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Dynamic multi-objective location-routing problem in post-earthquake logistics system

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ABSTRACT

This study has developed a dynamic multi-objective mathematics model for location-routing problem (DMLRP) to minimize the total time and cost. A multi-objective hybrid genetic algorithm has presented, and a test has designed to demonstrate reliability and effectively for the model and the algorithm. The test result showed that the proposed meta-heuristic can solve DMLRP effectively and also can avoid the limitation of traditional multi-objective optimization methods. Finally, the result of the numerical example has analyzed to help the decision maker making decision effectively and quickly.

Keywords: emergency logistics, location-routing problem, dynamic multi-objective.

INTRODUCTION

Recently, earthquakes and natural disasters occurred frequently, and often coursing great destructive, especially in the larger population density where thousands of people suffered injury or even death. Though the government has established some emergency rescue plans, the key to cut the losses down is to transfer emergency commodities to affected areas as soon as possible.

In post-earthquake logistic system, generally, the two most important activities are the civilian evacuation and the relief logistics. The civilian evacuation must be taken during in the initial phase of the post-earthquake response to transfer the injured out of the affected area [1,2]. Simultaneously, relief logistics should star and continue for a longer period to provide the necessary relief commodities for civilians within the affected area. In the last two decades, there are many literature works focusing on post-earthquake facility location problem [3,4], emergency commodities allocation and relief vehicle routing planning [5,6]. However, the relief vehicle routing planning, facility location and emergency commodities allocation are influenced with each other, therefore, from the point of integrated optimization in emergency logistics systems, there are some researchers attempted to study location-routing problem. [7] Developed a mixture integer linear programming model and employed hybrid genetic algorithm to solve the model. [8] Proposed a multi-objective location-routing problem model and taken two-stage heuristic algorithm to solve the model. [9] Assumed that the affected areas demands are triangle fuzzy, and then developed a multi-objective location-routing problem model and used hybrid multi-objective genetic algorithm to solve the model. To provide the relief necessary for multiple affected areas in a timely and fair manner, an efficient relief logistics planning is crucial. Besides, the objective of relief logistics will be changed because relief logistics continued for a longer period. Towards this end, this paper developed a dynamic multi-objective mathematics model for location-routing problem (DMLRP) model and designed a multi-objective hybrid genetic algorithm to solve the model, finally, a numerical example was abstracted to demonstrate the model and the algorithm both were effective and efficiency.

EXPERIMENTAL SECTION

Problem Description and Model

In the event of earthquake, it is very crucial and realistic to address three integrate problems mentioned in the previous section. Therefore, a dynamic multi-objective location routing problem model (DMLRP) is formulated to describe the considered in this section. In order to facilitate formulating the model, some reasonable assumptions are made as follows: (1) Locations of facility and affected areas are known for beginning at each period; (2) The vehicles should have been return to belongs relief facility; (3) All vehicles have the same capacity and beyond the affected area forecasted demand; (4) For each period, one affected area can only serve by one candidate facility; (5) All emergency commodities are un-consumable resource.

DMLRP:

$$Z_1 = \min \sum_{i\in S(t)} \sum_{j\in S(t)} \sum_{k\in K} c_{ij} d_{ij} x_{ijk}(t) + \sum_{i\in N(t)} \sum_{j\in M(t)} \left(F_i + \sum_{j=1}^{|M(t)|} z_{ij}(t) D_j(t) O_i \right) y_i(t) \tag{1}$$

$$Z_2 = \min \sum_{i\in S(t)} \sum_{j\in S(t)} \sum_{k\in K} t_{ij} x_{ijk}(t) \tag{2}$$

$$\sum_{k\in K} \sum_{i\in S(t)} x_{ijk}(t) = 1, \forall j \in M(t) \tag{3}$$

$$\sum_{i\in N(t)} z_{ij}(t) = 1, \forall j \in M(t) \tag{4}$$

$$\sum_{k\in K} \sum_{j\in M(t)} x_{ijk}(t) - y_i(t) \geq 0, \forall i \in N(t) \tag{5}$$

$$\sum_{j\in M(t)} x_{ijk}(t) - y_i(t) \leq 0, \forall i \in N(t), \forall k \in K \tag{6}$$

$$\sum_{i\in N(t)} \sum_{j\in M(t)} x_{ijk}(t) \leq 1, \forall k \in K \tag{7}$$

$$\sum_{k\in K} x_{ijk}(t) + y_i(t) + y_j(t) \leq 2, i \in N(t), j \in N(t) \tag{8}$$

