The location problem of emergency materials in uncertain environment

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Abstract

The hazards and unpredictability of emergencies have made people pay more and more attention to emergency response. A reasonable reserve of emergency materials can play an important role in post-disaster rescue. This paper uses the uncertain comprehensive evaluation method to grade the emergency materials, and establishes a location model for the uncertain emergency materials. The location of the reserve point is determined by maximizing the rescue satisfaction, the maximum number of service demand points under the maximum coverage, and pursuing the minimum sum of the distance from the demand point to the reserve point. Based on the uncertainty theory, the uncertain emergency materials location model is converted into an equivalent deterministic emergency materials location model, and the model is solved by a tabu search algorithm. Finally, a numerical experiment is given to illustrate the idea of the uncertain model.

Keywords: Emergency materials; Uncertain comprehensive evaluation method; Tabu search algorithm; Uncertain location model

1 Introduction

No matter how today's society develops, emergencies cannot completely disappear. In the past two decades, emergencies have occurred frequently in worldwide, which has brought heavy casualties and property losses to mankind, such as the "9 · 11" incident in 2001; the "SARS" epidemic in 2003; 2004 tsunami in Indonesia; southern snow disaster and Wenchuan earthquake in 2008; Haiti earthquake in 2010; Japan earthquake and Fukushima nuclear leak in 2011; Boston explosion in 2013 and Tianjin Port explosion in 2015; COVID-19 in 2020 and other events. How to do a good job of early warning and effectively respond to emergencies, so as to minimize the losses caused and to ensure social stability has become a major practical requirement for national development. Therefore, a systematic and in-depth study of the occurrence, development and evolution of emergencies are the premise of effective crisis response. It is of great research significance to establish regional emergency material reserve and dispatch optimization, so as to meet the material needs of the affected people to the greatest extent and reduce economic losses to the greatest extent.

In recent decades, many researchers have studied the location of emergency materials. Toregas et al. [1] studied the location problem of emergency service facilities and proposed a set coverage location model. Church and Revelle [2] proposed the maximum coverage location problem by locating a fixed number of facilities and maximizing coverage within the required service distance. Revele et al. [3] applied metaheuristic heuristic concentration to solve the maximum coverage location problem with high coverage. Zarandi et al. [4] proposed a customized genetic algorithm to solve he maximum coverage location problem instances with up to 2500 vertices. Yin and Mu [5] proposed a maximum coverage location problem with modular capacity constraints to consider several possible capacity levels of facilities at each potential site. Barbarosoğlu and Arda [6] proposed a two-stage stochastic programming model to plan the transportation of important first aid materials to disaster areas in the process of emergency response. A multi commodity and multi-modal network flow formula is proposed to describe the flow of materials in urban traffic network. Jia et al. [7] proposed a general facility location model for large-scale emergencies. And illustrate how the model can be used to optimize the location of medical supplies and facilities in response to large-scale emergencies in Los Angeles. In addition, In addition, by comparing the solutions obtained by the model and the traditional model respectively, the advantages of the model in reducing life loss and economic loss are illustrated. Caunhye et al. [8] proposed a two-stage random mixed integer programming to provide emergency response pre-positioning strategy for hurricanes or other disaster threats. AI et al. [9] studied the location allocation problem of emergency resources in marine emergency system, and proposed a discrete nonlinear integer programming model with location and allocation. Alizadeh and Nishi [10] proposed a hybrid covering model by the set covering problem and the maximum covering location problem. Yan et al. [11] based on the coverage model and considering the demand classification, proposed a double objective optimization model, determined the most location plan of graded materials through the maximum rescue satisfaction and the minimum number of warehouses, and designed a heuristic multi-center clustering location algorithm to solve the model.

We know that the high unpredictability of emergencies can lead to uncertainty of demand and response time. It is undeniable that probability theory is a useful tool to deal with random factors. However, a basic premise of applying probability theory is that we should obtain the probability distribution close to the real frequency through statistics. In emergencies, we often lack observational data. Usually, we have no choice but to invite some domain experts to evaluate the belief degree that each event will occur. Liu [12] put forward the uncertainty theory in 2007 and improved it in 2009 to make it a mathematical system based on normality axiom, duality axiom, subadditivity axiom and product axiom. Liu [13] introduced uncertainty theory into mathematical programming in 2009 and established uncertainty programming.

Many scholars have combined uncertainty theory with decision-making problems, developed a set of uncertain programming theory, and produced many research results, such as applying uncertainty theory to vehicle scheduling problem [14], transportation problem [15,16], minimum spanning tree problem [17], facility location problem [18,19], uncertain random network optimization problem [20]. Jiang and Guang [21] studied an uncertain programming model of chance constrains for empty container allocation. Uddin et al. [22] studied goal programming tactic for uncertain multi-objective transportation problem. Ke et al. [23] studied uncertain random multilevel programming with application to production control problem. Zhang et al. [24] studied the location of emergency service facilities under uncertain environment, and established the (α, β)-maximal covering location model and the α-chance maximal covering location model. The maximum coverage location problem in uncertain environment is modeled, and the two models are solved.

In this paper, we propose a maximum coverage location problem under emergency materials classification. In the uncertain environment, we have graded for the emergency materials and determined the location of the graded emergency materials. In Section 2, this paper mainly introduces the knowledge of uncertain comprehensive evaluation method. In Section 3, emergency materials is graded by using uncertain comprehensive evaluaton method, and the emergency materials maximum coverage location model in an uncertain environment and the corresponding expected value model are established. In addition, the tabu search algorithm is used to solve the model. In Section 4, numerical experiment are carried out. In Section 5, a brief summary is given.

2 Uncertain comprehensive evaluation method

In this section, we introduce uncertain comprehensive evaluation method. When conducting a systematic evaluation, on the one hand, experts always carry personal preferences and other information when determining the weights, and it is different that the degree of difficulty of determining weights of each indictor. In order to be more in line with objective reality, we use uncertain variables to express the weights; On the other hand, the comment set itself, such as "very satisfied" and "relatively satisfied", is also an uncertain language. Therefore, the comment set is converted into uncertain variables by a certain method, thereby obtaining the uncertain evaluation model.

2.1 Determination of weights

Suppose there are n evaluation factors to constitute an evaluation plan $U = \{u_1, u_2, \cdots, u_n\}$. The importance of different factors in the evaluation is determined by experts. For each evaluation factor, the evaluation given by the expert is uncertainty. For example, suppose there are five evaluation criteria as {very important, more important, important, not very important, not important}, using uncertain variables $\widetilde{q_1}$, $\widetilde{q_2}$, $\widetilde{q_3}$, $\widetilde{q_4}$, $\widetilde{q_5}$ to express. Through investigation, each expert $j(j = 1, 2, \cdots, s)$ assigns a different important degree to each factor u_i, assuming that there are s_1 experts choices $\widetilde{q_1}$, s_2 experts choices $\widetilde{q_2}$, s_3 experts choices $\widetilde{q_3}$, s_4 experts choices $\widetilde{q_4}$, s_5 experts choices $\widetilde{q_5}$, where $s_1+s_2+s_3+s_4+s_5 = s$, then the weight of u_i can be expressed as $\widetilde{\omega_i} = (\frac{s_1}{s}\widetilde{q_1} + \frac{s_2}{s}\widetilde{q_2} + \frac{s_3}{s}\widetilde{q_3} + \frac{s_4}{s}\widetilde{q_4} + \frac{s_5}{s}\widetilde{q_5})$, which is an uncertain variable.

