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Research Article

A decision support model for unmanned aerial vehicles assisted disaster response using AHP-TOPSIS method

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Abstract

The main objective of disaster response is to secure lives and livelihoods at first. However, policymakers need accurate information regarding disaster areas to make a quick decision right after the disaster. Especially at a large scale disaster, it is much more important to respond to it quickly due to the number of affected people. In the uncertain atmosphere of the disaster, decision-makers can utilize UAV (Unmanned Aerial Vehicles) to gather instant images of the disaster area for Search and Rescue Mission (SAR) and damage assessment. Also, it will be used as a communication tool between emergency units and the command center. This paper discusses the usage of UAV in a possible İstanbul earthquake. Considering the damages that may occur after a possible Istanbul earthquake, five criteria have been determined. These criteria have been weighted within the AHP (Analytic Hierarchy Process) method, and the TOPSIS (Technique for Order Preference by Similarity to an Ideal Solution) method has prioritized the districts of Istanbul according to these criteria (number of casualties, number of injured people, number of damaged buildings, number of hospitals and number of critical facilities). With the help of this ranking, when the Istanbul earthquake occurs, if a different duty was not given to UAVs, it was tried to be determined which districts should first look for the UAVs SAR mission.

Keywords: Unmanned Aerial Vehicles, Earthquake, Disaster Management, AHP, TOPSIS.

İnsansız hava araçları destekli afet müdahalesi için bir karar destek modeli: AHP-TOPSIS metodu

Öz

Afete müdahalenin temel amacı, öncelikle yaşamları ve yaşam kaynaklarını güvence altına almaktır. Bunu başarmak için, politika yapıcıların afetten hemen sonra hızlı karar verebilmeleri, bu sebeple afet bölgesi hakkında doğru bilgiye ihtiyaçları vardır. Özellikle büyük çaplı bir felakette, etkilenebilecek insan sayısı nedeniyle, daha hızlı bir şekilde cevap vermek çok daha önemlidir. Felaketin belirsiz atmosferinde karar vericiler, Arama ve Kurtarma Görevi (AVK) ve hasar değerlendirmesi için felaket alanının anlık görüntülerini toplamak için İHA'yı (İnsansız Hava AracıVehicles) kullanabilirler. Ayrıca acil durum birimleri ile komuta merkezi arasında bir iletişim aracı olarak kullanılabilmektedir. Bu makalede İHA'nın olası İstanbul depreminde kullanımı tartışılmaktadır. Olası bir İstanbul depreminden sonra meydana gelebilecek zararlar göz önüne alındığında, 5 kriter belirlenmiş (ölebilecek insan sayısı, yaralanabilecek insan sayısı, hasar görebilecek bina sayısı, hastane sayısı ve kritik tesisler), bu kriterler AHP (Analitik Hiyerarşi Süreci) yöntemiyle ağırlıklandırılmış ve TOPSIS yöntemi ile de bu ilçelerin önem sıralaması yapılmıştır. Bu sıralamanın yardımıyla, İstanbul depremi meydana geldiğinde, İHA'lara farklı bir görev verilmemişse, ilk olarak hangi bölgelerin AVK faaliyetinin yapılması gerektiği belirlenmeye çalışılmıştır.

Anahtar Kelimeler: İnsansız Hava Aracı, Deprem, Afet Yönetimi, AHP, TOPSIS.

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1. Introduction

From 1900 to 2015, 35,000 natural disasters happened, approximately 8 million people died, and more than 7 trillion dollar damages occurred worldwide (Technology, 2018). If human-made disasters were added to this number, it would increase considerably. According to the studies of the International Disaster Database(Em-Dat), the total number of people affected by disaster is rising, but disasters related deaths are decreasing, costs of disasters are increasing, disasters are affecting emerging countries disproportionately, and the number of disasters is increasing annually (Gutierrez, 2008). All these make disaster management more important than ever. Although the importance of disaster mitigation and risk management preparedness increases day by day, the ability to respond after a disaster is the most important element. The period until the start of disaster is "risk management," and the period after a disaster is "crisis management" (Tiwari, 2015).

The first and most important task during a disaster response is the protection of human life. Especially when a large-scale disaster occurs, its response should be large-scale, like the national or international level, to minimize loss. The first 72 hours after the disaster is vitally important, especially for the SAR mission, so disaster response must be fast and effective (Erdelj & Natalizio, 2016).

Policymakers, who have to manage a complex situation like disaster response, need to get accurate data about the disaster area in order to make the right decisions and then distribute the resources correctly. Inconsistency of information gathered from different stakeholders makes it almost impossible to make and apply the right decisions. Even the disaster might be a terrorist attack using a nuclear or chemical weapon. In those conditions, it is almost impossible to get reliable information about the contaminated area and it will be very difficult to assess the damage and apply the SAR mission (Spiers, 1986).

Therefore, after any disaster, decision-makers can use UAVs to watch disaster areas instantly and steer stakeholders expeditiously. Even if transportation and energy infrastructures are damaged, and the area is contaminated by flood, earthquake, avalanche, or any other disaster, UAVs can send live images of the disaster area to the command center. With the help of this, evacuation points, logistic routes, critical infrastructures' conditions, priority SAR areas can be decided. At the preparedness stage of the disaster, in a proactive way, possible damage of a disaster is predicted, and disaster drills are applied according to prepared scenarios. Yet all the possibilities can not be planned in the fuzzy atmosphere of the disaster. For that reason, disaster management must be flexible under all circumstances, and being flexible is possible with quick decision making.

