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Research Article

Multi Criteria Decision Making Approach to the Evaluation of Humanitarian Relief Warehouses Integrating Fuzzy Logic: A Case Study in Syria

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Abstract

A new disaster to humanity, called Coronavirus Disease (COVID-19), arose in and spread to worldwide at late December 2019. The most developed countries are affected from this pandemic more. However, the situation is more complex in some countries that are witnessed/witnessing a conflict, as in Syria. In Syria, the conflict continues more than 9 years and within the country there are more than 6 million internally displaced people (IDPs). This situation signifies millions of people living in hard conditions and seeking healthcare service, sheltering, food, safety and other related vital needs. In this context, since during a pandemic supplies and aid kits need to be stockpiled in a humanitarian relief warehouse to be protected and then distributed effectively to the most pandemic-affected people, we focused on the location research of relief warehouses in this study. We evaluated the locations of the relief warehouses to determine the most appropriate location based on a scientific humanitarian aid-based hybrid methodology. This novel methodology is implemented to a real case study in north of Aleppo/Syria. For this aim, firstly, data is collected directly from the target area; then humanitarian and economic criteria are selected by three experts to be included in the study. Criteria weights are computed by the Fuzzy Analytic Hierarchy Process (F-AHP). Finally, MULTIMOORA technique as a Multi Criteria Decision Making (MCDM) method is applied to assess the candidate warehouses and rank them. The proposed methodology showed its efficiency and effectiveness in evaluating relief warehouses and it can be utilized to facilitate the decision-making process. As a result, the suffering of the disaster-affected people can be reduced and high efficiency from donations in the target area can be achieved.

Keywords: COVID-19, Pandemic, Warehouse Location, Multi Criteria Decision Making (MCDM), Fuzzy Analytic Hierarchy Process (F-AHP), MULTIMOORA.

İnsani Yardım Depolarının Değerlendirilmesi için Bulanık Mantığın Entegre Edildiği Çok Kriterli Karar Verme Yaklaşımı: Suriye'de Bir Uygulama Çalışması

Öz

2019 yılının sonunda, Koronavirüs Hastalığı (COVID-19) olarak adlandırılan yeni bir afet insanlığa karşı ortaya çıkmış ve tüm dünyaya yayılmıştır. En gelişmiş ülkeler, bu pandemiden daha fazla etkilenmiştir. Fakat, Suriye'de olduğu gibi bir çatışmanın yaşandığı/yaşanmakta olduğu ülkeler için durum daha karmaşıktır. Suriye'de çatışma 9 yıldan fazla bir süredir devam etmektedir ve ülke dâhilinde 6 milyondan fazla ülke içinde yerlerinden edilmiş insan vardır. Bu durum, milyonlarca insanın zor koşullarda yaşadığını ve sağlık hizmeti, barınma, yiyecek, güvenlik ve ilgili diğer yaşamsal ihtiyaçların arayışında olduklarını göstermektedir. Bu bağlamda, bir pandemi boyunca malzemelerin ve yardım setlerinin korunmak ve daha sonra pandemiden en çok etkilenmiş insanlara etkili bir şekilde dağıtımını yapmak için bir insani yardım deposunda saklanmaları gerektiğinden ötürü, bu çalışmada, yardım

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depolarının yerleşiminin araştırmasına odaklanılmıştır. En uygun yeri belirlemek için yardım depolarının lokasyonları bilimsel insani yardıma dayalı hibrid bir metodoloji ile değerlendirilmiştir. Bu yeni metodoloji Suriye/Halep'in kuzeyinde gerçek bir vaka çalışmasına uygulanmıştır. Bu amaçla, öncelikle, veri, doğrudan hedef bölgeden toplanmıştır; akabinde çalışmaya dâhil edilecek insani ve ekonomik kriterler üç uzman tarafından seçilmiştir. Kriter ağırlıkları Bulanık Analitik Hiyerarşi Prosesi (B-AHP) ile hesaplanmıştır. Son olarak, aday depoları değerlendirmek ve sıralamak için bir Çok Kriterli Karar Verme (ÇKKV) yöntemi olan MULTIMOORA tekniği uygulanmıştır. Önerilen metodoloji yardım depolarını değerlendirmede etkinliğini ve etkililiğini göstermiştir ve karar verme sürecini hızlandırmak için kullanılabilir. Bunun neticesinde, afetten etkilenen insanların acıları azaltılabilir ve hedef bölgedeki bağışların yüksek etkinliği başarılabilir.

Anahtar Kelimeler: COVID-19, Pandemi, Depo Yerleşimi, Çok Kriterli Karar Verme (ÇKKV), Bulanık Analitik Hiyerarşi Prosesi (B-AHP), MULTIMOORA.

1. Introduction

Nowadays, every day a new disaster occurs in somewhere in the world and many people are affected by these disasters. Most of these disasters are natural disasters and these include floods, drought, landslides, earthquakes, pandemics, wildfires, etc. Between 2000 and 2019, there have been 7,344 natural disasters worldwide and the number of disasters for each year is demonstrated in Figure 1 below.

