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Study on the Site Selection of Emergency Material Reserve Point

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Abstract: The site selection of emergency material reserve point is a key problem to solving the distribution optimization of emergency materials reserve. In this paper, according to the characteristics of emergency material reserves, we comprehensively considered the shortest distance, the shortest time, transportation costs, construction costs, storage quantity and other factors, and established the analysis model to make optimization to the reserve point site selection.

Keywords: Analysis model, emergency materials, reserve point, site selection.

1. INTRODUCTION

Emergency material reserve point site selection is a key problem to solving the distribution optimization of emergency material reserve, which is, on the basis of the existing reserve points addresses, according to the possible task, the terrain and traffic conditions, the storage conditions and the allocation of resources, *etc.*, to scientifically determine or adjust the materials reserve distribution, thus, providing more effective material supply for the national material reserve construction and the dealing with emergencies [1, 2]. Under normal circumstances, the site selection model of emergency material reserve point is established on the basis of the demand situation of variety and quantity from the front supplying points. Then according to the emergency security demand, we select single or multiple emergency material reserves, so that the distribution of emergency material reserves can reach the optimal point. In the premise of meeting emergency material supply, the front time is the shortest, the quantity and quantity of reserves are the most reasonable [3].

2. THE GOAL OF SITE SELECTION OF EMERGENCY MATERIAL RESERVE POINT

2.1. The Shortest Distance [4]

On the premise that the distance between reserve and the furthest demanding point meets the requirement of material security, the shorter, the better. For instance: emergency material reserve point is at a distance of 150~200 km to the front, within which range it is better to have shorter front distance, the optimization goal is to find the a reserve that has the shortest distance to the demanding point.

2.2. The Minimum Time

If there are multiple reserves, under the situation of same time multiple security, the optimization goal is to find a reserve that has the shortest time to demanding point.

2.3. The Minimum Transport Cost

If there is the least transportation cost from a reserve point to each demanding point, it means that there is minimum number of total ton kilometer of material transportation. The goal is for the usual material supply management, to

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achieve the purpose of economization.

2.4. The Minimum Reserve Point Construction Cost

Emergency material reserve construction cost mainly refers to the construction cost of geography, including buildings, equipment, land and transport distance, *etc*. This cost is related to the geographical location and the scope of the reserve point.

2.5. The Minimum Number of Reserve on the Premise of Meeting Sustainable Consumption

The emergency material reserve quantity of a reserve point should meet the requirements of sustainable consumption within the time limit. Over the limitation it is wasteful while below the limitation it can not achieve the security requirements.

3. THE LIMITATIONS ON THE SITE SELECTION GOAL OF EMERGENCY MATIERIAL RESERVE POINT

Because of the continuity of material consumption, we can omit the consideration of the material transportation equipment restrictions. It is acceptable so long as the quantity shipped within the prescribed time limit can meet the emergency security demand.

3.1. Place of Production and Delivery Time of Materials

According to the reserve distribution and production quantity of rear material supplying point, we determine the position, the size and the number of the emergency material reserves [5, 6]. Reserves should have the capacity for continuous supply, and in a long time, the continual material security ability is not necessarily associated with reserve capacity. That is to say, as long as the rear supplying point can provide the latter material supply, the security capacity of emergency material reserve point can avoid the restriction from reserve capacity, and the continual security capacity can be greatly extended. As for the delivery time, materials must be delivered before the end of material consumption, that is, a breaking of supply is not allowed.

3.2. The Distance and Material Transport Modes

The determination of the distribution of emergency material reserve points should be comprehensively considered according to the various modes of transport used here [7]. And according to the requirements and the characteristics of different modes of transport, arrangement of emergency material reserve point configuration should be reasonable, so that the target of reserve optimization and transportation optimization can be achieved. In addition, in the practical use, not just one single mode of transport is used. Rather, it is usual that many modes of transport are combined together, railway, highway, waterway, *etc*., are integrated together. Considering this, the shift of mode of transport as well as the road transfer problem must also be taken into account.