2.2 Evaluation

In addition, experts evaluate each evaluation factor in the evaluation plan, and the comments in the comment set are also uncertain. For example, the comment set is composed of {very satisfied, relatively satisfied, satisfied, not very satisfied, dissatisfied}, using uncertain variables $\widetilde{r_1}$, $\widetilde{r_2}$, $\widetilde{r_3}$, $\widetilde{r_4}$, $\widetilde{r_5}$ to express. Suppose there is an uncertain evaluation matrix $R = \{\widetilde{r_{i1}}, \widetilde{r_{i2}}, \cdots, \widetilde{r_{im}}\}$, composed of m evaluation levels, where $\widetilde{r_{ij}}(i = 1, 2, \cdots, n, j = 1, 2, \cdots, m)$, represents the degree to which the i-th evaluation factor of the scheme is in the j-th grade. Similarly, $\widetilde{r_{ij}}$ is also an uncertain variable. When the expert selects the j-th rating for the i-th evaluation factor of the scheme, the corresponding $\widetilde{r_{ij}}$ is an uncertain variable, otherwise $\widetilde{r_{ij}}$ is taken as 0. For a certain evaluation factor i, suppose there are s_{i1} experts choices $\widetilde{r_{i1}}$, s_{i2} experts choices $\widetilde{r_{i2}}$, $\cdots$, s_{im} experts choices $\widetilde{r_{im}}$, where $s_{il} + s_{i2} + \cdots + s_{i5} = s$, the evaluation of the i-th evaluation factor can be expressed as a vector $(\widetilde{R_{i1}} = \frac{s_{i1}}{s}\widetilde{r_{i1}}, \widetilde{R_{i2}} = \frac{s_{i2}}{s}\widetilde{r_{i2}}, \cdots, \widetilde{R_{im}} = \frac{s_{im}}{s}\widetilde{r_{im}})$, thus the uncertainty evaluation matrix R is constituted by n evaluation factors.

2.2.1 The uncertainty evaluation matrix B

The calculation formula of the uncertainty evaluation matrix B is:

$$\mathrm{B} = \mathrm{W} * \mathrm{R} = (\widetilde{\omega_1}, \widetilde{\omega_2}, \cdots, \widetilde{\omega_n}) * \begin{bmatrix} \widetilde{R_{11}} & \widetilde{R_{12}} & \cdots & \widetilde{R_{1m}} \\ \widetilde{R_{21}} & \widetilde{R_{22}} & \cdots & \tilde{R_{2m}} \\ \vdots & \vdots & \vdots & \vdots \\ \widetilde{R_{n1}} & \widetilde{R_{n2}} & \cdots & \tilde{R_{nm}} \end{bmatrix} = \left(\widetilde{b_1}, \widetilde{b_2}, \cdots, \widetilde{b_m}\right). \tag{1}$$

2.2.2 Evaluation result

We can calculate $\mathrm{E}(\widetilde{b_i})$ using uncertain simulation technology, and the value of each comment is obtained, and the comment with the largest value is the evaluation result.

Next, we will grade emergency materails based on the uncertain comprehensive evaluation method, and establish the uncertain emergency materials maximum coverage location model.

3 Model establishment

In this part, this paper proposes an uncertain emergency materials location problem concerning the grading of emergency materials. When a disaster occurs, the location of emergency materials is related to the progress of the rescue. Reasonable grading of emergency materials can speed up the progress of rescue. Since disasters are unpredictable, some factors are uncertain and cannot be estimated by frequency. Therefore, this paper describes the parameters of the problem as uncertain variables, using the uncertain comprehensive evaluation method to grade emergency materials. And through the maximum coverage of demand points, the rescue of the reserve points to the demand points can be met. The pre-selected location map of emergency material reserves is shown in Figure 1.

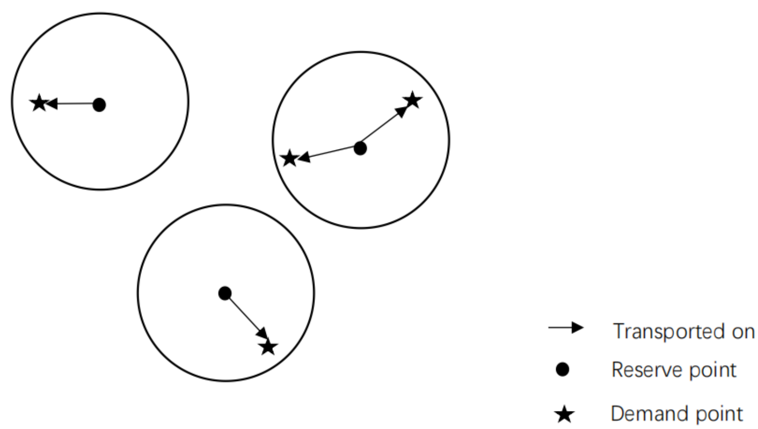

Figure 1: The pre-selected location map of emergency material reserves

3.1 Establishment of the uncertain emergency materials maximum coverage location model

Before establishing the model, first put forward some assumptions and describe the parameters in the model.

Assumption 1: A demand point can be provided rescue services by only one reserve point.

Assumption 2: Every demand point can be constructed as a reserve point.

Assumption 3: Each reserve point has a fixed capacity.

Assumption 4: Emergency materials are divided into three demand levels: very urgent, urgent and general.

Assumption 5: The demand for each demand point obeys a zigzag distribution.

Assumption 6: There are θ reserve points to be constructed.

Parameters:

I: Demand point set, $I = \{i \in I \mid i = 0, 1, 2, \cdots, n\}$

J: Reserve point set, $J = \{j \in J \mid j = 0, 1, 2, \cdots, n\}$

C: Emergency materials set, $C = \{c \in C \mid c = 0, 1, 2, \cdots, v\}$

L: Emergency level set, $L = \{l \in L \mid l = 0, 1, 2, \cdots, m\}$

K: Set of factors affecting the urgency of demand, $K = \{k \in K \mid k = 0, 1, 2, \cdots, h\}$

d_{ij}: The distance from demand point i to reserve point j

t_{ij}: The response time from demand point i to reserve point j

ζ_{ij}: The distance from the demand point i to the reserve point j due to road emergencies is recorded as an uncertain variable

η_{ic}: The demand for emergency materials c at demand point i is recorded as an uncertain variable

R_{max}: Maximum rescue radius of the reserve point

x_{ij}: If the reserve point j provides services for the demand point i, it is recorded as 1, otherwise it is recorded as 0

y_j: If point j is used as a reserve point, it is recorded as 1, otherwise it is recorded as 0

y_{cl}: If emergency material c belongs to level l material, it is recorded as 1, otherwise it is 0

θ: Number of reserve point

V_j: Capacity of the j-th reserve point

D_{il}: L-level emergency materials demand at demand point i

3.1.1 Grading of emergency materials

After the disaster, the victims of the disaster have a great demand for all kinds of emergency materials. However, the requirements for various emergency materials are different, and emergency materials need to be graded and dispatched according to the needs of each emergency material. Therefore, before a disaster occurs, a scientific and reasonable grading of various emergency materials is required. The importance of emergency materials, scarcity, irreplaceability, timeliness, and weight of emergency materials determined the urgency of the emergency materials, and established a grading indicator system for emergency materials, as shown in Figure 2.

