

## Research Article

# **Location Allocation Collaborative Optimization of Emergency Temporary Distribution Center under Uncertainties**

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Emergencies cause uncertainty in supply chain environment and risks of disruption. Mitigating such risks in emergency supply chain relies on efficient relief material distribution, and in the distribution logistics system, emergency facility location interacts with material allocation clearly. This paper aims to provide a collaborative optimization for the location allocation of temporary emergency distribution centers, with objectives of minimizing rescue time and maximizing demand satisfaction rate. A location allocation model of emergency logistics is formulated by considering uncertain demand and supply information at the response stage of disaster relief. The model is solved by a plant growth simulation algorithm. At last, the feasibility and effectiveness of the model and algorithm in practical application are verified by evaluating a case of COVID-19 prevention and control in Handan city. This paper provides references for decision makers to accomplish the location allocation of emergency facilities and material distribution when dealing with actual situations.

## 1. Introduction

Situations like emergency events such as a natural calamity or epidemic strike with no warning lead to a large degree of uncertainty in the supply chain environment such as a dramatic rise in the demand of emergency supplies. Such cases are often followed by supply shortage and risk of supply chain disruption. Therefore, implementing an efficient distribution plan of limited supplies to the affected areas by the local authority is critical in reducing morbidity and mortality [1]. The key decisions in setting up such a distribution plan include the number and locations of the distribution centers to be opened and the supplies and demand points assigned to each location [2].

While planning for an emergency scenario, facility location combining material allocation simultaneously optimizes supply chain and guarantees timely material delivery [3]. There exists an amount of literature on facility location allocation problems dealing with a response to an emergency. Sherali et al. proposed a nonlinear mixed-integer

programming model; the model selected a set of candidate shelters from given admissible alternatives with available resources and presented an evacuation plan with an objective of minimizing the total congestion-related evacuation time; a heuristic and an exact implicit enumeration algorithm were developed to solve the model [4]. Wei et al. designed an assignment system to support vehicles from candidate locations to deliver relief supplies to disaster-affected areas; the aim of this system was to find transfer depots to open, number of vehicles to use, and relief materials to supply; a hybrid ant colony optimization algorithm was used to identify the approximate Pareto frontier [5]. Panchalee et al. considered a shelter location-allocation problem responding to humanitarian relief logistics; objectives were set to minimize total costs, minimize total rescue time, and minimize the number of shelters required, in order to solve the problem. The epsilon constraint (EC) method and goal programming (GP) were employed [6]. Wang and Ma presented a dual objective mixed integer nonlinear programming (MINLP) model to analyze logistics center location and material allocation in urban emergency

logistics systems, and a genetic algorithm was applied to obtain Pareto optimal solution [7].

The above literature studies have made beneficial explorations in the characteristics, system, model design, and solution algorithm of emergency logistics location, respectively. But these studies locate the emergency problem as a deterministic problem and do not take into account the various uncertainties contained in the emergency problem. Disasters no matter natural or artificial are characterized by uncertainty and unpredictability [8]; therefore, it is more practical to consider uncertainties in the optimization of emergency location allocation problems. Methods often applied to address uncertainties in emergency response problems are stochastic programming, fuzzy theory, and robust optimization. Stochastic programming takes uncertain parameters as known probability distribution functions based on statistical results [9]. Sanci and Daskin proposed a two-stage stochastic programming model, which not only considered the facility location but also the location of restoration equipment; relief item distribution was carried out jointly, uncertainty was captured by incorporating repair times needed to restore the damaged roads, and a sample average approximation method was developed to solve this integrated model [10]. Based on managerial experience and judgment, the fuzzy theory uses a fuzzy set to incorporate imprecise information in a nonprobabilistic sense [11]. By assuming fuzzy demands of emergency supplies, Wang et al. established a fuzzy multiobjective optimization model to solve the vehicle-helicopter joint routing problem [12]. Robust optimization comes from robust control theory and can be regarded as a supplement of stochastic optimization and sensitivity analysis, which is not necessary to know the probability distribution of uncertain parameters [13]. Sun et al. proposed a biobjective robust optimization model to decide the facility location, emergency resource allocation, and casualty transportation plans in a three-level chain. The model considered various uncertainties in demand and was solved with thee-constraint method [14].

