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ARAŞTIRMA MAKALESİ / RESEARCH ARTICLE

AN APPLICATION of MULTI CRITERIA METHODS in CHOOSING LOCATION for DISASTER LOGISTICS

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Abstract

Emergency management is the managerial task of establishing the structure for decreasing community exposure to risks and dealing with crises. Logistics management in crises is challenging since it seeks to meet demand as efficiently as achievable while keeping timing constraints in mind. In this research, we first identified the most common and important factors in emergency management and location selection. Based on these factors, we set the importance weights for each criterion by using the CRITIC methodology and found the most convenient places for the logistics process by using the ROV method. This study helped to quantify some qualitative criteria which can be used in emergency management and evaluate them in an analytical way. As a result of the study, while the distance to transportation variable was determined as the most important factor, the A1 Alternative was chosen as the most suitable logistics location in Turkey.

Keywords: *CRITIC, ROV, Emergency Management, Disaster Logistics, Location Selection*

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AFET LOJİSTİĞİ İÇİN YER SEÇİMİNDE ÇOK KRİTERLİ YÖNTEMLERİN UYGULANMASI

Özet

Acil durum yönetimi, toplumun risklere maruz kalmasını azaltmak ve afetlerle başa çıkmak için bir kapsam oluşturmanın temel görevidir. Acil durumlarda ve afetlerde lojistik yönetimi, zaman kısıtlamalarını göz önünde bulundurarak talebi mümkün olan en verimli şekilde karşılamaya çalıştığı için zordur. Bu araştırmada, öncelikle acil durum yönetimi ve yer seçiminde en yaygın olarak kullanılan en önemli faktörleri belirledik. Bu faktörlerden yola çıkarak her bir kriterin önem ağırlıklarını CRITIC metoduyla belirledik ve ROV yöntemini kullanarak lojistik ve malzeme tedariği için en uygun yerleri bulduk. Bu çalışma ile acil durum yönetiminde kullanılabilecek bazı nitel kriterlerin sayısallaştırılması sağlanarak analitik bir şekilde değerlendirilmiştir. Çalışma sonucunda, ulaşıma uzaklık değişkeni en önemli faktör olarak belirlenirken A1 alternatifi Türkiye'de en uygun lojistik lokasyon olarak seçilmiştir.

Anahtar Kelimeler: *CRITIC, ROV, Afet Yönetimi, Afet Lojistiği, Yer Seçimi*

INTRODUCTION

A disaster is defined as a sudden and substantial occurrence or set of events that cause widespread destruction, loss of life, and serious disruption of normal community or societal functioning. Disasters can be natural like earthquakes, hurricanes, floods, wildfires, and tsunamis as well as man-made ones like terrorist attacks, industrial accidents, and civil unrest are examples of disasters. The size and severity of disasters can vary. Localized disasters may have an impact on a particular area or community, whereas large-scale disasters may have regional, societal, or even international effects.

Due to Turkey's geographic location and vulnerability to a variety of natural and man-made disasters, disaster logistics are extremely important. Turkey is vulnerable to earthquakes as well as other natural disasters like floods, landslides, and wildfires since it is located in the seismically active Mediterranean-Asian seismic zone. These disasters are further made worse by Turkey's urbanization and fast-expanding population. Building resilient infrastructure that can resist and recover from disasters more successfully is made possible by disaster logistics. This includes engineering structures to withstand earthquakes, putting in place flood control measures, and developing effective transit routes for disaster response. Public health issues can emerge in the wake of disasters as a result of the possibility of disease transmission, disruption of medical services, and lack of access to sanitary facilities and clean water. Medical team deployment, medical supply delivery, and disease prevention strategies are all aided by disaster logistics (Cavdur et al., 2020). Durhan and Cetin (2022) analyzed disaster logistic and disaster supply chain from the point of view of firms.

