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Disaster Logistics Warehouse Location Selection: An Application for Ankara Province

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Afet Lojistik Deposu
Küme Kapsama
P-Medyan
Yer Seçimi

Graphical/Tabular Abstract (Grafik Özet)

In this study, the problem of determining the location of Disaster Logistics Warehouses (DLWs) to be established in the districts outside the center of Ankara was examined. In the study, minimum number of DLWs to be opened was first determined and the districts and provinces to be assigned to the opened DLWs were determined. / Bu çalışmada, Ankara il merkezi dışında kalan ilçelerde kurulacak Acil Durum Depolarının yerlerinin belirlenmesi problemi incelenmiştir. Çalışmada önce açılacak minimum DLW sayısı belirlenmiş ve açılan DLW'lere atanacak ilçe ve iller belirlenmiştir.

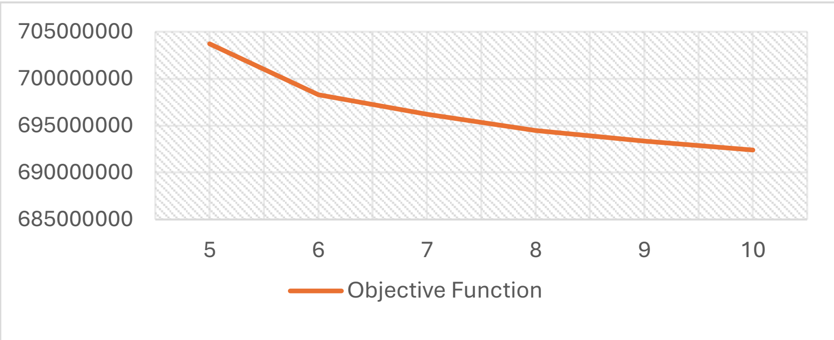

Figure A*: Relationship between the change in the number of DLWs and the objective function /****Şekil A:****Acil Durum Deposu sayısındaki değişim ile amaç fonksiyonu arasındaki ilişki*

Highlights (Önemli noktalar)

- *The number of DLWs to be opened was determined by the cluster coverage method. / Küme kapsama yöntemi ile açılacak DLW'lerin sayısı belirlenmiştir.*
- *Using the P-median method, the locations of DLWs to be established in the outlying districts of Ankara and the provinces and districts to be assigned to these DLWs were determined. / P-medyan yöntemi ile Ankara'nın merkez dışı ilçelerinde kurulacak DLW'lerin yerleri ile bu DLW'lere atanacak il ve ilçeler belirlenmiştir*
- *It has been tried to determine how considering the capacity in the DLWs to be opened affects the number of stations to be opened and the objective function./ Açılacak DLW'lerde kapasitenin dikkate alınmasının açılacak istasyon sayısı ve amaç fonksiyonunu nasıl etkilediği belirlenmeye çalışılmıştır.*

Aim (Amaç): *The aim of this study is to create disaster logistics warehouses in the non-central districts of Ankara in order to give assistance to both neighboring districts and bordering provinces./ Bu çalışmanın amacı, Ankara ilinin merkez ilçeleri dışında kalan ilçelerde afet lojistik depoları kurularak hem çevre ilçelere hem de sınır komşusu illere afet yardımının ulaştırılmasıdır.*

Originality (Özgünlük): In the study, unlike the literature, the locations of the warehouses to be established in non-central districts were tried to be determined and cluster coverage and p-median and capacitated p-median models were used in location selection. / Çalışmada literatürden farklı olarak merkez dışı ilçelerde kurulacak depoların yerleri belirlenmeye çalışılmış ve yer seçiminde küme kapsama, p-medyan ve kapasiteye sahip p-medyan modelleri kullanılmıştır.

Results (Bulgular): *According to the solution of the cluster coverage model, a minimum of 5 DLWs should be opened in the central districts of Ankara./ Küme kapsamının modelinin çözümüne göre Ankara'nın merkez ilçelerinden minimum 5 DLW açılmalıdır.*

Conclusion (Sonuç): *In the study, the places where DLWs will be opened and the provinces and districts to be assigned to these DLWs were determined./ Çalışmada DLW'lerin açılacağı yerler ve bu DLW'lere atanacak il ve ilçeler belirlenmiştir.*

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Disaster Logistics Warehouse Location Selection: An Application for Ankara Province

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Abstract

Disasters are events that cause human, material or environmental losses, have significant negative effects on the functioning of daily life, and that the region cannot overcome with its own resources. The most common natural disasters in Turkey are earthquakes. Reducing the negative effects of earthquakes is possible by ensuring effective disaster logistics before the disaster. Setting up catastrophe logistics warehouses in suitable places is crucial for efficiently carrying out disaster logistics and aiding disaster victims. Therefore, in this study, the location selection problem for disaster logistics warehouses (DLW) was examined. There are studies in the literature on establishing disaster logistics warehouses generally in city centers. The earthquakes that occurred on February 6, 2023 revealed how important the aid from surrounding provinces is. Thus, the objective of this project is to create disaster logistics warehouses in the non-central districts of Ankara in order to give assistance to both neighboring districts and bordering provinces. The study employed p-median and capacitated p-median models with cluster coverage to identify the optimal locations for disaster logistics warehouses and the corresponding provinces and districts that should be allotted to these warehouses. The final phase of the study was evaluating the efficacy of the models through sensitivity analysis.

