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Multi Criteria Decision Making for the Selection of a New Hub Facility Location in Humanitarian Supply Chains

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Öz

Dünyadaki yüzlerce felaketten etkilenen insanlara yardım etmeye çalışmak, "insan" olmanın bir gereği ve tüm insanlık için önemli bir harekettir. Bu çabaların bir parçası olarak, insani yardım kuruluşları ve akademisyenler insani lojistik üzerine odaklanmaktadır. Dünya Gıda Programı (World Food Programme, WFP) her yıl 80 milyondan fazla insana yardım eden lider kuruluşlardan biridir. WFP'ye göre, gerekli malzemelerin neredeyse yarısı krizin bulunduğu ülke veya bölgede, diğer yarısı uluslararası olarak tedarik ve sevk edilmektedir. Bu uluslararası hibeler, WFP tarafından yönetilen Birleşmiş Milletler İnsani Yardım Merkezleri tarafından sağlanmaktadır. Bu ağın kilit unsurları, acil durum malzemelerinin depolandığı afet bölgelerine yakın merkezlerdir. Bu çalışmada, gerektiğinde kullanım için değerlendirilen uygun yeni tesis adayları arasından seçim yapmak için bir karar destek planı önerilmiştir. Tartışılan çok kriterli karar verme probleminde alternatif yerler, acil seferberlik, maliyet verimliliği, barındırma bölgesinin istikrarı, afet eğilimli alan, insani hizmetler için eğitim yetenekleri ve ölçek ekonomileri gibi ilgili kriterlere göre incelenmektedir. Çalışmada, bulanık bilgilerle birlikte dilsel değerlendirmelerin dikkate alındığı güçlü bir yöntem kullanılmıştır.

Anahtar Kelimeler

"İnsani yardım lojistiği, Çok Kriterli Karar Verme, MULTIMOORA, Dünya Gıda Programı"

Abstract

Trying to help people affected by hundreds of disasters around the world, is a necessity of being a "human" and an important movement for all humanity. As part of these efforts, humanitarian agencies and academicians have been focusing on humanitarian logistics. The World Food Programme (WFP) is one of the leading organizations that help over 80 million people every year. According to WFP, almost half of the necessary materials are supplied in the country or region where the crisis is located, and the other half is supplied and shipped internationally. These international grants are provided by the United Nations Humanitarian Depots managed by the WFP. The key elements of this network are the centers located close to the disaster areas where the emergency materials are stored. In this study, a decision support plan has been proposed to choose among suitable new facility candidates evaluated for use when necessary. In the multi-criteria decision-making problem discussed, alternative locations are examined according to the related criteria such as immediate mobilization, cost efficiency, stability of the hosting zone, disaster-prone area, training abilities for humanitarian services, and economies of scale. A robust method is used considering the linguistic evaluations, together with the fuzzy information.

Key Words

"Humanitarian Logistics, Multi Criteria Decision Making, MULTIMOORA, World Food Programme"

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1. Introduction

Hundreds of disasters that are happening on the world every day open huge irreversible injuries in the lives of thousands of people. These disasters can be triggered by sudden, catastrophic events like hurricanes, earthquakes, or complex, continuing emergencies like conflicts, or slow onset disasters such as pandemic infections (Redmond, 2005). Whatever the reason is, they can cause more harm to the affected population even though they do not directly live in disaster area (Gossler et al., 2019). Helping these people to restore their lives is an important task for all humanity. Because, one shocking example is that more than 800 million people worldwide are facing with chronic malnutrition because of drought and floods (World Food Programme, 2020). There are various humanitarian organizations established for this purpose. Humanitarian organizations play a vital role in post-crisis relief and recovery periods. The activities carried out are crucial in delivering food and other services to the affected people (Resodihardjo, 2018). Therefore, their logistical needs are of great importance for the sustainability of such aids. Logistics is one of the most important subjects in disaster management such that approximately 75% of funding allocated to disaster response concerns supply chain expenditures (Van Wassenhove, 2006). Because of this excessive importance, UN adopted "Cluster Approach" to strengthen the coordination on the ground level management and response capacity in key sectors such as logistics, food. The Logistics Cluster, one of these Cluster Approachs, aims to improve coordination and access to common logistics services (Besiou & Van Wassenhove, 2019). During an emergency, both UN and other humanitarian agencies come together according to their Logistics cluster to consolidate all activities and develop coordinated response. A broad division of labor exists within the UN humanitarian system. On food sector, World Food Programme (WFP) is the responsible coordination agency in Logistics cluster for emergency food delivery (Rose & O'Keefe, 2017).

