Journal of Naval Science and Engineering
2017, Vol. 13, No.1, pp.23-30
Endüstri Mühendisliği/Industrial Engineering

A CASE STUDY FOR PRE-POSITIONING A GLOBAL HUMANITARIAN RELIEF NETWORK

Ertan YAKICI

Industrial Engineering Department,
National Defense University, Turkish Naval Academy, Tuzla, Istanbul
eyakici@dho.edu.tr

Date of Receive: 14.01.2017 **Date of Acceptance: 27.03.2017**

ABSTRACT

In this case study, we have investigated the optimal design of a network of warehouses to be pre-positioned for humanitarian relief operations to be executed when expected disasters happen. A model which is previously introduced in the literature is applied with the most recent data. The model responds to decision requirements in both locations of warehouses and allocation of resources to these warehouses, assuming the disaster pattern of last decade will continue. A sensitivity analysis is also conducted to observe how the average response time changes as the allowed number of warehouses increases.

ÖZ

Bu çalışmada, beklenen doğal afetlere karşı insani yardım kapsamında önceden konumlandırılacak depolara ait şebekenin dizaynı incelenmiştir. Daha önce literatürde tanıtılmış olan bir model en son elde edilen veri ile uygulanmıştır. Model, son on yılda gerçekleşen doğal afet paterninin önümüzdeki yıllarda da gerşekleşeceği varsayımını esas alarak, depoların yerleşimi ve kaynakların bu depolara dağıtımı için ortaya çıkan karar ihtiyaçlarına beraberce cevap vermektedir. Açılabilecek depo sayısındaki artışın ortalama tepki zamanı üzerindeki etkisini görebilmek için bir duyarlılık analizi çalışması da yapılmıştır.

Keywords: *Pre-positioning; Humanitarian Relief Logistics; Warehouse Location.*
Anahtar Kelimeler: *Ön-konumlandırma; İnsani Yardım Lojistiği; Depo Yerleştirme.*

1. INTRODUCTION

In the last decades, with the effect of global warming, the number of natural disasters increases. This phenomenon requires fast and coordinated humanitarian relief operations. Unpredictability of demand in humanitarian logistics makes pre-disaster activities more important. One of these activities is strategic positioning of warehouses built for supporting relief operations [1].

Pre-positioning can be defined as a tool to increase responsiveness by locating items which will be used in relief operations, like foods and medical material, closer to the regions under risk [2].

In this study we applied a model used by Duran et al. [3] with a data belongs to most recent decade (2007-2016) . In their paper, the authors report that they have supported the decision process in designing a pre-positioning network of warehouses. The employed model considers demand raised from 22 regions of the world, which is determined by United Nations, for relief supplies to be used after earthquakes, windstorms and floods. Candidate warehouse locations are determined by CARE International. It is assumed that, when inventory shortage occurs, main suppliers can send relief supplies to the regions with longer lead times. The model minimizes the weighted average response time.

To assign demand to discretized time periods, two-week time horizon is used in concordance with the estimation of CARE International suppliers [3]. Demand information is obtained from Emergency Events Database (EM-DAT) which keeps the data on the effects of disasters all around the world since 1900 [4].

This study is not the only one applying the model proposed by Duran et al. [3]. Bozkurt and Duran [5] observe three decades from 1977 to 2006 to see whether there is a significant change in the disaster locations and the number of affected people over this period. Our study can be considered as a follower of the work presented by Bozkurt and Duran [5], because we apply the same model with the data of the most recent decade.

In the following sections, the formulation of the problem is given and the results are reported. Finally, conclusion is given in the last section.

2. PROBLEM DEFINITION

Definitions of Index sets, variables and parameters are given below.