Acil Durum Deposu Yer Seçimi: Ankara İli Örneği

Makale Bilgisi

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Öz

Afetler, insan, malzeme veya çevresel kayıplara sebebiyet veren, günlük hayatın işleyişinde büyük ölçüde olumsuz etkileri olan, yaşanılan bölgenin kendi imkanları ile üstesinden gelemeyeceği olaylardır. Türkiye'de en çok yaşanılan doğal afetler ise depremlerdir. Depremlerin olumsuz etkilerinin azaltılması ise afet öncesinde gerçekleştirilen etkin afet lojistiğinin sağlanması ile mümkün olmaktadır. Afet sonrasında afetzedelere hizmet veren afet lojistik depolarının uygun yerlere kurulması, afet lojistiğinin başarılı bir şekilde uygulanmasında etkili olmaktadır. Bu yüzden bu çalışmada afet lojistik depoları için yer seçimi problemi incelenmiştir. Literatürdeki çalışmalarda afet lojistik depolarının genelde şehir merkezlerinde kurulmasına yönelik çalışmalar mevcuttur. 6 Şubat 2023 tarihinde meydana gelen depremler çevre illerden gelecek yardımların ne kadar önemli olduğunu gözler önüne sermiştir. Bu yüzden bu çalışmada Ankara'nın merkez dışı ilçelerinde kurulacak afet lojistik depoları ile hem komşu ilçelere hem de çevre illere hizmet verilmesi amaçlanmaktadır. Çalışmada afet lojistik depolarının yerlerinin belirlenmesi ile bu depolara atanacak il ve ilçelerin belirlenmesinde küme kapsama ile p-medyan ve kapasitelendilmiş p-medyan modelleri kullanılmıştır. Çalışmanın son bölümünde ise yapılan duyarlılık analizi ile modellerin etkinliği analiz edilmiştir.

1. INTRODUCTION (GİRİŞ)

Disaster can be defined as events that can affect people's lives and activities, cause large-scale destruction, damage and loss of life, require domestic or international assistance, and occur suddenly at unpredictable times [1]. Natural disasters are events that affect both human and natural life all over the world, cause significant losses and cannot be avoided [2]. Natural disasters may occur from time to time in Turkey, as in the rest of the world. Since there are many active fault lines in Turkey, the most common natural disaster is earthquake. Since it is of great importance to quickly reach the people affected by large and destructive earthquakes, necessary preparations must be made before the emergency. The

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Kahramanmaraş earthquakes that occurred on February 6, 2023 revealed how important the preparations that need to be made before the disaster are. Recently, importance has been given to pre-disaster preparation studies in order to overcome major earthquakes and other disasters that may occur in the near future with minimal losses.

It is seen that many major earthquakes have occurred in the recent history of Turkey, which is located on active faults. In particular, the two earthquakes that occurred on February 6, 2023 affected a very wide geography and caused great loss of life and property in 10 provinces. Additionally, there were problems in sending aid to the earthquake region due to destroyed roads and airports. This situation showed how important the aid that can be provided to the earthquake region from nearby provinces is. The notion of disaster logistics arose with the aim of mitigating the impact of natural disasters that occur globally. Disaster logistics refers to the operations involved in the effective transportation and storage of information and humanitarian goods from a secure location to the disaster area. It also include the creation and execution of plans to satisfy the needs of the people affected by the disaster [2]. Disaster logistics covers all activities carried out, from the delivery of emergency equipment, search and rescue teams, and materials needed by disaster victims from the first point to the area where the disaster occurred, to the delivery of disaster victims to safe regions and health centers. Disaster logistics consists of three stages: pre-disaster preparation activities, disaster response process activities and post-intervention logistics activities [3]. According to AFAD, the place where emergency materials required to be sent to damaged areas in disasters and emergencies are stored is defined as a disaster logistics Warehouse (DLW) [4].

When Türkiye's geographical features are examined, it is seen that the earthquake risk is high in 70% of the country. When an earthquake occurs, pre-disaster logistics activities must be implemented effectively in order to minimize the negativities of this disaster [3]. Supplying the necessary resources, including materials, tools, and equipment, is crucial for the survival of individuals affected by a disaster. In particular, the rapid delivery of these materials, tools and equipment to the disaster area is possible by establishing DLW in the right places [5]. DLWs refer to places where all kinds of materials, food, tools and equipment required for emergency response and aid activities before and after natural disasters are stored. Determining the places where DLWs will be established is of great importance as it will ensure that aid can be delivered as soon as possible after a natural disaster. Consequently, in recent years, numerous researchers have concentrated on conducting studies to identify the specific places where DLWs will be constructed [3].

In the earthquakes that occurred on February 6, 2023, 10 cities were affected by the earthquake, and this revealed how important the aid provided by the surrounding provinces was. The literature acknowledges the idea that DLWs are typically located in city centers and primarily cater to the districts within that metropolis. However, in case of any natural disaster, it is of great importance to deliver aid quickly from surrounding provinces. Therefore, in this study, the problem of determining the location of DLWs to be established in the districts outside the center of Ankara was examined. Planning was made to deliver aid to neighboring provinces within a 300 km radius of Ankara from the DLWs established in the study. In the study, the places where the DLWs will be established and the provinces that will be assigned to the stations were tried to be determined, taking into account the earthquake risks and populations of Ankara's non-central districts and neighboring provinces. As far as is known, this is the first study in which the locations of the DLWs were determined for the purpose of sending emergency aid materials to neighboring provinces and districts from DLWs established in districts outside the center of a big city.

The subsequent phase of the study incorporates a comprehensive examination of the existing literature pertaining to the identification of DLW positions. In the application part of the study, it was tried to determine in which of the 16 districts outside the center of Ankara DLWs should be established. While determining the locations where DLWs will be established, the distance to surrounding provinces and districts, population and earthquake risks of these places were taken into account. The study initially identified the minimal number of warehouses to be opened based on the cluster coverage problem. In the second phase, the DLWs commenced by utilizing the p median model to ascertain the allocation of cities and districts to these warehouses. Furthermore, an attempt was made to ascertain the impact of the alteration in the quantity of warehouses on the outcome. In the last part of the study, a capacity was determined for the opened DLWs and the model was solved again by adding a capacity constraint to the p-median problem and the results were interpreted.