Although each disaster has its own unique variables, in this study it is aimed to lead decision-makers quickly decide where to look first after the İstanbul earthquake through UAV. Therefore, 5 criteria; the number of casualties, the number of injured people, the number of damaged buildings, the number of hospitals, and the number of critical facilities were determined. Later, these criteria were weighted by the AHP method. According to these criteria, with the help of the report prepared by JICA in 2002 (JICA, 2002), the importance ranking was made with the TOPSIS method considering the damages that may occur in the districts after the earthquake according to these criteria.

The rest of the paper is organized as followed. Section two is prepared for related studies about UAV and disaster management. In the third section is the methodology of the paper. In this chapter, there is a brief summary of AHP and TOPSIS methods. The fourth part of the study is the findings of the paper, and there are results of the study, which are found by AHP and TOPSIS methods, and the final part of the work is the conclusion part, where the importance of this paper explained.

2. Literature Review

UAV(Unmanned Aerial Systems) is an autonomous or remote commanded aircraft that can carry loads and aerial photography. One of the most important features of UAV is that they can be used remotely or autonomously in dangerous and dangerous missions. In this context, UAV has many different uses such as geological surveys, international border patrols, exploration and surveillance, search and rescue, scientific research, and construction management. In addition, UAVs are used in disaster operations management for post-disaster. The initial assessment may include the damage level of the damaged areas in the disaster area and the condition of the transportation routes. Thus the situation after the disaster resource distribution planning can also be done more effectively as it can be better observed (Liu, Huang, Chen, & Han, 2014). Also, UAV can be used in disaster operations management to establish a makeshift communication network to create current maps of the disaster area and to find areas where rescue teams have more opportunities to save the victims (Camara, 2014).

Application areas frequently seen in the management of disaster operations of UAV are mapping affected areas after disasters, analyzing the images gathered, coordinating UAV networks, integrating UAV with other communication tools, and providing rapid and high-quality information transfer. However, when studies on UAV in the area of disaster management are analyzed, it is seen that UAVs are mostly used in post-disaster operations (Zurli, Leiras, & Bravo, 2015). For instance, Quaritsch et al. (Quaritsch, Kruggl, Wischounig-Strucl, & Bhattacharya, 2010), an air sensor network design and use of it in case of a disaster are discussed, and the use of integer linear programming model, instead of air sensor model, for the coverage problem of the optimum placement of these sensors, is discussed.

Mukherjee proposed a high altitude aerial platform that serves as a signal replenisher to increase the line of sight communication of UAV in post-disaster operations and developed data transfer between UAV and command center within a certain range (Mukherjee, ve diğerleri, 2014). Tuna et al., a UAV supported communication network was proposed to establish communication of UAV between employees in the field of search and rescue management in post-disaster scenarios (Tuna, Nefzi, & Conte, 2014). Luo et al. proposed a new cloud-supported UAV implementation framework to address the difficulties caused by network conditions where the connection was broken, disconnected and limited, by taking into consideration the post-disaster condition where the telecommunications infrastructures were damaged (Luo, Nightingale, Asemota, & Grecos, 2015). In the study conducted by Restas, the use of UAV for different disaster situations (earthquake, flood, forest fire, nuclear accident, and hazardous substance release) at operational and tactical levels was studied (Restas, 2015).

In order to establish efficient search and rescue systems with UAV support, some critical parameters need to be considered, including the energy limitations of UAV, the quality of gathered data, and hazards in the environment in which UAV systems operate. Mario et al. studied a multifunction UAV for mountain search and rescue operations. They aim to determine which properties UAVs should have. For example, in a mountainous terrain search and rescue mission, UAVs could be working low temperatures, high altitude, various payloads, and weather conditions. Also, UAV must be equipped with a high-resolution performance camera to gather better visual and thermal data (Silvagni, Tonoli, Chiaberge, & Zenerino, 2016).

UAVs are used in many different areas, as mentioned above, including the management of disaster search and rescue operations. Various problem types for the use of UAV in these areas are discussed in the field, and this study focuses on UAV route planning (route planning, routing) problems in disaster management. There are many studies addressing the UAV route planning problem in different aspects. For example, Lee presented a path planning strategy for a UAV to track a vehicle that could change its speed and waypoint (Zennaro, 2003). A decision support system was developed by using an integer programming model for route planning of UAVs (Gencer, Aydoğan, & Kocabaş, 2009).

Mufalli proposed a mathematical programming model for simple missions and various heuristic algorithms for problems, taking into account the selection of sensors used in UAVs and routing of UAVs from the targets set in military reconnaissance tasks (Mufalli, Batta, & Nagi, 2012). Ercan and Gencer proposed an integer programming model for route planning with different capabilities (Ercan & Gencer, 2013). UAV used in military operations aim to make the most appropriate planning or scheduling to fulfill various mission demands of different locations at different times using fixed-wing various types of UAV. Accordingly, the authors proposed a two-step approach, a graph-based search algorithm for UAV path planning, and a mixed-integer linear programming model for task scheduling.

Di Franco and Buttazzo, on the other hand, take a different approach to path planning for UAV, considering energy consumption. They proposed a road planning algorithm that minimizes energy consumption, considering the problem of coverage path planning, a pathfinding process that covers all points of a particular area (Cabreira , Di Franco, Ferreira, & Buttazzo, 2018). Yakıcı has developed a new ant colony-based method for solving the problem by formulating the problem of positioning and routing the small UAVs at the tactical level with integer linear programming (Yakıcı, 2016).