3.3. The Road Capacity (Passing Access) Used for Material Transportation

We use the general algorithm for the maximum flow in graph theory, to get network feasible flow between reserves and demanding points in the network. It is also the maximum flow through the road network, and its condition of equilibrium is in each intermediate point, the total amount of material imported equals to total goods exported. Then according to emergency conditions of other transport tasks, the passable flow of material transportation can be determined [8].

We can set D= (V, E, C(e), vs, vt) as a capacity network for emergency material transportation, and set two specific points in D. One is called the starting point of emergency materials, denoted as vs; the other is called the receiver (demanding point), denoted as vt. Other points in D are called the intermediate points. If f = (f_{ij}) is a feasible flow on network D, then the following two conditions should be satisfied:

$$\begin{cases} 0 \le f_{ij} \le c_{ij} \\ f(v_i, V) - f(V, v_i) = \begin{cases} v(f), v_i = v_s \\ 0, v_i \ne v_s, v_t \\ -v(f), v_i = v_t \end{cases} \end{cases} \tag{1}$$

The question is to get the feasible flow that can make v(f) reach the maximum on D, this feasible flow is the maximum flow of the network.

4. IMPLEMENTATION STEPS OF EMERGENCY MATERIAL RESERVE POINT SITE SELECTION

The key of the implementation of emergency material reserve point site selection is the determination of the alternative emergency material reserve. The establishment of an alternative emergency material reserve point should consider factors such as reserve conditions, traffic conditions, safety and the difficulty of supplement, *etc*. Not all the positions that can establish material base stations can be alternative reserve points.

4.1. To Determine Alternative Reserve Points According to the Task

According to the different tasks and the material sources, alternative reserve points are selected. The selection of the alternative point has a direct impact on the optimal scheme and calculation and operation costs. If there are too much alternatives, it will make the model more complex and the computational workload will be increased; while if there are too little alternatives, it may make the optimization scheme far away from the optimal solution, then it will not be up to the purpose of reasonable distribution.

4.2. The Comprehensive Evaluation on Each Reserve Point

After the determination of alternative emergency material reserve points, specific analysis and comprehensive evaluation on each alternative should then be carried out, from the point of view of the overall benefits, weighting the size of function of the alternative points in the distribution. Evaluation indexes include [9]:

1. Reserve conditions: water, land, topography, slope, *etc*.
2. Traffic conditions: railways nearby, road conditions, traffic access, *etc*.
3. Hidden terrain conditions: evacuation areas, land cover, *etc*.
4. Close to the material demanding point: standard transporting distance, the actual distance, arrival time.
5. Close to the material supplying point: the actual distance, delivery time.
6. To conduct a comprehensive evaluation by using correlation matrix method.

We set $A_1, A_2, \ldots, A_m$, is the number m evaluation schemes. $X_1, X_2, \ldots, X_n$ is the number n evaluation index of the alternative scheme of evaluation. $W_1, W_2, \ldots, W_n$ is the number n weighing of evaluation index. $V_{i1}, V_{i2}, \ldots, V_{in}$ is the number i alternative scheme concerning value assessment of X_j index (j=1, 2,... n). The relative correlation matrix is shown in Table **1**.

Table 1. The correlation matrix of alternative comprehensive evaluation.

	$x_1\ x_2 \ldots x_j \ldots x_n$	v_i
	$w_1\ w_2 \ldots w_j \ldots w_n$	
A_1	$v_{11}\ v_{12} \ldots v_{1j} \ldots v_{1n}$	$v_1=w_1 v_{11}+w_2v_{12}+\ldots+w_nv_{1n}$
A_2	$v_{21}\ v_{22} \ldots v_{2j} \ldots v_{2n}$	$v_2=w_1v_{21}+w_2v_{22+}\ldots+w_nv_{2n}$
…	… … … …	…
A_m	$v_{m1}\ v_{m2} \ldots v_{mj} \ldots v_{mn}$	$v_m=w_1v_{m1}+w_2vm_2\ldots+w_nvm_n$

$$\begin{pmatrix} v_1 \\ v_2 \\ \cdots \\ v_m \end{pmatrix} = V \quad VW = \begin{pmatrix} v_{11} & v_{12} & \cdots & v_{1n} \\ v_{21} & v_{22} & \cdots & v_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ v_{m1} & v_{m2} & \cdots & v_{mn} \end{pmatrix} \tag{2}$$