2. LITERATURE REVIEW (LİTERATÜR TARAMASI)

Existing literature on determining the location of DLWs encompasses studies employing various methodologies. In this section, a literature review of studies on the location selection of DLWs is included. When studies on disaster logistics in the literature are examined, it is seen that researchers focus on issues such as emergency station location selection, shelter location location selection, and the establishment of an emergency logistics network. In these studies, it is seen that researchers use multi-criteria decision-making methods in addition to mathematical models.

Studies that propose mathematical models for pre-disaster preparation studies, such as determining the location of emergency warehouses and shelter areas, are discussed in this section. Barbarosoğlu and Arda (2004) created a stochastic programming model to establish the delivery network for emergency supplies to regions affected by disasters. In this model, even if the facility location is not selected, the problem of routing the sent materials is associated with the location selection model [6]. The problems related to disaster logistics examined in the literature and the methods used to solve the problems are given in Table 1.

In their study, Dekle et al. (2005) aimed to ascertain the precise placements of emergency centers in Florida by considering the constraints imposed by distance. The study initially identified the minimum required number of emergency centers, and subsequently assessed the settlements based on multiple factors to identify suitable locations for establishing the emergency stations [7]. Hale and Moberg (2005) utilized a cluster coverage model to determine the optimal location for establishing a disaster relief warehouse. This model incorporates variables such as planning, detection, mitigation, and recovery in its analysis [8]. Gunneç and Salman (2007) devised a two-stage stochastic programming technique to ascertain the precise sites for establishing emergency storage [9]. Jia et al. (2007) tried to determine the locations where emergency warehouses will be established with the cluster coverage model, taking into account the uncertain demand that occurs as a result of a disaster and the assumptions that the facilities to store aid materials are inadequate [10]. In their study, Balçık and Beamon (2008) utilized the maximum coverage model to ascertain the optimal placement of emergency distribution facilities. They considered factors such as the quantity of goods and personnel that would need to be accommodated in these facilities [11]. In their study, Mete and Zabinsky (2010) devised a two-stage stochastic programming model to ascertain the optimal location for storing medical products and the appropriate stock levels for a designated warehouse [12]. Rawls and Turnquist (2011) devised a stochastic mixed integer programming model to ascertain the precise placement and size of warehouses for dispatching emergency relief supplies to the disaster-stricken regions in the case of a storm in the United States [13]. Zhu et al. (2010) introduced a mathematical model aimed at minimizing the overall cost associated with selecting emergency warehousing locations [14]. In their study, Görmez et al. (2011) introduced a two-stage linear programming approach for identifying the optimal positions of emergency warehouses within Istanbul. The primary objective in the first stage is to decrease the distance weighted by demand. In the second stage, the goal is to minimize both the average distance and the number of facilities [15]. In their study, Duran et al. (2011) devised a mathematical model to establish a distribution network. This model determines the specific products that should be supplied from emergency warehouses prior to a crisis [16]. In their 2012 study, Döyen et al. introduced a mathematical model for identifying the optimal placement of emergency warehouses. The model considers many factors such as facility setup costs, transportation expenses, and storage and disposal costs [17]. In their study, Liu et al. (2013) introduced a mathematical framework to determine the optimal locations for emergency material warehouses. They employed a heuristic method to solve this model [18]. In their 2014 study, Salman and Yücel introduced a stochastic 0-1 integer programming model to address the demand for aid among catastrophe victims. They employed the tabu search algorithm to solve this model [19]. Şahin and Altın (2016) examined the tent city site selection problem for Isparta province. In the study, the p-median model, with capacity and usage rates added, was used and the places where tent cities should be established were determined [20]. Aydin et al. (2017) investigated the difficulty of selecting the location for emergency warehouses in the Maltepe area of Istanbul. The initial phase of the project involved determining the minimal number of emergency warehouses required using the cluster coverage issue. In the subsequent phase, the sites for establishing these emergency warehouses were chosen using the p-median model [3]. Iqbal et al. (2018) employed Monte Carlo simulation to ascertain the precise position of the DLW within the domain of catastrophe logistics [21]

Table 1. Studies on disaster logistics (Afet lojistiği hakkındaki çalışmalar)

Authors	Year	Problem Examined	Method
Barbarosoğlu and Arda	2004	Establish the delivery network for emergency supplies	Stochastic Programming Model
Dekle et al.	2005	Identify suitable locations for establishing the emergency stations	Mathematical Programming Model
Hale and Moberg	2005	Optimal location for establishing a disaster relief warehouse	Cluster Coverage Model
Gunneç and Salman	2007	Precise sites for establishing emergency storage	Two-Stage Stochastic Programming Model
Jia et al.	2007	Emergency warehouse location selection	Cluster Coverage Model
Balçık and Beamon	2008	Optimal placement of emergency distribution facilities	Maximum Coverage Model
Mete and Zabinsky	2010	Optimal location for storing medical products	Two-Stage Stochastic Programming Model
Zhu et al.	2010	Emergency warehouse location selection	Mathematical Programming Model
Rawls and Turnquist	2011	Precise placement of warehouses for dispatching emergency relief supplies	Stochastic Mixed Integer Programming Model
Görmez et al.	2011	Emergency warehouse location selection	Two-Stage Linear Programming Model
Duran et al.	2011	Establish a emergency distibution network	Mathematical Programming Model
Döyen et al.	2012	Emergency warehouse location selection	Mathematical Programming Model
Liu et al.	2013	Emergency warehouse location selection	Mathematical Programming Model
Salman and Yücel	2014	Address the demand for aid among catastrophe victims	Stochastic 0-1 Integer Programming Model
Peker et al.	2016	Emergency warehouse location selection	AHP - VIKOR
Şahin and Altın	2016	Shelter site selection	P-Median Model
Aydın et al.	2017	Emergency warehouse location selection	Cluster Coverage and P-Median Model
Ofluoğlu et al.	2017	Emergency warehouse location selection	Entropi, VIKOR, SAW and TOPSIS
Iqbal et al.	2018	Emergency warehouse location selection	Monte Carlo Simulation
Temur et al.	2019	Emergency warehouse location selection	Mathematical Programming Model
Ergün et al.	2020	Emergency warehouse location selection	MAUT - SAW
Durdağ et al.	2021	Emergency warehouse location selection	In-Depth Interview Technique
Soyöz and Özyörük	2021	Establish the delivery network for emergency supplies	Three-Stage Mixed Integer Mathematical Programming Model
Derse	2022	Emergency warehouse location selection	DEMATEL - TOPSIS
Tezcan et al.	2022	Temporary distribution warehouse location selection	AHP – VIKOR, TOPSIS, PROMETHEE
Bayram and Eren	2023	Emergency station location selection	AHP – PROMETHEE, ELECTRE, TOPSIS
Soyöz and Özyörük	2024	Establish the delivery network for emergency supplies	Five-Stage Mixed Integer Mathematical Programming Model