Although many studies related to the UAV route problem are included in the literature, a limited number of studies addressing this problem have been encountered in disaster operations management. For example, Mersheeva and Friedrich (Mersheeva & Friedrich, 2012) proposed a method based on the variable neighborhood search approach for route planning of UAVs used in disaster operations to display the disaster area. To Nedjati et al. (Nedjati, Vizvari, & İzbırak, 2016), on the other hand, an intervention system was presented for rapid damage assessment after the earthquake. In this system, the authors proposed mixed-integer linear programming models regarding the problem of grid-based coverage path planning to collect images from the earthquake area and obtain useful information.

With the introduction of UAVs in disaster operations management, it is observed that the interest in research in this field has increased. In this context, the use of UAVs in disaster operations management for earthquake disaster was discussed in the study. Since the earthquake, which is one of the types of disasters, is a disaster whose effect increases rapidly, it is necessary to make aerial exploration many times for post-earthquake due diligence. Rapid damage assessment in post-earthquake situations plays an important role in response activities (such as the evacuation of injured persons, debris removal, and aid distribution), as in other disasters. While the survival rate is 91% in the first 30 minutes after the earthquake, this rate decreases to 36.7% in the second day. Therefore, due diligence becomes an important factor. After the earthquake, ground-based correction studies are widely used for investigations, especially since it takes a lot of time in heavily damaged locations (Macintyre, Barbera, & Smith, 2006).

In addition to search and rescue missions, UAVs also can be used for logistic transportation. When a disaster happened, the roads and streets will be blocked or collapsed. It is critical to delivering first aid and primary needs. For this reason, it is aimed to deliver medicines, food, and living materials to areas that are not particularly accessible or far away (Carlsson & Song, 2017).

Deployment of UAV's into disaster management could be more useful once difficulties and limitations associated with integration is overcoming through technologies, procedure, and policy issues. Besides, there should be laws and regulations for UAV usage in disaster management (Naser & Kodur, 220).

In this study, the use of UAVs for disaster location due diligence is discussed in cases where transportation to the disaster area cannot be achieved by using ground vehicles after a possible earthquake. Within the scope of post-disaster response activities of UAVs, a clustering and mathematical programming-based approach has been proposed with the aim of making route planning for surveillance of designated disaster areas. In the proposed approach, clusters should be created in order to determine the departure and landing ground stations of UAVs in the areas to be monitored. For this purpose, it is recommended to use three different methods within the scope of the study. In addition to the k-means algorithm and p-center problem model, which are frequently used in the literature, Cavdur et al. Temporary Disaster Response (GAM) facilities offered also focus on the solution of the settlement problem. The clustering result obtained by different methods is considered as the input of the Traveler Sales Problem (GSP) model, which is recommended to be used in the route planning of UAVs. The proposed approach is described in the next section of the study. In the third section, there are sample practices and results related to the proposed approach. In the fourth section, results and suggestions are given (Cavdur, Küçük, & Sebatlı, 2016).

3. Material and Method

3.1. AHP Method

The Analytic Hierarchy Process (AHP) is one of the multiple criteria decision-making tools for organizing and analyzing complex decisions and developed by Thomas L. Saaty (Saaty, 1987). AHP addresses how to determine the relative importance of a set of activities in a multi-criteria decision problem. The process makes it possible to include decisions on intangible qualitative criteria as well as concrete quantitative criteria (Badri, 2001). The AHP method is based on three rules: first, the structure of the model; second, the comparative judgment of the alternatives and the criteria; last one, synthesis of the priorities

(Dağdeviren, 2008). To obtaining the relative importance degree of the criteria at each level, a pairwise comparison matrix is developed using the "Saaty preference scale," as shown in Table 1.

The stepwise procedure of AHP is presented as follows:

Step 1: Construct the structural hierarchy.

Step 2: Construct the pairwise comparison matrix.

Assuming n attributes, the pairwise comparison of attribute i with attribute j yields a square matrix A_{nxn} where a_{ij} denotes the comparative importance of attribute i with respect to attribute j.

In the matrix, $a_{ij} = 1$ when i = j and $a_{ji} = 1/a_{ij}$.

$$A_{nxn}= \begin{pmatrix} a_{11} & a_{12} & a_{13} & \dots & \dots & a_{1n} \\ a_{21} & a_{22} & a_{23} & \dots & \dots & a_{2n} \\ a_{31} & a_{32} & a_{33} & \dots & \dots & a_{3n} \\ \dots & \dots & \dots & \dots & \dots & \dots \\ a_{n1} & a_{n2} & a_{n3} & \dots & \dots & a_{nn} \end{pmatrix}$$

Step 3: Construct normalized decision matrix

$$cij = aij \qquad \sum_{j=1}^{n} a_{ij}$$

$$i = 1,2,3,4, \dots \dots \dots ., n$$

$$j = 1,2,3,4, \dots \dots ., n$$

Step 4: Construct the weighted, normalized decision matrix

$$w_i = \frac{\sum_{j=1}^{n} c_{ij}}{n} \ , \ i = 1,2,3, \dots \dots \dots n$$

$$W = \begin{pmatrix} w1 \\ . \\ . \\ wn \end{pmatrix}$$

Step 5: Calculate Eigenvector & Row matrix

E = N^{th} rootvalue / $\sum N^t rootvalue$

Rowmatrix = $\sum_{j=1}^{n} a_{ij} * e_j$

Step 6: Calculate the maximum Eigenvalue, λ_{max}.

$$\lambda_{max} = Rowmatrix \ / \ E$$

Step 7: Calculate the consistency index & consistency ratio.

$$CI = (\lambda_{max} - n) \ / \ (n-1)$$

$$CR = CI \ / \ RI$$

3.2. TOPSIS Method

One of the MCDM methods, named TOPSIS (Technique for Order Performance by Similarity to Ideal Solution) was first developed by Hwang and Yoon (Hwang & Yoon, 1981). In the TOPSIS method, the best alternative would be the one that is nearest to the ideal solution and farthest from the negative ideal solution. The ideal solution is the solution that maximizes the benefit criteria and minimizes the cost criteria, whereas the negative ideal solution maximizes the cost criteria and minimizes the benefit criteria (Wang & Elhag, 2006).