$$\sum_{j\in S(t)} x_{ijk}(t) - \sum_{j\in S(t)} x_{jik}(t) = 0, \forall i \in S(t), \forall k \in K \tag{9}$$

$$\sum_{i\in S(t)} \sum_{j\in M(t)} D_j(t) x_{ijk}(t) \leq Q, \forall k \in K \tag{10}$$

$$\sum_{j\in M(t)} D_j(t) z_{ij}(t) \leq y_i(t) CAP_i, \forall i \in N(t) \tag{11}$$

$$U_{ik}(t) - U_{jk}(t) + |M(t)| x_{ijk}(t) \leq |M(t)| - 1, \forall i, j \in M(t), \forall k \in K \tag{12}$$

$$x_{ijk}(t) \in \{0,1\}, \forall i, j \in S(t) \tag{13}$$

$$y_i(t) \in \{0,1\}, z_{ij}(t) \in \{0,1\}, \forall i \in N(t), \forall j \in M(t) \tag{14}$$

Where T denotes period plan; $N(t)$ denotes the set of candidate facility foe period t, $|N(t)|$ denotes the number of candidate facility for period t; $M(t)$ denotes the set of affected areas for period t, $|M(t)|$ denotes the number of affected areas for period t; $S(t)$ denotes the set of candidate facility and affected areas for period t, $S(t) = N(t) \cup M(t)$; $P_j(t)$ denotes the number of changed for injured people at affected area j at period t; C denotes the set of emergency commodities, c as the index; P_{mc} denotes the volume of emergency commodities c for each person, unit is m^3; $D_j(t)$ denotes the number of emergency commodities needed for affected area j at period t, $D_j(t) = P_{mc} \cdot P_j(t)$; F_i denotes facility i start-up cost; O_i denotes facility i per emergency commodities service cost; CAP_i denotes the capacity of facility i (m^3); K denotes the set of relief vehicle, k as the index; Q denotes the capacity of relief vehicle; $U_{jk}(t)$ denotes the sorts for affected area j served by relief vehicle , if $U_{jk}(t)=0$ denotes affected area j didn't served by relief vehicle; d_{ij} denotes the distance from node i t node j , where $i,j\in S(t)$, $d_{ij}=1.4\cdot\sqrt{(x_i-x_j)^2+(y_i-y_j)^2}$; $\bar{v}$ denotes the average speed for relief vehicle; t_{ij} denotes the time needed from node i t node j , where $i,j\in S(t)$, $t_{ij}=d_{ij}/\bar{v}$; c_{ij} denotes the cost from node i t node j , where $i,j\in S(t)$; $x_{ijk}(t)$ denotes if the relief vehicle k passed from node i t node j , where $i,j\in S(t)$, then $x_{ijk}(t)$=1 ; $y_i(t)$ denotes if facility i provide service, then $y_i(t)$=1 ; $z_{ij}(t)$ denotes if affected area j accessed by facility i , then $z_{ij}(t)$=1 .

Where objective function (1) is to minimizing the total cost for each period and objective function (2) is to minimizing the total travel time for each period. Constraints set (3) denote one affected area can only accessed by one relief vehicle for each period. Constraints set (4) denote one affected area can only serve by one facility for each period. Constraints set (5) denote there are have more than one relief vehicle for opened facility. Constraints set (6) denote not opened facility have no relief vehicles. Constraints set (7) denote one relief vehicle only belongs to one facility. Constraints set (8) denote there are no paths between two facilities. Constraints set (9) denote the relief vehicle entered into affected area must be leaved. Constraints set (10) denote the capacity of relief vehicle is limited. Constraints set (11) denote the capacity of facility is limited. Constraints set (12) denote each relief vehicle routing only one facility and no loop. Constraints set (13)-(14) are binary variables constraint.

