International Conference on Education, Transportation and Disaster Management 2018

ISBN	978-81-933584-5-0	**VOL**	01
Website	www.coreconferences.com	**eMail**	mail@coreconferences.com
Received	20 – January – 2018	**Accepted**	05 - February – 2018
Article ID	CoreConferences014	**eAID**	CoreConferences.2018.014

Redistribution Problem of Relief Supply after a Disaster Occurrence

Etsuko Nishimura[1], Kentaro Uchida[2]
[1]Graduate School of Maritime Sciences, [2]Undergraduate Student,
Faculty of Maritime Sciences, Kobe University, Japan

Abstract- *The great earthquakes have occurred in various places of Japan after an interval of several years. After the disaster occurred, it seems that some shelters have oversupplied relief commodities, others have lacked them. Since some survivors cannot stay at shelters for some private reasons, they must stay at their home even if the lifeline stops. This paper proposes a methodology to redistribute the oversupply at shelters and relief supply at local distribution center to the shelters and other locations such as elderly care homes lacked relief commodities around one week from the disaster occurrence as the planning horizon. From the computational results, regardless of the balance between total volume of relief oversupplied and total volume of relief lacked, our approach can find the locations with or without relief supply.*

I. Introduction

The great earthquakes have occurred in various places of Japan after an interval of several years, and the mudslide disasters also have occurred about every rainy season for the past several years. The Japan government and municipality tackle kinds of countermeasures against disasters, in order to implement the disaster reduction. Some issues about relief supply after the disaster occurrence immediately were sometimes reported in the mass media. Especially related to emergency logistics, although relief arrives at local distribution centers, the survivors at the evacuation shelters cannot receive its relief timely. And after the disaster occurred around one week, it seems that some shelters have oversupplied relief commodities, others have lacked them. However, in the initial phase after the disaster occurred immediately, it is difficult to understand the scale and extent of the disaster. Then the government and municipality consider the strategic planning such as facility location and stock pre-position etc. and the pre-disaster operation before the disaster occurrence. In this phase, it is seemed that enough volume of relief must be sent to the disaster area regardless of commodities what survivors need at that time. Additionally, since some survivors cannot stay at shelters for some private reasons, they must stay at their home even if the lifeline (electricity, gas or water supply) stops. Those survivors cannot receive relief supply or they have low priority for relief supply in most cases, because they do not stay at the shelters. Then we investigate the survivors at locations except evacuation shelters, such as their own homes, special support schools and more. From our investigation, we also consider the problem for the target locations including the elderly care homes that will increase from now on.

Therefore, this study consider to redistribute the oversupply at shelters and relief supply at local distribution center to the shelters and other locations lacked relief commodities for the time being able to understand oversupply or shortage of relief supply around one week from the disaster occurrence as the planning horizon. We propose the approach for the vehicle routing problem and the redistribution problem for relief supply, in order to find feasible solution effectively.

II. Literature Review

Various natural disasters occur all over the world, academic researches address those challenges for emergency logistics. Sheu [1] define the process of planning, managing and controlling the flows of resources among locations to meet the urgent needs of the affected people under emergency condition as the emergency logistics. And Caunhye et al. [2] reviews the papers published at journal papers and conference proceedings about emergency logistics that searched by keywords such as disaster, emergency, humanitarian logistics and optimization. The literature can be classified into two main categories: (a) Facility location and (b) Relief distribution and casualty transportation. Most facility location optimization models in emergency logistics combine the process of location with stock pre-positioning or relief distribution. Their surveyed models about facility location are found to be single-period, since they are used for pre-disaster planning. Relief distribution models are used for post-disaster planning and are mostly multi-period, due to the large amount of uncertainty involved in post-disaster environments. From Caunhye et al. [2] observation, in most cases of resource allocation and commodity flow models, the objective function includes the transportation cost and sum of unsatisfied demand, the decision making includes the vehicle routing and unmet demands. Sheu [3] considers the emergency logistics distribution approach for quick response to urgent relief in affected area during a three-day crucial rescue period. His proposed approach involves mechanisms including group-based relief distribution and relief supply. Opit and Nakade [4] consider a single distribution center, multiple disaster areas, multi-items and multi-periods. They consider the distribution problem to maximize the expected value of total relief supplies delivered to each area as objective function. Yi and Kumar [5] proposed the meta-heuristics of ant colony optimization for disaster relief activities in order to consider the route construction in real time situation. They consider the objective aims at minimizing the weighted sum of unsatisfied demand and unserved wounded people waiting at demand nodes.