Step 1: Establish a normalized decision matrix for the ranking

$$rij = xij \ \frac{x_{ij}}{\sqrt{\sum_{j=1}^{J} x_{ij}^2}} \qquad j = 1,2,3, \dots \dots .., J; \ i = 1,2,3, \dots \dots .. n$$

Where x_{ij} and r_{ij} are original and the normalized score of decision matrix respectively.

Step 2: Construct the weighted normalized decision matrix by multiplying the weights w_i of evaluation criteria with the normalized decision matrix r_{ij}.

$$vij = wi * rij \qquad j = 1,2,3, \dots \dots .., J; \ i = 1,2,3, \dots \dots .. n$$

Step 3: Determined the positive ideal solution (PIS) and negative ideal solution (NIS)

$$A^* = \left\{ v_1^*, \ v_2^*, v_3^*, \dots \dots v_n^* \right\} \quad \text{maximum values}$$

Where $v_i^* = \left\{ max(vij) \ if \ j \in J; \ min(vij) \ if \ j \in J- \right\}$

$$A- = \left\{ v_1^- , v_2^-, v_3^-, \dots \dots, v_n^- \right\} \quad \text{minimum values}$$

Where $v- = \left\{ min(vij) \ ) \ if \ j \in J; \ max(vij) \ if \ j \in J- \right\}$

Step 4: Calculate the separation measures of each alternative from PIS and NIS

$$d_i^* = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^*)^2} \ , j = 1,2,3, \dots \dots J$$

$$d_i^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^-)^2} \ , i = 1,2,3, \dots \dots J$$

Step 5: Calculate the relative closeness coefficient to the ideal solution of each alternative

$$CCi = \frac{d_i^-}{d_i^* + d_i^-} \quad i = 1,2,3, \dots\dots\dots.. n$$

Step 6: Closeness coefficient values of alternatives are ranked from most valuable to worst. The alternative having the highest closeness coefficient (CC_i) is selected (Wang & Elhag, 2006).

Table 1. Saaty's pairwise comparison scale

Definition	Intensity of İmportance
Equally important	1
Moderately more important	3
Strongly more important	5
Very strongly more important	7
Extremely more important	9
Intermediate values	2,4,6,8

3. Results and Discussion

Earthquake, flood, landslide, heavy rain etc. are natural events occurring at certain intervals. If these events happen in areas where people do not live, it is just a natural event that people are not affected. However, if such an incident occurs in human settlements, it can seriously affect human life as well as many social situations, and this event becomes a natural disaster.

It is too often to face a natural disaster in Turkey, and the high financial losses occur as a result. Lack of legal, administrative and technical conditions and awareness further increases disaster losses.

An earthquake disaster that can be counted among these natural disasters mentioned in Istanbul is expected, and this is a fact accepted by scientists. Being aware of the damages to be caused by any disaster in the settlement, the Japanese International Cooperation Agency (JICA) and Istanbul Metropolitan Municipality prepared "The Republic of Turkey Istanbul In the Disaster Prevention / Mitigation Basic Plan". This plan includes Seismic Micro-Zoning of the Province scenario earthquakes and possible losses in Istanbul were prepared (Ajansı, 2002).

Considering the damages that may occur after a possible Istanbul earthquake, 5 criteria; the number of casualties(C1), the number of injured people(C2), the number of damaged buildings(C3), the number of hospitals(C4), and the number of critical facilities(C5) were determined. Later, these criteria were weighted by the AHP method. According to these criteria, with the help of the report prepared by JICA (Ajansı, 2002), the importance ranking was made with the TOPSIS method considering the damages that may occur in the districts after the earthquake. AHP and TOPSIS have been calculated by using MATLAB as a tool.

In Table 2, a double comparison was made between the criteria. As a result of the binary comparison, the consistency rate is 1%. Since this ratio is less than 10%, it means that the binary comparison is consistent.

Table 2. Pairwise Comparison Matrix

	C_1	C_2	C_3	C_4	C_5
C_1	1	2	3	5	7
C_2	1/2	1	2	3	5
C_3	1/3	1/2	1	2	3
C_4	1/5	1/3	1/2	1	2
C_5	1/7	1/5	1/3	1/2	1

Table 3 shows the weighted version of the criteria and the order of importance among them. While determining the criteria, potential human losses are taken into consideration primarily. Because the first and most important aim of disaster response is securing human lives, for that reason, possible death numbers and injured people numbers are the most important criteria. Besides, the possible number of damaged buildings is taken as criteria because UAVs can easily make damage assessment of buildings and guide rescue units. Hospitals are also taken into consideration, due to quick response is vital, especially to wounded people right after the earthquake. For that reason, UAVs can determine damaged or undamaged hospitals quickly, and it helps decision-makers to plan rapid and more effective first aid services. Critical facilities are one of the other criteria because, after the earthquake, critical facilities estimated damages might be worse than expected, or it will be impossible for ground units to determine the damage because of the biological, chemical, or great fire etc.