While there exist lots of literature studies in the area of location allocation of emergency logistics, there have not been many papers considering the uncertainty of both supply and demand simultaneously. What is more, most models do not strictly distinguish emergency facilities as prepositioned or temporary. In this paper, we extend the model in work [7] to a model associated with fuzzy demand and stochastic scarce supply.

The structural arrangement of this paper is as follows: Section 2 introduces the location allocation model of emergency temporary distribution center, Section 3 discusses the solution approach, Section 4 presents a case study and the result of model solution, and Section 5 gives the research conclusions of this paper.

## 2. Location Allocation Model of Emergency Temporary Distribution Center under Uncertainties

2.1. Problem Description. This paper focuses on the emergency response phase. In this phase, the local authority

deploys emergency services to protect people and reduce damages within disaster areas. Because the needed relief products are not available locally, those materials have to be dispatched from the production place to the demand points. As there are various relief products from different factories, distribution centers are required to serve as transit points. Although emergency demand is usually supplied through the allocation of resources at prepositioned facilities, prepositioned facilities with limited coverage may not be able to meet the requirements of affected areas by costing longer travel time and additional funds. In such a case, temporary distribution centers located close to demand points can transship relief resources and decrease response time [15]. Constraints in this kind of emergency setting are insufficient and face uncertain supply and difficulty in estimating the emergency demand.

Based on this particular context, significant related decisions are to be made as follows:

- (1) the number and the position of temporary distribution centers
- (2) demand points assigned to each temporary distribution center and supply quality delivered to each demand point

In order to solve the above problems, this paper extends the mixed integer nonlinear programming (MINLP) model in this work [7]. Two objectives of the MINLP model are minimum total rescue time and maximum satisfaction rate of relief demand.

The following assumptions are put forward before constructing the model:

- (1) Different transportation modes are not considered; single accessible road transportation is used in this paper.
- (2) The centroid of each demand region, representing the demand points, that is demand zones are aggregated into demand points; various needed rescue resources are grouped into generic humanitarian functions.
- (3) Working time limit and turnover time in distribution centers are not considered, and there is no vehicle capacity constraint.

Based on the above problem description, parameter setting and model formulation are presented in the following study with improvements of stochastic supply and fuzzy demand based on work [7].

2.2. Parameter Setting. Parameter settings are shown in Table 1.

2.3. *Multiobjective Model.* Based on the above parameters, the location allocation model of temporary emergency distribution centers is established as follows:

TABLE 1: Parameter s	settings.
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	Implication
Set	
U	Set of emergency material supply point $u, u = 1, 2, 3, \dots, U$ .
Ι	Set of emergency distribution center $i, i = 1, 2, 3,, I$
J	Set of resource demand point $j, j = 1, 2, 3,, J$
	Parameter
w <sub>i</sub>	Weight of material demand point <i>j</i>
$A_{\mu}$	Supply capacity of the emergency material supply point u, which is a random variable
$(x_u, y_u)$	Position coordinate of the emergency material supply point u
$(x_i, y_i)$	Position coordinate of the emergency distribution center $i$
$(x_i, y_i)$	Position coordinate of the emergency material demand point j
r	Maximum distribution radius of the emergency distribution centers
s <sub>ui</sub>	Distance between material supply point $u$ and distribution center $i$
s <sub>ii</sub>	Distance between distribution center $i$ and material demand point $j$
V <sub>ui</sub>	Transportation speed between material supply point <i>u</i> and distribution center <i>i</i>
$v_{ij}$	Transportation speed between distribution center $i$ and material demand point $j$
t <sub>ui</sub>	Transportation time between material supply point $u$ and distribution center $i$
t <sub>ij</sub>	Transportation time between distribution center $i$ and material demand point $j$
c <sub>i</sub>	Relative size of the emergency distribution center <i>i</i>
$\widetilde{ED}_i$	Material demand of emergency material demand point <i>j</i> which is a triangular fuzzy number
h <sub>i</sub>	Material demand satisfaction rate of material demand point <i>j</i>
$\vec{Z}_i$	Material reserve capacity of distribution center <i>i</i>
m <sub>ui</sub>	Quantity of emergency materials transported from material supply point $u$ to distribution center $i$
$m_{ij}$	Quantity of emergency materials transported from distribution center $i$ to demand point $j$
$\theta_i$	Material demand per person of material demand point $j$
	Desision annialla