Humanitarian organizations focus mainly on four basic steps of disaster management: mitigation, preparedness, response, rehabilitation (Tomasini and Van Wassenhove, 2009). The activities in all four steps are affected heavily by the funding. If the funding is sufficient, organizations can strengthen supply chain capabilities like geographical (pre)positioning of relief items and base facilities (Besiou and Van Wassenhove, 2019). So, humanitarian organizations implement the basics of commercial supply chain management. These operations have been realized as decision making and operations management topics by academics. We refer the interested reader to review studies of Besiou and Van Wassenhove (2019), Heaslip et al.(2019), and Rodriguez-Espindola et al. (2018). Broad number of studies on humanitarian supply chain and logistics are carried out. Nowadays, there are relevant papers of different problems in the field such as network design (Stephonson Jr., 2005; Stauffer et al., 2018), product distribution (Gossler et al., 2019), outsourcing (Gossler et al., 2019; Falagara Sigala and Wakolbinger, 2019), location-routing (Elluru et al., 2019), disaster competence (Goldschmidt and Kumar, 2019), decision support with information fusion (Smirnov et al. 2007), supplier selection (Kim et al., 2019), facility planning and selection (Kako et al., 2020). Several types of both qualitative and quantitative methods have been used like mathematical modelling (Elluru et al., 2019), simulation (Stauffer et al., 2018). But contrary some methods have been rarely taken into account such as multi criteria decision making (MCDM) methods in humanitarian logistics topics.

A few studies have been carried out in which MCDM methods are used when the keywords of humanitarian logistics and MCDM were searched. All of these studies are published in last decade. The study of Celik et al. (2014) could be given as an early exemplary to mentioned studies. They took into consideration the identifying and evaluating the success factors that are critical for effective disaster management in context of humanitarian logistics operations. They proposed a method that combines the typ-2 fuzzy sets and analytic hierarchy process (AHP) and suggested that it is efficient. Saksrisathaporn et al. (2016) evolved a decision model through which they took the problems of supplier, warehouse and vehicle selection into consideration by using MCDM. As a supplementary study, Saksrisathaporn and Reeveerakul (2016) presented two case scenarios and implemented a decision model proposed by the authors in previous study. They took into account the humanitarian logistics life cycles of French Red Cross to the Haiti earthquake and Thai Red Cross to the Nan flooding as the case studies. Another study is Venkatesh et al. (2019)'s one which is interested with continuous aid humanitarian supply chains. They introduced a supply partner selection framework by proposed MCDM model that uses fuzzy AHP to compute weights and fuzzy TOPSIS to rank alternatives. When we focused on the facility location and selection decisions in humanitarian logistics topic, we encounter really a few studies which taken into consideration MCDM techniques (Roh et al., 2013; Roh et al., 2015; Bastian et al., 2016; Drakaki et al., 2018; Song et al., 2019). In this context, there is a notable gap in humanitarian logistics literature.