Use uncertain comprehensive evaluation methods to determine the demand level of emergency materials. After determining the demand level, calculate the demand for graded emergency materials at each demand point according to the following formula:

$$D_{il} = \sum_{i=1}^{n} \sum_{c=1}^{v} \eta_{ic} y_{cl}. \tag{2}$$

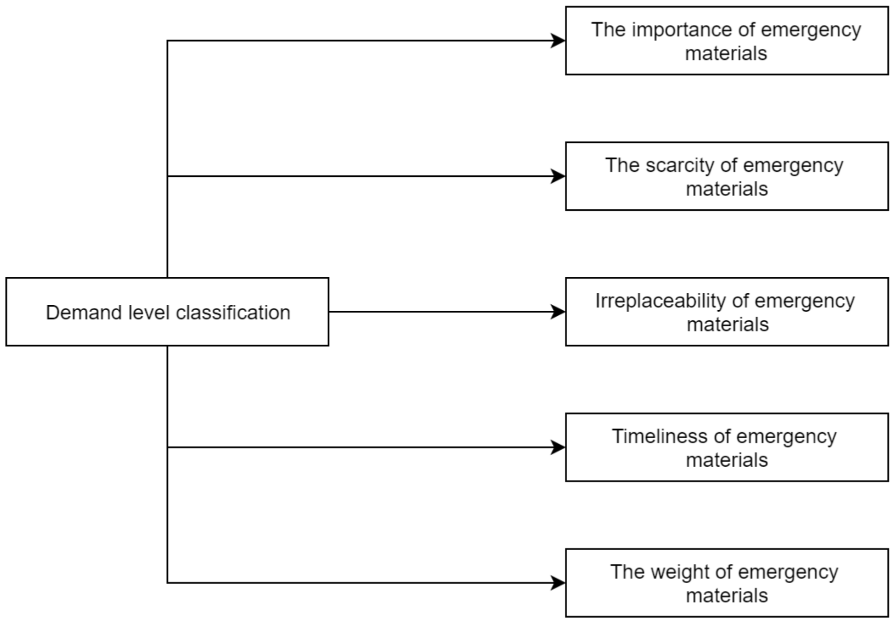

Figure 2: Emergency materials grading index system for urgent needs

Formula (2) contains uncertain variables and cannot be directly calculated, so assuming that the expected value of the variable η_{ic} exists, then the expected value of formula (2) also exists.

$$\mathrm{E}\left(D_{il}\right)=E\left(\sum_{i=1}^{n}\sum_{c=1}^{v}\eta_{ic}y_{cl}\right)=\sum_{i=1}^{n}\sum_{c=1}^{v}E\left(\eta_{ic}\right)y_{cl}. \tag{3}$$

3.1.2 Establishment of rescue satisfaction function

Due to different levels of emergency materials have different urgency levels, in the rescue period, when emergency materials of different levels are delivered to the demand point, the satisfaction of the victims will be different. This paper describes the rescue quality through the time-effect function $f_l(t)$. Table 1 shows the time-effect functions of the each level of emergency materials. The satisfaction trend of very urgent and urgent emergency materials in the rescue period is similar to that as the rescue time increases from 1 to 0, when the rescue ends. For general emergency materials, the satisfaction trend is similar to a decrease from 0.5 to 0 as the rescue time increases, when the rescue ends. T represents the time from the beginning of the rescue to the end of the rescue, and t represents the material response time.

Table 1: Time effect functions of different demand levels

Level of emergency materials	$f_l(x)$
l=1	$\left(\frac{\mathrm{t-T}}{\mathrm{T}}\right)^2$
l=2	$1-\left(\frac{\mathrm{t}}{\mathrm{T}}\right)^2$
l=3	$0.5\left(\frac{\mathrm{t-T}}{\mathrm{T}}\right)^2$

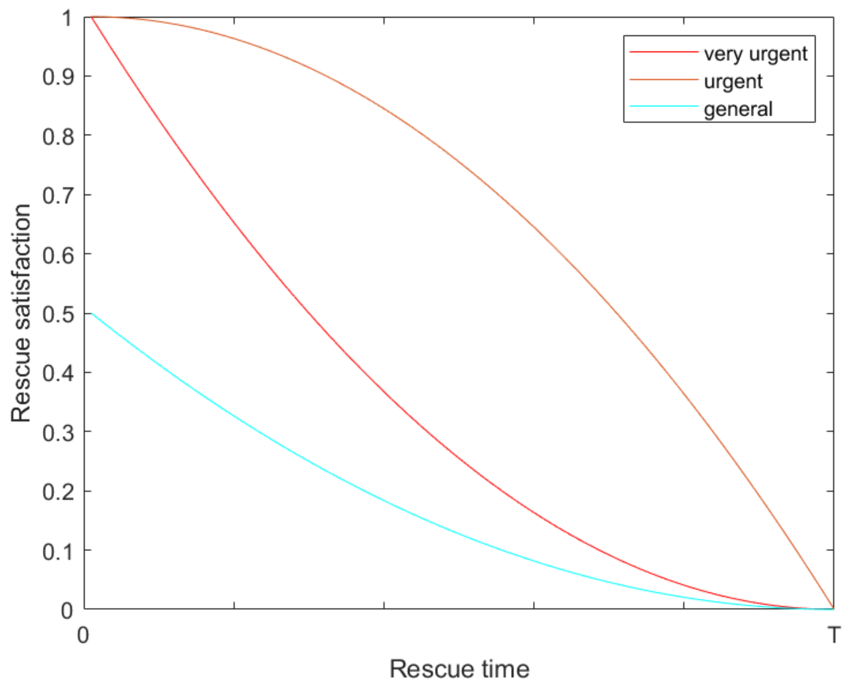

Figure 3: Time effect function graph under different demand levels

The location of demand points should consider the efficiency of rescue materials transportation, and the rescue satisfaction is described by the rescue time effect function. The rescue satisfaction function is:

$$\begin{aligned} \mathrm{F} &= \sum_{l=1}^{m}\sum_{i=1}^{n}\sum_{j=1}^{n} f_l\left(t_{ij}x_{ij}\right) \\ &= \sum_{l=1}^{m}\sum_{i=1}^{n}\sum_{j=1}^{n} f_l\left(g\left(d_{ij}+\zeta_{ij}\right)x_{ij}\right), \end{aligned} \tag{4}$$

where, $t_{ij}=g(d_{ij}+\zeta_{ij})$, ζ_{ij} has an independent uncertain variable with a regular uncertain distribution, and its uncertain distribution is ϕ_{ij}.

