

ARTICLE

Location Determination Of Optimal Emergency System For Hurricane Disaster Based On Mathematical Modeling

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ABSTRACT

This article first introduces the current research status of space optical communication, and gives a brief overview of the development and application prospects of space optical communication, explaining its important research significance. Then, the working principle of ATP in space optical communication system is studied, the mathematical model of ATP control system is established according to the actual needs, and the ATP control system design of space optical communication is designed. By selecting appropriate motors and gyroscopes as the actuators and detection elements of the system, substituting the actual parameters for simulation analysis, and correcting and verifying the results, some useful results are obtained. The simulation results show the rationality and effectiveness of the ATP design scheme.

1. Methodology

Reserve Sites Selection Model: In this section, through the realistic evaluation of disaster situation, considering the demand, efficiency and fairness, center allocation model, median location model and the maximum coverage model based on the demand degree of emergency medical package are selected. Synthesizing the advantages of the three models, are the minimum. Multi-objective mixed integer programming model was proposed based on the minimum of the maximum weighted distance and the average weighted distance of the reserve sites supporting the disaster areas. Then, the optimal result of the maximum area supported by the reserve sites is obtained by using the principle of maximum

coverage to improve the model.

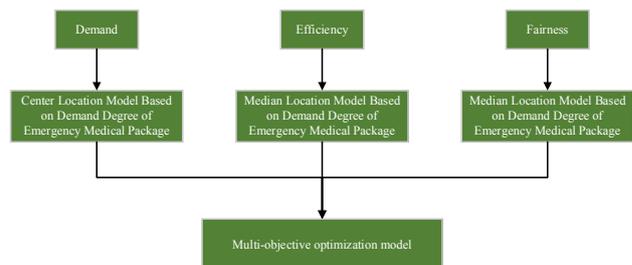


Figure 1. Road map for location analysis of reserve points

Emergency medical packages allocation optimization model: Emergency medical packages allocation model is based on the minimum rescue time and total cost. Considering that the total number of emergency medical pack-

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ages dispatched by each reserve sites does not exceed its reserve, the total number of emergency medical packages reserved by a reserve sites equals its demand, and the time of dispatching emergency medical packages to each demand sites does not exceed the prescribed rescue time, the optimization model of material distribution is established.

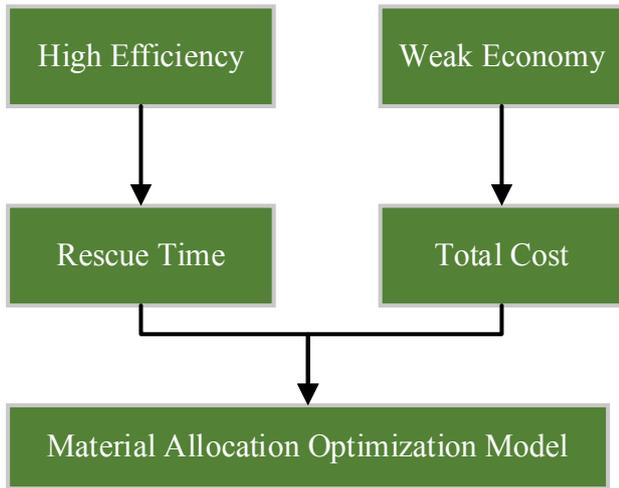


Figure 2. Road map of emergency medical package distribution

Center Location Model Based on Demand Degree of Emergency Medical Package: Different from the traditional P-center model, the location problem is transformed into a centralized location model based on the degree of emergency medical packages demand. The model chooses the concrete location of the reserve sites under the condition that the number of reserve sites is limited and the disaster degree of the affected area is different. You should be considered to minimize the emergency rescue time and meet the emergency when making decision to the maximum extent. Therefore, the rescue time can be described by the geographic support distance (calculated by the given latitude and longitude). Considering the different disaster emergency degree of each disaster areas, the corresponding weight can be incorporated into the calculation of the distance. It can better reflect the urgency of demand. Therefore, the decision-making goal of the model should be the maximum distance of each reserve point to support each disaster-stricken area. The constraints are:

- (1) Each affected area has and only one reserve point to support it;
- (2) All reserve points are selected within the affected area;
- (3) There are P reserve points by default;
- (4) The weighted distance between the disaster area and the reserve point is the largest.

Specific models are as follows:

$$\min L$$

$$s.t. \begin{cases} \sum_{j \in J} x_{ij} = 1 \\ x_{ij} - z_j \leq 0 \\ \sum_{j \in J} z_j = p \\ L - \sum_{j \in J} r_i d_{ij} x_{ij} \geq 0 \\ x_{ij}, z_j \in \{0, 1\} \\ \forall i \in I, \forall j \in J \end{cases}$$

Among them, x_{ij} refers to whether reserve point supports disaster-stricken area, if so, $x_{ij} = 1$, otherwise, $x_{ij} = 0$; z_j denotes that candidate reserve points are selected as reserve points, if so, $z_j = 1$, otherwise, $z_j = 0$;

Median Location Model Based on Demand Degree of Emergency Medical Package: The traditional P-median location model of operational research is integrated into the idea of disaster weight and transformed into a median location model based on disaster weight. Under the condition of limited number of reserve points, the objective of this model is to minimize the average time for the reserve points to reach each disaster area. From the above model, we can see that the average time is expressed in the average distance. Considering the different degree of disaster, the target is the shortest average weight distance, which is obviously different from the center location model based on disaster weight. The constraints can refer to the central location model based on disaster weight. Specific models are as follows:

$$\min \sum_{i \in I} \sum_{j \in J} r_i d_{ij} x_{ij}$$

$$s.t. \begin{cases} \sum_{j \in J} x_{ij} = 1 \\ x_{ij} - z_j \leq 0 \\ \sum_{j \in J} z_j = p \\ \forall i \in I, j \in J \end{cases}$$

Each index is interpreted in the same way as the central

location model based on disaster weight.