Temur et al. (2019) tried to determine which neighborhoods would be served from the DLWs in Ümraniye district of Istanbul after any emergency, and the acquired model was resolved under various scenarios and the outcomes were compared [22]. Durdağ et al. (2021) tried to determine the most suitable location by evaluating 4 different options for the DLW to be established in the Beykoz district of Istanbul, using the in-depth interview technique with firefighters [23]. In their study, Soyöz and

Özyörük (2021) developed a three-stage mixed integer mathematical programming model for the purpose of transporting disaster victims to shelters and health centers after a disaster, delivering essential needs to people from warehouses, and transporting health supplies. They solved the model for a small data set and interpreted the results [24]. In another study, Soyöz and Özyörük (2024) developed a five-stage mathematical model for the delivery of relief supplies to disaster victims from suppliers to warehouses, from shelters to warehouses and from distribution centers to health centers. In the developed model, solutions were made for earthquake scenarios that may occur Ankara and the results obtained were evaluated [25].

It is seen in the literature that multi-criteria decision-making methods are widely used in determining the location of emergency warehouses. Peker et al. (2016) conducted a study to determine the location of the emergency warehouse to be established in Erzincan province. The initial phase of the study involved determining the weights of the selection criteria using the Analytic Hierarchy Process (AHP). In the subsequent phase, the alternatives were evaluated and selected using the VIKOR method [26]. Ofluoğlu et al. (2017) examined the DLW location selection to be established in Trabzon province as a multi-criteria decision-making problem. The study utilized the Entropy weight method-based SAW, TOPSIS, and VIKOR methodologies to identify the optimal location for DLW among the available possibilities [27]. Ergun et al. (2020) determined emergency warehouse location selection with AHP-based MAUT and SAW methods to ensure sustainable disaster logistics in Giresun [5]. Derse (2022) conducted a study to identify the specific locations of Disaster Logistics Warehouses (DLWs) in the Aegean Region. The study utilized the DEMATEL-based TOPSIS technique and Cluster Coverage Model [28] for this purpose. Tezcan et al. (2023) selected a location for a temporary warehouse that will serve in Kırıkkale province after the disaster. The study utilized the AHP, TOPSIS, PROMETHEE, and VIKOR techniques to evaluate and compare the different choices [29]. Bayram and Eren (2023) conducted a study to determine the location of the DLW to be established in order to reduce the effects of a 7.5 magnitude earthquake that may occur in Istanbul. In the study, the suitable one among the alternatives was determined using AHP, TOPSIS, ELECTRE and PROMETHEE methods [30].

3. MATERIALS AND METHODS (MATERYAL VE METOD)

The location selection problem is a ubiquitous issue that arises in various domains of everyday life. The most important issues that are taken into consideration during the establishment of a workplace are the location of establishment, production management and production capacity. Choosing the location of the establishment incorrectly can lead to both increased costs and inefficient use of resources [31]. Hence, the selection of a business's operating site is a strategic decision that has a direct impact on long-term productivity, since it influences the resources required for production and the expenses associated with manufacturing and distribution. The location selection problem involves the allocation of m facilities to n clients (where m is less than n) in order to reduce costs associated with collection, transportation, and production. Maximum coverage, cluster coverage, p-median, p-center models are widely used in site selection in the literature.

3.1. Cluster Coverage Model (Küme Kaplama Modeli)

The cluster coverage model aims to identify the smallest possible number of facilities needed to cover the demand points, while adhering to specific constraints such as distance or capacity. Location set covering model was developed by Toregas et al. in 1971 [32]. In addition, the cluster coverage model aims to minimize the facility location cost that will provide a certain level of service [31]. Upon reviewing the literature, various studies have been conducted on different topics such as DLW selection [3], rail system station location determination [33], determination of electronic product collection points [34], determination of the location of fire stations [35], finding aircraft warning areas [36], location of emergency medical services [37], determining military warehouses and distribution centers [38], and determining the location of air and land ambulances [39].