Table 3. Results obtained with AHP

Criteria	Weights
C_1	0,444
C_2	0,262
C_3	0,053
C_4	0,230
C_5	0,049

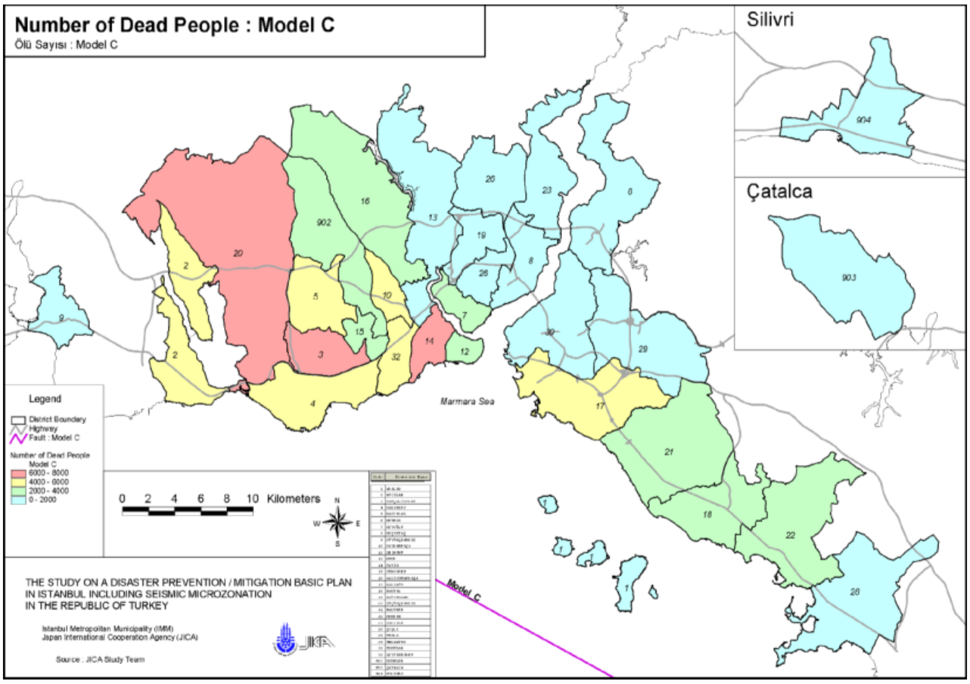

Figure 1. Number of Dead People

According to the worst-case scenario for Istanbul in the JICA report, loss of life will be 87,000 at an earthquake. This is 1.0% of the population in the Study Area. It is estimated that more than 6,000 people in Bahçelievler, Fatih, and Küçükçekmece districts will die right after an earthquake in İstanbul (Ajansı, 2002).

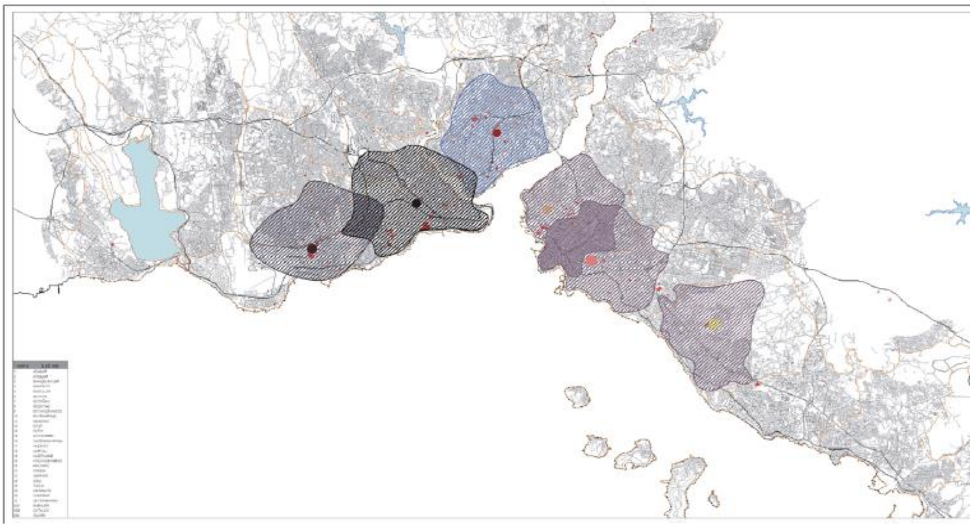

Figure 2. Number of Injured People

According to the JICA report, the number of seriously injured people is estimated to be 135,000. Existing medical care facilities in the metropolitan area are 19,433 beds, 201 hospitals, and 267 polyclinics. Current medical care facilities will be insufficient at the time of disaster due to the following reasons;

- More than half of the existing number of beds (12,000) will be used by permanent patients,
- Seven thousand extra beds must be distributed to public areas within hospitals, and tents should be set up in and around its premises. According to these two factors, only about 10% of severely injured people will use medical care facilities effectively (Ajansı, 2002). Therefore the number of injured people that could occur after the earthquake is taken as a second criterion.

Over 17,000 people in the 1999 Izmit earthquake lost their lives due to building collapses. When taking into consideration the weakness of the buildings in Istanbul, the most important cause of the casualties of a future earthquake is building (Ajansı, 2002). For that reason, the third criterion is heavily damaged buildings because unmanned aerial vehicles are considered to be able to easily spot from the sky and direct search and rescue units more quickly. Heavily damaged buildings shows in Figure 3.