3.1.3 Establishment of maximum coverage location model

In the rescue process, it is necessary to maximize the number of service demand points, and pursue the shortest sum of the distance from the demand point to the reserve point on the basis of maximum coverage. Therefore, the objective function is as follows:

$$\mathrm{Z} = \max \sum_{i=1}^{n} \sum_{j=1}^{n} x_{ij} \tag{5}$$

$$\mathrm{L} = \min \sum_{i=1}^{n} \sum_{j=1}^{n} \left(d_{ij} + \zeta_{ij}\right) x_{ij}. \tag{6}$$

The constraints are:

$$\sum_{j=1}^{n} y_j = \theta \tag{7}$$

$$\sum_{j=1}^{n} x_{ij} = 1 \tag{8}$$

$$\sum_{i=1}^{n} \sum_{l=1}^{m} E\left(D_l\right) x_{ij} \leq E\left(V_j\right) \tag{9}$$

$$x_{ij} \geq y_j \tag{10}$$

$$d_{ij} \leq \mathrm{R}_{\max} \tag{11}$$

$$x_{ij}, y_{cl}, y_j \in \{0,1\}, i \in I, j \in J, c \in C. \tag{12}$$

Constraint 1 indicates that there are θ reserve points constructed in the planning stage. Constraint 2 indicates that in the planning stage, only one reserve point can be allocated to a demand point. Constraint 3 indicates that the capacity of the reserve point is greater than the quantity of emergency materials transported to the demand point. Constraint 4 indicates to ensure that each demand point has a reserve point to provide services. Constraint 5 indicates that reserve points can only provide services to demand points within the maximum coverage radius. In the formula (12), x_{ij}, y_{cl}, y_j are all 0-1 variables.

Since the objective function contains uncertain variables, it is meaningless to maximize the objective function. Assuming that the expected value of the variable η_{ic} exists, the expected value of the objective function also exists.

$$\mathrm{E}\left(\min \sum_{\mathrm{i}=1}^{\mathrm{n}} \sum_{\mathrm{j}=1}^{\mathrm{n}} \left(d_{ij} + \zeta_{ij}\right) x_{ij}\right) = \min \sum_{\mathrm{i}=1}^{\mathrm{n}} \sum_{\mathrm{j}=1}^{\mathrm{n}} E\left(d_{ij} + \zeta_{ij}\right) x_{ij}.$$

$$\begin{aligned}
\mathrm{E}\left(\max \sum_{l=1}^{m} \sum_{i=1}^{n} \sum_{j=1}^{n} f_l\left(g\left(d_{ij} + \zeta_{ij}\right) x_{ij}\right)\right) &= \max E\left(\sum_{l=1}^{m} \sum_{i=1}^{n} \sum_{j=1}^{n} f_l\left(g\left(d_{ij} + \zeta_{ij}\right) x_{ij}\right)\right) \\
&= \max \sum_{l=1}^{m} \sum_{i=1}^{n} \sum_{j=1}^{n} E f_l\left(\left(g\left(d_{ij} + \zeta_{ij}\right)\right) x_{ij}\right) \\
&= \max \sum_{l=1}^{m} \sum_{i=1}^{n} \sum_{j=1}^{n} \int_0^1 \left(f_l\left(g\left(d_{ij} + \Phi_{ij}^{-1}(1-\alpha)\right)\right) x_{ij} \mathrm{d}\alpha\right.
\end{aligned}$$

Therefore, the expected model is as follows:

$$\begin{cases} \min \sum_{i=1}^{n} \sum_{j=1}^{n} \mathrm{E}\left(d_{ij} + \zeta_{ij}\right) x_{ij} \\ \max \sum_{l=1}^{m} \sum_{i=1}^{n} \sum_{j=1}^{n} \int_0^1 \left(f_l\left(g\left(d_{ij} + \Phi_{ij}^{-1}(1-\alpha)\right) x_{ij} \mathrm{d}\alpha\right.\right. \\ \max \sum_{i=1}^{n} \sum_{j=1}^{n} x_{ij} \\ \text{subject to:} \\ (7) \ -(12). \end{cases} \tag{13}$$

3.2 Tabu search algorithm

In this paper, tabu search algorithm is used to solve the emergency material location model in uncertain environment. The idea of tabu search algorithm was first proposed by Professor Glover, academician of American Academy of Engineering in 1986, and further defined and developed this method in 1989 and 1990. In the research field of natural computing, tabu search algorithm avoids detour search with its flexible storage structure and corresponding tabu criteria. It is unique in intelligent algorithms and has become a research hotspot, which has attracted extensive attention of scholars at home and abroad. In recent years, there has been more research on global optimization of functions, and there is a rapid development trend. The so-called tabu is to prohibit the repetition of the previous operation. In order to improve the problem that local neighborhood search is easy to fall into local optimality, tabu search algorithm introduces a tabu table to record the locally optimal point that has been searched. In the next search, the information in the tabu table is no longer searched or selectively searched, so as to jump out of the locally optimal point, and finally achieve global optimization. Tabu search algorithm is an extension of local neighborhood search. It is a global neighborhood search and step-by-step optimization algorithm.

The algorithm steps are as follows:

(1) Initialization. Clear the tabu table and set the tabu length.

(2) Generate the initial solution and calculate its fitness function value.

(3) Candidate solutions are generated through neighborhood search. According to the initial solution generated in (2), the candidate solution is generated by the search operator and the fitness function value of the candidate solution is calculated.

(4) Whether the best solution among the candidate solutions is better than the current global best solution.

(5) If the best solution among the candidate solutions is better than the current global best solution, then the best solution among the candidate solutions is selected; otherwise, the best solution among the candidate solutions that is not tabu is selected.

(6) Update the current solution and update the tabu table.

(7) Whether the number of iteration terminations has been reached. If yes, the iteration ends; otherwise, go back to step (3).

4 Numerical Examples

4.1 Examples

After a disaster in an area, there is a great demand for these six emergency materials: life detectors, first-aid drugs, bottled water, tents, cotton padded clothes and compressed food. There are twelve demand points with serial numbers from 1 to 12 that require these six emergency materials. The coordinates of the twelve demand points are (88, 16), (25, 76), (69, 13), (73, 56), (80, 100), (22, 92), (32, 84), (73, 46), (29, 10), (92, 32), (44, 44), (55, 26). When the demand point is used as the reserve point, the capacity of each reserve point is 30000 and the maximum service radius is 35. Through experts' evaluation of each type of emergency materials from the five factors of importance, scarcity, timeliness, irreplaceable and weight of emergency materials, the evaluation scheme $U = \{$importance, scarcity, timeliness, irreplaceable, weight of emergency materials$\}$. The three evaluation criteria for the above evaluation plan are very urgent, urgent, general, and these three evaluation criteria are expressed as three zigzag uncertain variables $\widetilde{q_1}$, $\widetilde{q_2}$, $\widetilde{q_3}$, where $\widetilde{q_1} \sim \mathcal{Z}(0.8, 0.9, 1.0)$, $\widetilde{q_2} \sim \mathcal{Z}(0.5, 0.6, 0.7)$, $\widetilde{q_3} \sim \mathcal{Z}(0.4, 0.6, 0.8)$. The evaluation of the urgency of the evaluation indicators by 10 experts is shown in Table 2. There are three types of comments for each factor: general, urgent and very urgent. Therefore, the comment set = $\{$very urgent, urgent, general$\}$. Set these three comments as uncertain variables $\widetilde{r_1}$, $\widetilde{r_2}$, $\widetilde{r_3}$, Where $\widetilde{r_1} \sim \mathcal{Z}(0.8, 0.9, 1.0)$, $\widetilde{r_2} \sim \mathcal{Z}(0.5, 0.6, 0.8)$, $\widetilde{r_3} \sim \mathcal{Z}(0, 0.3, 0.5)$. The emergency comments of experts on the evaluation indicators are shown in Table 3. The demand of six emergency materials at each demand point is shown in Table 4. The distance generated by road emergencies from demand point i to reserve point j is shown in Table 5.