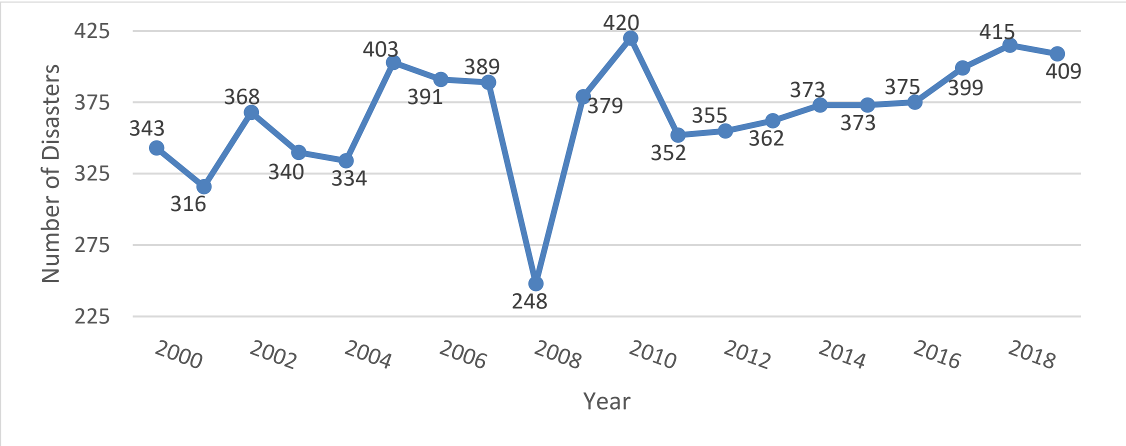

Figure 1. The Distribution of Natural Disasters Between 2000-2019 in the World (data taken from www.statista.com)

As seen from Figure 1, except the year of 2008, every year at least 316 natural disasters took place worldwide. Due to these thousands of disasters, there have been fatalities, as well. The number of global deaths by virtue of natural disasters between 2000 and 2019 are given in Figure 2.

In 2019, there have been 11,719 deaths of which majority of these occurred in Asia continent (approximately %45). However, at the end of 2019, a new threat and disaster to humanity arose from the Wuhan city in China in late December: Coronavirus Disease 2019 (COVID-19). It is caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and spread worldwide from the beginning. The disease is stated as a Public Health Emergency of International Concern by World Health Organization (WHO) on 30 January 2020 (Yen et al., 2020). Nonetheless, the outbreak has become a humanitarian emergency and finally stated as a pandemic by WHO on 11 March 2020. Although there has been one year since the beginning of the disease, the number of infections and deaths are still increasing rapidly day by day. The total number of COVID-19 cases worldwide is more than 86 million and the deaths are more than 1,8 million. Though more than 61 million COVID-19 patients have been recovered, there are still more than 20 million active cases (https://www.worldometers.info/coronavirus/).

Affecting USA, India, Brazil, Russia and France most, COVID-19 is an unprecedented pandemic (Di Gennaro et al., 2020). However, the situation is more complicated in some countries such as the ones where there is an ongoing conflict, as in Syria.

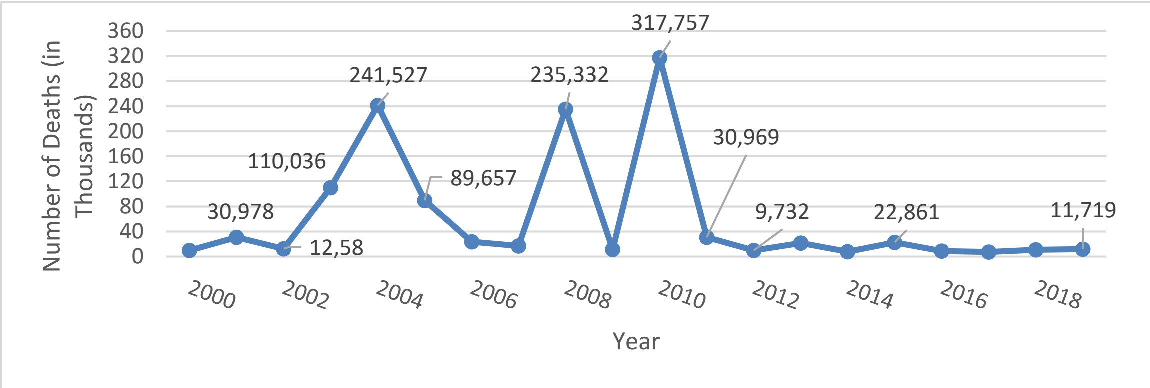

Figure 2. The Distribution of Global Deaths Due to Natural Disasters Between 2000-2019 Years (data taken from www.ourworldindata.org)