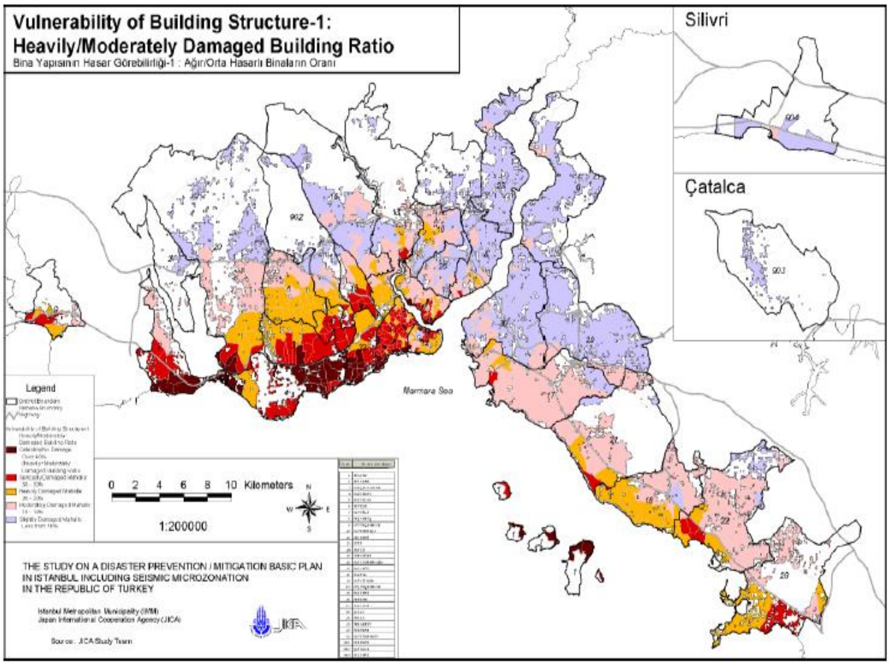

Figure 3. Heavily Damaged Building Ratio

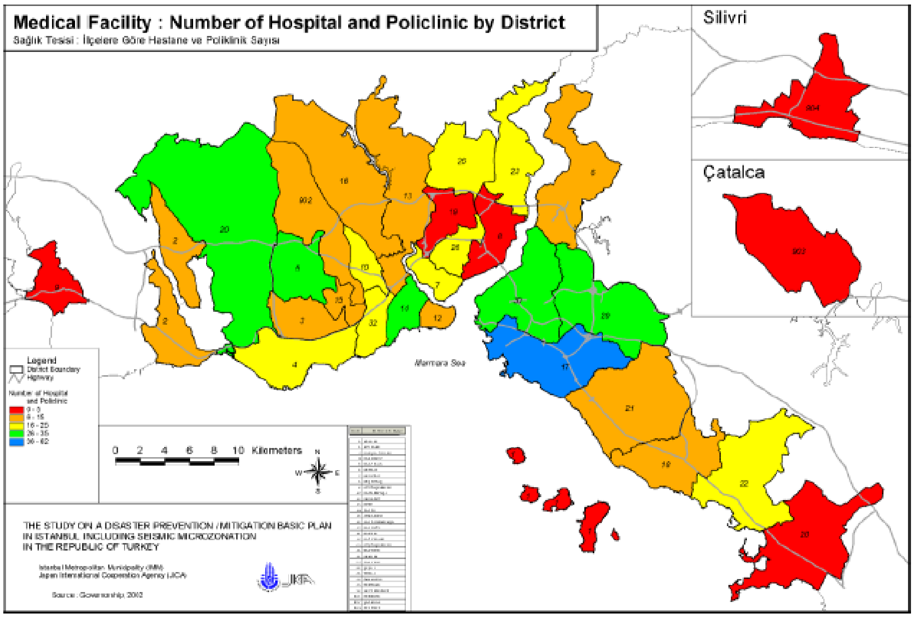

Figure 4. Number of Hospital and Policlinic by Districts

Because of the insufficient hospital numbers, it is vital to check undamaged hospitals. For that reason, hospital numbers are taken as the fourth criterion which is presented in Figure 4. Because it is evaluated that determining the hospital conditions in the districts after the earthquake will increase the effectiveness in intervening the injured people.

In an earthquake, flammable and combustible material facilities lead to a secondary disaster. According to JICA Report (Ajansı, 2002) 882 hazardous material facilities, including large LPG warehouses, factories producing paint / polish materials, chemical material tanks, Fuel / LPG filling places, and fuel storage locations are located in İstanbul. Due to the high number of critical facilities, it is taken as the fifth criterion. Because critical facilities damages during the earthquake could cause great harm, like a secondary disaster, to the environment and first aid teams would not approach right after the disaster. Number of hazardous facilites by district highligted in Figure 5.