Emergency management is the managerial task of establishing the structure for decreasing community exposure to risks and dealing with crises. Emergency management actions, such as search and rescue operations, medical aid, sheltering, offering necessary supplies and services, as well as long-term recovery and rebuilding efforts, are often taken in response to a disaster.

Emergency or disaster management can be defined under four different levels. The first step is an alleviation of risk, which attempts to lower the risk; the second is readiness, which guarantees that a strategy to gather resources and assist individuals is in place; and the third is the reaction, which sets a goal of minimizing losses. and the final stage is recovery, which helps repair the structures and system that was harmed (Goncu and Cetin, 2022).

Logistics management in crises is challenging since it seeks to meet demand as efficiently as achievable while keeping timing constraints in mind. Furthermore, disaster logistics management is a more difficult assignment since it has to cope with greater unpredictability, unreliable demand information, and breakdowns in transportation systems. The enormity of the scenario, among many others that adhere to several tough requirements, frequently overwhelms the available resources.

Although there are a lot of studies in the literature about disaster management and emergency logistics, Little work has been done on the weighting of these criteria and the selection of alternative sites. The originality of this study is that it uses CRITIC and ROV methods together to weight the selection criteria and select alternative sites. In this paper, we first aimed to identify the importance and weight of criteria that affect logistic management in emergencies by using CRITIC methodology. Second, the

ROV methodology was taken into consideration to evaluate alternative places and find the best proper place to respond in a desired time.

The remaining part of the research is planned as follows. The literature review is provided in Section 2. The theoretical background and methodology part is given in Section 3 and Section 4 indicates the results of the analysis. Finally, Section 5 concludes the research and provides recommendations for future studies.

1.LITERATURE REVIEW

Disaster management seeks to successfully safeguard individuals and infrastructure in devastated regions, reduce human and material losses, and rebuild quickly. Emergency logistics refers to the undertaking of organizing, overseeing, and regulating the distribution of these essential provisions to deliver aid to individuals impacted by a crisis.

Emergency logistics, commonly referred to as humanitarian logistics, refers to a specialized set of logistical operations aimed at quickly meeting the goods, staff, and financial requirements of disaster-stricken areas. Its primary function is to respond to catastrophic emergencies such as natural catastrophes and military disputes.

There are plenty of studies in the literature which focus on disaster management and emergency logistics. Abid et al. (2021) provided recent applications of AI in disaster management to show how it responds faster, more concisely, and more equipped response. They figured out that the incorporation of a geographic information system (GIS) and remote sensing (RS) into disaster management allows for improved planning, analysis, situational awareness, and recovery activities. Sawalha (2020) investigated the traditional disaster management cycle and explored the value of incorporating contemporary management principles into the disaster management cycle. He provided a conceptual model for the disaster management cycle that reflects contemporary management knowledge. Sun et al.(2020) presented a review of existing Artificial intelligence (AI) applications in disaster management’s four phases. They provided examples of several AI methodologies and their advantages for disaster management with AI-based decision assistance tools. AlHinai (2020) figured out that the impact of digital transformation on Natural Disaster Management is substantial, irrational multi-directional, and prompted by a diverse set of factors. Rehman et al.(2019) considered system-thinking approaches such as the Causal Loop Diagram (CLD) and the Driver-Pressures-States-Impacts-Responses (DPSIR) framework to identify key stakeholders in minimizing disaster risk in Pakistan. They provided policy implications for long-term flood disaster response and examined research papers on floods and disaster prevention.

Decision-making is critical in disaster management because it affects the effectiveness and efficiency of response and recovery activities (Goncu and Cetin, 2022). In the effect of an incident, making quick decisions is critical for initiating a timely response. To minimize loss of life or wealth, assessing the situation, deciding priorities, and mobilizing resources necessitate well-informed judgments. Decision-making aids in the efficient allocation of limited supplies. Resources such as personnel, equipment, and supplies may be scarce during a crisis. Decisions must be made to prioritize and distribute resources where they will have the greatest impact (Goncu and Cetin, 2022).