The conflict continues more than 9 year in Syria and there are more than 6 million internally displaced people (IDPs) within the country. This means that millions of people are living in hard conditions and seek for healthcare service, sheltering, food, safety and other related vital needs (Miç et al., 2019). Along with the continuous conflict in the country, the observation and control of COVID-19 is more problematic in Syria. As of 9 December, there are 8,580 total confirmed cases; 4,059 recoveries and 458 deaths in the country (OCHA, 2020). Still, validating the actual number of cases countrywide is troublesome, because testing across Syria is limited and due to the utilized testing strategy, a significant number of asymptomatic and mild cases are not being detected. Hence, together with COVID-19's strong infectivity and long incubation period; there is a pressing need for scientific and technological support to suppress and mitigate the spread of pandemic. At the moment, some key priorities in Syria can be summarized as developing observation capacity and increasing national and sub-national laboratory capacity to test for punctual determination, preserving health care workers via training and additional Personal Protective Equipments (PPE), acquiring COVID-19 supplies (such as diagnostic or biomedical equipment) and improving awareness within society (OCHA, 2020). These priorities have led us to the topic of humanitarian relief warehouses since PPE and supplies (biomedical equipments, pills, etc.) need to be stockpiled in a humanitarian relief warehouse to be protected and then distributed.

Many past global disasters proved the significance of humanitarian relief logistics and warehouses. This is because when a disaster outbreaks, supplying adequate amount of emergency supplies when and where they are needed is both crucial and challenged (Roh et al., 2018). Besides, its noteworthy to point out that humanitarian relief logistics struggles to decrease the negative impacts of disasters. Throughout a disaster, logisticians initially endeavor to acquire related supplies from local resources. If the relief organization possess a centralized warehouse, the logistician then investigates useable supplies in those warehouses.

Especially after outbreak of COVID-19 around the world, civil society organizations worked on delivering aids and COVID-19 hygiene kits to those affected people by the crisis in Syria. Therefore; they collect relief material, hygiene kits and donations according to the needs of the affected areas, then store it, arrange it in kits and prepare it to be sent to the neediest groups in a timely manner. Due to the lack of resources and capabilities inside Syria, relief warehouses are sometimes chosen based on personal opinions that lack a real and scientific deep study of the variables and requirements in the region. This result in many problems in terms of increasing the time period for the delivery of aid to the affected people or increasing additional costs that were rather avoided. These issues reflect negatively on the effectiveness of the relief operations and thus cause loss of money and sometimes they have an impact on the life of vulnerable people.

These points are the motivation of this paper and in this study, we evaluate the locations of the warehouses, choose the best one based on a scientific humanitarian-based hybrid methodology that makes it easier for decision-makers to increase the effectiveness of the relief process. Thus, we aim reducing the suffering of the pandemic-affected people and achieving high efficiency from donations that deliver to them.

Furthermore, warehouse location problem contains a large number of conflicting criteria and in this paper this situation is overcome by adopting an integrated fuzzy multi criteria decision making approach.

As a matter of fact, there are many studies handling warehouse location problem in literature. In a general perspective, while Ballou (1986) addressed dynamic warehouse location analysis, Lee (1993) dealt with the multiproduct warehouse location problem and applied a decomposition algorithm. Kudláčková and Chocholáč (2017) focused on warehouse location problem in the delivery time shortening context and Yuan (2019) discussed the existence of environmental justice problem in warehouse locations utilizing data for four metro areas in California. Zhang and Swaminathan (2020) studied the optimal warehouse location strategies of retailers in both centralized and decentralized supply chains. Other topics in which warehouse location problems are handled can be summarized as strategic capacity planning and robust optimization under uncertainty (Aghezzaf, 2005), multi objective mixed integer linear programming (Chen et al., 2007), Geographic Information System (GIS) integrated remote sensing (Huifeng and Aigong, 2008), nonlinear programming (Huang et al., 2015; Monthatipkul, 2016), genetic algorithm (Wang et al., 2017) and the radiation therapy method (Danchuk et al., 2018).

Naturally, as constituting a multi criteria decision problem, warehouse location problems are addressed in Multi Criteria Decision Making (MCDM) framework, as well.

Chatterjee and Kar (2013) employed a fuzzy-Rasch-VIekriterijumsko KOmpromisno Rangiranje (VIKOR) method under supply chain risks. Dey et al. (2015) applied Technique for Order Preference by Similarity to the Ideal Solution (TOPSIS), Simple Additive Weight (SAW) and Multi-Objective Optimization on the basis of Ratio Analysis (MULTIMOORA) methods and integrated the fuzzy set theory to the problem. Malmir et al. (2015) proposed a new MCDM method by virtue of balancing and ranking methods. Emeç and Akkaya (2019) adopted Stochastic Analytic Hierarchy Process (SAHP) to weight the criteria and fuzzy MOORA to assess and rank the alternatives. Khaengkhan et al. (2019) utilized SAW, AHP and TOPSIS based on seven main criteria for the warehouse locations of agricultural products. Çalık (2020) utilized Analytic Hierarchy Process (AHP) and TOPSIS via interval type-2 fuzzy sets.

