ISSN (e): 2250 – 3005 || Volume, 08 || Issue, 2|| February – 2018 ||
International Journal of Computational Engineering Research (IJCER)

Positioning Of Unmanned Aerial Vehicles for the Natural Disasters

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ABSTRACT
Unmanned aerial vehicles have been used in many areas nowadays. Unmanned aerial vehicles (UAV) have been gained importance because of the reasons such as degradation of nature balance, increasing internal and external wars, border security, and archaeological studies due to the advantages of such as discovery, surveillance and data transfer. In this study, there is a choice of the optimum location to facilitate the UAVs in natural disasters. In the study, the most appropriate location is found in the GAMS optimization program, taking into consideration the probability of disaster according to the catastrophe, the severity according to catastrophe, the population, population density, the height and range that can be reached according to the types and types of UAVs and the availability of hydrogen energy for the using it for UAVs. The work aims to perform the distribution of the needs at minimum time.
KEYWORDS: Unmanned aerial vehicles, Location problem, Mathematical programming approach, Hydrogen energy, Natural disasters, Disaster management, optimization.

I. INTRODUCTION

Natural Disasters such as earthquakes, floods, landslides, fires are critical events and threat the human lives. So, taking measures for this events and prevent the effects of a disaster are important. Natural disasters require supply activities to transfer needs in the shortest time. This makes location problems of the vehicles that will distribute materials critical. UAVs have been used for this purpose. Technological developments have emerged the drones or UAVs ([1], [2]). UAVs can be controlled remotely and can be routed for the planned route [3]. The widespread use of small unmanned aircraft systems (UAS) for military applications has been a major reason for accelerating technological progress and making unmanned aircraft ready for new fields and marketplace in civilian space [4]. Unmanned aerial systems are a technology that has the potential to revolutionize transport, agriculture, conservation and many other industries as well as disaster management. Findings related to the use of UAS in disaster management are summarized. The ease of use and low cost of a small UAS model means that local governments, humanitarian agencies and companies will find useful uses. UAS currently provides vital information on flights around the world and can be used in many ways, including search and rescue, medical transport, real-time imaging of critical infrastructures, and renewal of networks. With the potential benefits of UAS in disaster management and other areas being evident, the smooth, orderly and safe transformation of the shared airspace is less clear [5]. In addition to the natural disasters problem, sustainability has gained more importance day by day. Environmental concerns provide to tend to renewable energies for the vehicles. Hydrogen energy is one of the most important renewable energy sources. It is a clean energy that uses natural sources such as water, solar, air to be produced. This work motivation is both of the post disaster distribution management by the UAVs and the using clean energy for the distribution vehicle for the UAVs.

Disaster management includes several problems for the affected people. One of these problems is location decisions of the vehicles that will distribute needs. Studies for optimum locating the UAVs in the literature have not been met. Some studies about the localization of the UAVs examine the using a laser scanner control and sensor fusion quality, vision-based search for the position of the vehicle ([6], [7], [8]). Location analysis for the emergency vehicles is studied by many researchers. A location problem is developed for emergency vehicles such as fire trucks, ambulances, patrols [9]. In addition, types and number of vehicles, dispatch decisions are handled. They use a queuing model for this problem. A location problem is presented for ambulances to meet the demand and they use a Stochastic programming [10]. Coverage model is used to meet all the requirements by optimizing [11]. A model is provided that minimizes number of vehicles that can be serviced to cover all demands [12]. A location problem is developed of emergency vehicles called patrol using real data. They use a queueing model for the case of a congested service system [13]. Hydrogen energy using for the UAVs is usually about the design a fuel cell system with hydrogen source ([14], [15]).

In this study, the problem is applied firstly for the location of UAVs that will meet the needs urgently in the case of the disasters. The contributions are as follows:

- Position of UAVs after disasters is critical to meet the demands urgently.
- The problem involves an environmental effect with the hydrogen energy using for UAVs.
- A new mathematical model is formulated for the problem using real case data.

II. MATERIAL- METHOD

The positioning problem aims the transportation of aids by UAVs urgently. The network of the problem comprises UAVs location and emergency nodes shown in Figure 1.