4.3. Comprehensive Evaluation

For different evaluation indexes, it is difficult to compare in the same standard, because the convenient transport hubs are often in poor hidden conditions, the reserve position that near the front are usually poorly secured, those areas that are convenient for material supply are often geographically distant from front supplementing points [10]. In this case, pair comparison can be used on different evaluation indexes for weighting, which is, to make assessment on alternative schemes, basing on a certain standard while using all the evaluation indexes. comprehensive evaluation value by the weighted method of evaluation of alternatives, then to make comprehensive evaluation on all the evaluation indexes of alternative schemes by using the method of weighting.

After pair comparison on the evaluation indexes, we think that the relative important indexes get score of 1, the relative less important indexes get score of 0. In this way, the evaluation indexes weightings after comparison are shown in Table **2** [11].

Table 2. The pair comparison for calculation of weighting.

Evaluation Index	Judge										Score	Weighting
	1	2	3	4	5	6	7	8	9	10		
Reserve condition	1	1	1	0							3	0.3
Transport condition	0				1	1	1				3	0.3
Hidden terrain conditions		0			0			1	1		2	0.2
Close to demand point			0			0		0		1	1	0.1
Close to supplying point				1			0		0	0	1	0.1
Sum	1	1	1	1	1	1	1	1	1	1	10	1

After getting the weighting value of evaluation indexes, then we made comprehensive evaluations on each alternative reserve point, and the criteria are classified into: good, average, bad. For instance, the evaluations on 8 alternative emergency material reserves are shown in Table **3**.

Table 3. The alternative point evaluation situations.

Evaluation Index Alternative Reserve	Storage Conditions	Transport Conditions	Hidden Terrain Conditions	Close to Demand Point	Close to Supplying Point
b_1	Good	Average	Average	Good	Bad
b_2	Bad	Bad	Good	Average	Bad
b_3	Average	Average	Average	Average	Average
b_4	Good	Good	Bad	Good	Bad
b_5	Average	Good	Average	Bad	Good
b_6	Average	Good	Bad	Bad	Good
b_7	Bad	Bad	Good	Bad	Average
b_8	Bad	Average	Average	Average	Average

According to the evaluation of each alternative point, the good get scores of 2, the average get 1, the bad get 0. In this way, the alternative points scores are shown in Table **4**.

According to Table **4** the scores of each reserve point are:

b_1:2×0.3+1×0.3+1×0.2+2×0.1+0×0.1=1.3
b_2:0×0.3+0×0.3+2×0.2+1×0.1+0×0.1=0.5
b_3:1×0.3+1×0.3+1×0.2+1×0.1+1×0.1=1.0
b_4:2×0.3+2×0.3+0×0.2+2×0.1+0×0.1=1.4
b_5:1×0.3+2×0.3+1×0.2+0×0.1+2×0.1=1.3
b_6:1×0.3+2×0.3+0×0.2+0×0.1+2×0.1=1.1
b_7:0×0.3+0×0.3+2×0.2+0×0.1+1×0.1=0.5
b_8:0×0.3+1×0.3+1×0.2+1×0.1+1×0.1=0.7

4.4. The Selection of Alternative Points

According to the comprehensive evaluation on the below alternatives, we can omit some alternatives that cannot meet the requirements of an emergency material reserve, so that to reduce the complexity of subsequent model. For example taking the evaluation score of 1 as the standard, if the score is greater than 1 then it can be taken as an alternative point, if the score is less than 1 then it can not be taken as an alternative point. In this way, alternative b_2, b_7, b_8, which meet the requirement, can be removed, while the remaining 5 alternative points are reserved [12].

