Research on National Park Emergency Supplies Management in Fuzzy Environment

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Abstract: At present, most of the researches on emergency supply management in fuzzy environment are focused on single-supply cases. This paper discusses a multi-demand point optimization in fuzzy environment with two decision variables amount and route. We present a feasible replenishment strategy and a hybrid model with fuzzy chance-constrained programming and genetic algorithm. In the proposed algorithm, firstly optimize replenishment amount in fixed route by fuzzy chance-constrained programming. Finally, take every route's target value from previous step as genetic algorithm's fitness to optimize second decision variables route. The result of example indicates the mixed model is effective and feasible.

1. Introduction

In 2019, Tibet will launch the construction of Third Pole national park group to drive the green development. After the opening of the Qinghai-Tibet Railway in 2006, the development of tourism has developed rapidly in Tibet. Only 6 years, the total number of tourists increased from 929 thousand in 2006 to 10.584 million with 103 times growth. The ratio of the tourists to permanent population

In Tibet is largely greater than the same in eastern coastal cities[1]. Meanwhile, the climate characteristics of high-cold and high-altitude area and diversified landforms result in frequent disasters. Wang made statistics on 299 natural disasters in Tibet during 2008 to 2014, with an average of 43.7 disasters each year[2]. However, limited emergency rescue conditions of security department and health department in Third Pole national park group alternative region lead to difficulties in emergency rescue. Therefore, it is beneficial to set up several safety houses with emergency supplies in advance to deal with emergencies.

Liu presents crisp equivalents of chance constraints in fuzzy environments analogous to stochastic programming[3]. Lu converts constraint with fuzzy parameters to crisp equivalent which can be solved by linear programming[4]. Qian establish a single-cycle and single-item emergency supply inventory model at a certain level of inventory service in uncertain environment by using fuzzy and random theory[5]. Guo established a single-demand dynamic emergency supply inventory model in triangular fuzzy information environment and represents equivalent fuzzy chance-constrained programming model[6]. This paper discusses a multi-demand point optimization in fuzzy environment with two decision variables amount and route. Comparing with single-demand point, multi-demand point, multi-demand point optimization need to deal with the uncertainty of the number of satisfied demand points and order in which demand points are satisfied. In this paper, we establish fuzzy chance-constrained programming for every situation in fixed route to optimize every route's best replenishment amount. Then take every route's target cost value as genetic algorithm's fitness to optimize second decision variables route.

2. Discussed Problem

2.1 Problem Description

There are multiple safety houses in the national park. Each safety house has fuzzy need for seasonal emergency supplies. The emergency supplies warehouse is responsible for replenishing

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each safe house inventory to the upper limit of fuzzy consumption at the beginning of each time cycle. Under the condition that the remaining amount of emergency supplies in the safety house at the beginning of the period is unknown, the manager needs to measure the risk of amount of emergency supplies. If amount is too large, it will pay more on cost for more weight in each transportation. If amount is too little, it will pay more on cost for more transportation times. So managers need to reasonably arrange the quantity and route of emergency supplies for the first time at the beginning of each period to achieve economic optimality.

2.2 Problem Assumption

(1) Transportation cost on every route is related to weight, and can be calculated by multiplying the weight of vehicle with emergency supplies and unit transportation cost.
(2) Number of safety houses is more than one.
(3) Number of emergency supplies warehouse is one.
(4) Number of transport vehicle is one.
(5) Each safety house's uncertain emergency supplies consumption for every period is triangular fuzzy number.

2.3 Parameter Setting

Parameters are set as follows . T represents number of periods. I represents number of safety houses. f represents transportation cost function of every period. X^t represents amount of emergency supplies for first time at the beginning of every period. $\widetilde{D_i^t}$ represents triangle fuzzy number of each safety houses' emergency supplies consumption for every period. $\widetilde{S_i^t}$ represents residual emergency supplies for each safety house at the beginning of every period. $\widetilde{Q_i^t}$ represents the amount of each safety houses' e mergency supplies demand at the beginning of every period. L : presents distance matrix between warehouse and safety houses. C_1 represents unit transportation cost for vehicle weight. C_2 represents unit transportation cost for emergency supplies weight. R represents Route to replenish safety houses' emergency supplies inventory. In discussed problem, f is the target value, X^t and R are decision variables.