In this study, a location model considering the catastrophe, the severity according to catastrophe, the population, population density, the height and range that can be reached according to the types and types of UAVs and the availability of hydrogen energy is proposed.

The aim of this paper is to maximize the coverage of the population who need materials after the disasters. The handled parameters are population, population density, disaster periods, numbers and severity yearly, the height, range of the location of UAVs, producibility of hydrogen. In addition, availability cost of the hydrogen energy and purchasing cost of the UAVs are minimized in the objective function. The decision variables are the where the locations of UAVs positioning and the decision of the availability of the UAV types and the number of the UAVs at each locations. Model formulation is as bellows:

Sets:

i	indices of region	i =	1 ,…, I
b	indices of disaster type	b =	1 ,…, B
k	indices of energy	k =	1 ,…, K
h	indices of UAVs type	h =	1 ,…, H
j	indices of disaster region	j =	1 ,… , J

Decision variables:

x_{ih} : the number of h vehicle from the i region

r_{ih} : the decision of h vehicle from the i region

$$= \begin{cases} 1, & \text{if any facility is opened at i.region} \\ 0, & \text{otherwise} \end{cases}$$

y_i :the decision of any facility opened at i.region

$$= \begin{cases} 1, & \text{if a facility is opened at i.region} \\ 0, & \text{otherwise} \end{cases}$$

Parameters:

n_i :population of i.region

g_i :population density of i.region

lm_{ki} :energy amount of k at i.region

lc_{ki} :availability cost of k.resource at i.region

lk_{ki} : H2 producibility from the k.resource at i.region

d_{bj} :disaster numbers of b.disaster at i .region

ex_{bj} : severity of b.disaster at i .region

ey_{bj} : effect of b.disaster at i .region

h_{xh} :range of h vehicle

hy_h : height of h vehicle

hz_h : unit cost of h vehicle

fx_{bh} :range need of h vehicle for b disaster

fy_{bh} : height need of h vehicle for b disaster

p :total facility numbers

M :a large value

Objective Function:

$$\max Z=\sum_{i}^{I} n_i.g_i.y_i + \sum_{b}^{B}\sum_{j}^{J}\sum_{i}^{I} d_{bj}.ex_{bj}.ey_{bj}.y_i + \sum_{h}^{H}\sum_{b}^{B}\sum_{i}^{I} fx_{bh}.hx_h.y_i$$
$$+\sum_{h}^{H}\sum_{b}^{B}\sum_{i}^{I} fy_{bh}.hy_h.y_i + \sum_{k}^{K}\sum_{i}^{I} lk_{ki}.lm_{ki}.y_i$$
$$-\sum_{i}^{I}\sum_{k}^{K} lc_{ki}.lk_{ki} - \sum_{h}^{H}\sum_{i}^{I} x_{ih}.hz_h.y_i \qquad (2.1)$$

Objective function includes the items below:

• It is requested that the population and density exist in the regions to be maximum (item 1 in the objective function)
• It is requested that the number of disasters, the frequency and severity of disasters on a regional basis is the maximum (objective function 2)
• It is requested that the maximum range of the vehicle is reached (item 3 in the objective function)
• It is requested that the maximum height of the vehicle is reached (item 4 in the objective function)
• It is requested that the amount of H2 that can be obtained on the basis of the region is maximum (the fifth item in the objective function)
• It is requested that the H2 cost that can be obtained on a regional basis is minimum (item 6 in the objective function)
• It is requested that the number of vehicles in total be minimum (item 7 in the objective function)
Equations:
Facility numbers Equation 2.2 describes maximum facility numbers.

$$\sum_{i}^{I} y_i = p \qquad (2.2)$$

vehic(i) Equation 2.3 describes the numbers of UAVs needed for the facilities.

$$\sum_{h}^{H} x_{ih} \le M . \sum_{h}^{H} r_{ih}.y_i \qquad ,\forall i \qquad (2.3)$$

cover (i,h) Equation 2.4 ensures to cover the disaster regions.