In this study, we consider the facility evaluation and selection in UN WFP supply chain which is the one leading example of humanitarian aid supply chains. The United Nations humanitarian response depots (UNHRD) which is managed by WFP, is an international humanitarian network of 6 hubs strategically located around the world that provide supply chain solutions to the international humanitarian community in Logistics Cluster. As can be seen from Figure 1, the individual warehouses are located in Italy, United Arab Emirates, Ghana, Panama, Malaysia and Spain. Through this network, basic services like warehousing, inspection and handling of prepositioned relief items in any of the six UNHRDs worldwide for its range of partners, are offered at no charge. In addition, UNHRD Laboratories offers extensive services such as procurement, transportation, technical assistance and technological innovation. UNHRD technicians are also involved in setting up mobile warehouses, training local staff and setting up treatment units and decontamination areas (http://www1.wfp.org/unhrd).

UNHRD tries to maximize a coordinated response effort, including the following criteria (https://unhrd.org/):

- Immediate mobilization of relief items within 24 to 48 hours.
- Cost efficiency through the use of single network.

- Turnkey solutions and support throughout the humanitarian supply chain.
- Harmonization of relief items.
- A "one-stop-shop" customer service.
- Staging areas at the onset of an emergency.
- Training facilities for humanitarian organizations.

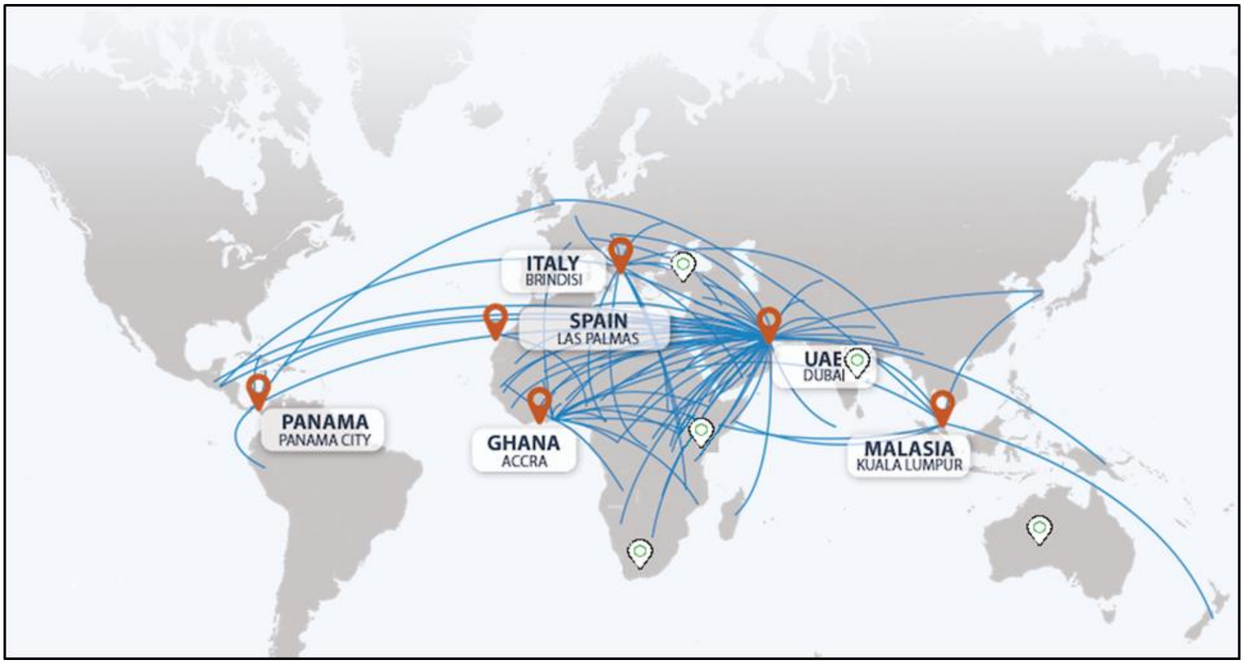

Figure 1. Current Hub Locations Used by WFP (https://unhrd.org/) *
**(White spots show the candidate hub facility locations)*.