 $\begin{array}{c} Decision variable \\ X_i \in \{0,1\} & X_i = 1 \text{ means distribution center set at point } i, \text{ and } X_i = 0 \text{ means distribution center not set at point } i \\ W_{ui} \in \{0,1\} & W_{ui} = 1 \text{ means materials shipping from supply point } u \text{ to distribution center } i \\ W_{ij} \in \{0,1\} & W_{ij} = 1 \text{ means materials shipping from distribution center } i \\ W_{ij} \in \{0,1\} & W_{ij} = 1 \text{ means materials shipping from distribution center } i \text{ to material demand point } j, \text{and } W_{ij} = 0 \text{ means materials not shipping from distribution center } i \\ W_{ij} \in \{0,1\} & W_{ij} = 1 \text{ means materials shipping from distribution center } i \text{ to material demand point } j. \end{array}$ 

$$\min Z_1 = \sum_{i=1}^{I} \sum_{j=1}^{J} t_{ui} W_{ui} + t_{ij} W_{ij}, \qquad (1)$$

$$\max Z_2 = \sum_{j=1}^J w_j h_j,\tag{2}$$

$$s.t.h_j = \frac{\sum_{i=1}^{I} W_{ij} m_{ij}}{\widetilde{E} D_j},$$
(3)

$$s_{ui} = \sqrt{(x_i - x_u)^2 + (y_i - y_u)^2},$$
 (4)

$$s_{ij} = \sqrt{(x_j - x_i)^2 + (y_j - y_i)^2},$$
 (5)

$$t_{ui} = \frac{s_{ui}}{v_{ui}},\tag{6}$$

$$t_{ij} = \frac{s_{ij}}{v_{ij}},\tag{7}$$

$$c_{i} = \frac{\sum_{j=1}^{I} m_{ij}}{\sum_{i=1}^{I} \sum_{j=1}^{J} m_{ij}}, \quad \forall i \in I,$$
(8)

$$\sum_{i=1}^{I} W_{ij} = 1, \quad \forall j \in J,$$
(9)

$$\sum_{i=1}^{I} W_{ij} m_{ij} \le \widetilde{E D}_j, \quad \forall j \in J,$$
(10)

$$\sum_{u=1}^{U} X_i m_{ui} = \sum_{j=1}^{J} W_{ij}, \quad \forall i \in I,$$
(11)

$$\sum_{i=1}^{I} \sum_{j=1}^{J} W_{ij} m_{ij} = \min\left\{\sum_{u=1}^{U} \sum_{j=1}^{J} d_j\right\}, W_{ij} \le X_i, \forall i \in I, j \in J,$$
(12)

$$W_{ij} \le X_i, \forall i \in I, j \in J, \tag{13}$$

$$\sum_{i=1}^{I} X_i \le I,\tag{14}$$

$$P\left(\frac{\sum_{i=1}^{I} m_{ui} - E(A)}{\sqrt{\operatorname{var}(A)}} \le \frac{A_u - E(A)}{\sqrt{\operatorname{var}(A)}}\right) \ge \alpha, \ \forall u \in U,$$
(15)

$$s_{ij} \le r, \forall i \in I, j \in J,$$
 (16)

$$\sum_{T=1}^{U} X_i m_{ui} \le Z_i, \quad \forall i \in I,$$
(17)

$$X_i, W_{ui}, W_{ij} \in \{0, 1\}, \quad \forall i \in I, j \in J,$$
 (18)

$$m_{ui}, m_{ii} \in \mathbb{R}^+, \forall u \in U, \quad \forall i \in I, j \in J.$$
 (19)