In the previous literature, there are important factors in emergency management and the selection of a location. In this context, Guo and Matsudo (2023) identified the most important criteria in the literature analytically as follows: Distance to the nearest highway (Polat 2022), Floor area (Goncu and Cetin, 2022), Built-up area (Matteo et al., 2016), Earthquake hazard level (Nong, 2021), Population density (Niroomand et al., 2018), Distance to the nearest airport (Peker et al., 2016), Land cost (Roh et al., 2013) and we also used these criteria in our study to find out most convenient logistic center.

2.METHODOLOGY

In this study, which deals with the importance of determining the appropriate place in the event of a disaster under the title of disaster logistics, it has been revealed that it is meaningful to get help from methods to show the differences and contrasts between the criteria. MCDM tools were practiced to assess many criteria and alternatives in determining the disaster logistics center location.

The CRITIC method was practised to determine the importance weight of the criteria. the ROV method was used to evaluate the alternatives. First of all, the weights of the criteria were discussed with the CRITIC method. Then, alternatives were determined by ROV based on criterion weights. In short, the study with the CRITIC-based ROV method is discussed.

2.1. CRITIC METHOD

The CRITIC method was first introduced by Diakoulaki et al in 1995 and brought to the literature. It is a multi-criteria decision making method used to weight the criteria (Diakoulaki et al., 1995). While the Shannon method only reflects the contradiction (Li et al., 2015), the CRITIC method also includes the contradiction and the contradictions included in th decision criterion (Peng et al., 2020). Therefore, the standard deviation of the normalized matrix and the correlation coefficients between the criteria are used to determine the contradiction between the criteria in obtaining the criteria weights (Ghorabaee et al., 2018).

The steps of the CRITIC method are as follows (Jahan et al., 2012):

1) Creating the decision matrix

$$X = [x_{ij}] = \begin{bmatrix} x_{11}\ x_{12} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1}\ x_{m2} & \cdots & x_{mn} \end{bmatrix} \quad (1)$$

As shown in Equation 1, there are n criteria and m alternatives in the matrix.

2) Generating the Normalized Decision Matrix

$$r_j^{+} = \frac{x_{ij} - x_j^{min}}{x_j^{max} - x_j^{min}} \quad (2)$$

$$r_j^{-} = \frac{x_j^{max} - x_{ij}}{x_j^{max} - x_j^{min}} \quad (3)$$

Normalization is done in Equation 2 and 3 to remove anomalies for the data.

3) Calculation of Pairwise Correlations Between Criteria

$$p_{jk} = \frac{\sum_{i=1}^{m}\left(r_{ij}-\overline{r_J}\right)\left(r_{ik}-\overline{r_k}\right)}{\sqrt{\sum_{i=1}^{m}\left(r_{ij}-\overline{r_J}\right)^2 \sum_{i=1}^{m}\left(r_{ik}-\overline{r_k}\right)^2}} \quad (4)$$

With the help of Equation 4, the relations between the criteria are examined.

4) Calculation of the amount of information

$$c_{iJ} = \sigma \sum_{i=1}^{m}\left(1 - p_{jk}\right) \quad (5)$$

The total the amount of information is calculated with the Equation 5 formula.

5) Calculation of Criteria Weights

$$w_J = c_J / \sum_{k=1}^{n} c_k \quad (6)$$

Equation 6 calculates the weight of the criteria.

2.2. ROV METHOD

It is a method based on ranking the alternatives according to the distances between the criteria by Yakowitz et al. in 1993 (Hajkowicz and Higgins, 2008). It is based on the average of benefit and cost outcomes (Madić and Radovanović, 2015; Madić et al., 2016).