Although most studies consider relief supply and resource allocation for the evacuation shelters, however they do not consider those issues for survivors at locations except shelters. Therefore, we consider the relief redistribution problem for survivors at shelters and other locations such as elderly care homes.

III. Problem Description

The redistribution problem of relief supply (RPRS) is defined on a graph $G = (N, A)$ with N is a node set representing the vehicle depot, distribution centers, evacuation shelters and elderly care homes, and A is the arc set. Fig.1 shows the locations and routes for relief transportation in the target area as an example. In this example, two vehicles are assigned to 16 locations as vehicle depot "0" and other locations 1 to 15. If total oversupply at locations does not exceed total shortage at locations, it is assumed that there are some locations where are not serviced. Indeed, the vehicle depot is not always but often the same locations as distribution center. Therefore, it is assumed that the vehicle depot is given as the different location of distribution center. Both locations are same or not, can be controlled by the way to give location data.

From this example, one vehicle leaves from a vehicle depot "0", and then it visits the distribution center "1", elderly care homes "13" and "14", evacuation shelters with shortages "5" and "6" in turn, and then it goes back to the vehicle depot. Another vehicle leaves from a vehicle depot "0", and then it visits the evacuation shelter with oversupply "4", elderly care homes "10", "9" and "7", evacuation shelters with oversupply "3", elderly care home "12", evacuation shelter with oversupply "2", elderly care home "15" in turn, and then it goes back to the vehicle depot. It is considered that the working time limit for each vehicle and handling operation at each location are set. Additionally, under such a situation as total shortage of relief supplies is more than total oversupply, it can be interpreted locations 8 and 11 where the dotted line shown in Fig.1 is connected to, are no serviced to relief transportation.

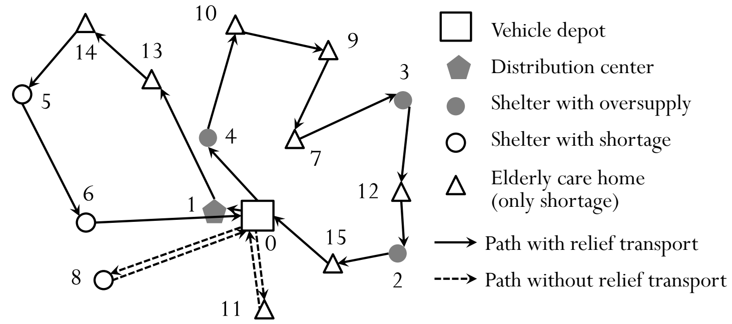

Figure 1. Concept of this problem.

IV. Problem Formulations

Its minimizes weighted total travel distances for relief transportation, and weighted total travel distances from oversupply points to shortage points for relief transportation, and weighted shuttle service distance without relief transportation as the objective function value. It is assumed that there is a homogeneous fleet of vehicles and each point is serviced by each one vehicle. Each vehicle has the maximum capacity to be loaded and the working time limit without considering the overtime work.

This problem RPRS will be formulated as follows:

[RPRS] Minimize $$\alpha \sum_{i \in N} \sum_{j \in N} C_{ij} \max\{0, \sum_{k \in V} x_{ijk} - z_j M\} +$$

$$\beta\,(\sum_{i\in N\setminus\{0\}} C_{i0}\max\{0,\sum_{k\in V} x_{i0k}-(z_i-1)M\}+\sum_{i\in N\setminus\{0\}} C_{0i}\max\{0,\sum_{k\in V} x_{0ik}-(z_i-1)M\} \tag{1}$$

Subject to

$$\sum_{j\in N} x_{ijk}=y_{ik} \qquad \forall i\in N, k\in V \tag{2}$$

$$\sum_{i\in N} x_{ijk}=y_{jk} \qquad \forall j\in N, k\in V \tag{3}$$

$$\sum_{k\in V} y_{ik}\begin{cases}\le |N|-1 & \forall i\in\{0\}\\ =1 & \forall i\in N\setminus\{0\}\end{cases} \tag{4}$$

$$\sum_{j\in N} x_{ijk}-\sum_{j\in N} x_{jik}=0 \qquad \forall j\in N, k\in V \tag{5}$$

$$z_i=(1-\frac{\max\{S_i-D_i,0\}}{S_i-D_i})\times\max\{0,\sum_{k\in V}(x_{0ik}+(x_{i0k}-1)M)\} \qquad \forall i\in N\setminus\{0\} \tag{6}$$

$$u_{ik}-u_{jk}+1\le N(1-x_{ijk}) \qquad \forall i,j\in N\setminus\{0\}, k\in V \tag{7}$$

$$u_{jk}-u_{ik}-1\le N(1-x_{ijk}) \qquad \forall i,j\in N\setminus\{0\}, k\in V \tag{8}$$