The generalized cluster coverage problem is defined by a specific model, which includes many characteristics. These parameters are described in detail [32]:

Sets

i: Demand points

j: Warehouses

Parameters

n: Number of candidate warehouses

m: Number of demand points to be served

S: Maximum coverage distance of opened warehouses

Decision Variables

$$b_{ij} = \begin{cases} 1, \text{If the distance between warehouse} \\ \quad j \text{ and } i \text{ is lessthan } S \\ 0, \quad \text{Otherwise} \end{cases}$$

$$x_j = \begin{cases} 1, & \text{If warehouse } j \text{ is opened} \\ 0, & \text{Otherwise} \end{cases}$$

Mathematical Model

$$Min\ Z = \sum_{j=1}^{n} x_j \quad (1)$$

$$\sum_{j=1}^{n} b_{ij} x_j \geq 1 \qquad \forall i \quad (2)$$

$$x_j, b_{ij} \in \{0,1\}, \ \ i = 1,2,\ldots,m; j = 1,2,\ldots,n \quad (3)$$

The objective of Eq 1 is to reduce the quantity of facilities that are opened. Eq. 2 guarantees that a facility is allocated to each demand point. Sign constraints on the decision variables are illustrated in Eq. 3.

3.2. P-Median Model (P-Medyan Modeli)

Hakimi initially presented the P-Median problem in the academic literature in 1965 [41]. The P-median model is the model that is most commonly employed in the literature for location selection. The term "median problem" refers to the expansion of the P-median issue. In this type of problem, locating the facility that will supply all demand points on the network is the primary objective. If there is a need to open many facilities on the network, the model is referred to as the p-median model [32]. The primary objective of the P-Median model is to minimize the distance traveled, taking into account the demand and the location of the p facilities that will meet the demand points [42]. The p-median model is commonly employed in various facility location challenges, as evidenced in the literature. The p-median model is commonly used to model a wide range of problems in various disciplines, such as determining temporary residence areas [43], locating rail system stations [32], designing logistics networks for post-earthquake services [22], selecting vaccine distribution centers [44], selecting fire department locations [45], and selecting hospital locations [46], as found in the literature.

The p-median model aims to reduce the distance weighted by demand by serving n clients from p facilities. The mathematical model of the P-median problem, together with its parameters, is shown below [32, 41]:

Parameters:

a_i: the demand of the customer at point i

d_{ij} : distance between demand point i and warehouse j

p: number of warehouses to be opened

$$y_{ij} = \begin{cases} 1, \text{If the demand of demand point } i \\ \quad \text{is met from warehouse } j \\ 0, \text{Otherwise} \end{cases}$$

Mathematical Model

$$\min z = \sum_{i=1}^{m} \sum_{j=1}^{n} a_i d_{ij} y_{ij} \quad (4)$$

$$\sum_{j=1}^{n} y_{ij} = 1 \qquad \forall i \quad (5)$$

$$y_{ij} \leq x_j \qquad \forall i, j \quad (6)$$

$$\sum_{j=1}^{n} x_j = p \quad (7)$$

$$y_{ij}, x_j \ \in \ \{0,1\} \qquad \forall i, j \quad (8)$$

Eq. 4 represents the objective function of the model. The objective of the model is to minimize the total distance traveled, taking into account the weight of each demand. Equation 5 guarantees that each demand point is allocated to a single warehouse. Eq. 6 prohibits the allocation of any demand point to a warehouse that has not been opened, but Eq. 7 guarantees the opening of p warehouses. Eq. 8 ensures that the decision variables can only have values of either 0 or 1.

Upon reviewing the literature, it becomes evident that facility location selection commonly employs approaches such as cluster coverage, maximum coverage, p-median, and p-center. This study examines the issue of selecting the locations for disaster logistics warehouses in the non-central districts of Ankara. These warehouses will provide assistance to adjacent provinces in the event of a disaster. A two-stage model was developed in the study to facilitate venue selection. The initial phase involved determining the minimal number of emergency facilities to be opened using the cluster coverage model. In the subsequent phase of the study, the specific facilities to be opened and the provinces and districts to be assigned to these facilities were decided. The studies carried out are discussed in the next section.

4. LOCATION SELECTION FOR DISASTER LOGISTICS WAREHOUSES (AFET LOJİSTİK DEPOLARININ YER SEÇİMİ)

Existing literature reveals that during a disaster, DLWs are typically established in city centers to cater specifically to the affected population within that city [29, 30]. The earthquakes that occurred in Kahramanmaraş on February 6, 2023 affected 10 provinces, especially Kahramanmaraş, Hatay, Malatya and Adıyaman. The earthquake, which affected a wide region in this way, revealed how important the aid to be sent from surrounding provinces was. Therefore, it is important that the DLWs planned to deliver aid to disaster victims after a disaster are planned to be able to serve for disasters that may occur in neighboring provinces, rather than planning to serve only that area. Considering that the Istanbul earthquake that may occur in the coming years may also affect the surrounding provinces, it is important to create plans accordingly. In this study, it was determined in which districts the DLWs to be established in the off-center districts of Ankara, which has a low earthquake risk, should be established [4]. It is aimed to plan the DLWs established in the study to serve the surrounding provinces within the determined coverage area, as well as the non-central districts. Furthermore, when selecting the sites for the new facilities, the model considered the earthquakes of these areas, as well as the demographics of Ankara's peripheral districts and adjacent provinces.

The problem of determining the locations of DLWs to be established in the non-central districts of Ankara is modeled in two stages. In the first stage, it was determined how many DLWs should be opened using the cluster coverage model. In the second stage, it was tried to determine which cities and districts would be assigned to the DLWs opened with the p-median model. At this stage, first of all, calculations were made without taking into account the capacities of the DLWs, and the districts where the warehouses would be opened and the cities and districts to be assigned to these warehouses were determined. Afterwards, the model was solved again by adding the capacity constraint for the p-median model facilities, and considering the warehouse capacities, it was determined to which districts the warehouses would be opened and to which provinces and districts aid would be sent from these warehouses. In the final phase of the project, the model's performance was assessed by solving it through the creation of various scenarios. These scenarios involved altering the number of warehouses to be opened and adjusting their capacities. The resulting outcomes were then compared and analyzed.