The steps of the ROV method are as follows (Chakraborty and Chatterjee 2013):

1) Creating the decision matrix

$$c = \left[z_{iJ}\right] = \begin{bmatrix} z_{11} & z_{12} & \cdots & z_{1n} \\ \vdots & & \ddots & \vdots \\ z_{m1} & z_{m2} & \cdots & z_{mn} \end{bmatrix} \quad (7)$$

As displayed in Equation 7, there are n criteria and m alternatives in the matrix.

2) Generating the Normalized Decision Matrix

$$r_{ij}^{+} = \frac{z_{ij} - z_j^{min}}{z_j^{max} - z_j^{min}} \quad (8)$$

$$r_{ij}^{-} = \frac{z_j^{max} - z_{ij}}{z_j^{max} - z_j^{min}} \quad (9)$$

Normalization is done in Equation 8 and 9 to remove anomalies for the data.

3) Determining the best and worst utility functions

$$u_i^{+} = \sum_{i=1}^{n} r_{ij}\, w_j \quad (10)$$

$$u_i^{-} = \sum_{i=1}^{n} r_{ij}\, w_j \quad (11)$$

The values of the best and worst utility functions are multiplied by the normalized value and the weight to get the benefit criteria Equation 10 and the cost criteria Equation 11.

4) Determination of average utility value

$$u_i = \frac{u_i^{-} + u_i^{+}}{2} \quad (12)$$

The average of the best and worst utility functions and the average utility value are determined by Equation 12.

3.CASE STUDY

In this study, it was carried out on the determination of the logistics location in the event of a disaster. Therefore, firstly, the criteria affecting disaster logistics were determined. In determining the criteria, the opinions of the previous studies and experts were discussed. In the weighting of the criteria, the CRITIC method, which is one of the multi-criteria decision-making techniques, was applied in the light of the evaluation of the experts.

For this, 6 criteria have been determined. The criteria are determined for the general disaster situation.

These criteria are respectively;

C1: Floor Area (Goncu and Cetin, 2022)

C2: Distance to transportation (Peker et al., 2016; Polat, 2022)

C3: Earthquake risk (Nong, 2021)

C4: Settlement (Matteo et al., 2016)

C5: Land Expense (Roh et al., 2013)

C6: High Population (Niroomand et al., 2018)

Then, 5 alternative places are given. The ROV method, which is one of the multi-criteria decision-making techniques, was adopted to determine the ranking among alternative places. Thus, the ideal location was determined. Therefore, first the CRITIC method and then the ROV method were applied. A score between 1 and 10 was given based on the opinions of 3 decision makers. 10 means important, 1 means unimportant.

First, a decision matrix was created according to Equation 1 to apply the CRITIC method.

Table 1. Decision matrix for CRITIC method

DM1	Max	Min	Min	Max	Min	Max
Alternatives	C1	C2	C3	C4	C5	C6
A1	6	4	6	8	5	8
A2	4	5	7	5	6	5
A3	4	3	7	5	5	4
A4	7	4	7	5	8	7
A5	8	7	6	4	7	5
DM2	Max	Min	Min	Max	Min	Max
Alternatives	C1	C2	C3	C4	C5	C6

A1	7	5	8	9	7	9
A2	6	4	5	6	3	5
A3	6	4	8	5	7	5
A4	7	7	9	3	8	5
A5	8	7	4	2	5	3
DM3	Max	Min	Min	Max	Min	Max
Alternatives	C1	C2	C3	C4	C5	C6
A1	8	5	9	9	8	9
A2	5	9	6	6	4	5
A3	5	4	6	5	6	5
A4	4	5	8	4	8	6
A5	8	4	5	3	6	2
DM AVG	Max	Min	Min	Max	Min	Max
Alternatives	C1	C2	C3	C4	C5	C6
A1	7	4,666667	7,666667	8,666667	6,666667	8,666667
A2	5	6	6	5,666667	4,333333	5
A3	5	3,666667	7	5	6	4,666667
A4	6	5,333333	8	4	8	6
A5	8	6	5	3	6	3,333333
Max	8	6	8	8,666667	8	8,666667
Min	5	3,666667	5	3	4,333333	3,333333

In the 2nd step, the normalized decision matrix is created according to Equation 2 and 3, and in the 3rd step, the correlation decision matrix is created according to Equation 4.