$$y_{ik}\le u_{ik}\le Ny_{ik} \qquad \forall i\in N\setminus\{0\}, k\in V \tag{9}$$

$$w_{jk}=0 \qquad \forall j\in\{0\}, k\in V \tag{10}$$

$$w_{jk}\ge\sum_{i\in N}(w_{ik}+S_j-D_j)\times\max\{0,x_{ijk}-z_jM\} \qquad \forall j\in N\setminus\{0\}, k\in V \tag{11}$$

$$w_{jk}\le\sum_{i\in N}(w_{ik}+S_j-D_j)\times\max\{0,x_{ijk}-z_jM\} \qquad \forall j\in N\setminus\{0\}, k\in V \tag{12}$$

$$w_{ik}\le CAP^k \qquad \forall i\in N\setminus\{0\}, k\in V \tag{13}$$

$$b_0=0 \tag{14}$$

$$a_j\ge b_0+T_{0j}+H_j-(1-\sum_{k\in V} x_{0jk})M \qquad \forall j\in N\setminus\{0\} \tag{15}$$

$$a_j\ge b_i+T_{ij}+H_j-(1-\sum_{k\in V} x_{ijk})M \qquad \forall i,j\in N\setminus\{0\} \tag{16}$$

$$a_{N+1}\ge b_i+T_{i0}+H_i-(1-\sum_{k\in V} x_{i0k})M \qquad \forall i\in N\setminus\{0\} \tag{17}$$

$$b_i=\max\{0,a_i\} \qquad \forall i\in N\cup\{|N|+1\} \tag{18}$$

$$b_{N+1}\le TL_k \qquad \forall k\in V \tag{19}$$

$$x_{ijk}=\{0,1\} \qquad \forall i,j\in N, k\in V \tag{20}$$

$$y_{ik}=\{0,1\} \qquad \forall i\in N, k\in V \tag{21}$$

$$z_i=\{0,1\} \qquad \forall i\in N\setminus\{0\} \tag{22}$$

$$u_{ik}, w_{ik}\ge 0 \qquad \forall i\in N\setminus\{0\}, k\in V \tag{23}$$

$$a_i, b_i\ge 0 \qquad \forall i\in N\cup\{|N|+1\} \tag{24}$$

where $N(\in N^C\cup N^S\cup N^H\cup\{0\})$ represents the set of locations that consistes of distribution centers, evacuation shelters, eldely care homes and a vehicle depot; V is set of vehicles; N^C is set of distribution centers where the relief are stored at the time of pre-disaster and post-disaster; N^S is set of evacuation shelters with over-supplied or shortage; N^H is set of elderly care homes with shortage only; C_{ij} is the distances between location i and j (Note that $C_{ii}=\infty$); T_{ij} is traveling time between locations i and j; H_i is handling time spent by vanning or devenning relief supplies at location i; TL_k is working time limit for vehicle k; S_i is volume of oversupply relief at location i (this means that available volume supplied from location i to other locations); D_i is volume of lack-relief at location i (this means that available volume demanded from other locations to location i); CAP^k is maximum capacity which the relief can be loaded on vehicle k; α and β are the weights for travel distance with or without relief transportation, respectively; x_{ijk} is 1 if vehicle k moves between locations i and j, 0 otherwise (0-1 decision variables); y_{ik} is 1 if vehicle k visits to location i, 0 otherwise (0-1 decision variables); z_i is 1 if relief is not transported at location i by any vehicle, 0 otherwise (0-1 decision variables); u_{ik} is order of visiting to location i by vehicle k; w_{ik} is relief volume loaded on vehicle k at location i; a_i and b_i are arrival time and leaving time by any vehicle at location i, respectively.

The objective function (1) minimizes weighted total travel distances from oversupply locations to shortage locations for relief transportation, and weighted shuttle service distance without relief transportation. Constraint sets (2) and (3) show the relationship between variables x_{ijk} and y_{ik}, x_{ijk} and y_{jk}. Constraint set (4) ensure that a vehicle must visit each location except the vehicle depot exactly once. Constraint set (5) guarantee that the number of times arriving is same as the number of times leaving by a vehicle at each location. Constraint set (6) shows that variable zi is defined by variables x_{0ik} and x_{i0k}. z_i is set to 1 if both variables x_{0ik} and x_{i0k} equal to 1, 0 otherwise. Constraint sets (7) and (8) mean that a sub-tour visited only points except the vehicle depot "0" is forbidden. Constraint set (9) guarantee that variable u_{ik} is greater than and equal to 0 if y_{ik} equals to 1, and u_{ik} equals to 0 otherwise. Constraint sets (10) to

(12) define the volume of relief loaded on each vehicle which visits just before location j except the vehicle depot "0". Constraint set (13) guarantees that each vehicle must service as its maximum capacity not exceeded. Constraint set (14) defines the time when any vehicle leaves from the vehicle depot "0" is 0. Constraint sets (15) to (17) define that the time a_j when vehicle k arrives to location j by the arrival time a_i at location i where its vehicle visited just before location j and variable x_{ijk}. Constraint set (18) defines the time when each vehicle arrives at each location. Constraint set (19) guarrantees that each vehicle must service its assigned workload within its working time limit.