Within the scope of this study, we focus on new hub facility evaluation in UNHRD supply chain. For ongoing disasters, a study is conducted to determine the appropriate location candidates for the establishment of new centers that may be needed. Five alternatives of hub facility location are evaluated under the following criteria, some of which are already in use by WFP:

- Immediate Mobilization (C1): The ability of transport the relief items within 24 to 48 hours from a request via airports, ports or main road. So, it is important to be close to international ports, airports or main roads.
- Cost Efficiency (C2): It consists of costs through the use of network to procure, host and deploy relief items. Hosting and deployment are especially important branches. It could be measured with inflation and expenses.
- Stability of Hosting Region (C3): Socio-political and economic stability of hosting country.
- Disaster- Prone Area (C4): Proximity of area to the disaster area.
- Training Abilities for Humanitarian Services (C5): Hub locations also served as training center facilities. Training activities compose from rescue actions to logistics services. It is a benefit for hub location country to have a well-established institution of aid and relief service.
- Economies of Scale (C6): The present supply chain network also provides its partners economies of scale from market research and procurement of relief items to storage, transportation, installation of equipment and building. So, it is wishful that the hosting countries have an economy of scale.

Examining the WFP operations of 2017 and mid-2018, Africa (DRC Ebola crisis, SAHEL countries [North Africa and Sub-Sahara], South Sudan emergency), South East Asia (Bangladesh emergency and hurricanes, and floods) and Middle East regions (Syria and Yemeni crises) have faced with emergencies and needed humanitarian relief items supply. Current locations of UNHRD hubs have been chosen for their transport connections and especially proximity to disaster-prone areas (https://www.wfp.org/unhrd). Besides, WFP seeks to create a network of UNHRDs in Africa, the Middle East, South East Asia based on its own requirements (https://unhrd.org/). Therefore, five alternative hub facility locations are determined due to the closeness to aforementioned and similar regions, and their levels of development; being Australia, India, Kenya, South Africa and Turkey.

UN programs, such as WFP, UN International Strategy for Disaster Reduction, tend to building and increasing their resilience for worldwide disaster risk reduction (Kimber, 2019). According to sociological analyses, idea of resilience is a vague concept. Handling with that vagueness in all stages of the UN operations is primarily needed to not hinder the organization's disaster reduction operations. In order to handle the vagueness of our decision problem and also due to the structure of the determined criteria, fuzzy data sets are taken into account, and the evaluation is carried out using Fuzzy MULTIMOORA, which is a robust commonly used multi criteria decision making (MCDM) method presented in Section 2. It is stated that only two studies were carried out in the facility planning area and only one in the warehouse selection area, among the application studies conducted on the MULTIMOORA method (Hafezalkotob et al., 2019). Therefore, this study also has contributed related literature.

The rest of the paper is organized as follows. In next section, a summary definition of the MCDM method used in this study is provided. Then, we present the application of the selected method to the problem and present our analytical results in Section 3. Finally, we give the conclusions of our work together with some future directions.

2. Method

We solved this problem using an MCDM technique, namely the MULTIMOORA The method is introduced by Brauers and Zavadskas (2010), and is realized by combining the results of Multi Objective Optimization on the basis of Ratio Analysis (MOORA) method of Brauers and Zavadskas (2006) and Full Multiplicative Form method of Brauers (2002). It is possible to apply The MOORA Method to optimize two or more contradictory objectives subject to certain constraints, solving complex decision problems (Brauers and Zavadskas, 2006; Gadakh, 2011). MULTIMOORA evaluates the alternatives, using various MOORA methods. According to related literature, there are some conditions to be met in order to be defined as a robust multi criteria method, and MULTIMOORA method is said to be one of the most robust MCDM methods (Brauers and Zavadskas, 2012). Furthermore, MULTIMOORA method is reliable and simple when its performance is compared with other MCDM methods (Hafezalkotob et al., 2019). Low computational time, using three different methods for determining subordinate rankings, and employing ranking aggregation tools for integrating the subordinate rankings are also other advantages of the method. The method is then updated by Brauers et al. with the use of Triangular Fuzzy Numbers (TFNs) (Brauers et al, 2011).