Maximum Coverage Model: The purpose of building the reserve point is to carry out rescue operations rationally and to achieve the timeliness. Therefore, the reserve point should be able to cover the disaster area to the maximum extent, so as to start rescue work in time and facilitate the dispatch of materials. Therefore, the construction of reserve points should follow the principle of maximum coverage. Maximum coverage model does not require all affected areas to be covered. It maximizes the needs of affected areas under the premise of limited number of reserve points, so as to maximize the number of people covered in affected areas. The constraints are:

(1) There are P reserve points in default;

(2) To ensure that the selected reserve point j can cover the disaster area i in the candidate reserve point. Specific models are as follows:

$$\begin{aligned} \max \quad & z = \sum_{i \in I} r_i y_i \\ \text{s.t.} \quad & \begin{cases} \sum_{j \in J} x_j = p \\ y_i \leq \sum_{j \in N_i} x_j, \forall i \in I \\ x_j \in \{0, 1\}, \forall j \in J \\ y_i \in \{0, 1\}, \forall i \in I \end{cases} \end{aligned}$$

Among them, variable x_j , when candidate reserve point j is selected, $x_j = 1$; otherwise, $x_j = 0$; variable y_i , when disaster area i is covered, $y_i = 1$; otherwise, $y_i = 0$.

The difference between this model and the two models is that each disaster area can be supported by multiple reserve points, which contradicts that each disaster area of the two models has only one reserve point. Therefore, priority should be taken into account when establishing the model. Therefore, the maximum coverage model is used as an improved model after solving the above two models.

Freight Container Location Model: According to the analysis of the above-mentioned central location model, considering the three factors of efficiency, fairness and demand, the model is improved by taking the minimum maximum distance from the reserve point to each disaster-stricken area and the minimum average distance from the reserve point to each disaster-stricken area as the ob-

jective function and incorporating the idea of maximum coverage. Firstly, the constraints are as follows:

(1) There P reserve points in default;

(2) Each affected area has and only one reserve point to support it.;

(3) Maximum weighted distance between disaster-stricken areas and reserve points;

(4) All reserve points are selected within the candidate reserve points. Combined with the central location model based on the degree of demand for emergency medical packages and the median location model based on the degree of demand for emergency medical packages, the following models are established:

$$\min \quad W_1 = L$$

$$\min \quad W_2 = \sum_{i \in I} \sum_{j \in J} r_i d_{ij} x_{ij}$$

$$\text{s.t.} \quad \begin{cases} \sum_{j \in J} x_{ij} = 1 \\ x_{ij} - z_j \leq 0 \\ \sum_{j \in J} z_j = p \\ L - \sum_{j \in J} r_i d_{ij} x_{ij} \geq 0 \\ x_{ij}, z_j \in \{0, 1\} \\ \forall i \in I, \forall j \in J \end{cases}$$

Considering the maximum demand of the disaster area, the results are re-modeled and the reserve point has been found. For existing reserve points, using the idea of maximum coverage, the reserve points will be scheduled to support the surrounding disaster areas, and the objective function is to support the areas that can be supported to the maximum extent. The constraint condition is that the distance between the reserve point and the support area is within a certain range. Namely $d_{ij} \leq R$, $\forall i \in I, j \in J$, At this time, the j th reserve point supports the i th disaster area. d_{ij} false indicates the distance between i and reserve point j in the affected area. R represents constrained radius.

2. Location of Reserve Points

In 2017, the worst hurricane to ever hit the United States territory of Puerto Rico left the island with severe damage

and caused over 2900 fatalities. Demands for medical supplies, lifesaving equipment, and treatment strained health-care clinics, hospital emergency rooms, and non-governmental organizations' (NGOs) relief operations. Demand for medical care continued to surge for some time as the chronically ill turned to hospitals and temporary shelters for care. Five locations with anticipated medical packaging requirements are given: There are Caribbean Medical Center in Jajardo, Hospital HIMA in San Pablo, Hospital Pavia Santurce in San Juan, Puerto Rico Children's Hospital in Bayamon, Hospital Pavia Arecibo in Arecibo, as shown below. According to the demand of each Delivery Location for Emergency Medical Packages, the forecasted demand of each reserve point is calculated. The place of delivery is marked as $j = 1, 2, 3, 4, 5$. Emergency Medical Packages type is MED 1, MED 2, MED 3. Record it as $k = 1, 2, 3$ separately.



Figure 3. The diagram of demand sites

In the figure above, the red triangle represents the location of the optimal reserve point. The blue square represents the location of the candidate reserve point. The black circle represents the location of five demand points. The dotted line represents the coverage area of the reserve point. As

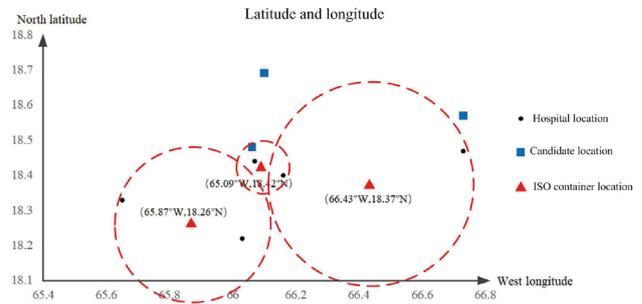


Figure 4. ISO standard dry cargo containers' position coordinates

can be seen from the figure, each hospital has a reserve point support. The reserve point is scattered in the scope of the hospital, which accords with the influence of the central model and the median model. The result satisfies the practical significance. The selected reserve point can make the rescue efficiency reach the maximum and fairness better.

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