3. Model Building and Analysis

3.1 Replenishment Strategy

Each safety houses' emergency supplies consumption can be represented by a triangular fuzzy number $\widetilde{D_i^t}$. Each safety houses' emergency supplies consumption at $t-1$ period can be represented by $\widetilde{D_i^{t\text{-}1}} = (\underline{d_i^{t\text{-}1}}, d_i^{t\text{-}1}, \overline{d_i^{t\text{-}1}})$. So Each safety houses' residual emergency supplies can be calculated by $\widetilde{S_i^t} = \overline{d_i^{t\text{-}1}} \text{-} (\underline{d_i^{t\text{-}1}}, d_i^{t\text{-}1}, \overline{d_i^{t\text{-}1}}) = (0, \overline{d_i^{t\text{-}1}} - d_i^{t\text{-}1}, \overline{d_i^{t\text{-}1}} - \underline{d_i^{t\text{-}1}})$. Considering the weak economic characteristic of emergency supplies, it is necessary to add every safety houses' inventory to the upper limit of the consumption $\widetilde{D_i^t}$. So the demand $\widetilde{Q_i^t}$ can be calculated by $\widetilde{Q_i^t} = \overline{d_i^t} - (0, \overline{d_i^{t\text{-}1}} - d_i^{t\text{-}1}, \overline{d_i^{t\text{-}1}} - \underline{d_i^{t\text{-}1}}) = (\overline{d_i^t} - \overline{d_i^{t\text{-}1}} + \underline{d_i^{t\text{-}1}}, \overline{d_i^t} - \overline{d_i^{t\text{-}1}} + d_i^{t\text{-}1}, \overline{d_i^t})$.

Replenishment strategy is to transport emergency supplies according to the given route. Even if a safety house can't be satisfied, workers still drive vehicle to check the following safety houses' inventory to know the actual demand, then returns to the emergency warehouse for second replenishment time.

3.2 Technology Roadmap

In discussed problem, wo have two decision variables X^t and R . First use fuzzy chance-constrained programming to optimize first decision variable X^t under the fixed route R. Then regard fuzzy chance-constrained programming's target value as genetic algorithm's fitness to optimize last decision variables route R.

3.3 Fuzzy Chance-Constrained Programming

Under the fixed route R, there are $I+1$ possible situations. Take three safety houses for example, the amount X^t of emergency supplies for the first time may satisfy zero, one, two or three safety houses. For each situation, wo have different route and objective function with respective constraints. So we can use piecewise function to represent cost expression $f(X^t, Q_1^t, Q_2^t, Q_3^t)$.

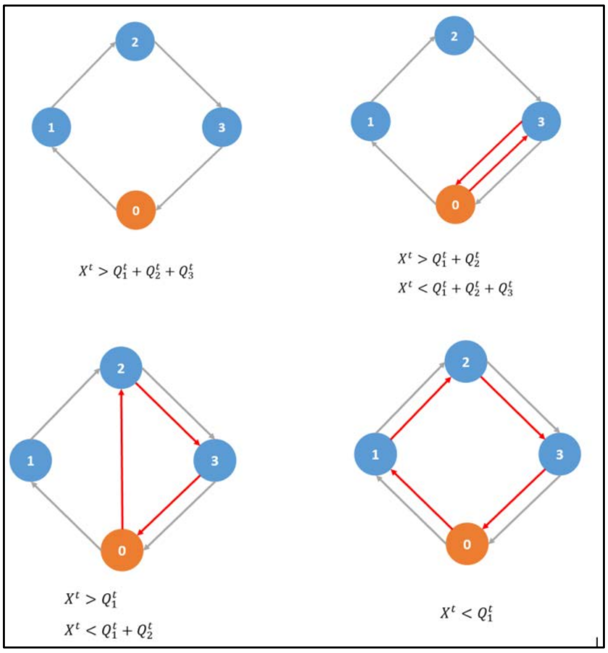

Fig.1 Different Situations for Three Safety Houses

$$f(X^t,Q_1^t,Q_2^t,Q_3^t)=\begin{cases} C_1\cdot(L_{0,1}+L_{1,2}+L_{2,3}+L_{3,0})+C_2\times\left[X^t\cdot L_{0,1}+(X^t-Q_1^t)\cdot L_{1,2}+(X^t-Q_1^t-Q_2^t)\cdot L_{2,3}+(X^t-Q_1^t-Q_2^t-Q_3^t)\cdot L_{3,0}\right], X^t\ge Q_1^t+Q_2^t+Q_3^t \\ C_1\cdot(L_{0,1}+L_{1,2}+L_{2,3}+L_{3,0}+L_{0,3}+L_{3,0})+C_2\times\left[X^t\cdot L_{0,1}+(X^t-Q_1^t)\cdot L_{1,2}+(X^t-Q_1^t-Q_2^t)\cdot L_{2,3}+(Q_1^t+Q_2^t+Q_3^t-X^t)\cdot L_{0,3}\right], Q_1^t+Q_2^t+Q_3^t>X^t\ge Q_1^t+Q_2^t \\ C_1\cdot(L_{0,1}+L_{1,2}+L_{2,3}+L_{3,0}+L_{0,2}+L_{2,3}+L_{3,0})+C_2\times\left[X^t\cdot L_{0,1}+(X^t-Q_1^t)\cdot L_{1,2}+(Q_1^t+Q_2^t+Q_3^t-X^t)\cdot L_{0,2}+Q_3^t\cdot L_{2,3}\right], Q_1^t+Q_2^t>X^t\ge Q_1^t \\ C_1\cdot(L_{0,1}+L_{1,2}+L_{2,3}+L_{3,0}+L_{0,1}+L_{1,2}+L_{2,3}+L_{3,0})+C_2\times\left[X^t\cdot L_{0,1}+(Q_1^t+Q_2^t+Q_3^t-X^t)\cdot L_{0,1}+(Q_2^t+Q_3^t)\cdot L_{1,2}+Q_3^t\cdot L_{2,3}\right], X^t<Q_1^t \end{cases}$$