The MOORA method consists of the combined results of the MOORA Ratio and MOORA Reference Point approaches. In the Fuzzy Ratio system, the responses of alternatives on the criteria are first normalized and the total assessment of each alternative with respect to the criteria are obtained using Eqn. (1), where x_{ij}^* defines the value of alternative i for criterion j:

$$x_{ij}^* = \frac{x_{ij}}{\sqrt{\sum_{j=1}^{m} x_{ij}^2}} \tag{1}$$

In order to optimize the result, Eqn. (2) is used summing up the values for the ones to be maximized (for $j = \{1, \dots, g\}$) and/or subtracting for the ones to be minimized (for $j = \{g+1, \dots, n\}$). Here, y_i^* corresponds to the normalized assessment of alternative i.

$$y_i^* = \sum_{j=1}^{g} x_{ij}^* - \sum_{j=g+1}^{n} x_{ij}^* \tag{2}$$

Then the Best Non-Fuzzy Performance (BNP) values are obtained by Eqn. (3) (by defuzzifying the assessments if necessary), and a ranking according to these values is applied.

$$BNP_i = \frac{(y_{i3}^* - y_{i1}^*) + (y_{i2}^* - y_{i1}^*)}{3} + y_{i1}^* \tag{3}$$

For the second part, the Reference Point system, the ratios (obtained in Eqn. (1)) are used to calculate the maximal objective reference point, which is defined as follows:

$$\tilde{r}_j = \begin{cases} x_j^+ = (\max_i x_{ij1}^*, \widetilde{\max_i x_{ij2}^*}, \max_i x_{ij3}^*), j \le g; \\ x_j^- = (\min_i x_{ij1}^*, \min_i x_{ij2}^*, \min_i x_{ij3}^*), j > g; \end{cases} \tag{4}$$

Then, this vector is normalized and the deviation from reference point is obtained by Eqn. (5) and Eqn. (6). These results are ranked in an increasing order, giving the final ranking of the problem.

$$d(\tilde{r}_j, \tilde{x}_{ij}^*) = \sqrt{\frac{1}{3}[(\tilde{r}_{j1} - \tilde{x}_{ij1})^2 + (\tilde{r}_{j2} - \tilde{x}_{ij2})^2 + (\tilde{r}_{j3} - \tilde{x}_{ij3})^2]} \tag{5}$$

$$\min_i(\max_j d(\tilde{r}_j, \tilde{x}_{ij}^*)) \tag{6}$$

In order to obtain the solution for the next part, namely the Fuzzy Full Multiplicative Form, we calculate the overall utilities of alternatives by using Eqn. (7) and final ranking is obtained by defuzzifying these values using Eqn. (3).

$$\widetilde{U}_i' = \tilde{A}_i \oslash \tilde{B}_i \tag{7}$$

where $\tilde{A}_i = (A_{i1}, A_{i2}, A_{i3}) = \prod_{j=1}^{g} \tilde{x}_{ij}$ and $\tilde{B}_i = (B_{i1}, B_{i2}, B_{i3}) = \prod_{j=g+1}^{n} \tilde{x}_{ij}$ are calculated for the alternatives to be maximized and minimized, respectively.

As can be followed from the above explanations, there are three solutions obtained by the three methods. These three results are ranked according to the dominance states of the Fuzzy MULTIMOORA, and final ranking is obtained.

Figure 2 shows the relation between the two methods of MOORA, namely the ratio system and the reference point, and the Full Multiplicative Form.

