickly transport people to the fixed evacuation site. Compared with the fixed evacuation site, the construction and operation costs of the temporary evacuation site are very low. The layout of key areas will significantly improve the evacuation efficiency and reflect the idea of layered services for emergency facilities.

Table 1. Cost reference table for each candidate evacuation site

Emergency shelter	A	B	D	E	F	G	H	I
cost	12300	15600	7000	12900	12200	13200	12100	9100
Emergency shelter	J	K	L	M	N	O	P	
cost	13200	10700	9500	11700	13600	10800	13000	

5. Summary

This paper studies the location of emergency shelters considering blockages. Quantitative analysis of the impact of disasters on the evacuation process during the evacuation process, comprehensively considering the efficiency, fairness, and cost of the facility location to establish a refuge site location model, designing a simulated annealing algorithm embedded in the algorithm, and analyzing the model through an example The impact of several parameters on the site selection strategy. The analysis results show that: (1) Improving the "fairness" of emergency facilities by sacrificing part of the "efficiency" of the emergency; (2) When the number of evacuation sites is large, the cost is high and the evacuation time Lower, emergency efficiency is higher, at this time, if the emergency efficiency is slightly reduced, the total cost can be greatly reduced; when the number of evacuation sites is small, reducing the total cost will cause a significant reduction in emergency efficiency.

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