Because $C_1\cdot(L_{0,1}+L_{1,2}+L_{2,3}+L_{3,0})$ is the same part, $f(X^t, Q_1^t, Q_2^t, Q_3^t)$ can be modified into the following form. Considering that the parameters (Q_1^t, Q_2^t, Q_3^t) are fuzzy variables in discussed problem, use fuzzy chance-constrained programming for each situation to deal with uncertainty of constraints. Take the situation that the amount X^t of emergency supplies satisfy two safety houses for example.

$$\begin{cases} \min \overline{f_2^t} \\ s.t. \\ \mathrm{Cr}\left\{C_1\cdot(L_{0,3}+L_{3,0})+C_2\times\left[X^t\cdot L_{0,1}+(X^t-Q_1^t)\cdot L_{1,2}+(X^t-Q_1^t-Q_2^t)\cdot L_{2,3}+(Q_1^t+Q_2^t+Q_3^t-X^t)\cdot L_{0,3}\right]\le \overline{f_2}\right\}\ge\alpha_1 \\ \mathrm{Cr}\left\{X^t\ge Q_1^t+Q_2^t\right\}\ge\alpha_2 \\ \mathrm{Cr}\left\{X^t< Q_1^t+Q_2^t+Q_3^t\right\}\ge\alpha_3 \\ X^t\ge 0 \end{cases}$$

Furthermore, every cost expression's fuzzy chance-constrained programming model can be transformed into a standard form to separate decision variable X^t and fuzzy variable $\widetilde{Q_i^t}$. In this standard form, decision variable X^t is not coefficient of fuzzy variables $\widetilde{Q_i^t}$ which can be solved by linear programming.

$$\text{Cr}\left\{C_1\cdot(L_{0,3}+L_{3,0})+C_2\times\left[\left(L_{01}+L_{12}+L_{23}-L_{03}\right)X^t-\left(L_{12}+L_{23}-L_{03}\right)Q_1^t-\left(L_{23}-L_{03}\right)Q_2^t+L_{03}\cdot Q_3^t\right]\le\overline{f_2^t}\right\}\ge\alpha_1$$

Meanwhile constraints of $\text{Cr}\left\{X^t\ge Q_1^t+Q_2^t\right\}\ge\alpha_2$ and $\text{Cr}\left\{X^t<Q_1^t+Q_2^t+Q_3^t\right\}\ge\alpha_3$ can't always achieve at the same time with addition of fuzzy numbers. On the basis of guaranteeing the first constraint, relax the second constraint. X^t is less than $\alpha_2+\mu$ degree optimistic value of $Q_1^t+Q_2^t$ where μ is a very small number. In this way of processing, all situations have a solution. While four models can be established and solved , amount of emergency supplies X^t corresponding to the minimum of the target value set $(\overline{f_1},\overline{f_2},\overline{f_3},\overline{f}_4)$ is the result of optimization.

3.4 Genetic Algorithm

Genetic algorithm is a heuristic algorithm widely used in route optimization. In above, every route has its own optimal replenishment amount X^t and target value $\overline{f}$ which can be regarded as fitness in genetic algorithm which is developed as the following. By genetic algorithm, second decision variable route R can be optimized.

(1) Encoding. There are I safe houses, and route of the safe house can be used as the code.

(2) Generate initial population. Several paths are randomly generated.

(3) Calculate the fitness. For each route, the optimal amount X^t and the pessimistic value $\overline{f}$ are calculated in the previous model. The reciprocal of $\overline{f}$ is taken as the fitness.

(4) Select operation. Select the best individual to directly inherit to the next generation or generate a new individual through pairing crossover to inherit to the next generation.

(5) Cross operation. Two individuals in a group are crossed.

(6) Mutation operation. Two individuals in a population are mutated.

(7) Repeat steps (1)-(6). R and X^t corresponding to the best adaptable fitness are the optimization result.