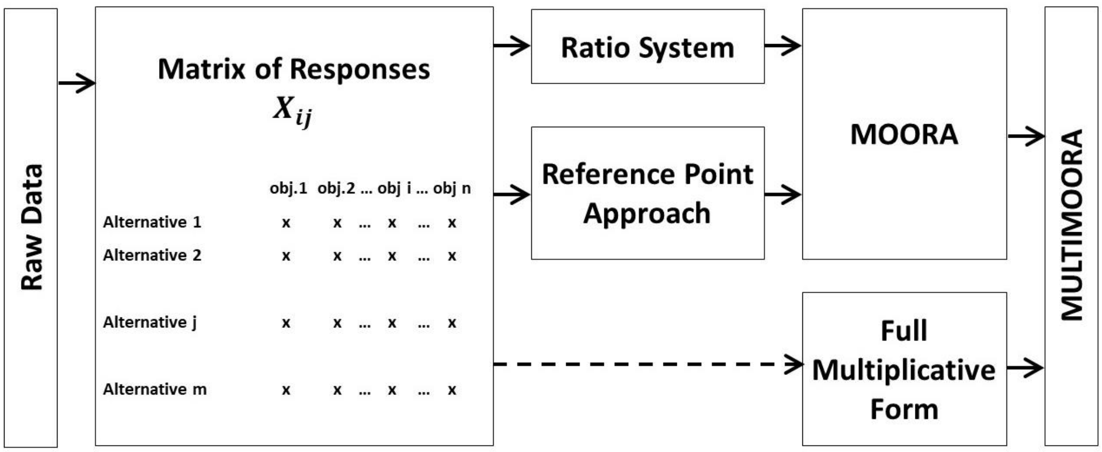

Figure 2. Diagram of MULTIMOORA (Brauers and Zavadskas, 2012)

3. Application

Throughout the application of Fuzzy MULTIMOORA, candidate facility locations are evaluated according to given criteria. Many different types of TFNs have been employed in the linguistic scales (Chen and Ku, 2008). When summarized all applications in TFNs, the most detailed scale is found to be 7-point scale. Therefore, we use the 7-point linguistic scale proposed by Chen et al. and TFNs in order to convert the evaluations (Chen et al., 2006). The scale levels are shown in Figure 3.

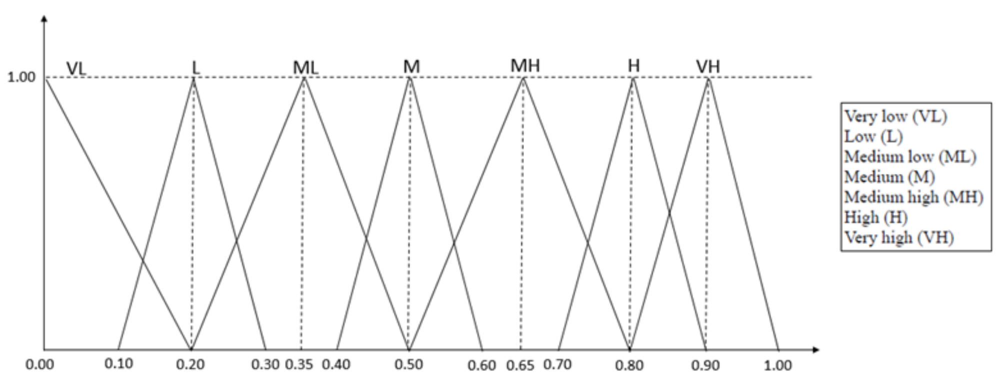

Figure 3. Linguistic Scale for Evaluation

Human subjective judgment is generally fuzzy and imprecise, so fuzzy data can be expressed in linguistic terms to make easy interpret (Chen and Ku, 2008). The data for evaluation of alternatives are derived from countries' statistics reports. Immediate mobilization (C1) and Stability of Hosting Region (C3) related data are derived from Logistics Performance Index and Political Stability Index, respectively, which are provided by World Bank. Cost Efficiency (C2) data is derived from Cost of Living Index by using global database called Numbeo. Training Abilities for Humanitarian Services (C5) data is obtained from the information and references of selected countries' national aid and relief agencies. Lastly, Economies of scale (C6) data is also derived from GDP data and Human Development Index provided by World Bank and UN Development Program, respectively. Then, informed colleagues are asked to evaluate the alternatives according to the linguistic scale taking these data into account. Final evaluation matrix is given in Table 1. Then the linguistic data is converted into TFNs using the scale in Figure 3. Resulting data is given in Table 2.