From the humanitarian perspective, it is observed that the papers addressing humanitarian warehouse location problems are limited. Trivedi and Singh (2014) assessed the potential warehouse locations in humanitarian logistics via Interpretive Structural Modelling (ISM), fuzzy set theory, TOPSIS and AHP; and presented a numerical example. Roh et al. (2015) integrated AHP and Fuzzy TOPSIS for the pre-positioning of warehouses for a humanitarian relief organization and applied two case studies with macro- and micro- perspectives. Ofluoğlu et al. (2017) employed SAW, TOPSIS and VIKOR for the ranking of alternative humanitarian warehouses and utilized Borda Count method to acquire a final ranking of alternatives. The suggested method is applied for a case study in Trabzon, Turkey which is a natural disaster region. Roh et al. (2018) adopted fuzzy AHP and fuzzy TOPSIS and implemented a numerical example for humanitarian warehouse locations. Hakim and Kusumastuti (2018) adopted AHP to specify relief warehouse locations in the flood affected East Jakarta area, Indonesia.

However, despite the work described above, insufficient attention has been paid to the humanitarian warehouse location problem in a conflict area. With respect to such a goal, this paper aims to fill this gap in literature and this is accomplished through integrating fuzzy AHP and MULTIMOORA techniques. Within the study, the weights of each criteria are specified by fuzzy AHP and then the alternative warehouses are ranked by different MOORA versions: MOORA-Ratio, MOORA-Significance Coefficient, MOORA-Reference Point and MOORA-Full Multiplication. The final ranking of MULTIMOORA is obtained by ordinal dominance theory. The proposed method is applied for a real case study in Syria and the results are analyzed.

The remainder of this paper is organized as follows. In Section 2, the material utilized in the study is given and employed MCDM method is summarized briefly. The case study and its results are given in Section 3 along with tables supporting results. Conclusions including final remarks and some recommendations for future works are presented in Section 4.

2. Material and Method

2.1. Material

In order to choose a relief material warehouse, organizations usually announce publicly warehouse specifications in the advertisement to invite venders to apply their technical and financial quotations. Then, companies and warehouse owners submit their offers to the organizations which contain the specifications of each warehouse and its financial value. Later, a field visit to each warehouse is made to set its specifications accurately by a committee, as this survey is made on all the warehouse alternatives presented to the organization, which will be the essential inputs for our study.

In this study, a specialized committee of three experts in the field of supply chain (an expert from the local community, a technical person from the organization, an expert from the donor) determined the criteria on the basis of which the warehouse will be selected. After obtaining the warehouse information, their proposed locations are placed on a map in the target area, in order to know its exact location in relation to the ongoing clashes in the conflict area, position to main roads, and its proximity to the places of camps in need of aid. The process obtaining all these information, uploading them to maps, and obtaining values for each criterion took place from the date range of 10/8/2020 to 19/11/2020.

2.2. Method

Along with the study, a new methodology is suggested to evaluate the relief warehouses in crisis areas based on five steps. This methodology is shown in Figure 3 and the steps are explained below:

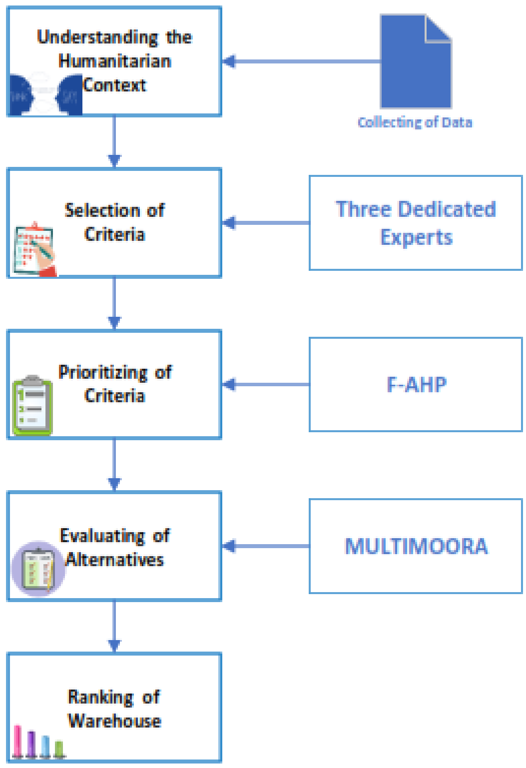

Figure 3. The Proposed Methodology for the Relief Warehouse Evaluation in This Study

i. First step is understanding the situation inside the affected area by collecting data from directly affected people throughout meetings and surveys with the representative in the communities. The main aim of this step to identify the issues according to direct beneficiaries and local councils and sharing the process with them.

ii. Second step is selection of related criteria to be utilized in the study. For this stage, three specialized experts in the Syrian crisis are consulted to define the criteria; one from the local councils, another from the implementing partner (the organization that will manage the warehouse) and the third one is working as donor representative.

iii. Third step of the methodology is prioritizing of criteria. We utilized Fuzzy Analytic Hierarchy Process (F-AHP) to define the importance of each criterion based on the fuzzy pairwise comparison and according to the three experts' opinions.

iv. Fourth step is evaluating of relief warehouse alternatives in the crisis area by MULTIMOORA technique.

v. Final and fifth step is ranking of relief warehouses. After implementing MULTIMOORA to evaluate each alternative, we ranked them accordingly to facilitate the selection process for decision makers.