RESULTS AND DISCUSSION

Comparison of Models

With the rescue time lapse and rescue continued, the weight of travel time and cost would be changed. The main purpose of "golden" 72 hours is to rescue more people's life and the weight of travel time would higher than the weight of travel cost. But, when time over 72 hours, the people lived property would become very low, and then the weight of travel cost would be higher than the weight of travel time [11]. In this paper, we employed a function to process dynamic multi-objective, which showed as follows and where $w_1(t)+w_2(t)=1$, $w_1(t)$, $w_2(t)\ge 0$.

$$\begin{cases} w_1(t)=-0.08t+0.84 \\ w_2(t)=0.08t+0.16 \end{cases} \tag{15}$$

Multi-objective Hybrid Genetic Algorithm

In this paper, we improved simple genetic algorithm, employed hybrid coding method with the parameters cascade. We divided one chromosome into 3 substrings, where substring 1 adapted binary code, occupied $|N(t)|$ gen, and substring 2 adapted integer code, the value of gen range is (Tex translation failed) , which length determined by the number of encode which gen value equals 1 in substring 1, and substring 3 adapted nature number code, occupied $|M(t)|$. For clearly, we assumed that there are 7 facilities, means $|N(t)|=7$, 10 affected areas, means $|M(t)|=10$, at period t , and the index of 1, 4, 6 serve in this period, then a chromosome can encoding which shown in Fig. 1.

$$\underbrace{1\ 0\ 0\ 1\ 0\ 1\ 0}_{\text{Substring 1}}\quad \underbrace{3\ 7}_{\text{Substring 2}}\quad \underbrace{2\,4\,5\,|\,1\,3\,6\,8\,|\,7\,9\,10}_{\text{Substring 3}}$$

Fig. 1 A representative chromosomes graphic

Initial Chromosome and Fitness Function

Generate chromosome by rand, and $chrom(p)$ denotes one population in populations, $p=1,2,...,Popsize$, where $Popsize$ denotes populations' size.

After decoding, then the objective value can calculated and the population's fitness also can get by follows steps:

Step 1: calculated the population's each objective, and marked by f_p^i, where i denotes the i-th objective, p denotes the p-th population;

Step 2: marked the maximum and minimum of objective i by $f_{\max^i}$ and $f_{\min^i}$;

Step 3: sorted objectives by ascend, we assumed $R_i(p)$ denotes the order of objective i for population p;

Step 4: calculated each population's fitness by formulate (16), which showed as follows.

$$f^i(p) = \frac{f_{max}^i - f_p^i}{f_{max}^i - f_{min}^i}(Popsize - R_i(p)) \tag{16}$$

Table 1. Candidate facility information

No.	X Point	Y Point	Capacity (m^3)	Start-up cost	Operation cost/emergency commodity
1	12.0	70.0	2000.0	230.0	0.9
2	34.0	25.0	1800.0	260.0	0.7
3	54.0	64.0	1600.0	130.0	1.1
4	70.0	77.0	1500.0	180.0	1.0
5	62.0	16.0	1600.0	120.0	1.2
6	23.0	83.0	1900.0	200.0	0.6
7	8.0	19.0	1000.0	190.0	0.9
8	92.0	32.0	2500.0	300.0	0.5
9	53.0	36.0	2300.0	170.0	1.2
10	27.0	44.0	1200.0	130.0	1.4
11	82.0	66.0	800.0	90.0	1.6
12	40.0	57.0	2400.0	200.0	0.7

Table 2. Affected areas information

NO.	Point X	Point Y	Injured People	Assistance Ability(μ , δ^2)	NO.	Point X	Point Y	Injured People	Assistance Ability(μ , δ^2)
1	31	8	340	(44,10)	31	87	72	420	(50,8)
2	37	48	280	(36,8)	32	3	23	510	(62,11)
3	3	98	450	(57,12)	33	82	61	630	(76,13)
4	18	5	600	(83,23)	34	10	81	740	(88,14)
5	98	87	400	(51,11)	35	49	39	830	(99,16)
6	66	22	520	(70,18)	36	32	41	980	(116,18)
7	57	99	380	(47,9)	37	60	90	880	(103,15)
8	49	99	430	(55,12)	38	80	1	760	(90,14)
9	7	71	420	(54,12)	39	14	67	320	(38,6)
10	66	44	600	(81,21)	40	98	99	410	(53,12)
11	90	54	1200	(163,43)	41	16	72	450	(58,13)
12	92	12	900	(123,33)	42	37	22	470	(58,9)
13	49	65	800	(116,36)	43	34	61	570	(71,14)
14	55	66	700	(98,28)	44	78	31	600	(75,15)
15	5	1	560	(78,22)	45	64	62	430	(55,12)
16	56	98	640	(88,24)	46	53	51	340	(42,8)
17	79	82	610	(87,26)	47	26	33	320	(41,9)
18	4	83	740	(103,29)	48	47	73	340	(44,10)
19	51	5	820	(113,31)	49	5	24	130	(15,2)
20	91	94	910	(124,33)	50	17	25	240	(27,3)
21	96	16	340	(42,8)	51	4	17	180	(22,4)
22	73	28	230	(29,6)	52	75	33	190	(24,5)
23	83	55	760	(103,27)	53	2	54	510	(68,17)
24	44	66	840	(113,29)	54	21	88	360	(45,9)
25	51	59	730	(99,26)	55	29	64	520	(69,17)
26	18	52	600	(75,15)	56	81	12	430	(55,12)
27	49	32	460	(58,12)	57	68	34	360	(45,9)
28	34	22	730	(99,26)	58	27	13	640	(82,18)
29	23	25	800	(110,30)	59	70	68	270	(36,9)
30	12	79	920	(123,31)	60	95	37	430	(55,12)