Table 2: The evaluation of the urgency of the evaluation indicators

	Factor 1			Factor 2		
emergency materials	very urgent	urgent	generally	very urgent	urgent	generally
Life detectors	6	4	0	5	3	2
Bottled water	5	3	2	0	5	5
Emergency medicines	6	4	0	5	5	0
Cotton-padded clothes	0	4	6	0	5	5
Tents	2	1	7	0	4	6
Compressed foods	6	3	1	4	4	2

	Factor 3			Factor 4		
emergency materials	very urgent	urgent	generally	very urgent	urgent	generally
Life detectors	4	3	3	6	2	2
Bottled water	6	2	2	4	3	3
Emergency medicines	6	3	1	6	2	2
Cotton-padded clothes	3	2	5	3	4	3
Tents	3	2	5	2	3	5
Compressed foods	6	2	2	6	2	2
	Factor 5					
emergency materials	very urgent	urgent	generally			
Life detectors	0	3	7			
Bottled water	4	3	3			
Emergency medicines	2	5	3			
Cotton-padded clothes	4	3	3			
Tents	4	2	4			
Compressed foods	4	3	3			

Table 3: The emergency comments of experts on the evaluation indicators

	Factor 1			Factor 2		
emergency materials	very urgent	urgent	generally	very urgent	urgent	generally
Life detectors	5	4	1	6	2	2
Bottled water	6	2	2	0	5	5
Emergency medicines	6	4	0	5	5	0
Cotton-padded clothes	0	7	3	1	6	3
Tents	1	2	7	0	3	7
Compressed foods	6	3	1	0	5	5

	Factor 3			Factor 4		
emergency materials	very urgent	urgent	generally	very urgent	urgent	generally
Life detectors	7	2	1	7	3	0
Bottled water	7	3	0	6	3	1
Emergency medicines	6	3	1	6	2	2
Cotton-padded clothes	3	6	1	2	4	4
Tents	3	1	6	0	2	8
Compressed foods	6	2	2	6	2	2

	Factor 5		
emergency materials	very urgent	urgent	generally
Life detectors	4	3	3
Bottled water	6	3	1
Emergency medicines	2	5	3
Cotton-padded clothes	2	6	2
Tents	4	2	4
Compressed foods	4	3	3

Table 4: The demand of six emergency materials at each demand point

	1	2	3	4
Life detectors	$\mathcal{Z}$(600,650,680)	$\mathcal{Z}$(1000,1250,1380)	$\mathcal{Z}$(400,450,500)	$\mathcal{Z}$(300,350,400)
Bottled water	$\mathcal{Z}$(1200,1250,1280)	$\mathcal{Z}$(1500,1800,2000)	$\mathcal{Z}$(900,950,1000)	$\mathcal{Z}$(700,750,860)
Emergency medicines	$\mathcal{Z}$(1000,1030,1060)	$\mathcal{Z}$(1200,1400,1580)	$\mathcal{Z}$(700,730,760)	$\mathcal{Z}$(540,650,680)
Cotton-padded clothes	$\mathcal{Z}$(840,880,900)	$\mathcal{Z}$(1100,1250,1300)	$\mathcal{Z}$(500,540,580)	$\mathcal{Z}$(460,520,580)
Tents	$\mathcal{Z}$(500,540,580)	$\mathcal{Z}$(900,950,980)	$\mathcal{Z}$(300,350,400)	$\mathcal{Z}$(100,150,260)
Compressed foods	$\mathcal{Z}$(1300,1450,1500)	$\mathcal{Z}$(1800,1950,2100)	$\mathcal{Z}$(1000,1200,1300)	$\mathcal{Z}$(930,950,970)
	5	6	7	8
Life detectors	$\mathcal{Z}$(1500,1630,1760)	$\mathcal{Z}$(1200,1250,1300)	$\mathcal{Z}$(100,130,160)	$\mathcal{Z}$(1000,1030,1060)
Bottled water	$\mathcal{Z}$(2200,2300,2500)	$\mathcal{Z}$(1800,1950,2020)	$\mathcal{Z}$(600,650,700)	$\mathcal{Z}$(2000,2100,2300)
Emergency medicines	$\mathcal{Z}$(1800,1940,2060)	$\mathcal{Z}$(1500,1640,1780)	$\mathcal{Z}$(500,540,580)	$\mathcal{Z}$(1600,1730,1780)
Cotton-padded clothes	$\mathcal{Z}$(1600,1630,1660)	$\mathcal{Z}$(1000,1060,1120)	$\mathcal{Z}$(400,460,520)	$\mathcal{Z}$(1300,1430,1560)
Tents	$\mathcal{Z}$(1000,1030,1100)	$\mathcal{Z}$(800,830,860)	$\mathcal{Z}$(80,130,160)	$\mathcal{Z}$(860,930,980)
Compressed foods	$\mathcal{Z}$(2500,2630,2700)	$\mathcal{Z}$(2000,2300,2460)	$\mathcal{Z}$(800,900,960)	$\mathcal{Z}$(2100,2260,2360)

	9	10	11	12
Life detectors	$\mathcal{Z}$(500,630,760)	$\mathcal{Z}$(1400,1450,1500)	$\mathcal{Z}$(200,230,260)	$\mathcal{Z}$(1200,1230,1260)
Bottled water	$\mathcal{Z}$(1200,1300,1500)	$\mathcal{Z}$(2000,2150,2200)	$\mathcal{Z}$(700,750,800)	$\mathcal{Z}$(2200,2300,2500)
Emergency medicines	$\mathcal{Z}$(1300,1540,1760)	$\mathcal{Z}$(1700,1840,1980)	$\mathcal{Z}$(600,640,680)	$\mathcal{Z}$(1800,1930,1980)
Cotton-padded clothes	$\mathcal{Z}$(1100,1130,1160)	$\mathcal{Z}$(1200,1260,1320)	$\mathcal{Z}$(500,560,620)	$\mathcal{Z}$(1500,1630,1760)
Tents	$\mathcal{Z}$(400,530,600)	$\mathcal{Z}$(1000,1030,1060)	$\mathcal{Z}$(180,230,260)	$\mathcal{Z}$(1060,1130,1180)
Compressed foods	$\mathcal{Z}$(1500,1630,1700)	$\mathcal{Z}$(2200,2500,2660)	$\mathcal{Z}$(900,1000,1060)	$\mathcal{Z}$(2300,2460,2560)

In Table 2 and Table 3, factor 1 represents the importance of emergency materials; factor 2 represents the scarcity of emergency materials; factor 3 represents the timeliness of emergency material;, factor 4 represents the irreplaceable nature of emergency materials; and factor 5 represents the weight of emergency materials.