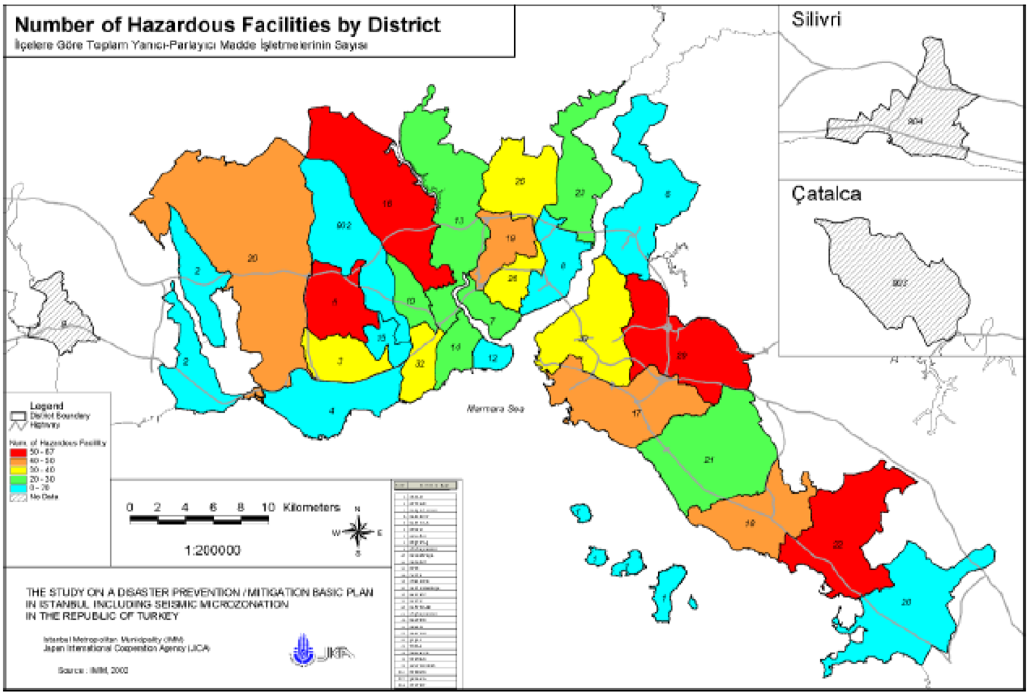

Figure 5. Number of Hazardous Facilities

Table 4. District of İstanbul with Weighted Criteria

Locations	Weights				
	0,444	0,262	0,053	0,23	0,049
	C_1	C_2	C_3	C_4	C_5
Adalar	1648	3255	1710	2	0
Avcılar	4678	6841	2311	5	17
Bahcelievler	6724	8165	3184	12	36
Bakırköy	4204	6310	2119	10	19
Bağcılar	5167	7294	2899	1	61
Beykoz	374	807	521	3	13
Beyoğlu	3464	5482	2644	8	22
Beşiktaş	1226	2547	692	4	18
Bayrampaşa	4180	6283	2846	6	21
Eminönü	2871	4820	2156	3	7
Eyüp	1938	3742	2044	4	29
Fatih	6866	8245	5776	16	29
Güngören	3703	5750	1550	6	18
G.osmanpaşa	2526	4435	2183	11	59
Kadıköy	4040	6127	2321	20	46
Kartal	2905	4858	2236	6	46

According to the JICA report, 16 districts(alternatives) in Istanbul province were included in thestudy. As seen in Table 4, there are 16 districts, weighted criteria and values belonging to districts.

Table 5. Normalized Matrix

Locations	C_1	C_2	C_3	C_4	C_5
Adalar	0,154	0,221	0,304	0,119	0,000
Avcılar	0,438	0,464	0,411	0,297	0,223
Bahcelievler	0,629	0,553	0,567	0,713	0,471
Bakırköy	0,393	0,428	0,377	0,594	0,249
Bağcılar	0,483	0,494	0,516	0,059	0,798
Beykoz	0,035	0,055	0,093	0,178	0,170
Beyoğlu	0,324	0,372	0,471	0,476	0,288
Beşiktaş	0,115	0,173	0,123	0,238	0,236
Bayrampaşa	0,391	0,426	0,507	0,357	0,275
Eminönü	0,269	0,327	0,384	0,178	0,092
Eyüp	0,181	0,254	0,364	0,238	0,380
Fatih	0,642	0,559	1,028	0,951	0,380
Güngören	0,346	0,390	0,276	0,357	0,236
G.osmanpaşa	0,236	0,301	0,389	0,654	0,772
Kadıköy	0,378	0,415	0,413	1,189	0,602
Kartal	0,272	0,329	0,398	0,357	0,602

In Table 5 the squares of each of the alternative values are squared, and the column totals of these values are obtained, and normalization is performed by dividing each value by the square root of the column to which it belongs.

Table 6. Weighted Normalized Matrix

Weighted Normalized Matrix					
Weights	**0,444**	**0,262**	**0,053**	**0,23**	**0,049**
Locations	**C_1**	**C_2**	**C_3**	**C_4**	**C_5**
Adalar	0,068	0,058	0,016	0,027	0,000
Avcılar	0,194	0,121	0,022	0,068	0,011
Bahcelievler	0,279	0,145	0,030	0,164	0,023
Bakırköy	0,175	0,112	0,020	0,137	0,012
Bağcılar	0,215	0,130	0,027	0,014	0,039
Beykoz	0,016	0,014	0,005	0,041	0,008
Beyoğlu	0,144	0,097	0,025	0,109	0,014
Beşiktaş	0,051	0,045	0,007	0,055	0,012
Bayrampaşa	0,174	0,112	0,027	0,082	0,013
Eminönü	0,119	0,086	0,020	0,041	0,004
Eyüp	0,080	0,066	0,019	0,055	0,019
Fatih	0,285	0,146	0,054	0,219	0,019
Güngören	0,154	0,102	0,015	0,082	0,012
G.osmanpaşa	0,105	0,079	0,021	0,150	0,038
Kadıköy	0,168	0,109	0,022	0,273	0,030
Kartal	0,121	0,086	0,021	0,082	0,030

Acording to Table 6, each value of the normalized matrix is weighted. The weighting process reveals the subjective aspect of the TOPSIS method. Because weighting process is done, according to the importance of the factors. The only subjective parameter of the TOPSIS method is the weights.