Table 1. Linguistic Evaluation Matrix of Alternatives

	C1	C2	C3	C4	C5	C6
Australia	H	ML	H	ML	H	H
India	M	H	ML	MH	L	VH
Kenya	ML	H	L	VH	L	L
South Africa	MH	MH	ML	H	L	M
Turkey	M	H	ML	H	L	MH

Table 2. Evaluation Matrix of Alternatives in Terms of TFNs

	C1	C2	C3	C4	C5	C6
Australia	(0.7, 0.8, 0.9)	(0.2, 0.35, 0.5)	(0.7, 0.8, 0.9)	(0.2, 0.35, 0.5)	(0.7, 0.8, 0.9)	(0.7, 0.8, 0.9)
India	(0.4, 0.5, 0.6)	(0.7, 0.8, 0.9)	(0.2, 0.35, 0.5)	(0.5, 0.65, 0.8)	(0.1, 0.2, 0.3)	(0.8, 0.9, 1)
Kenya	(0.2, 0.35, 0.5)	(0.7, 0.8, 0.9)	(0.1, 0.2, 0.3)	(0.8, 0.9, 1)	(0.1, 0.2, 0.3)	(0.1, 0.2, 0.3)
South Africa	(0.5, 0.65, 0.8)	(0.5, 0.65, 0.8)	(0.2, 0.35, 0.5)	(0.7, 0.8, 0.9)	(0.1, 0.2, 0.3)	(0.4, 0.5, 0.6)
Turkey	(0.4, 0.5, 0.6)	(0.7, 0.8, 0.9)	(0.2, 0.35, 0.5)	(0.7, 0.8, 0.9)	(0.1, 0.2, 0.3)	(0.5, 0.65, 0.8)

Fuzzy Ratio System is the beginning step of our solution approach. In order the reader to get the insight of the algorithm, we present the calculations of the first alternative, Australia. First, the response values are calculated using Eqn. (1). The values of Australia for the six criteria are determined to be as follows:

$$x_{1j}^{*} = \begin{Bmatrix} (0.307, 0.351, 0.394), j = 1 \\ (0.073, 0.127, 0.182), j = 2 \\ (0.384, 0.439, 0.494), j = 3 \\ (0.070, 0.123, 0.176), j = 4 \\ (0.443, 0.506, 0.569), j = 5 \\ (0.272, 0.311, 0.350), j = 6 \end{Bmatrix}$$

As is mentioned before, now it is time to obtain total assessments of the alternatives. Focusing on Australia again, we calculate the normalized assessment of this alternative to be $(0.380, 0.478, 0.576)$. Obviously, these values are also TFNs, which means that they need to be defuzzified using Eqn. (3), giving the final BNP values. Final preference values for the alternatives are determined as follows:

$$BNP_i = \{0.609, 0.617, 0.581, 0.682, 0.617\}$$

Now we have the ordinal ranking which is constructed according to these values, giving the preference of Fuzzy Ratio System. Obtained ranking result is presented in Table 3.

Our second method is the Fuzzy Reference Point, in which we calculate the Maximal Objective Reference Point by Eqn. (4) using the ratios found by Eqn. (1). Final ranking is obtained by Eqn.s (5) and (6), giving the deviation of the elements from the reference point. For our case, related values are determined as follows:

$$d(\tilde{r}_j, \tilde{x}_{ij}^{*}) = \text{alternatives} \overset{\text{criteria}}{\begin{bmatrix} 0 & 0.164 & 0 & 0.194 & 0 & 0.039 \\ 0.131 & 0 & 0.248 & 0.089 & 0.379 & 0 \\ 0.198 & 0 & 0.329 & 0 & 0.379 & 0.272 \\ 0.068 & 0.057 & 0.248 & 0.035 & 0.379 & 0.155 \\ 0.131 & 0 & 0.248 & 0.035 & 0.379 & 0.098 \end{bmatrix}}$$

Related ranking is obtained sorting the "max"s of these values with respect to each of the alternatives in descending order, which are $[0.194, 0.379, 0.379, 0.379, 0.379]$. The result exists in the third column of Table 3.