Objective function (1) is to minimize the emergency rescue time, and objective function (2) is to maximize the satisfaction rate of material demand. Constraint (3) calculates the demand satisfaction rate. Constraint (4) is the Euclidean distance from the material supply point u to the emergency distribution center *i*, and constraint (5) is the Euclidean distance from emergency distribution center i to material demand point *j*. Constraints (6) and (7) calculate the emergency rescue time. Constraint (8) calculates the relative scale of the emergency distribution center *i*. Constraint (9) replies that emergency supplies for each demand point are provided by one emergency distribution center only. Constraint (10) indicates that the quantity of emergency supplies provided to each material demand point does not exceed the demand at that demand point. Constraint (11) indicates that the emergency materials received by each emergency distribution center are equal to the number shipped by the emergency distribution center. Constraint (12) shows that if the supply capacity of the material supply point is less than the demand of the material demand point, all the emergency materials shall be transported to the material demand point; otherwise, the emergency rescue materials shall be distributed according to the demand of the emergency demand point. Constraint (13) says that only established emergency distribution centers can deliver emergency supplies to material demand points. Constraint (14) indicates that the number of emergency distribution centers cannot exceed the original upper limit. Constraint (15) indicates that the quantity of emergency supplies provided at each supply point does not exceed its supply capacity; P represents the probability, and  $\alpha$  is the confidence level of supply. Constraint (16) indicates that the distances between the material demand point and the emergency distribution center do not exceed its maximum distribution radius. Constraint (17) indicates the storage capacity limits of the emergency distribution center. Constraints (18) and (19) represent the types of decision variables and several state variables.

2.4. Model Transformation. Firstly, as  $A_u - E(A)/\sqrt{\operatorname{var}(A)}$  complies standard normal distribution, the above expression can be further converted as follows:

$$\sum_{i=1}^{I} m_{ui} \le E(A) + (1-\alpha)\sqrt{\operatorname{var}(A)}, \quad \forall u \in U.$$
(20)

Secondly, a triangular fuzzy number method [16, 17] is adopted in this paper to estimate the emergency material demand  $\widetilde{ED}_j$ , and it is converted to the determined value by the weighting method, which is

$$\widetilde{ED}_{j} = \omega_{1} \left[ ED_{j} \right]^{o} + \omega_{2} \left[ ED_{j} \right]^{l} + \omega_{3} \left[ ED_{j} \right]^{p}.$$
(21)

Then, the opposite number of objective function  $Z_2$  is added to objective function  $Z_1$ , making sure both objectives are the minimum value.

$$\min Z_1 = \sum_{i=1}^{I} \sum_{j=1}^{J} t_{ui} W_{ui} + t_{ij} W_{ij} - \sum_{j=1}^{J} w_j h_j.$$
(22)

At last, the driving speed of the transport vehicle is assumed to be constant and unchanged; therefore, time can be presented by distance, and expression (22) is updated as follows:

$$\min Z_1 = \sum_{i=1}^{I} \sum_{j=1}^{J} s_{ui} W_{ui} + s_{ij} W_{ij} - \sum_{j=1}^{J} w_j h_j.$$
(23)

#### **3. Plant Growth Simulation Algorithm (PGSA)**

3.1. Principle of PGSA. Literature [18] analyzed the growth mechanism of plants from the perspective of mathematics and established a probabilistic growth model to simulate plant tropism. The main idea can be summarized as follows: after completing the first growth of the initial growth point  $x_0$ , plants are assumed to generate k growth points with a set of  $SM = (SM_1, SM_2, ..., SM_K)$ ; the morphactin concentration at each node  $PM = (PM_1, PM_2, ..., PM_K)$  is calculated by following formulas:

$$P_{Mi} = \frac{f(x_0) - f(S_{Mi})}{\sum_{i=1}^{q} f((x_0) - f(S_{Mi})) + \sum_{j=1}^{l} f((x_0) - f(S_{mj}))},$$

$$P_{mj} = \frac{f(x_0) - f(S_{Mi})}{\sum_{i=1}^{q} f((x_0) - f(S_{Mi})) + \sum_{j=1}^{l} f((x_0) - f(S_{mj}))},$$
(24)

Where  $x_0$  is the initial feasible solution and  $f(\cdot)$  is the objective function of each viable growth point. The growth point changes after each growth, which results in the dynamic value change of morphactin concentration; the value of whole plant morphactin concentration adds to 1.

$$\sum_{i=1}^{q} \sum_{j=1}^{l} \left( P_{Mi} + P_{mj} \right) = 1.$$
 (25)