Table 7. Positive Ideal Distance Table

Pozitive Ideal Distances					
Locations	**C_1**	**C_2**	**C_3**	**C_4**	**C_5**
Adalar	0,044	0,008	0,000	0,000	0,000
Avcılar	0,007	0,001	0,000	0,003	0,000
Bahcelievler	0,000	0,000	0,000	0,023	0,001
Bakırköy	0,011	0,001	0,000	0,015	0,000
Bağcılar	0,004	0,000	0,000	0,000	0,002
Beykoz	0,070	0,017	0,001	0,001	0,000
Beyoğlu	0,018	0,002	0,000	0,009	0,000
Beşiktaş	0,052	0,010	0,001	0,002	0,000
Bayrampaşa	0,011	0,001	0,000	0,005	0,000
Eminönü	0,026	0,004	0,000	0,001	0,000
Eyüp	0,040	0,006	0,000	0,002	0,000
Fatih	0,000	0,000	0,001	0,042	0,000
Güngören	0,016	0,002	0,000	0,005	0,000
G.osmanpaşa	0,030	0,004	0,000	0,019	0,001
Kadıköy	0,012	0,001	0,000	0,067	0,001
Kartal	0,025	0,003	0,000	0,005	0,001

After the weighted normalized matrix is obtained, the maximum values of each column are determined if the purpose is maximization, provided that it adheres to the structure of the problem. These maximum values are ideal solution values. In Table 7, The closest distance to the ideal solution is determined.

The minimum values of each column are calculated. These are the negative ideal solution values which are shown in Table 8

Table 8. Negative Ideal Distances Table

Negative Ideal Distances					
Locations	**C_1**	**C_2**	**C_3**	**C_4**	**C_5**
Adalar	0,003	0,002	0,000	0,019	0,002
Avcılar	0,032	0,011	0,000	0,009	0,001
Bahcelievler	0,070	0,017	0,001	0,000	0,000
Bakırköy	0,025	0,010	0,000	0,001	0,001
Bağcılar	0,040	0,013	0,001	0,023	0,000
Beykoz	0,000	0,000	0,000	0,015	0,001
Beyoğlu	0,016	0,007	0,000	0,003	0,001
Beşiktaş	0,001	0,001	0,000	0,012	0,001
Bayrampaşa	0,025	0,009	0,000	0,007	0,001
Eminönü	0,011	0,005	0,000	0,015	0,001
Eyüp	0,004	0,003	0,000	0,012	0,000
Fatih	0,073	0,017	0,002	0,003	0,000
Güngören	0,019	0,008	0,000	0,007	0,001
G.osmanpaşa	0,008	0,004	0,000	0,000	0,000
Kadıköy	0,023	0,009	0,000	0,012	0,000
Kartal	0,011	0,005	0,000	0,007	0,000

The relative proximity to the ideal solution is calculated in Table 9. In calculating the relative proximity of each decision point to the ideal solution, distances to ideal and non-ideal points are used.

Table 9. Relative Closeness Table

Locations	$s*$	$s-$	$C*$
Adalar	0,158	0,158	**0,500**
Avcılar	0,230	0,232	**0,502**
Bahcelievler	0,296	0,296	**0,500**
Bakırköy	0,190	0,191	**0,502**
Bağcılar	0,278	0,276	**0,498**
Beykoz	0,123	0,127	**0,507**
Beyoğlu	0,165	0,165	**0,500**
Beşiktaş	0,120	0,122	**0,505**
Bayrampaşa	0,205	0,206	**0,501**
Eminönü	0,177	0,180	**0,505**
Eyüp	0,139	0,140	**0,500**
Fatih	0,310	0,310	**0,500**
Güngören	0,185	0,185	**0,500**
G.osmanpaşa	0,118	0,112	**0,487**
Kadıköy	0,213	0,211	**0,498**
Kartal	0,155	0,153	**0,496**

According to 5 criteria (number of casualties, number of injured people, number of damaged buildings, number of hospitals, and number of critical facilities), the order of importance is made between 16 districts of İstanbul are presented in Table 10. With high C* value has priority than the others for SAR mission with UAV. As seen in Table 10, the most critical districts are; Beykoz, Beşiktaş, and Eminönü. The least important ones are; Bağcılar, Kartal, and Gaziosmanpaşa.

Table 10. Ranking of the districts.

Locations	C*	Rank
Beykoz	0,5070	1
Beşiktaş	0,5054	2
Eminönü	0,5046	3
Bakırköy	0,5020	4
Avcılar	0,5016	5
Bayrampaşa	0,5014	6
Eyüp	0,5005	7
Fatih	0,5001	8
Adalar	0,5000	9
Beyoğlu	0,5000	10
Güngören	0,5000	11
Bahcelievler	0,4996	12
Kadıköy	0,4978	13
Bağcılar	0,4975	14
Kartal	0,4959	15
G.osmanpaşa	0,4865	16

4. Conclusions and Recommendations

The period until the earthquake occurs is the risk management period, and the period after the earthquake is the crisis management period. Especially the first hours after the earthquake are very important to save human lives. Technological developments are also used to disasters that respond in a fast and effective way.

In the earthquake in Elazığ, which was happened on January 20, 2020, UAVs were used for damage assessment first time. However, this use was limited to detecting what local authorities wanted. In addition, the limited number of damaged areas facilitated the use of UAVs.

It is considered that if the earthquake occurs in a more crowded city like Istanbul and more severe, it should be done in a system for the use of UAVs. For this reason, this study has been carried out by considering the number of deaths, number of injured people, number of heavily damaged buildings, number of hospitals, and critical facilities that may occur in a possible Istanbul earthquake.

As a result of the study, five criteria were weighted by the AHP method. Then, 16 districts in Istanbul were ranked by the TOPSIS method in order of importance, considering these five criteria.

It is aimed at the officials who are in charge of crisis management after the Istanbul earthquake to use unmanned aerial vehicles more effectively and efficiently.

In this study, the JICA report, which was made in 2002 used, because it is the most comprehensive report ever made related possible İstanbul earthquake. But it is a fact that, while the population of Istanbul was estimated at around 11 million in 2002, but it is estimated to exceed 16 million in 2020. However, this is just evidence that an earthquake that will occur in İstanbul will cause more severe damages and human losses than expected.

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