2.2.1 Prioritizing Risks Using F-AHP

In this study; employing F-AHP, the goals and criteria are arranged in a hierarchical arrangement and evaluated by experts. The relative importance of each criterion is specified by linguistic variables, which are symbolized as triangular fuzzy numbers, as shown in Figure 4. The center of gravity defuzzification method is utilized to transform the fuzzy assessments into their corresponding crisp values (Buckley, 1985).

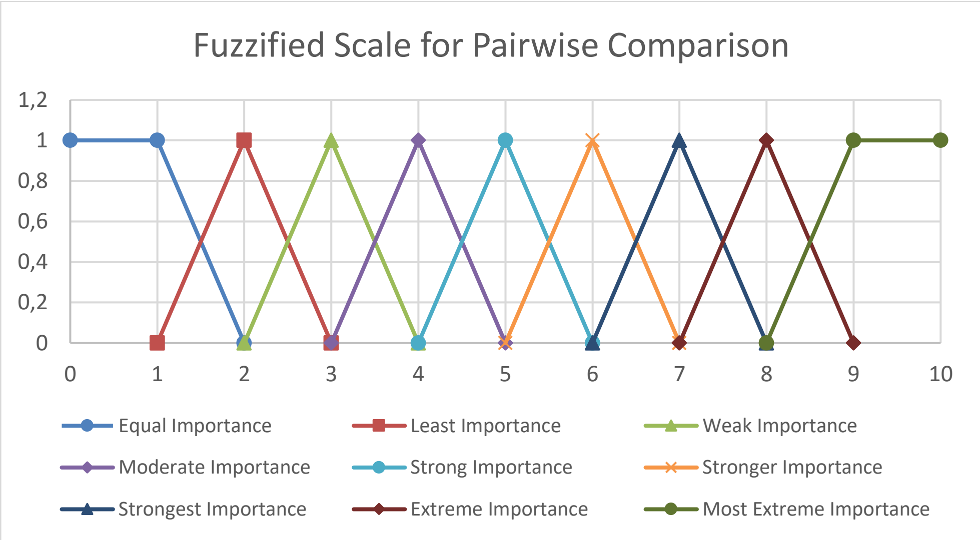

Figure 4. Membership Function for Linguistic Values by Fuzzified Scale

A 9-point scale is utilized to identify the relative importance of each criterion with respect to the other (Tsaur et al., 2002), as summarized in Table 1. The weights of different criteria are computed are computed via the geometric mean method (Buckley, 1985).

Table 1. Saaty's Crisp Scale and Developed Fuzzified Scale for Pairwise Comparison (Tsaur et al., 2002)

Saaty's Crisp Scale	Judgment Explanation	Triangular Fuzzy Scale	Triangular Fuzzy Reciprocal Scale
1	Equal Importance	(1,1,2)	(1/2,1,1)
2	Least Importance	(1,2,3)	(1/3,1/2,1)
3	Weak Importance	(2,3,4)	(1/4,1/3,1/2)
4	Moderate Importance	(3,4,5)	(1/5,1/4,1/3)
5	Strong Importance	(4,5,6)	(1/6,1/5,1/4)
6	Stronger Importance	(5,6,7)	(1/7,1/6,1/5)
7	Strongest Importance	(6,7,8)	(1/8,1/7,1/6))
8	Extreme Importance	(7,8,9)	(1/9,1/8,1/7)
9	Most Extreme Importance	(8,9,9)	(1/9,1/9,1/8)

Fuzzy comparison matrix $\tilde{F}$ representing the fuzzy relative importance of each pair elements is defined by the equations below (Buckley, 1985):

$$\tilde{F} = \begin{bmatrix} 1 & \tilde{r}_{12} & \cdots & \tilde{r}_{1n} \\ \tilde{r}_{21} & 1 & \cdots & \tilde{r}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{r}_{n1} & \tilde{r}_{n2} & \cdots & 1 \end{bmatrix} = \quad (1)$$

$$\begin{bmatrix} 1 & \tilde{r}_{12} & \dots & \tilde{r}_{1n} \\ 1/\tilde{r}_{12} & 1 & \dots & \tilde{r}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ 1/\tilde{r}_{1n} & 1/\tilde{r}_{2n} & \dots & 1 \end{bmatrix}$$

$$1/\tilde{f}_{12} = (l, m, u)^{-1} = \left(\frac{1}{u}, \frac{1}{m}, \frac{1}{l}\right) \quad (2)$$