Once the morphactin concentration  $PM = (PM_1, PM_2, ..., PM_K)$  is determined, the growth point for the next growth can be selected by certain principles. Depending on the tropism, the closer the growth point is to the light source, the greater the probability selected. The morphactin concentration of the (k + 1) growth points constitutes the growth space; the random numbers within [0,1] are systematically generated, and then the growth point corresponding to the random values is chosen as the next growth point. The higher the concentration of morphactin, the greater the probability of being selected. The previously selected growth points will be eliminated from the growth

point set SM. Then, the plant continues to grow new branches, which become new growth points and are added to set PM. Repeating this process, the plant growth model can cover the entire growth space and obtain the optimal solution.

*3.2. Algorithm Steps.* The specific algorithm steps of the location allocation problem of emergency distribution center are as follows:

Step 1. Determine an initial solution  $x_0$ ,  $X_{\min} = x_0$ . To improve the quality of the initial solution, ensure its generality and make it close to the optimal solution as much as possible; it can be generated randomly by the greedy method. Set step size $\lambda$ , calculate the optimal value function  $F_{\min} = f(x_0)$ , and set the maximum number of iterations and the frequency of solution repetitions.

*Step 2.* Take  $x_0$  as the initial state, grow new growth points in 2n directions, respectively, according to the step size set in step 1 and calculate the function value of each growth point.

*Step 3.* Select the growth points which are better than the initial value, calculate their morphogen concentration, and retain the best growth point.

*Step 4.* Establish the probability space between [0,1] and use the random number generated by computer to select the growth point of the next growth.

*Step 5.* If no new branches are generated when the optimal value appears repeatedly to the set frequency or the number of loop iterations reaches the set maximum number of iterations, the growth process ends; otherwise, return to step 3.

The flowchart of the above steps is shown in Figure 1.

#### 4. Case Study

4.1. Case Description. This paper takes the COVID-19 prevention and control of Handan city which was affected by the epidemic in Shijiazhuang in early 2021 as an example to verify the effectiveness of the model and solution algorithm. Eighteen districts and counties in Handan are taken as 18 material demand points j (j = 1, 2, 3, ..., 18). By hypothetical conditions, material demand is aggregated in the seats of each district or county government. The weight of each material demand point is determined by the population proportion, and material demand is vaguely uncertain which is estimated by triangular fuzzy number by the population distribution and degree of disaster. According to the most likely value method proposed by Pishvaee et al. [19],  $\omega_1 = \omega_3 = 1/6$ ,  $\omega_2 = 4/6$  are taken, the estimated demand is calculated by equation (21). The parameters of each demand point are shown in Table 2. The geographical coordinates of the two supply points u(u =1,2) are (113.42, 36.32) and (115.76,36.65), respectively, and the available supply capacity at the first assignment of



FIGURE 1: PGSA flowchart.

emergency response corresponds to normal distribution N (3900, 502) and N (4050, 702), respectively, and  $\alpha$  is set as 0.01. According to the existing logistics service system in Handan city, decision makers need to select the appropriate number of sites from 6 candidate commercial logistics distribution centers i(i = 1, 2, 3, 4, 5, 6) as temporary emergency distribution centers or temporary transit points. The parameters of 6 candidate sites are shown in Table 3.

Population data come from the Seventh National Census Bulletin of Hebei Province (No.2).