In step 4, the amount of information for Equation 5 is calculated as Table 2.

Table 2. Calculation of the amount of information

Cj	Max	Min	Min	Max	Min	Max
	C1	C2	C3	C4	C5	C6
	1.370603	1.507531	1.528908	1.229163	1.378963	1.330523

In step 5, importance weights are calculated for the decision variables as in Equation 6. The results for the criteria are as in Table 3.

Table 3. Criteria Weights

Weights	C1	C2	C3	C4	C5	C6
wj	0.164229	0.180636	0.183197	0.147281	0.165231	0.159426

After the criteria weights were determined, an alternative location for disaster logistics was selected. For this, the ROV method, which provides the ranking of the alternatives, was used. After the criterion weights were determined, the decision matrix for the ROV method was created according to Equation 7.

The decision matrix for the ROV method is as in Table 4.

Alternatives	Max	Min	Min	Max	Min	Max
	0.164229	0.180636	0.183197	0.147281	0.165231	0.159426
	C1	C2	C3	C4	C5	C6
A1	7	4,666667	7,666667	8,666667	6,666667	8,666667
A2	5	6	6	5,666667	4,333333	5
A3	5	3,666667	7	5	6	4,666667
A4	6	5,333333	8	4	8	6
A5	8	6	5	3	6	3,333333
Max	8	6	8	8,666667	8	8,666667
Min	5	3,666667	5	3	4,333333	3,333333

Table 4. Decision matrix for ROV method

The normalized decision matrix is calculated for Equation 8 and Equation 9. In Step 3, the best and worst utility functions are calculated for Equation 10 and Equation 11. In Step 4, the average utility value is calculated for Equation 12.

The results for the alternatives are as seen in Table 5.

Tablo 5. Ranking the Alternatives

Alternatives	Sum of Best(ui)+	Sum of Worst(ui)-	ui	Ranking
A1	0.416193	0.18366	0.299926	1
A2	0.119129	0.287362	0.203246	4
A3	0.091838	0.331827	0.211833	3
A4	0.160447	0.05161	0.106029	5
A5	0.164229	0.273323	0.218776	2

When we examine the results, it is seen that the most important criterion among the 6 criteria for the CRITIC method is C3. This criterion is followed by C2. On the other hand, it was determined that the criterion for the least importance value was C4. Accompanied by the weights of these criteria, the most important of the 5 alternatives is A1, followed by A5. On the other hand, A4 stands out as the weakest alternative.

CONCLUSION

Turkey has suffered a lot of loss of life and property due to the disasters it has experienced in recent years. Therefore, taking quick action in this regard is important in terms of minimizing the loss of life. It is extremely critical to position the logistic support in the right places after disaster. There are numerous criteria in chosing these places. In this study, it is aimed to determine the importance weights of these criteria with the CRITIC method and to choose them according to the right points. In addition, the ROV method was applied to correctly rank the logistics centers among the alternatives determined for the disaster site. Earthquake risk was obtained as the most significant criterion among the 6 criteria determined in this study. In addition, A1 was chosen as the most ideal place among the 5 alternative places determined. At the end of the study, the distance in terms of earthquake was found to be the most important criterion. In the studies conducted to date, Ağdaş et al. (2014) stated that the duration of transportation, that is, the distance, is the most important criterion, while Ergün et al. (2020) expressed infrastructure as the most important criterion. With this study, workplaces or related organizations can choose the most suitable location by making such analysis. Different methods of MCDM can be used for future studies. In addition, changes can be made in the number of criteria and alternatives. The number of decision makers and the scope of the selected area can be expanded.

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