The geometric mean method is utilized to get the fuzzy geometric mean $\tilde{r}_i$ with Equation 3 is given below:

$$\tilde{r}_i = \left(\tilde{f}_{i2} \times \tilde{f}_{i2} \times \dots \times \tilde{f}_{in}\right)^{\frac{1}{n}} \quad (3)$$

The fuzzy weight $\widetilde{fw}_i$ of the i th criterion is calculated with Equation 4 given below;

$$\widetilde{fw}_i = \tilde{r}_i \times (\tilde{r}_1 + \tilde{r}_2 + \dots + \tilde{r}_n)^{-1} \quad (4)$$

2.2.2 Multi-Objective Optimization on the Basis of Ratio Analysis (MULTIMOORA)

In practice and literature, Multi-Objective Optimization on the Basis of Ratio Analysis (MULTIMOORA) technique is commonly applied by means of its simple application procedure, appropriateness to different situations and advancements by virtue of experimental surveillance. As its name signifies, it is a multi-objective optimization method and it was suggested by Brauers and Zavadskas in 2006. In comparison with other MCDM methods, it is a relatively novel method for the solution of MCDM problems (Brauers and Zavadskas, 2006).

The technique is based to scoring various prospects and the results procured from this method demonstrate measurable results for each alternative.

There are various versions method such as MOORA-Ratio, MOORA-Significance Coefficient, MOORA-Reference Point, MOORA-Full Multiplication and MULTIMOORA. In this paper, all these versions are applied. To obtain the most accurate results; all effected factors, all relationships between alternatives and criterion are taken into consideration. After generating initial decision matrix and normalizing the decision matrix, we applied the aforementioned MOORA methods. The detailed information about the procedures of these methods applied in this paper can be found in Brauers and Zavadskas (2006, 2010. 2012, 2013).

The final ranking of the results of the MOORA-Ratio, MOORA-Significance Coefficient, MOORA-Reference Point and MOORA-Full Multiplication approaches are achieved with ordinal dominance theory. Thus, MULTIMOORA solution demonstrated the rankings of relief warehouses.

3. Case Study and Results

The novel methodology is applied for a case study of a conflict area in the north of Aleppo/Syria where has an approximate area of 6,580 km^2; population of approximately 727,000 and three cross border gates to the neighbor country “Turkey”. A map of the target area and the locations of candidate warehouses is demonstrated in Figure 5. Approximately half of the population are internally displaced persons (IDPs) in the area and 75% of them are in need of assistance. Therefore, selecting the optimum relief warehouse location will reflect positively on increasing the value of donated money, aid and in-kind materials. On the other hand, it will facilitate the process of delivering aids to vulnerable people in the target area and accelerate the decision process made by the local councils and implementing organizations.

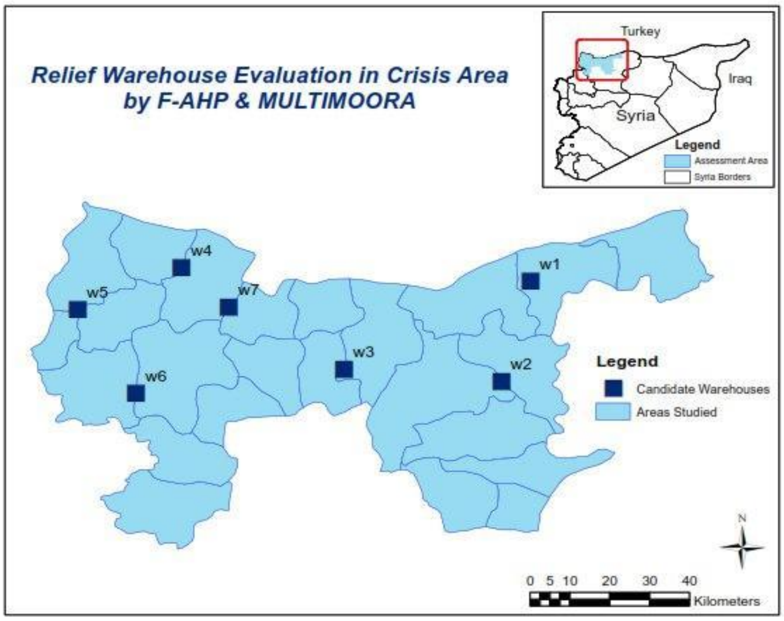

Figure 5. Map of the Studied Area and Locations of Candidate Warehouses

Criteria to be utilized in the study are prepared and discussed by three experts as shown in Table 2 where nine criteria are identified to be included in the next step “F-AHP” under three categories of economic, operating and infrastructure.