4.5. The Site Selection of Emergency Material Reserves by Multi-target Decision Making Method

In practical application, there are different site selection criteria on the assemble scheme of emergency material reserves. We consider using multi-objective decision making method, comprehensively considering the factors as emergency material reserve distance, time, transport cost, construction cost, reserves number, *etc*., and to give different weighted coefficient and then to get the optimal scheme of emergency material reserves.

Table 4. The alternative points scores.

Evaluation Index Alternative Reserve	Storage Conditions	Transport Conditions	Hidden Terrain Conditions	Close to Demand Point	Close to Supplying Point
b_1	2	1	1	2	0
b_2	0	0	2	1	0
b_3	1	1	1	1	1
b_4	2	2	0	2	0
b_5	1	2	1	0	2
b_6	1	2	0	0	2
b_7	0	0	2	0	1
b_8	0	1	1	1	1

4.5.1. The Establishment of the Model

Firstly we need to determine the purpose of evaluation and the establishment of evaluation index. The evaluation index can be established through expert scoring and the comprehensive review; alternative schemes can be determined by review from policy-makers and experts.

According to the evaluation index and evaluation purposes, as well as the alternative schemes, the analysis model is established. See in Fig. (**1**).

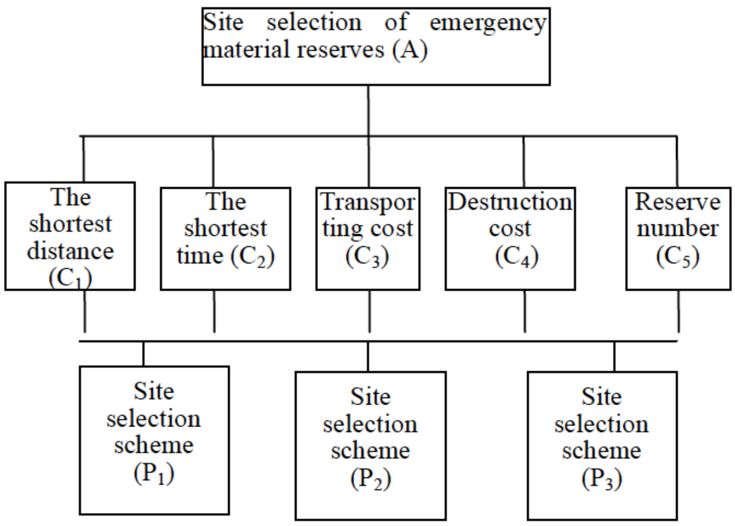

Fig. (1). The emergency material reserve optimization level model.

4.5.2. The Integration of Criteria

As can be seen from the graph, measurement criteria of each evaluation unit is different, including distance, time, cost, quantity and so on, which makes it unable to make comparison. Therefore, we must transfer the values of these units into the comparable utility value to represent. The utility value is all the numbers of 0 to 1, the utility value of the worst level of each target is 0, eliminating the ones lower than the worst; the utility value of the worst level of each target is 1, taking the ones higher than the best as the same level of the best and get a value of 1.

Thus, we can draw the utility curve of each target, and calculate out the utility value of each target in each scheme. In this way, the curve of utility value taking distance as the optimization objective are shown in Fig. (**2**).