4. Example and Conclusion

Selincuo Lake is one of the selected areas of the third pole national park with poor signal up till the present moment. According to the survey, there are some troubles in Selincuo Lake caused by poor signal. Apart from the smooth provincial roads, there are some trails near Selincuo Lake where dirvers are easy to get lost. Managers can periodically replenish food and warmth supplies in safety house providing for lost tourists.

We suppose I=10 , C_1=4 , C_2=1. Every safety houses' fuzzy consumption $\widetilde{D_i^t}$ and distance matrix L are shown in the following tables. Order number 0 represents warehouse.

Table 1 Distance Matrix

Distance	0	1	2	3	4	5	6	7	8	9	10
0	0	6	1	6	4	4	4	4	4	6	4
1	6	0	6	12	3	4	10	2	10	8	3
2	1	6	0	6	4	5	5	4	5	4	5
3	6	12	6	0	9	9	3	10	4	8	10
4	4	3	4	9	0	1	7	1	7	7	1
5	4	4	5	9	1	0	7	2	6	9	1
6	4	10	5	3	7	7	0	8	1	9	8
7	4	2	4	10	1	2	8	0	8	7	1
8	4	10	5	4	7	6	1	8	0	9	7
9	6	8	4	8	7	9	9	7	9	0	8
10	4	3	5	10	1	1	8	1	7	8	0

Table 2 Fuzzy Consumption $\widetilde{D_i^t}$

Period	1	2	3	4	5	6	7	8	9	10
1	(3,6,9)	(1,2,3)	(1,3,5)	(3,6,9)	(1,2,3)	(1,3,5)	(3,6,9)	(1,2,3)	(1,3,5)	(3,6,9)
2	(9,12,15)	(4,8,12)	(5,10,15)	(9,12,15)	(4,8,12)	(5,10,15)	(9,12,15)	(4,8,12)	(5,10,15)	(9,12,15)

According $\widetilde{Q_i^t} = \overline{d_i^t} - (0, \overline{d_i^{t-1}} - d_i^{t-1}, \overline{d_i^{t-1}} - \underline{d_i^{t-1}}) = (\overline{d_i^t} - \overline{d_i^{t-1}} + \underline{d_i^{t-1}}, \overline{d_i^t} - \overline{d_i^{t-1}} + d_i^{t-1}, \overline{d_i^t})$, $\widetilde{Q_i^2}$ can be calculated. We set route $R=(1,2,3,4,5,6,7,8,9,10)$. In fixed route, the model above with phased fuzzy chance-constrained programming can optimize replenishment amount X^t. When $X^t=40$, we get optimal target value 2900, which can be used for this route's fitness in genetic algorithm.

Table 3 Optimization Results of Fixed Path

X^t	0	14	26	40	55	67	81	96	107	122	136
$\overline{f}$	5085	3718	3738	2900	3155	3013	3133	3509	4005	4878	6018

Then we use genetic algorithm to optimize route. Parameters are set as follows: sample size is 100, replacement number is 20, crossover probability is 90%, variation probability is 30%, maximum number of iterations is 80. Finally, two optimal results are as follows: route $R=(2,7,4,1,10,5,3,6,8,9)$, cost $\overline{f}=893$. This paper's hybrid model with fuzzy chance-constrained programming and genetic algorithm help reduce cost effectively.

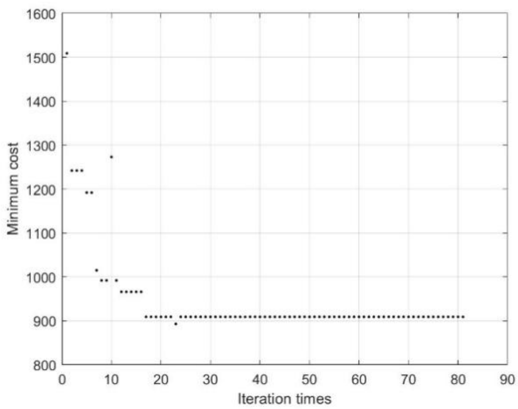

Fig.2 Iterative Process of Genetic Algorithm

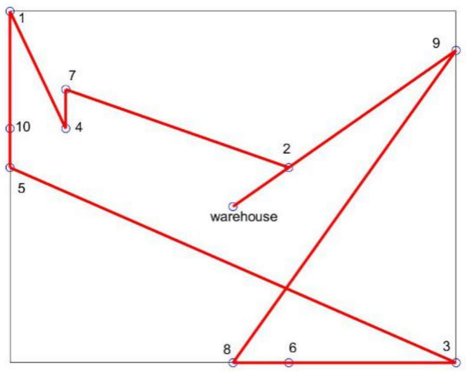

Fig.3 Result of Optimal Route

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