$$y_i = r_{ih} * M \qquad ,\forall i,h \qquad (2.4)$$

numb1 Equation 2.5 ensures the UAVs number according to the range of the vehicles.

$$\left(\sum_{b}^{B}\sum_{h}^{H} fx_{bh}\right) / \left(\sum_{h}^{H} hx_h\right) \le M . \sum_{i}^{I}\sum_{h}^{H} x_{ih} \qquad (2.5)$$

numb2 Equation 2.6, ensures the UAVs number according to the height of the vehicles.

$$\left(\sum_{b}^{B}\sum_{h}^{H} fy_{bh}\right) / \left(\sum_{h}^{H} hy_h\right) \le M . \sum_{i}^{I}\sum_{h}^{H} x_{ih} \qquad (2.6)$$

numb3(i,h) Equation 2.7 shows the number of UAVs according to the facility location.

$$x_{ih} \ge r_{ih} \qquad ,\forall i,h \qquad (2.7)$$

III. RESULTS

In the study, the problem of choosing the location of unmanned aerial vehicles is addressed firstly. The mathematical programming model developed in the study is formulated in the GAMS 23.5 program and the optimum solution is presented. In the developed mathematical programming model, 20 regions have been taken into consideration. Population densities for 20 regions are entered as parameters in the system. Earthquake, landslide, fire and water pressure are taken into consideration as disaster indices in the regions. The number, severity and effect of these disaster indices are entered into the system as parameters. Range, height and cost indices are also taken into account when making the selection of the UAVs. In addition, the system considers the amount of H_2 acquisition and the cost of acquisition, since the UAV operates with hydrogen energy sources and hydrogen energy is obtained from the sun and water. As a result of this study, it is revealed that in the 20 regions, the UAV facility will be established and the number of the UAV facilities will be determined. The installations are processed in a system where the IHA is installed and the cost of H2 installation is minimum. At the end of the study cost is found as 159046305 TL.

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----    334 VARIABLE y.L  the decision of any facility opened at i.region

2  1.000,    10 1.000,    14 1.000,    18 1.000,    20 1.000
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Figure 1. The decision of any facility opened at i.region

In Figure 1, 5 regions are chosen to provide maximum help and minimum cost within 20 regions. In regions 2, 10, 14, 18 and 20, UAV positioning is realized.

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----    334 VARIABLE r.L  the decision of h vehicle from the i region

             h1          h2          h3

2         1.000       1.000       1.000
10        1.000       1.000       1.000
14        1.000       1.000       1.000
18        1.000       1.000       1.000
20        1.000       1.000       1.000
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Figure 2. The decision of h.vehicle from the i.region

In Figure 2, it is clear that UAV vehicles will not be positioned or positioned in the areas to be planted. As can be seen, it is seen that all of the 2, 10, 14, 18 and 20 regions to be installed will be positioned by UAV vehicles.

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----    334 VARIABLE x.L  the number of h vehicle from the i region

             h1          h2          h3

2         2.000       1.000       1.000
10        2.000       1.000       1.000
14        4.000       1.000       3.000
18        2.000       1.000       1.000
20        4.000       1.000       1.000
```

Figure 3. The number of h.vehicle from the i.region

Figure 3 shows how many positioning operations are possible for UAVs in the facilities. As seen in the figure, it is seen that h1 is the type of vehicle which has the highest positioning, and IHA vehicles in all 2, 10, 14, 18 and 20 regions will be installed.

IV. CONCLUSION

Disaster processes are critical for the human lives and the processes must be controlled and organized. An effective disaster management consists of the selecting the disaster areas, sending the vehicles for the affected people needs, etc,. In this study, a location decision for the UAVs to distribute the needs timely and using renewable energy for this purpose is examined. This study presents a mathematical model for this problem. Locations of UAVs positioning and and the number of the UAVs at each locations are given in results.

In the future works, heuristic methods can be used for larger cases such as applying this problem for all country or some additional constraints.

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Onur Derse " Positioning Of Unmanned Aerial Vehicles for the Natural Disasters" International Journal of Computational Engineering Research (IJCER), vol. 08, no. 02, 2018, pp. 43-47.