Table 5: The distance generated by road emergencies from demand point i to reserve point j

$\zeta_{1,2} \sim \mathcal{Z}(0, 0.5, 0.6)$	$\zeta_{1,3} \sim \mathcal{Z}(0.2, 0.4, 0.6)$	$\zeta_{1,4} \sim \mathcal{Z}(0.3, 0.6, 0.9)$	$\zeta_{1,5} \sim \mathcal{Z}(0.3, 0.5, 0.6)$
$\zeta_{1,6} \sim \mathcal{Z}(0.4, 0.5, 0.7)$	$\zeta_{1,7} \sim \mathcal{Z}(0.6, 0.8, 0.9)$	$\zeta_{1,8} \sim \mathcal{Z}(0.5, 0.6, 0.8)$	$\zeta_{1,9} \sim \mathcal{Z}(0.2, 0.4, 0.8)$
$\zeta_{1,10} \sim \mathcal{Z}(0.2, 0.3, 0.5)$	$\zeta_{1,11} \sim \mathcal{Z}(0.5, 0.7, 0.9)$	$\zeta_{1,12} \sim \mathcal{Z}(0.1, 0.2, 0.4)$	$\zeta_{2,3} \sim \mathcal{Z}(0.3, 0.6, 0.9)$
$\zeta_{2,4} \sim \mathcal{Z}(0.2, 0.5, 0.8)$	$\zeta_{2,5} \sim \mathcal{Z}(0.1, 0.3, 0.5)$	$\zeta_{2,6} \sim \mathcal{Z}(0.2, 0.4, 0.5)$	$\zeta_{2,7} \sim \mathcal{Z}(0.4, 0.5, 0.6)$
$\zeta_{2,8} \sim \mathcal{Z}(0.6, 0.8, 0.9)$	$\zeta_{2,9} \sim \mathcal{Z}(0.2, 0.3, 0.4)$	$\zeta_{2,10} \sim \mathcal{Z}(0.4, 0.6, 0.7)$	$\zeta_{2,11} \sim \mathcal{Z}(0.5, 0.6, 0.7)$
$\zeta_{2,12} \sim \mathcal{Z}(0.3, 0.5, 0.6)$	$\zeta_{3,4} \sim \mathcal{Z}(0.4, 0.6, 0.8)$	$\zeta_{3,5} \sim \mathcal{Z}(0.5, 0.7, 0.9)$	$\zeta_{3,6} \sim \mathcal{Z}(0.7, 0.8, 0.9)$
$\zeta_{3,7} \sim \mathcal{Z}(0.3, 0.5, 0.7)$	$\zeta_{3,8} \sim \mathcal{Z}(0.3, 0.4, 0.5)$	$\zeta_{3,9} \sim \mathcal{Z}(0.2, 0.4, 0.6)$	$\zeta_{3,10} \sim \mathcal{Z}(0.4, 0.7, 0.8)$
$\zeta_{3,11} \sim \mathcal{Z}(0.5, 0.7, 0.9)$	$\zeta_{3,12} \sim \mathcal{Z}(0.3, 0.6, 0.9)$	$\zeta_{4,5} \sim \mathcal{Z}(0.6, 0.7, 0.8)$	$\zeta_{4,6} \sim \mathcal{Z}(0.7, 0.8, 0.9)$
$\zeta_{4,7} \sim \mathcal{Z}(0.1, 0.2, 0.4)$	$\zeta_{4,8} \sim \mathcal{Z}(0.2, 0.3, 0.5)$	$\zeta_{4,9} \sim \mathcal{Z}(0.6, 0.8, 1)$	$\zeta_{4,10} \sim \mathcal{Z}(0.4, 0.6, 0.9)$
$\zeta_{4,11} \sim \mathcal{Z}(0.3, 0.5, 0.7)$	$\zeta_{4,12} \sim \mathcal{Z}(0.6, 0.7, 0.8)$	$\zeta_{5,6} \sim \mathcal{Z}(0.5, 0.6, 0.7)$	$\zeta_{5,7} \sim \mathcal{Z}(0.1, 0.3, 0.4)$
$\zeta_{5,8} \sim \mathcal{Z}(0.2, 0.4, 0.5)$	$\zeta_{5,9} \sim \mathcal{Z}(0.3, 0.5, 0.6)$	$\zeta_{5,10} \sim \mathcal{Z}(0.4, 0.6, 0.9)$	$\zeta_{5,11} \sim \mathcal{Z}(0.8, 0.9, 1)$
$\zeta_{5,12} \sim \mathcal{Z}(0.5, 0.6, 0.7)$	$\zeta_{6,7} \sim \mathcal{Z}(0.1, 0.3, 0.5)$	$\zeta_{6,8} \sim \mathcal{Z}(0.4, 0.6, 0.7)$	$\zeta_{6,9} \sim \mathcal{Z}(0.5, 0.7, 0.8)$
$\zeta_{6,10} \sim \mathcal{Z}(0.2, 0.4, 0.5)$	$\zeta_{6,11} \sim \mathcal{Z}(0.6, 0.8, 0.9)$	$\zeta_{6,12} \sim \mathcal{Z}(0.4, 0.5, 0.7)$	$\zeta_{7,8} \sim \mathcal{Z}(0.5, 0.6, 0.7)$
$\zeta_{7,9} \sim \mathcal{Z}(0.5, 0.6, 0.8)$	$\zeta_{7,10} \sim \mathcal{Z}(0.6, 0.8, 0.9)$	$\zeta_{7,11} \sim \mathcal{Z}(0.6, 0.7, 0.8)$	$\zeta_{7,12} \sim \mathcal{Z}(0.6, 0.8, 0.9)$
$\zeta_{8,9} \sim \mathcal{Z}(0.5, 0, 6, 0.7)$	$\zeta_{8,10} \sim \mathcal{Z}(0.2, 0.3, 0.4)$	$\zeta_{8,11} \sim \mathcal{Z}(0.5, 0.7, 0.8)$	$\zeta_{8,12} \sim \mathcal{Z}(0.1, 0.2, 0.3)$
$\zeta_{9,10} \sim \mathcal{Z}(0.2, 0.3, 0.6)$	$\zeta_{9,11} \sim \mathcal{Z}(0.5, 0.6, 0.8)$	$\zeta_{9,12} \sim \mathcal{Z}(0.2, 0.3, 0.5)$	$\zeta_{10,11} \sim \mathcal{Z}(0.2, 0.4.0.6)$
$\zeta_{10,12} \sim \mathcal{Z}(0.1, 0.2, 0.4)$	$\zeta_{10,12} \sim \mathcal{Z}(0.4, 0.6, 0.8)$		

4.2 Conduct uncertain comprehensive evaluation on six kinds of emergency materials

According to the weight determination method in the uncertain comprehensive evaluation method, calculate the weight of five factors for each material, as shown in Table 6.