4.1. Determining The Number of DLWs with the Cluster Coverage Model (Küme Kaplama Modeli ile DLW Sayısının Belirlenmesi)

The study utilized two-stage cluster coverage and p-median models to identify the optimal places for establishing DLWs in the non-central districts of Ankara. The initial phase involved determining the optimal number of DLWs to be established in the non-central districts of Ankara using the cluster coverage model. In creating the model, two coverage limits were determined since urban and extra-urban speed limits are different. With the aim of sending the product between districts within 2 hours, the coverage distance between districts has been determined as 100 km. The coverage distance was determined as 300 km, with the aim of transporting emergency equipment from districts to neighboring provinces in approximately 4 hours.

As seen in Table 2, Ankara has 16 off-center districts, and the study tried to determine in which districts the DLWs should be opened, taking into account the 100 km coverage distance. In addition, 15 provinces located 300 km away from Ankara were determined and it was aimed to provide service to these provinces from the disaster logistics warehouses opened. The cluster coverage approach was employed to ascertain the precise placement of DLWs in districts that are not centrally located. The objective of the model is to provide assistance to the districts within a maximum of 2 hours, with a coverage distance of 100 km. Additionally, the purpose is to offer aid to the bordering provinces within a maximum of 4 hours, with a coverage distance of 300 km. The "Distance from District to District" module on the website of the General Directorate of Highways was used to determine the distance between provinces/districts [47]. In addition, costs such as station opening costs, installation costs, and warehouse costs were not taken into account in the developed model. The data was utilized to encode the model into the GAMS 24.1.3 program and subsequently solved using the CPLEX solver. As a result of the calculation, it was determined that these regions could be served with a minimum of 5 warehouses, and it was found that the warehouses should be established in Beypazarı, Elmadağ, Evren, Güdül and Haymana districts.

Table 2. Population and earthquake risks of the provinces/districts (İl/ilçelerin nüfus ve deprem riskleri)

Provinces/District	Population	Earthquake Risk
Akyurt	40625	3
Ayaş	12998	4
Bala	20521	2
Beypazarı	48357	3
Çamlıdere	8100	1
Çubuk	95449	3
Elmadağ	44379	2
Evren	2952	1
Güdül	8079	3
Haymana	26016	4
Kahramankazan	59123	3
Kalecik	12794	3
Kızılcahamam	26872	2
Nallıhan	26553	2
Polatlı	128378	4
Şereflikoçhisar	33140	2
Eskişehir	906617	3
Sakarya	1080080	1
Düzce	405131	1
Bolu	320824	1
Kırıkkale	277046	3
Kırşehir	244519	3
Çankırı	196766	1
Kastamonu	378115	1
Karabük	252058	1
Afyonkarahisar	747555	2
Konya	2296347	4
Aksaray	433055	4
Nevşehir	310011	3
Yozgat	418442	3
Çorum	524130	3

In the first part of the study, the minimum number of DLWs that should be opened according to the determined coverage distances was determined with the cluster coverage model. However, with this model, the cities and districts to be assigned to warehouses could not be determined. The cities and districts to be assigned to the warehouses and the amount of population living in these places are of great importance in determining the capacity of the warehouses. Hence, in the latter phase of the investigation, the allocation of cities and districts to the warehouses was attempted to be decided using the utilization of the p-median model. Subsequently, an attempt was made to determine the locations for establishing the warehouses using the capacitated p-median model.

4.2. Determination of Districts DLWs Be Opened (DLW'lerin Açılacağı İlçelerin Belirlenmesi)

r_i: earthquake risk of i province/district

c_i: population of province/district i

Q_j: j disaster logistics warehouse capacity

S_i: Ratio of disaster-affected victims to the population

$$\min z = \sum_{i=1}^{m}\sum_{j=1}^{n} c_i \frac{1}{r_i} d_{ij} y_{ij} \tag{9}$$

With the objective function given in Eq 9, it is aimed to assign provinces and districts to warehouses in a way that minimizes the product of distance, earthquake risk and population components served from the warehouse. At this stage, the capacity of the facilities was assumed to be unlimited and no capacity constraint was added to the model. The mathematical model created is GAMS 24.3.1. It was coded in the program and solved with the help of CPLEX solver. Since it was found that a minimum of 5 DLWs should be established in the model solved with cluster coverage. At this time, the decision was made to open 5 (p) warehouses. The table provided, Table 3, lists the DLWs that need to be established based on the solution to the p-median problem. This solution considers factors such as population, distance, and earthquake risk. The table also specifies the cities and districts that will be assigned to each of these warehouses.

Table 3. Provinces/Districts assigned to DLWs (DLW'lere atanan il ve ilçeler)

DLW	Province/Districts Assigned to DLW
Kalecik	Akyurt Bala Çubuk Elmadağ Kalecik Kırıkkale Çankırı Kastamonu Yozgat Çorum
Kızılcahamam	Çamlıdere Güdül Kahramankazan Kızılcahamam Karabük
Nallıhan	Beypazarı Nallıhan Eskişehir Sakarya Düzce Bolu
Polatlı	Ayaş Haymana Polatlı Afyonkarahisar
Şereflikoçhisar	Evren Şereflikoçhisar Kırşehir Aksaray Nevşehir

Planning before the disaster how many people can be served from DLWs after any disaster will make disaster management more effective. Therefore, determining the capacities of DLWs is of great importance. The magnitude of the disaster's impact on individuals directly influences the capability of DLWs. The study considered the population assigned to the warehouse while deciding where to place DLWs in order to ensure efficient disaster management. In the study, it was assumed that 10% of the population of the province or district was affected by the disaster and aid would be sent to these disaster victims. It is assumed that the capacities of the warehouses are equal and that aid can be sent to 250000 people from one facility and 5 DLWs will be opened. Taking these assumptions into consideration, Eq.10 constraint was added and the model was solved again.

$$\sum_{j} x_{ij} * c_i * s_i \leq Q_j * y_j \qquad \forall j \qquad (10)$$

In the model solved by taking into account the capacities of the facilities, it was determined that there were changes in both the DLWs opened and the cities and districts assigned to these warehouses. The districts where DLWs were opened and the cities and districts assigned to these warehouses are given in Table 4.