V. Solution Procedure

It will be proposed the heuristic algorithm used Genetic Algorithm (GA), in order to find feasible solution effectively. In this section, it is explained that the chromosome representation and its interpretation. Table I shows the attribute information of each location in the example of Fig.1. Location 1 is a distribution center "D", locations 2 to 7 are evacuation shelters, locations 8 to 15 are elderly care homes. Relief can be supplied from a distribution center to other locations, is classified in oversupply category in table I. An evacuation shelter with oversupply or shortage is included, and an elderly care home with shortage only is included as the target location of this problem. Although oversupply or shortage volume of each location depends on its location capacity or its serious damage size, it is seems that the relief for fifty persons with minimum unit size "1" can be supplied in an elderly care home. Volume of relief supplied to other locations is given and multiplied several times as the above unit size.

Table II shows the chromosome representation of the example shown in Fig.1 and the balance with oversupply and shortage (S_i - D_i) at location i. The visiting order and location number from the left side are shown in table II. Table III shows the vehicle number assigned as not exceed the vehicle capacity "10", and order of visiting to each location. In this example, vehicle-1 visits 0, 4, 10, 9, 7, 3, 12, 2, 15 in turn and then goes back to 0, and vehicle-2 visits 0, 1, 13, 14, 5, 6 in turn and then goes back to 0. Locations 8 and 11 are not serviced to relief supply. Note that travel distances with shuttle service from a vehicle depot are included. The more locations without relief transportation are, the larger the objective function value becomes.

Table I Attribute Information for Each Location

Location (i)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Facility type	D	Evacuation shelters						Elderly care homes							
Volume of oversupply	10	5	5	5	0	0	0	0	0	0	0	0	0	0	0
Volume of shortage	0	0	0	0	3	3	3	1	1	1	1	1	1	1	1

Table II Chromosome Representation

Order of visiting	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Location No.	4	1	10	9	7	13	14	5	6	8	11	3	12	2	15
Balance between oversupply and	5	10	-1	-1	-3	-1	-1	-3	-3	-3	-1	5	-1	5	-1

Table III Way to Find Feasible Solution as Vehicle Dispatch and Routes

																k: Vehicle number
Location No.		4	1	10	9	7	13	14	5	6	8	11	3	12	2	15
$k = 1$	Num. of relief loaded on	5	15x	4	3	0	-1x	-1x	-3x	-3x	-3x	-1	5	4	9	8
	Location where a vehicle	**4**	**-**	**10**	**9**	**7**	**-**	**-**	**-**	**-**	**-**	**-**	**3**	**12**	**2**	**15**
$k = 2$	Num. of relief loaded on		10				9	8	5	2	-	-				
	Location where a vehicle	**-**	**1**	**-**	**-**	**-**	**13**	**14**	**5**	**6**	**-**	**-**	**-**	**-**	**-**	**-**
$k = 3$	Num. of relief loaded on										-3					
No	Location where a vehicle	No distribute to relevant location →									**8**					
$k = 4$	Num. of relief loaded on											-1				
No	Location where a vehicle	No distribute to relevant location →										**11**				

Vehicle-1 : 0 – 4 – 10 – 9 – 7 – 3 – 12 – 2 – 15 – 0, Vehicle-2 : 0 – 1 – 13 – 14 – 5 – 6 – 0
Locations 8 and 11 are not serviced to relief supply. Note that travel distances with shuttle service from a vehicle depot are included. The more locations without relief transportation are, the larger the objective function becomes.

VI. Computational Experiments

There is our campus "Graduate School of Maritime Sciences, Kobe University" in Higashinada area of Kobe city, Japan. Indeed, there are one vehicle depot, one distribution center, 35 evacuation shelters and 36 elder care homes in this area. Then in order to conduct computational experiments, it is assumed that 25 evacuation shelters and 24 elder care homes are randomly selected among the above Kobe data, and the relief commodity has to be redistributed to those locations at that time.