Table 6: Five factor weights of six emergency materials

weight	$\widetilde{\omega_1}$	$\widetilde{\omega_2}$	$\widetilde{\omega_3}$
Life detectors	$\mathcal{Z}$(0.68,0.78,0.88)	$\mathcal{Z}$(0.63,0.75,0.87)	$\mathcal{Z}$(0.59,0.72,0.85)
bottled water	$\mathcal{Z}$(0.63,0.75,0.87)	$\mathcal{Z}$(0.45,0.6,0.75)	$\mathcal{Z}$(0.66,0.78,0.9)
Emergency medicines	$\mathcal{Z}$(0.68,0.78,0.88)	$\mathcal{Z}$(0.65,0.75,0.85)	$\mathcal{Z}$(0.67,0.78,0.89)
Cotton-padded clothes	$\mathcal{Z}$(0.44,0.6,0.76)	$\mathcal{Z}$(0.45,0.6,0.75)	$\mathcal{Z}$(0.54,0.69,0.84)
Tents	$\mathcal{Z}$(0.49,0.66,0.83)	$\mathcal{Z}$(0.44,0.6,0.76)	$\mathcal{Z}$(0.54,0.69,0.84)
Compressed foods	$\mathcal{Z}$(0.67,0.78,0.89)	$\mathcal{Z}$(0.6,0.72,0.84)	$\mathcal{Z}$(0.66,0.78,0.9)
weight	$\widetilde{\omega_4}$	$\widetilde{\omega_5}$	
Life detectors	$\mathcal{Z}$(0.66,0.78,0.9)	$\mathcal{Z}$(0.43,0.6,0.78)	
bottled water	$\mathcal{Z}$(0.59,0.72,0.85)	$\mathcal{Z}$(0.59,0.72,0.85)	
Emergency medicines	$\mathcal{Z}$(0.68,0.81,0.94)	$\mathcal{Z}$(0.53,0.66,0.79)	
Cotton-padded clothes	$\mathcal{Z}$(0.56,0.69,0.82)	$\mathcal{Z}$(0.59,0.72,0.85)	
Tents	$\mathcal{Z}$(0.51,0.66,0.81)	$\mathcal{Z}$(0.58,0.72,0.86)	
Compressed foods	$\mathcal{Z}$(0.66,0.78,0.9)	$\mathcal{Z}$(0.59,0.72,0.85)	

According to the evaluation factor determination method, the evaluation matrix of six emergency materials is obtained, as shown in Table 7.

Table 7: The evaluation matrix of six emergency materials is obtained

		Ri1	Ri2	Ri3
Life detectors	Factor 1	ℤ(0.4,0.45,0.5)	ℤ(0.2,0.24,0.32)	ℤ(0,0.03,0.05)
	Factor 2	ℤ(0.48,0.54,0.6)	ℤ(0.1,0.12,0.16)	ℤ(0,0.06,0.1)
	Factor 3	ℤ(0.56,0.63,0.7)	ℤ(0.1,0.12,0.16)	ℤ(0,0.03,0.05)
	Factor 4	ℤ(0.56,0.63,0.7)	ℤ(0.15,0.18,0.24)	ℤ(0,0,0)
	Factor 5	ℤ(0.32,0.36,0.4)	ℤ(0.15,0.18,0.24)	ℤ(0,0.09,0.15)
bottled water	Factor 1	ℤ(0.48,0.54,0.6)	ℤ(0.1,0.12,0.16)	ℤ(0,0.06,0.1)
	Factor 2	ℤ(0,0,0)	ℤ(0.25,0.3,0.4)	ℤ(0,0.15,0.25)
	Factor 3	ℤ(0.56,0.63,0.7)	ℤ(0.15,0.18,0.24)	ℤ(0,0,0)
	Factor 4	ℤ(0.48,0.54,0.6)	ℤ(0.15,0.18,0.24)	ℤ(0.5,0.6,0.8)
	Factor 5	ℤ(0.48,0.54,0.6)	ℤ(0.15,0.18,0.24)	ℤ(0.5,0.6,0.8)
Emergency medicines	Factor 1	ℤ(0.48,0.54,0.6)	ℤ(0.2,0.24,0.32)	ℤ(0,0,0)
	Factor 2	ℤ(0.4,0.45,0.5)	ℤ(0.25,0.3,0.4)	ℤ(0,0,0)
	Factor 3	ℤ(0.48,0.54,0.6)	ℤ(0.15,0.18,0.24)	ℤ(0,0.03,0.05)
	Factor 4	ℤ(0.48,0.54,0.6)	ℤ(0.1,0.12,0.16)	ℤ(0.,0.06,0.1)
	Factor 5	ℤ(0.16,0.18,0.2)	ℤ(0.25,0.3,0.4)	ℤ(0.,0.09,0.15)
Cotton-padded clothes	Factor 1	ℤ(0,0,0)	ℤ(0.35,0.42,0.56)	ℤ(0.,0.09,0.15)
	Factor 2	ℤ(0.08,0.09,0.1)	ℤ(0.3,0.36,0.48)	ℤ(0.,0.09,0.15)
	Factor 3	ℤ(0.24,0.27,0.3)	ℤ(0.3,0.36,0.48)	ℤ(0,0.03,0.05)
	Factor 4	ℤ(0.16,0.18,0.2)	ℤ(0.2,0.24,0.32)	ℤ(0,0.12,0.2)
	Factor 5	ℤ(0.16,0.18,0.2)	ℤ(0.3,0.36,0.48)	ℤ(0,0.06,0.1)
Tents	Factor 1	ℤ(0.08,0.09,0.1)	ℤ(0.1,0.12,0.16)	ℤ(0,0.21,0.35)
	Factor 2	ℤ(0,0,0)	ℤ(0.15,0.18,0.24)	ℤ(0,0.21,0.35)
	Factor 3	ℤ(0.24,0.27,0.3)	ℤ(0.05,0.06,0.08)	ℤ(0,0.18,0.3)
	Factor 4	ℤ(0,0,0)	ℤ(0.1,0.12,0.16)	ℤ(0,0.24,0.4)
	Factor 5	ℤ(0.32,0.36,0.4)	ℤ(0.1,0.12,0.16)	ℤ(0,0.12,0.2)
Compressed foods	Factor 1	ℤ(0.48,0.54,0.6)	ℤ(0.15,0.18,0.24)	ℤ(0,0.03,0.05)
	Factor 2	ℤ(0,0,0)	ℤ(0.25,0.3,0.4)	ℤ(0,0.15,0.25)
	Factor 3	ℤ(0.48,0.54,0.6)	ℤ(0.1,0.12,0.16)	ℤ(0,0.06,0.1)
	Factor 4	ℤ(0.48,0.54,0.6)	ℤ(0.1,0.12,0.16)	ℤ(0,0.06,0.1)
	Factor 5	ℤ(0.32,0.36,0.4)	ℤ(0.15,0.18,0.24)	ℤ(0,0.09,0.15)

In the table 7, factor 1 represents the importance of emergency materials, factor 2 represents scarcity, factor 3 represents timeliness, factor 4 represents irreplaceable, and factor 5 represents the weight of emergency materials.