Table 4. Provinces/Districts assigned to DLWs with capacited p-median model (Kapasitelendirilmiş P-medyan modeli ile DLW'lere atanan il ve ilçeler)

DLWs	Province/Districts Assigned to DLW
Evren	Evren Kırşehir Aksaray Nevşehir Yozgat
Kalecik	Akyurt Bala Çubuk Elmadağ Kalecik Kırıkkale Çankırı Kastamonu Çorum
Nallıhan	Beypazarı Güdül Nallıhan Sakarya Düzce Bolu Karabük
Polatlı	Ayaş Çamlıdere Haymana Kahramankazan Kızılcahamam Polatlı Eskişehir Afyonkarahisar
Şereflikoçhisar	Şereflikoçhisar Konya

The computations revealed that the capacitated p-median problem yielded different outcomes compared to the uncapacitated p-median problem. In the solution of the capacitated p-median model, it was determined that DLWs should be established in Evren, Kalecik, Nallıhan, Polatlı and Şereflikoçhisar districts, and as seen in Table 3, it was determined that there were changes in the provinces and districts assigned to these DLWs.

4.3. Sensitivity Analysis (Duyarlılık Analizi)

This part aims to assess the efficacy of the model by generating various situations. The initial phase of the study aimed to assess the impact of varying the number of DLWs on the objective function. This was done using a capacity-free p-median model, which is commonly employed to estimate the optimal sites for DLWs. Therefore, the model was recoded and solved with different warehouse numbers and the results obtained are discussed in this section. Figure 1 was generated to establish the correlation between the quantity of DLWs and the objective function.

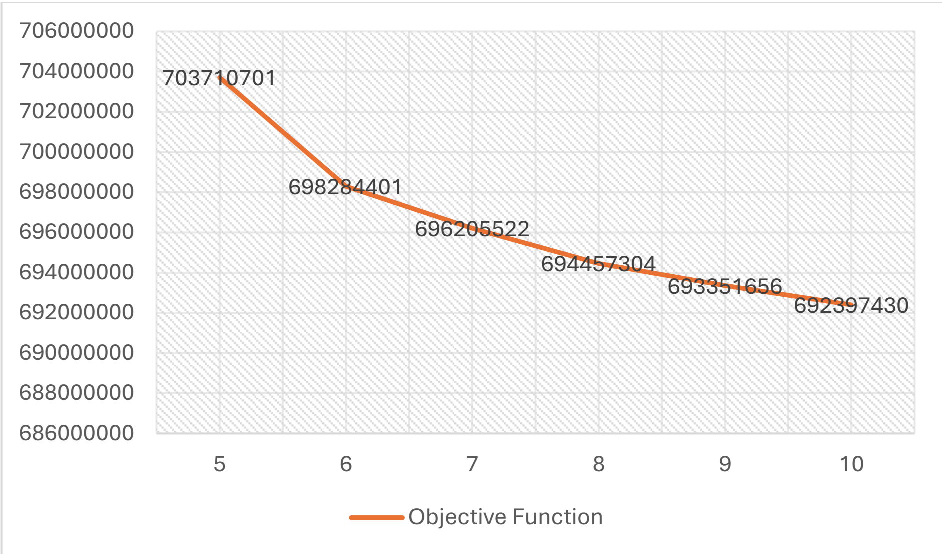

Figure 1. Relationship between the change in the number of DLWs and the objective function (DLW sayısındaki değişim ile amaç fonksiyonu arasındaki ilişki)

It will be more costly due to reasons such as opening more DLWs, renting more buildings for these warehouses, and employing more personnel. Nevertheless, as the number of warehouses grows, in the event of a catastrophe, the provinces and districts to be assisted will be allocated to warehouses that are in close proximity to one another. Figure 1 examines the impact of altering the number of warehouses on the goal function. Upon analyzing Figure 1, it becomes evident that the objective function value decreases as the number of DLWs assigned to service disaster victims grows. Consequently, it has been established that as the quantity of opened warehouses rises, there is a decline in the value of the objective function, which considers earthquake risk, population, and distance.

In the second phase of the study, a capacitated p-median model was established. By solving this model, the provinces suitable for establishing warehouses were identified, along with the provinces and districts that would be allotted to each of these provinces. Therefore, in this part of the study, sensitivity analysis was performed for the capacitated p-median model. The initial phase of the study aimed to ascertain the impact of altering storage capacities on the model. In the study, it was assumed that 10% of the population in a province or district was affected by the disaster and needed assistance and that aid would be delivered to these people. In the model, it is assumed that the number of DLWs opened is 5 and that aid will initially be delivered to 250,000 people from this warehouse. To assess the impact of the change in warehouse capacity on the model, the warehouse capacity was augmented in each trial to accommodate an additional 50,000 individuals. Figure 2 was created with the results obtained from the calculations made for DLWs with different capacities. The calculations reveal that the objective function value declines when the warehouse capacity is raised, reaching a minimum at 350,000 people. It has been established that increasing the DLW capacity to service more than 350,000 individuals does not have any impact on the objective function value. Accordingly, it has been determined that the lowest cost is achieved when the warehouse capacity is increased to serve 350000 people.