Table IV shows the computational results as total travel distances (objective function), total travel distances with relief transportation, dummy distances for shuttle service without relief transportation, and number of locations without relief supply.

Case studies #1 to #10 show the results in the case that total volume of relief oversupplied is less than total volume of relief lacked. Case studies #11 to #20 show the results in the case that total volume of relief oversupplied is greater than total volume of relief lacked. Case studies #21 to #30 show the results in the case that total volume of relief oversupplied is greater than total volume of relief lacked. And the weights of dummy distances in cases #21 to #30 are heavier than those of dummy distances in cases #11 to #20. As shown in #1 to #10, if total volume of relief oversupplied is less than total volume of relief lacked, some locations are not serviced to relief supply and this approach can find the locations with no relief supply. However, as shown in #11 to #20, even if total volume of relief oversupplied is greater than total volume of relief lacked, and if the weight of travel distances with relief transportation is same as that of dummy distances for shuttle service without relief transportation, this approach find some locations where no relief is supplied. Therefore, the weight of dummy distances without relief supply transportation is set to large value. Then if total volume of relief oversupplied is greater than total volume of relief lacked, all locations are serviced to relief supply, shown in case #21 to #30. In our future works, we investigate more information of a real situation, and it needs to find the type of service priority and to consider how to give it to the locations.

Table IV Computational Results

Case study	Location data #	Balance between total volume of relief oversupplied and lacked	Weights of α and β	Total travel distances (km)	Total travel distance with relief transportation (km)	Dummy distance for shuttle service without relief transportation (km)	Number of locations without relief supply
1	1	Total volume of relief oversupplied < Total volume of relief lacked	$\alpha = 1$, $\beta = 1$	81.86	61.26	20.60	4
2	2			89.47	71.87	17.60	5
3	3			79.11	64.11	15.00	4
4	4			91.92	74.52	17.40	5
5	5			93.46	74.66	18.80	5
6	6			84.94	61.54	23.40	5
7	7			81.83	65.64	16.20	5
8	8			98.09	77.29	20.80	4
9	9			81.36	63.16	18.20	4
10	10			84.69	65.29	19.40	4
11	1	Total volume of relief oversupplied > Total volume of relief lacked	$\alpha = 1$, $\beta = 1$	84.80	84.80	0.00	0
12	2			85.92	85.82	0.00	0
13	3			81.21	81.21	0.00	0
14	4			89.76	89.76	0.00	0
15	5			84.31	80.51	3.80	1
16	6			86.22	86.22	0.00	0
17	7			80.97	80.97	0.00	0
18	8			77.58	77.58	0.00	0
19	9			88.22	88.22	0.00	0
20	10			82.78	76.78	6.00	2
21	1	Total volume of relief oversupplied > Total volume of relief lacked	$\alpha = 1$, $\beta = 10$	84.80	84.80	0.00	0
22	2			80.90	80.90	0.00	0
23	3			84.38	84.38	0.00	0
24	4			88.20	88.20	0.00	0
25	5			73.52	73.52	0.00	0
26	6			83.55	83.55	0.00	0
27	7			89.87	89.57	0.00	0
28	8			83.86	83.86	0.00	0
29	9			74.95	74.95	0.00	0
30	10			80.35	80.35	0.00	0

VII. CONCLUSION

After the disaster occurred around one week, it seems that some shelters have oversupplied relief commodities, others have lacked them. As some survivors cannot stay at shelters for some private reason, they must stay at their home even if the lifeline stops. This study consider to redistribute the oversupply at shelters and relief supply at local distribution center to the shelters and other locations as elderly care home lacked relief commodities. From the computational results, regardless of the balance between total volume of relief oversupplied and total volume of relief lacked, it is clear that our approach can find the locations with or without relief supply. In our future works, it will need to find the types of service priority to locations and also consider the issues in real situation.

References

1. Sheu, J.B., “Challenges of emergency logistics management”, Transportation Research Part E, Vol.43, pp.655-659, 2007.
2. Caunhye, A.M., Nie, X., Pokharel, S., “Optimization models in emergency logistics: A literature review”, Socio-Economic Planning Sciences, Vol.46, pp.4- 13, 2012.
3. Sheu, J.B., “An emergency logistics distribution approach for quick response to urgent relief demand in disasters”, Transportation Research Part- E, Vol.43, pp.687-709, 2007.
4. Opit, P.F., Nakade, K., “Distribution model of disaster relief supplies by considering route availability”, Journal of Japan Industrial Management Association, Vol. 66, pp.154-160, 2015.
5. Yi, W., Kumar, A., “Ant colony optimization for disaster relief operations”, Transportation Research Part E, Vol.43, pp.660-672, 2007.