I set of canditate locations for warehouses,
D set of disaster types,
J set of demand points,
R set of relief items,
E set of demand instances,

y_i 1 if warehouse i is activated, 0 otherwise,
q_{ir} quantity of item r held at warehouse i,
x_{ijer} quantity of item r supplied to demand point j from warehouse i for demand instance e,
x'_{jer} quantity of item r supplied to demand point j from suppliers for demand instance e,

N maximum number of warehouses allowed to be activated,
Q total inventory,
P_e probability of occurring for demand instance e,
t_{ij} response time from warehouse i to demand point j,
t'_{jr} response time from suppliers to demand point j for item r,
d_{dje} number of affected people at demand point j by a disaster of type d for demand instance e,
p_{djr} probability of item r being required at demand point j by a person affected by a disaster of type d,
a_{djr} quantity of item r required by a person affected by a disaster of type d in demand point j,
d'_{jer} expected demand for item r at demand point j in demand instance e.

According to the notation given above, the mathematical formula of mixed integer programming model is given as follows:

$$z = \min \sum_{e \in E} P_e \left(\frac{\sum_{j \in J} \sum_{r \in R} x'_{jer} t'_{jr} + \sum_{i \in I} \sum_{j \in J} \sum_{r \in R} x_{ijer} t_{ij}}{\sum_{j \in J} \sum_{r \in R} d'_{jer}} \right) \quad (1)$$

$$d'_{jer} = \sum_{d \in D} a_{djr} p_{djr} d_{dje} \qquad j \in J, e \in E, r \in R \qquad (2)$$

$$\sum_{i \in I} x_{ijer} + x'_{jer} \geqq d'_{jer} \qquad j \in J, e \in E, r \in R \qquad (3)$$

$$\sum_{j \in J} x_{ijer} \leq q_{ir} \qquad i \in I, e \in E, r \in R \qquad (4)$$

$$q_{ir} \leq Qy_i \qquad i \in I, r \in R \qquad (5)$$

$$\sum_{i \in I} \sum_{r \in R} q_{ir} \leq Q \qquad (6)$$

$$\sum_{i \in I} y_i \leq N \qquad (7)$$

$$x_{ijer}, x'_{jer}, q_{ir} \geq 0 \qquad i \in I, j \in J, e \in E, r \in R \qquad (8)$$

$$y \in 0,1 \qquad i \in I \qquad (9)$$

The travel of a relief item is normally equal to the fly time of a usual cargo aircraft between the warehouse and the demand point plus one additional preparation day. However, if warehouse inventory is not sufficient to meet the demand, the global suppliers provide the relief items with a response time of two-weeks. Therefore, average response time which is reflected by objective function (1) is calculated as the weighted sum of these two response times, where weights are equal to the proportions of demand satisfied by each method.

Constraint set (2) assigns the value of expected demand of each relief item at each demand location for each disaster instance. Constraint set (3) ensures the requirement of demand satisfaction of each relief item at each demand point for each disaster instance. Constraint set (4) ensures that total amount of an item shipped from a warehouse cannot exceed the inventory of this warehouse of that item type. Constraint (5) set reflects that a warehouse should be activated to hold any inventory. Constraint (6) forces that total inventory cannot be exceeded. Constraint (7) satisfies the requirement of allowed number of active warehouses should not be exceeded. Remaining constraint sets (8-9) defines the variable domains.

3. APPLICATION AND RESULTS

Our case includes 22 demand points, 12 candidate locations for warehouses, seven types of relief items; cold tent, hot tent, household utensils, medical relief items, hygiene sets, sanitation sets and water as in the previous work of Bozkurt and Duran [5]. Since the detailed information about the used data is given in the thesis of Bozkurt [6] and the study of Bozkurt and Duran [5], if they are kept same, we do not mention the parameter details here.

As in the previous works [5, 6], each demand instance is created by grouping disasters occurred in two-week time periods in a region. This assumption creates 237 demand instances from the disaster data of the last decade. Each disaster type may require different combination of relief items per affected person according to the region of the world. Although model allows such a detailed level of analysis, since there is no evidence for differentiating the regions with respect to required relief items, we assume all of the affected people regardless of their regions will demand the same combination of relief items.

In contrary to Bozkurt and Duran [5], we only used one demand level. To be on the safe side, we assume that all affected people are included in the demand and all disaster events have 100% probability of occurring. Total inventory is assumed to be the average demand of a demand instance.

A commercial solver, CPLEX 12.6.2.0, is run to the optimality. It is observed that the solver has provided the optimal solution in a few minutes depending on number of warehouses allowed to be activated.