Step 5: the comprehensive fitness for population is $f(p) = w_i(t) f^i(p)$, where w_i denote the weight of objective i.

We adopted take lonely operation for crossover and mutation. In substring 1, single point crossover and mutation operation was adopted. We adopted uniform crossover and mutation in substring 2. In substring 3, we adopted two-pointed crossover operation and reserved transcription variations.

Numerical Example

In this section, we generated a numerical example by rand. We assumed that there are 12 candidate facilities (showed in Table 1), 60 affected areas (showed in Table 2). Where they are point are generated by range from 0 to $100 \times 100 m^2$

The proposed meta-heuristic has been programed in Matlab language, the configurations of the laptop for the experiment were as follows: 2.27GHz CPU and 4G RAM. The parameters of the genetic algorithm were as follows: $Maxgen = 700$, $Popsize = 100$, $p_c = 0.9$, $p_m = 0.1$, $\bar{v} = 40\text{Km/h}$, $c_{ij} = 1.4$, $T = 10$, $Q = 1500\text{m}^3$, $P_{mc} = 2.61\text{m}^3$. The average computation time of ten optimization runs was 903.21s. And the convergence of the proposed algorithm objectives of period 1 and 9 are demonstrated by Fig. 2 and Fig. 3. And the statistics showed in Table 3.

Table 3. Each period strategy

Period	Opened Facilities	Number of Paths	Some Transfer Path
1	1,6,12	7	S1-6-44-8-37-4-53-S1
			S6-19-56-21-20-1-46-S6
			S6-17-5-55-25-13-3-16-45-S6
			S12-31-11-27-38-35-15-51-50-49-54-18-23-40-S12
2	1,6,8,11	8	S1-3-30-16-49-S1
			S6-29-10-53-9-54-8-34-46-48-41-S6
			S8-8-25-18-7-19-60-12-47-14-S8
			S11-4-24-27-57-43-S11
3	3,4,6,12	9	S3-45-58-S3
			S4-4-16-44-2-47-7-11-60-56-57-S4
4	4,5,6,9	14	S4-59-S4
			S5-36-8-3-19-S5
			S6-49-57-60-31-40-29-S6
			S9-7-16-51-28-S9
5	6,8,12	10	S6-60-S6
			S8-1-53-32-58-10-S8
			S12-42-19-22-S12
6	5,8,12	9	S5-10-S5
			S8-11-49-32-28-50-48-22-6-54-S8
			S12-57-53-42-44-5-S12
7	12	6	S12-24-5-20-17-59-53-4-51-32-29-S12
8	12	5	S12-16-37-20-5-4-53-41-9-43-55-26-S12
9	3	8	S3-24-55-26-37-7-8-9-S3
10	11	3	S11-36-37-S11