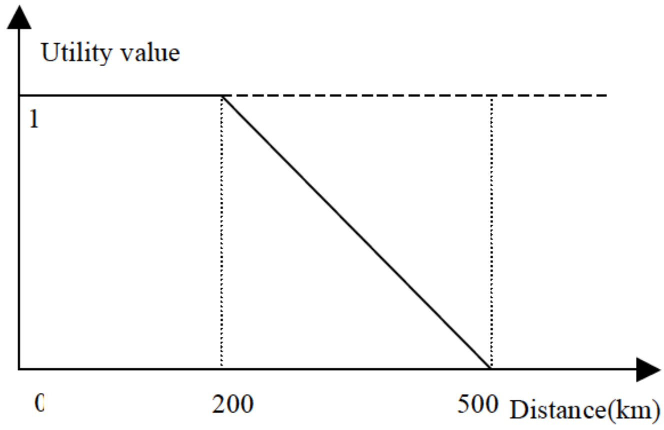

Fig. (2). The curve of utility value taking distance as the optimization objective.

In this way, the curve of utility value taking time as optimization target are shown in Fig. (**3**).

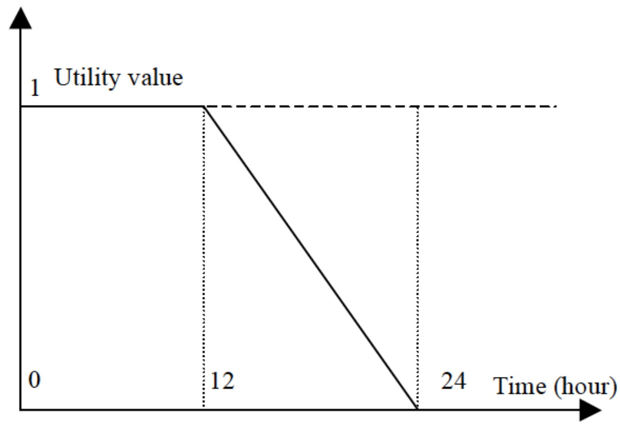

Fig. (3). The curve of utility value taking time as the optimization objective.

In this way, the curve of utility value taking transport cost as optimization target are shown in Fig. (**4**).

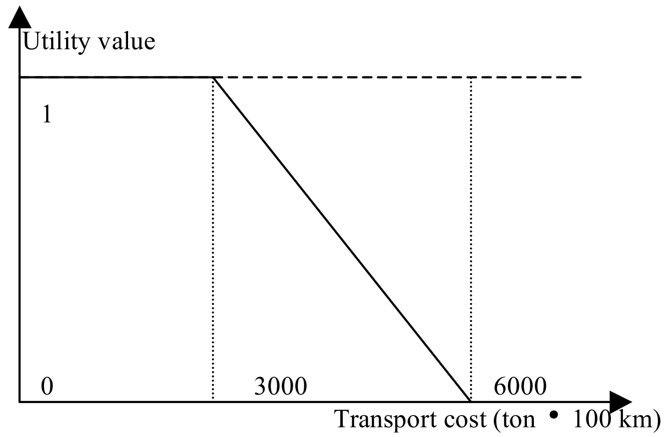

Fig. (4). The curve of utility value taking transport cost as the optimization objective.

In this way, the curve of utility value taking construction cost as optimization target are shown in Fig. (**5**).

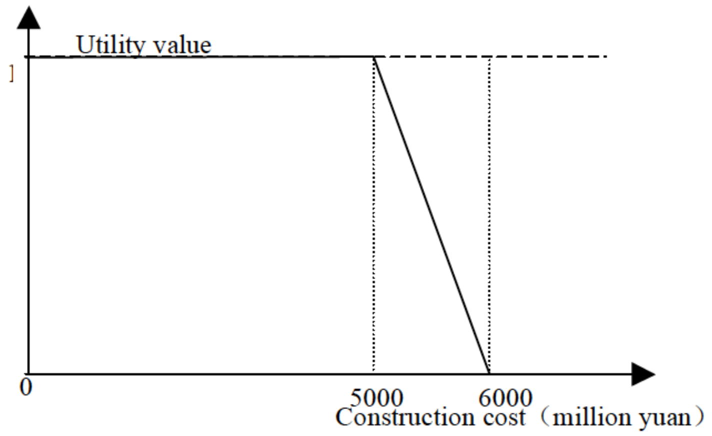

Fig. (5). The curve of utility value taking construction cost as the optimization objective.