To observe the sensitivity to the number of warehouses, we have expanded the warehouse network one by one. If we open one warehouse, it is optimal to open it in Denmark. If we increase the number of warehouses to two, it is optimal to open them in Kenya and Honduras. Optimal places for three warehouses are Denmark, Kenya and Honduras. Then, if we continue to increase the number to four and five, Hong Kong and Italy are added to the set, respectively. As observed from the graph in Figure 1, after four warehouses, there is no need to activate another, since its marginal contribution is insignificant.

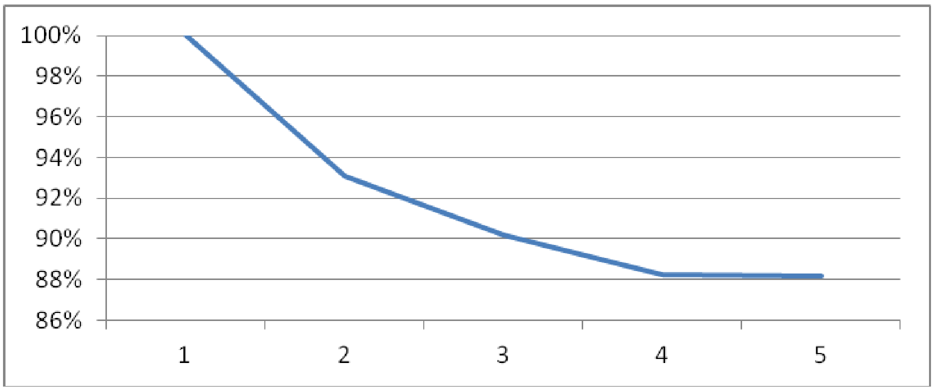

Figure 1. Decrease in response time as the number of warehouses increases

In Table 1, we give the allocation of items in each activated warehouse in percentages.

Table 1. Allocation of relief items to warehouses

	Cold Tent	Hot Tent	Household Utensils	Medical Relief Items	Hygiene Sets	Sanitation Sets	Water
Denmark	4%	4%	8%	21%	21%	24%	17%
Honduras	4%	4%	8%	20%	20%	21%	23%
Hong-Kong	5%	5%	9%	21%	21%	21%	19%
Kenya	4%	4%	8%	22%	21%	19%	22%

4. CONCLUSION

In this study, we have investigated the optimal design of a network of warehouses to be located for humanitarian relief operations. A model which is previously introduced in the literature is applied with the most recent data that belong to the period of 2007-2016. With the assumption of the disaster pattern of the last decade will continue, the model attempts to minimize the average response time, while supporting the decisions in both locations of warehouses and allocation of relief items to activated warehouses.

We have conducted a sensitivity analysis to observe how the average response time changes as the allowed number of warehouses increases. We have seen that, there is no need to activate fifth warehouse, because of its insignificant marginal contribution. We also present the suggested allocation of relief items to the four warehouses which are suggested to be activated.

REFERENCES

[1] Ergun O., Karakus G., Keskinocak P., Swann J., and Villarreal, M., (2008). Overview of Supply Chains for Humanitarian Logistics. In *Encyclopedia in Operations Research and Management Science*; Cochran, J., Ed.; John Wiley Sons: Hoboken, NJ, USA.

[2] Van Wassenhove L.N., (2006). *Blackett memorial lecture-humanitarian aid logistics: Supply chain management in high gear*, J. Oper. Res. Soc., 57, pp. 475–489.

[3] Duran S., Gutierrez M.A., and Keskinocak P., (2011). *Pre-positioning of emergency items for care international,* Interfaces, vol. 41(3), pp. 223–237.

[4] EM-DAT The International Disaster Database Homepage. Available online: http://www.emdat.be (accessed on 5 March 2017).

[5] Bozkurt M., and Duran S., (2012). *Effects of Natural Disaster Trends: A Case Study for Expanding the Pre-Positioning Network of CARE International*, Int. J. Environ. Res. Public Health, *9*, pp. 2863-2874.

[6] Bozkurt M., (2011). *The effects of natural disaster trends on the prepositioning implementation in humanitarian logistics networks*, MS Thesis, METU, Ankara.