No.	Material demand point <i>j</i>	Geographic coordinate $(x_j, y_j)$	Population	Weight $w_j$	Fuzzy demand of emergency demand point $\widetilde{ED}_i$
1	Congtai	(114 499307 36 64270)	572175	0.065	(500, 504, 510)
2	Hanshan	(114.537471 36.60024)	614303	0.005	(660, 663, 670)
2	Fuving	(114.337471, 30.00024) (114.468586, 36.64537)	319980	0.005	(310, 319, 320)
4	Fengfeng	(114,239285,36,42212)	429245	0.030	(310, 319, 320) (420, 422, 430)
5	Feiviang	(114.25)205, 50.42212) (114.806635, 36.55425)	372245	0.042	(120, 122, 150) (340, 345, 350)
6	Yongnian	(114.5000055, 50.55425) (114.543486, 36.74784)	851227	0.096	$(1000 \ 1090 \ 1100)$
7	Wu'an	(114,210535,36,70264)	811631	0.092	(900, 907, 910)
8	Linzhang	(114,592178, 36,32938)	589003	0.067	(630, 632, 640)
9	Cheng'an	(114.676567, 36.44983)	401052	0.045	(390, 394, 400)
10	Daming	(115.154601, 36.29208)	726396	0.082	(640, 648, 650)
11	Shexian	(113.698024, 36.59137)	379559	0.043	(360, 364, 370)
12	Cixian	(114.380259, 36.38098)	440728	0.050	(400, 402, 410)
13	Oiuxian	(115,20645, 36,818644)	210998	0.024	(130, 134, 140)
14	lize	(114.896634, 36.91699)	297425	0.034	(260, 269, 270)
15	Guangping	(114,955115, 36,49018)	264025	0.030	(150, 154, 160)
16	Guantao	(115.287453, 36.55409)	307912	0.035	(320, 321, 330)
17	Weixian	(114.945665, 36.36542)	796806	0.090	(780, 782, 790)
18	Quzhou	(114.963955, 36.77241)	463727	0.052	(450, 455, 460)

TABLE 2: Locations and demand of material demand points.

TABLE 3: Parameters of candidate distribution centers.

No.	Candidate emergency distribution centers	Geographic coordinate	Maximum distribution radius r	Material storage capacity
1	Wu'an	(114.840707, 36.8750)	0.6	3000
2	Fengfeng	(114.017121, 36.5449)	0.7	4000
3	Fuxing	(114.366065, 36.6467)	0.7	4000
4	Feixiang	(114.814008, 36.6072)	0.6	4000
5	Jinan xinqu	(114.451021, 36.4778)	0.5	3500
6	Guangping	(114.105367, 36.4694)	0.7	3500

TABLE 4: The iterative process of PGSA.

No.	X	$W_{ij}$	Function value
1	(1 0 1 1 0 0)	$\begin{split} W_{1j\cdot} &= (0\ 0\ 0\ 0\ 0\ 1\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0)\\ W_{3j\cdot} &= (0\ 1\ 1\ 0\ 1\ 0\ 1\ 0\ 1\ 0\ 1\ 0\ 1\ 0\ 0\ 1\ 0\ 0\ 1)\\ W_{4j\cdot} &= (1\ 0\ 0\ 1\ 0\ 0\ 0\ 1\ 0\ 1\ 0\ 1\ 0\ 1\ 1\ 1\ 0\ 1\ 1\ 0) \end{split}$	9.2026
2	(0 1 1 1 0 0)	$ \begin{split} W_{2j\cdot} &= (0 \ 0 \ 0 \ 1 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ $	8.1002
50	$(0\ 1\ 1\ 0\ 0\ 1)$	$W_{2j} = (0 \ 0 \ 0 \ 1 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ $	6.0748

4.2. Test Results. Since the decision variables are 0-1 variable, step size is set as  $\lambda = 1$ , maximum number of iterations as 50, and the frequency of solution repetitions as 3. As there are 6 candidate locations and 18 demand points in this study case, the decision variables are designed as Boolean vectors in the iterative process of PGSA.  $X = (x_1, x_2, \dots, x_6)$  indicates whether to open a candidate distribution center; element value of 1 is open while 0 is not. Similarly,  $W_{ij}$  decides which demand point the selected distribution center is to serve.  $W_{ij} = 1$  indicates that distribution center i serves demand point *j*, while  $W_{ij} = 0$  means not. Table 4 presents the iterative process of the optimal solution of opening 3 distribution centers calculated by MATLAB software.

In order to illustrate the solution quality produced by PGSA, a comparison between PGSA and genetic algorithm (GA) is presented in Table 5.

According to the iterative process of PGSA described above, the optimal solutions of other distribution centers can be obtained in the same way. A comparison of test results with different number of opening distribution centers is presented in Table 6 and Figure 2.