At the last method, Fuzzy Full Multiplicative Form is arrived. We calculate the overall utilities of alternatives by using Eqn. (7), which results to be $(7.29 * 10^{-5}, 3.81 * 10^{-4}, 1.24 * 10^{-3})$ for Australia. Related BNP values are found by defuzzifying these values using Eqn. (3), to be as follows:

$$BNP_i = \{5.66 * 10^{-4}, 2.11 * 10^{-4}, 3.61 * 10^{-5}, 1.65 * 10^{-4}, 1.89 * 10^{-4}\}$$

Final ranking obtained accordingly is given in Table 3.

Finally, the ordinal rankings of the Fuzzy Ratio System, the Fuzzy Reference Point approach, and the Fuzzy Full Multiplicative Form are on hand and the final ranking of alternatives, which is calculated according to the dominance states of the Fuzzy MULTIMOORA, is given in the last column of Table 3.

Table 3. The Ranking of Alternatives

Alternative	Fuzzy Ratio System	Fuzzy Reference Point	Fuzzy Full Multiplicative Form	FINAL RANKING
Australia	4	1	1	1
India	2	2	2	2
Kenya	5	2	5	5
South Africa	1	2	4	4
Turkey	2	2	3	3

4. Conclusion

In this study, we focus on humanitarian supply chain network including six hub facilities used by WFP. This network is especially important to relief emergencies such as floods, droughts, refugee crisis etc. With gradually increasing threats and climate changes, there will be a need to expand the existing network. Taking this highly possible situation into account, a hub facility evaluation framework based on multi criteria decision making is proposed. Five possible hub facility locations are evaluated, in terms of 6 criteria; i.e. immediate mobilization, cost efficiency, stability of the hosting zone, disaster-prone area, training abilities for humanitarian services, and economies of scale.

Throughout the solution procedure, MULTIMOORA method is preferred among various techniques on the area. Following the main steps of the method, the rankings of the Fuzzy Ratio System, the Fuzzy Reference Point approach and the Fuzzy Full Multiplicative Form are first obtained. As can be seen from Table 3, the orderings obtained in the first two methods changes taking the third one into account. As is mentioned by Brauers and Zavadskas (2010), the use of three different methods of multi-objective optimization is more robust than the use of two methods. Being consistent with this remark, the strongest aspect of MULTIMOORA is the use of three different methods simultaneously and it is defined as one of the most robust methods in the literature. This feature is the most important reason of us to use MULTIMOORA in this study.

The evaluations of the study are made according to the data obtained from countries' statistics. As there are inherent uncertainties of related objects, it is more appropriate to express these properties in terms of fuzzy values instead of real numbers. Therefore, we took fuzzy data sets into account with respect to the structure of the considered criteria, and the usage of fuzzy logic benefited us being a useful tool to prevent loss of information regarding the evaluation of qualitative criteria.

The final ranking is determined according to the previous sub-results for this specific problem and found as follows: Australia, India, Turkey, South Africa and Kenya, respectively. The results are logical and consistent under the specified criteria. One of the most important reasons for this result is Australia's level of economic and social development, hence the socio-cultural competencies of people and the superiority of the country's transport facilities. Despite the proximity of Kenya, South Africa and Turkey to the disaster areas, the lack of socio-political and economic stability in these countries shifted them to lower ranked orders. Similarly; Turkey, India and Kenya, although advantageous in terms of hosting and distribution costs, lack of training skills necessary to provide humanitarian services made these countries less preferable.

More detailed studies will be focused on by taking different criteria into account in addition to the ones that are discussed in this one. Besides, number of possible alternatives can be increased in order to be able to evaluate more choices to be used in the humanitarian supply chain network.

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