Table 2. Detailed Information About the Criteria Utilized in the Study

Criteria Category	Criterion		Clarification	Criterion Type
Economic	C_1	Warehouse Expenses	C_1: Expenses of one unit per warehouse including the rent of warehouse and other expenses.	Minimize
	C_2	Labor Cost	C_2: Expenses paid to labor for loading and unloading one unit.	Minimize
	C_3	Availability of Labor	C_3: The labors' availability in warehouses' area; 1 corresponds to rare availability, 2 to moderate, 3 to good enough.	Maximize
Operating	C_4	Proximity to Demand Camps	C_4: Distance in km to come across the demand camps.	Minimize
	C_5	Proximity to Main Roads	C_5: Distance in km to the main roads	Minimize
	C_6	Away from Clash Lines	C_6: Distance in km to areas containing clashes.	Maximize
Infrastructure	C_7	Availability of Water, Electricity	C_7: If both are available 2 value; if one is available 1 value; if both are not available 0 value.	Maximize
	C_8	Availability of Safety Equipments	C_8; If all equipment is working 2 value, if they need maintenance 1 value, if there is no safety equipment's 0 value.	Maximize
	C_9	Capacity of the Warehouse	C_9: Number of kits that can be stored in the warehouse.	Maximize

The data related to each criterion are presented in Table 3 below. The experts defined the importance of each criterion compared with the others to establish the pairwise comparison and calculated the fuzzy weight of each criterion. Equations described before (Eq (1) to Eq (4)) are utilized to calculate the fuzzy weights and calculated fuzzy weights and the rankings according to these values are presented in Table 4.

Table 3. Alternative Warehouses' Values for Each Criterion

Warehouse	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
W_1	0.10	0.034	1	60	4.3	18	0	0	13132.8
W_2	0.09	0.047	1	72	3.2	40	1	0	9398
W_3	0.08	0.046	2	57	1.2	48	0	1	9583
W_4	0.07	0.048	1	50	2.5	30	2	0	9296
W_5	0.10	0.041	3	35	1.5	47	2	0	10727
W_6	0.09	0.047	3	69	2.6	49	2	2	9379
W_7	0.07	0.050	1	64	0.5	36	1	1	8936

Table 4. Criterion Fuzzy Weights and Their Rankings

Criterion No	Fuzzy Weights	Criterion Weight (CW)	Normalized Weight (NW)	Criterion Ranking (from 1 to 9)
C_1	(0.074, 0.148, 0.293)	0.172	0.149	3
C_2	(0.014, 0.026, 0.053)	0.031	0.027	9
C_3	(0.021, 0.039, 0.085)	0.048	0.042	7
C_4	(0.112, 0.216, 0.411)	0.246	0.214	2
C_5	(0.032, 0.062, 0.133)	0.076	0.066	5
C_6	(0.169, 0.311, 0.548)	0.343	0.298	1
C_7	(0.019, 0.039, 0.085)	0.048	0.041	8
C_8	(0.046, 0.096, 0.194)	0.112	0.098	4

C_9	(0.029, 0.062, 0.133)	0.075	0.065	6

Following Table 5, Table 6, Table 7 and Table 8 presents the calculations of MOORA-Ratio; MOORA-Significance Co-efficient; MOORA-Reference Point and MOORA-Full Multiplication, and warehouses' rankings, respectively.

Table 5. MOORA-Ratio Calculations and Warehouses' Rankings

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	$Total\ Max$ $-Total\ Min$	$Ranking$
	Min	Min	Max	Min	Min	Max	Max	Max	Max		
W_1	0.44	0.29	0.20	0.38	0.64	0.17	0.00	0.00	0.49	-0.88	7
W_2	0.39	0.39	0.20	0.46	0.47	0.38	0.27	0.00	0.35	-0.53	6
W_3	0.35	0.39	0.39	0.36	0.18	0.46	0.00	0.41	0.36	0.34	3
W_4	0.31	0.40	0.20	0.32	0.37	0.29	0.53	0.00	0.35	-0.04	5
W_5	0.44	0.34	0.59	0.22	0.22	0.45	0.53	0.00	0.40	0.74	2
W_6	0.39	0.39	0.59	0.44	0.38	0.47	0.53	0.82	0.35	1.14	1
W_7	0.31	0.42	0.20	0.41	0.07	0.34	0.27	0.41	0.33	0.34	4

Table 6. MOORA-Significance Coefficient Calculations and Warehouses' Rankings

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	$Total\ Max$ $-Total\ Min$	$Ranking$
	Min	Min	Max	Min	Min	Max	Max	Max	Max		
W_1	0.13	0.00	0.39	0.16	0.56	0.30	0.53	0.82	0.00	-0.11	7
W_2	0.09	0.11	0.39	0.24	0.40	0.09	0.27	0.82	0.14	-0.04	6
W_3	0.04	0.10	0.20	0.14	0.10	0.01	0.53	0.41	0.13	0.06	3
W_4	0.00	0.12	0.39	0.10	0.30	0.18	0.00	0.82	0.14	-0.01	5
W_5	0.13	0.06	0.00	0.00	0.15	0.02	0.00	0.82	0.09	0.07	2
W_6	0.09	0.11	0.00	0.22	0.31	0.00	0.00	0.00	0.14	0.10	1
W_7	0.00	0.13	0.39	0.18	0.00	0.12	0.27	0.41	0.16	0.03	4