As shown in Table 6 and Figure 2, when opening 3 temporary distribution centers, the objective function reaches the optimal value of 6.0748. The total shortest rescue distance (10.2311) is obtained when 2 distribution centers are selected. The highest demand satisfaction rate is achieved

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Algorithm	X	$W_{ij}$	Function value
PGSA	(0 1 1 0 0 1)	$ \begin{split} W_{2j} &:= (0 \ 0 \ 0 \ 1 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ $	6.0748
GA	(0 1 1 1 0 0)	$W_{2j} = (0 \ 0 \ 0 \ 1 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ $	6.2175

TABLE 5: Computing result comparison between PGSA and GA.

TABLE 6: Comparison of test results of distribution centers in number from 2 to 6.

No. of distribution centers	2	3	4	5	6
Distance from supply point to distribution center	4.7544	7.1449	9.4836	11.8785	14.3502
Distance from distribution center to demand point	5.4767	10.2136	7.2114	7.6793	7.0549
Total distance	10.2311	17.3585	16.6950	19.5577	21.4051
Optimal value of objective function	6.1449	6.0748	6.2897	7.0643	7.5516
Distribution center	4, 2	3, 2, 6	3, 2, 5, 6	5, 2, 4, 3, 6	5, 1, 2, 3, 4, 6
Demand satisfaction rate	93.28%	93.39%	93.39%	92.92%	92.15%



FIGURE 2: Comparison of test results of distribution centers in number from 2 to 6.

No.	Geography coordinate	Distribution center	Relative size	No. of material demand point
1	(114.366065, 36.646)	Fuxing	0.4729	1 2 3 6 7 8 12
2	(114.017121, 36.544)	Fengfeng	0.0935	4 11
3	(114.105367, 36.469)	Guangping	0.4336	5 9 10 13 14 15 16 17 18

at both 3 and 4 locations. Therefore, opening 3 distribution centers is a fair solution. It is obvious that the difference of satisfaction rate among different distribution centers is quite small, which suggests that objective (2) is a weak determining factor when planning material allocation. Therefore, the key to solving unmet demand lies in sufficient supply while weighted allocation may not be very efficient. In addition, when opening 4 distribution centers, the solution has a highest demand satisfaction rate with a relatively short delivery distance. Consequently, the model proposed in this paper has flexibility responding to risk in emergency logistics. The appropriate decision of how many distribution centers to be open can be made when confronting changeable conditions.

Table 7 and Figure 3 present the specific location result of the solution with 3 distribution centers. Figure 4 shows the location layout of other solutions.

According to Table 7, Fuxing distribution center undertakes the emergency material supply of Congtai, Hanshan, Fuxing, Yongnian, Wu'an, Linzhang, and Cixian,



FIGURE 3: Locations of 3 emergency distribution centers.



FIGURE 4: Locations of emergency distribution centers with Nos. 2, 4, 5, and 6.

while Fengfeng distribution center distributes materials to Fengfeng and Shexian, and the Guangping distribution center is responsible for the material distribution of Feixiang, Cheng' an, Daming, Qiuxian, Jize, Guangping, Guantao, Weixian, and Quzho. Distribution centers located in Fuxing and Guangping undertake the larger material turnover in the emergency logistics network, with 47.29% and 43.36%, respectively, while distribution center located in Fengfeng undertakes smaller material turnover of 9%.

#### **5.** Conclusion

In this paper, we consider the problem of locating temporary distribution centers for relief products in response to disaster and risk emergency scenarios. The main contribution of this study is in designing a response strategy to address the location allocation problem with uncertain demand and supply. In addition, the model proposed in this work offers some managerial insights associated with the number of temporary distribution centers. Their locations and distribution strategy with limited supply in designing and deploying aid distribution networks. Specifically, a biobjective MINLP model with minimum emergency rescue time and maximum demand satisfaction rate is formulated. Then, a plant growth simulation algorithm is employed to solve the model. At last, the feasibility and effectiveness of the model and algorithm are verified in a COVID-19 prevention and control case in Handan city. In general, the model is suitable to the complex problem of multiobjective, multivariable, and nonlinear objective functions with great flexibility and adaptability. The inadequacy of this paper is that it only considers static demand of emergency supplies while the demand in emergency response is periodically changed which calls for the dynamic research of emergency logistics in the future.

#### **Data Availability**

The research data used to support the findings of this study are included within the article. The data used are shown in Tables 2 and 3.

#### **Conflicts of Interest**

The authors declare no conflicts of interest.

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