Calculate the uncertain evaluation matrix according to formula (1), and obtain the evaluation results of six kinds of emergency materials and the grades of emergency materials, as shown in Table 8 and table 9.

Table 8: Evaluation results

Emergency materials	very urgent	urgent	general	Evaluation results
Life detectors	1.917	0.638	0.578	very urgent
bottled water	1.674	0.698	0.163	very urgent
Emergency medicines	1.7361	0.883	0.12	very urgent
Cotton-padded clothes	0.4941	1.189	0.233	urgent
Tents	0.5049	0.411	0.581	general
Compressed foods	1.5228	0.701	0.266	very urgent

Table 9: Level of emergency materials

Emergency materials	very urgent	urgent	general
Life detectors	1	0	0
bottled water	1	0	0
Emergency medicines	1	0	0
Cotton-padded clothes	0	1	0
Tents	0	0	1
Compressed foods	1	0	0

4.3 Implementation of tabu search algorithm

4.3.1 Coding

In this paper, the 01 code and the natural number code are combined to generate chromosomes. In the example, there are 12 demand points, among which 4 demand points are selected as a reserve point. The code design is: [0, 1, 1, 0, 0, 0, 1, 0, 0, 1, 2, 1, 3, 4, 3, 3, 1, 2, 1, 4, 2], of which the first 12 digits [0, 1, 1, 0, 1, 0, 0, 1, 0, 0, 0, 0] indicate whether the demand point numbered 1-12 is selected as a reserve point, Here, demand points 1, 2, 4 and 8 are selected as reserve points, and their serial numbers are 1, 2, 3 and 4. The following 12 bits [1, 2, 1, 3, 4, 3, 3, 1, 2, 1, 4, 2] correspond to demand points 1-12. 1, 2, 3 and 4 represent that the service is provided by reserve points 1, 2, 3 and 4, that is, 1, 2, 4 and 8 corresponding to demand point serial numbers.

4.3.2 Design of tabu search algorithm

The idea of the tabu search algorithm is to improve the search efficiency by not repeating the search for the solution that has been searched. The algorithm designed two tabu tables in the process of solving: a global tabu table and a local tabu table. In the neighborhood search, it uses random pairs to exchange the locations of the two cities with a certain probability to obtain a new path. Among them, the global tabu table stores the results of the latest n generations in the iteration process (n is the length of the tabu), and the local tabu table stores the new path traversed in each generation of domain search to achieve global tabus (global non-repetitive search) and local tabu (neighborhood). Domain traversal does not repeat search).

4.3.3 Result

According to the above algorithm principle, use python software to program and solve the emergency material location model, obtain the location plan of the reserve point and the iterative convergence curve of the tabu search algorithm, as shown in Figure 4 and Figure 5, and obtain the results of the location selection and reserve amount of the graded emergency materials through calculation , as shown in Table 10.

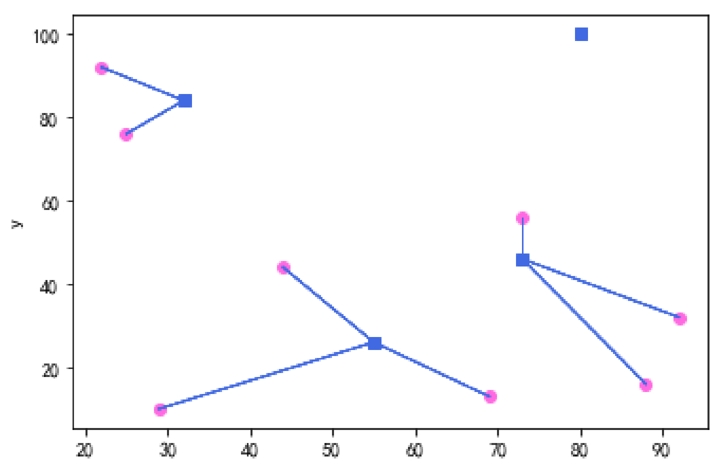

Figure 4: Location map of emergency materials reserve point

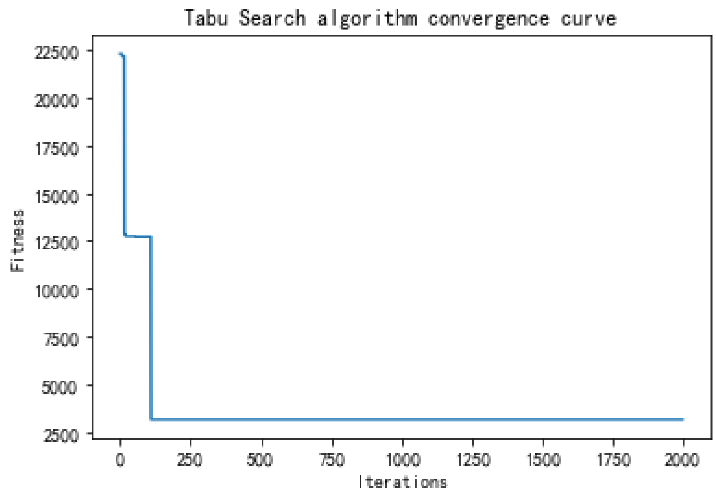

Figure 5: Convergence curve of tabu search algorithm

Table 10: Location selection and reserve of graded emergency materials

Reserve points	Demand points	Very urgent	Urgent	General
5	5	8055	1630	1040
6	2 6 7	15635	2745	1900
10	1 4 8 10	21882	4085	2145
12	3 9 11 12	18875	3860	2215

In Figure 4, the blue dot represents the selected reserve point, the pink dot represents the demand point, and the line represents that the reserve point provides services to the demand point. Selecting 5, 6, 10 and 12 as reserve points can minimize the transportation time.

5 Conclusion

Although many scholars have done a lot of work on the location problem, the parameters are determined. Few articles discuss the location problem in uncertain environment. When a disaster occurs, the demand for various emergency materials is very large. Many factors are uncertain in the process of emergency material preparation. We can only estimate the severity of this emergency based on previous disasters and experts experience.

In this paper, we have done the following work. Firstly, the demand of emergency materials, the distance caused by road emergencies, and the response time from demand point to reserve point were considered as uncertain variables. Secondly, considering the time urgency of emergency materials, in order to grade emergency materials according to the emergency needs, we put forward several main factors affecting the urgency of demand: the importance, scarcity, timeliness, irreplaceable and the weight of emergency materials. And the uncertain comprehensive evaluation method was used to grade the emergency materials. Finally, considering that different emergency materials have different demand levels, the time effect function was introduced to express the satisfaction of different levels of emergency materials, and the uncertain emergency material location model was established. The model was transformed into a deterministic form, and satisfactory reserve points were obtained by using tabu search algorithm. In the future research, we will further consider the allocation of transport vehicles and transportation routes.

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