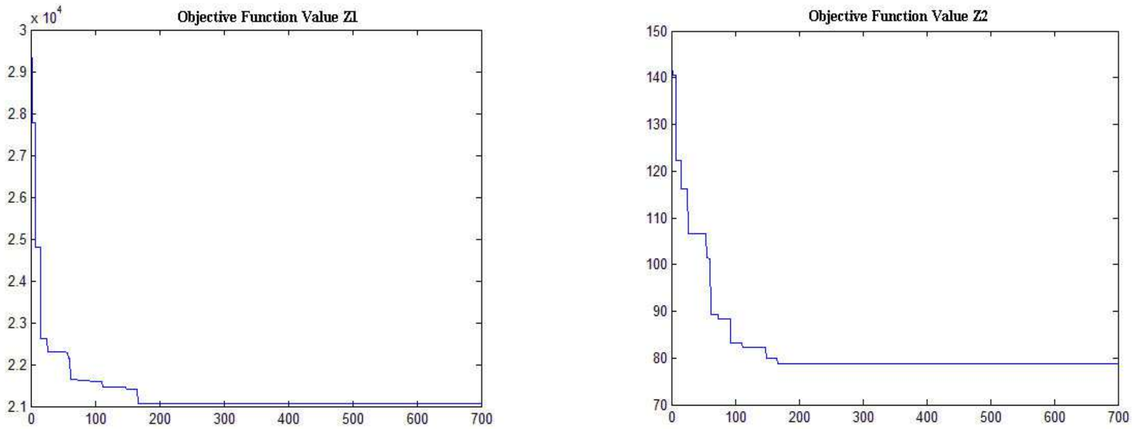

Fig. 2 the convergence of the proposed algorithm objective of period 1

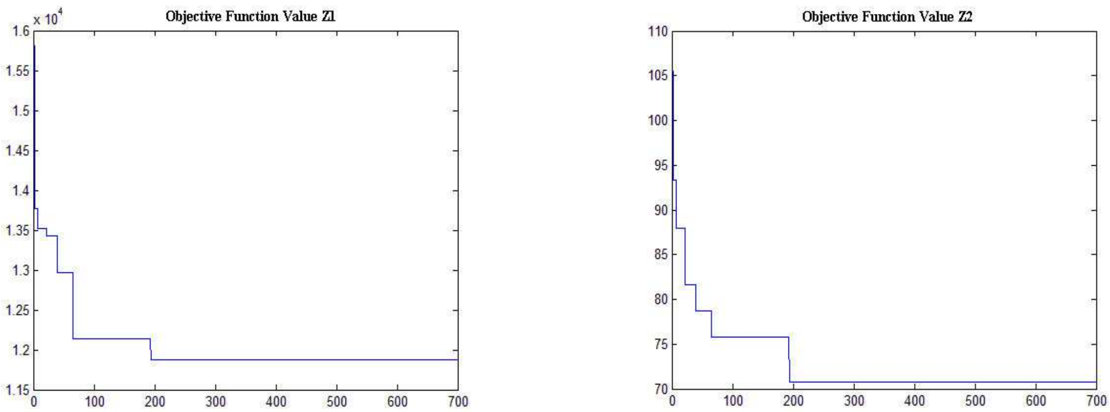

Fig. 3 the convergence of the proposed algorithm objective of period 9

CONCLUSION

The contributions of this paper include: (1) Developed a multi-objective (to minimize the total travel time and to minimize the total travel cost for each period) facility Location-routing problem. (2) Employed Delphi method to transform the weight of multi-objective to single objective and changed by dynamic. (3) A meta-heuristic that incorporates hybrid multi-objective genetic algorithm is proposed to solve the proposed programming model, finally, the proposed optimization model and meta-heuristic are demonstrated via a numerical example. The results indicate that the proposed meta-heuristic is computationally affordable to solve the model.

REFERENCES

[1] F. Fiedrich, Gehbauer F., Rickers U. *Safety Science*, **2000**, 35(1-3):41-57.
[2] Jotshi A, Gong Q, Batta R. *Socio-Economic Planning Sciences*, **2009**, 43(1):1-24.
[3] C. Toregas, Swain R., ReVelle C. et al. *Operations research*, **1971**, 19(6):1363-1373.
[4] B. Liu. *Theory and Practice of Uncertain Programming*, **2009**:157-165.
[5] Li S.L., Ma Z.J., Zheng B., Dai Y. *Chinese Journal of Management Scinece*, **2013**, 21(2):144-151. *(in chinese)*
[6] Afshar A M, Haghani A. *Socio-Economic Planning Sciences*, **2012**. Doi: http://10.1016/j.seps.2011.12.003
[7] Zheng B., Ma Z. J, Fang T. *System engineering*, **2009**, 27, 188(8):21-25. *(in chinese)*
[8] Dai Y. Ma Z. J, Zheng, B. *Management review*, **2010**, 22(1):121-128. *(in chinese)*
[9] W. Yi, Özdamar L. *European Journal of Operational Research*, **2007**, 179(3):1177-1193.
[10] Ma, Y. H., Xie, L. L. *Earthquake engineering and engineering vibration*, **2000**, (4):140-147.
[11] L. Ming, Lindu Z. A composite weighted multi-objective optimal approach for emergency logistics distribution[C]. 2007 IEEE International Conference on Industrial Engineering and Engineering Management, Singapore. **2007**, 968-972.