In this way, the curve of utility value taking reserve number as optimization target are shown in Fig. (**6**).

4.5.3. The Case of Omitting

Taken as a alternative scheme, if there is one in all the target that surpass the worst degree, then it will be taken as a bad case for omitting.

4.5.4. The Additional Coefficient

In the above targets, not all the targets are of equal importance, therefore we need to consider the degree of importance of each target in optimization and give it appropriate coefficient.

Table 5. The comparison table of target value of reserve distribution scheme.

Optimization Target Scheme	The Shortest Distance (km)	The Shortest Time (Hour)	Transporting Cost (Ton100 km)	Construction Cost (Million Yuan)	Reserve Number (Ton)
P_1	350	15	4000	55	12000
P_2	410	18	4500	58	15000
P_3	320	20	5000	54	16000

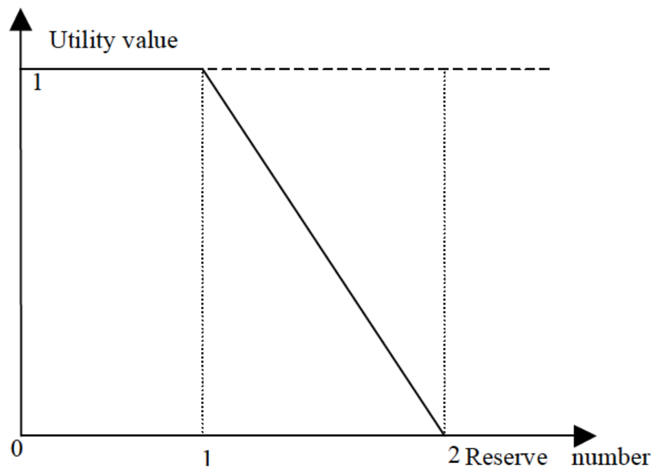

Fig. (6). The curve of utility value taking reserve number as optimization target.

4.5.5. The Additional Coefficient

In the above targets, not all the targets are of equal importance, therefore we need to consider the degree of importance of each target in optimization and give it appropriate coefficient.

$$\begin{cases} \min F \\ F = \sum_{i=1}^{n} K_i C_i = K_1 C_1 + K_2 C_2 + K_3 C_3 + K_4 C_4 + K_5 C_5 \end{cases} \quad (3)$$

4.5.6. Examples of Application

Suppose there are P_1, P_2, P_3, the distribution scheme, we comprehensively take into consideration optimization targets--- the shortest distance, the minimum time, the minimum cost, and minimum construction cost and the minimum reserve number, *etc*., to make comparing optimization of emergency material reserve. The 3 reserve scheme target values are shown in Table **5**.

According to the utility degree set above, utility value calculation is made and we get result shown in Table **6**.

From the table we can see when using the scheme of P_1, multi-target utility value gets the maximum, *i.e.*, the optimal reserve effectiveness can get. So the optimal result of multi-target decision making is selection scheme of P_1.

Table 6. Utility value comparison of reserve distribution scheme.

Target Utility Scheme	Minimum Distance (×2)	Minimum Time (×3)	Transport Cost (×3)	Construction Cost (×1)	Reserve Number (×1)	Total Sum of Utility
P_1	0.5/1	0.75/2.25	0.67/2	0.5/0.5	0.8/0.8	6.55
P_2	0.3/0.6	0.5/1.5	0.5/1.5	0.2/0.2	0.5/0.5	4.3
P_3	0.6/1.2	0.33/1	0.33/1	0.6/1.2	0.4/0.4	4.8

CONCLUSION

The optimization model above is the optimization of multi-condition and multi-target in general circumstances, multi-objective. We can see from the optimization target that some optimization targets may be contradictory. As for solving these questions, generally there is no optimal solution existed. In a range of feasible solution, calculating by fuzzy logic multi-target genetic algorithm, we can receive a better efficiency.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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