Table 7. MOORA-Reference Point Calculations and Warehouses' Rankings

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	Max $-\ Min$	$Ranking$
	Min	Min	Max	Min	Min	Max	Max	Max	Max		
W_1	0.13	0.00	0.39	0.08	0.00	0.30	0.53	0.82	0.00	0.82	5
W_2	0.09	0.11	0.39	0.00	0.16	0.09	0.27	0.82	0.14	0.73	4
W_3	0.04	0.10	0.20	0.10	0.46	0.01	0.53	0.41	0.13	0.53	3
W_4	0.00	0.12	0.39	0.14	0.27	0.18	0.00	0.82	0.14	0.82	5
W_5	0.13	0.06	0.00	0.24	0.41	0.02	0.00	0.82	0.09	0.82	5
W_6	0.09	0.11	0.00	0.02	0.25	0.00	0.00	0.00	0.14	0.31	1
W_7	0.00	0.13	0.39	0.05	0.56	0.12	0.27	0.41	0.16	0.41	2

Table 8. MOORA-Full Multiplication Calculations and Warehouses' Rankings

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	$\frac{Max}{Min}$	$Ranking$
	Min	Min	Max	Min	Min	Max	Max	Max	Max		
W_1	0.10	0.03	1.00	60.00	4.30	18.00	0.00	0.00	13132.80	0.00	3
W_2	0.09	0.05	1.00	72.00	3.20	40.00	1.00	0.00	9398.00	0.00	3
W_3	0.08	0.05	2.00	57.00	1.20	48.00	0.00	1.00	9583.00	0.00	3
W_4	0.07	0.05	1.00	50.00	2.50	30.00	2.00	0.00	9296.00	0.00	3
W_5	0.10	0.04	3.00	35.00	1.50	47.00	2.00	0.00	10727.00	0.00	3
W_6	0.09	0.05	3.00	69.00	2.60	49.00	2.00	2.00	9379.00	$7x10^9$	1

W_7	0.07	0.05	1.00	64.00	0.50	36.00	1.00	1.00	8936.00	$2x10^9$	2

Eventually, the dominance comparisons and final MULTIMOORA rankings are presented in Table 9.

Table 9. Dominance Comparisons for MOORA Method and MULTIMOORA Rankings

	Ratio	**Significance Coefficient**	**Reference Point**	**Full Multiplication**	**MULTIMOORA**
W_1	7	7	5	3	7
W_2	6	6	4	3	6
W_3	3	3	3	3	3
W_4	5	5	5	3	5
W_5	2	2	5	3	2
W_6	1	1	1	1	1
W_7	4	4	2	2	4

According to Table 9, the ranking of alternative warehouses is: $W_6 > W_5 > W_3 > W_7 > W_4 > W_2 > W_1$. Thus, we can conclude that the warehouse represented by W_6 is the best alternative to locate the humanitarian relief warehouse in the case study region.

4. Conclusions and Recommendations

Every year, the number of natural or human made disasters are increasing. In addition to these, this year a new burden has imposed worldwide as a devastating pandemic: COVID-19. Thus, humanitarian relief logistics that aim to store and distribute required relief supplies become more and more important topic, both in implementation and literature. Location of humanitarian relief warehouses in right places is crucial to carry out the operations in this area effectively. In the literature, there are many studies addressing warehouse location problems in different aspects (Ballou, 1986; Lee, 1993; Aghezzaf, 2005; Chen et al., 2007; Huifeng and Aigong, 2008; Huang et al., 2015; Monthatipkul, 2016; Wang et al., 2017; Kudláčková and Chocholáč, 2017; Danchuk et al., 2018; Yuan, 2019; Zhang and Swaminathan, 2020). Although there are studies in which MCDM methods are used in this area, it is observed that the papers addressing humanitarian warehouse location problems are limited. As a matter of fact, humanitarian warehouse location problem in a conflict area has taken quite insufficient attention.

Thus, within this study, we handled the problem from the MCDM perspective: criteria to be utilized for MCDM are identified by three experts; fuzzy logic is applied to determine the criteria weights and MOORA technique is employed to obtain the rankings of alternative humanitarian relief warehouses. The MULTIMOORA final rankings after different versions of MOORA is acquired by employing dominance comparisons. In other words, the content of this study is enriched by integrating fuzzy logic and MOORA methods together to solve the problem of choosing the location of a humanitarian relief warehouse. Within the study, the proposed methodology is applied for a real case study in Syria.

In further studies; other MCDM methods and hybrid MCDM methods can be utilized and compared, different fuzzy sets can be included, the case study area can be extended to increase the comprehension of the study or another region can be selected for case study.

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