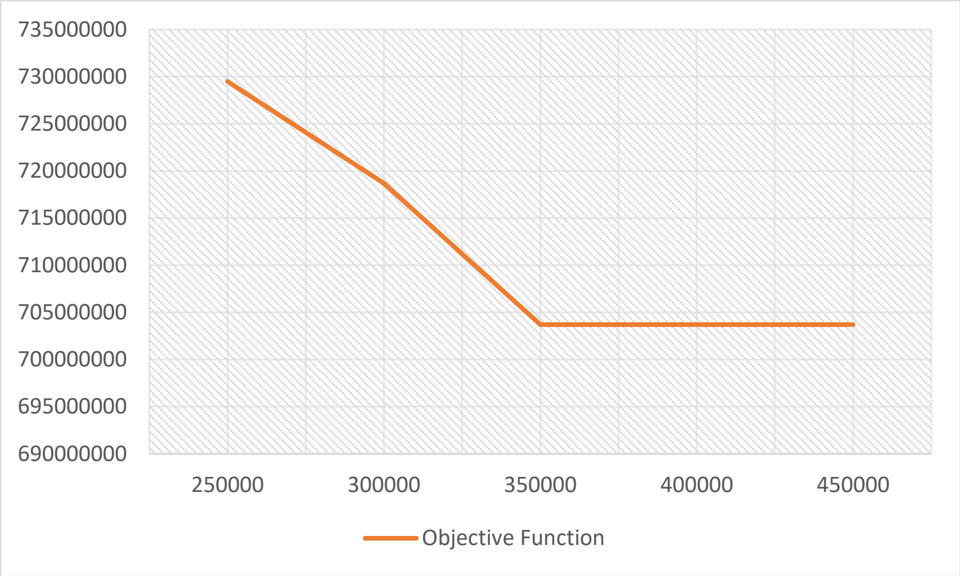

Figure 2. Relationship between the change in the capacity of the DLW and the objective function (DLW kapasitesindeki değişim ile amaç fonksiyon arasındaki ilişki)

Ultimately, this part aims to ascertain the impact of altering the number of warehouses on the model in the capacitated p-median problem. In the problem, the warehouse capacity was taken as 250000 and it was solved by changing the number of warehouses between 5 and 10. Figure 3 was created with the results obtained. Upon analyzing Figure 3, it becomes evident that the goal function attained its minimum value in the problem that was addressed using 7 warehouses. The highest objective function values are achieved when the number of DLWs opened is 5 and 6, respectively. While the goal function generally decreases as more warehouses are created, it is important to note that the smallest value is achieved when 7 warehouses are opened. In this case, it can be said that when 7 DLWs were opened, optimum service was provided to neighboring provinces and districts.

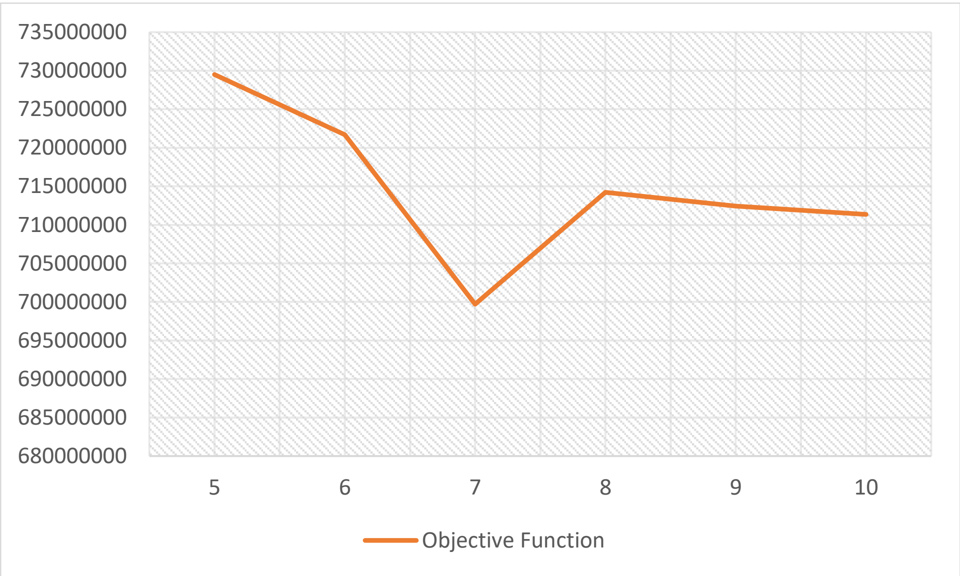

Figure 2. Relationship Between the change in the number of DLWs and the objective function (DLW sayısındaki değişim ile amaç fonksiyonu arasındaki ilişki)

This section aims to assess the influence of the proposed models on various scenarios. In order to achieve this objective, the study analyzed the impact of altering the number of warehouses in the p-median model. It has been established that there is an inverse relationship between the number of warehouses and the value of the objective function. The capacitated p-median model, employed in the second stage of the investigation, was solved by altering the number of warehouses and their respective capacities. Subsequently, the obtained results were compared. It has been established that the objective function value decreases as the warehouse capacity increases, but only up to a particular capacity of 350000.

5. CONCLUSIONS (SONUÇLAR)

Disasters are nature, technological or human-induced events that occur at unexpected times and cause economic, social and physical losses for all or part of the society. Although it is very difficult to predict disasters in advance, their effects can be minimized by taking precautions before the disaster. In taking these measures, it is necessary to determine in advance which disasters occur most in those regions and how many people they may affect. Activities carried out before disasters to minimize the damages that may occur due to disasters are defined as disaster logistics. Disaster logistics includes many activities such as planning, storage, location selection, distribution and control. Accurately identifying the whereabouts of DLWs is crucial for promptly distributing the necessary supplies following a calamity. Hence, the study focused on the issue of selecting suitable locations for DLWs, which are efficient in promptly providing assistance to victims of disasters.

Upon reviewing the literature on DLW location selection, it becomes evident that researchers are focused on constructing DLWs in urban metropolitan centers. However, the Kahramanmaraş earthquakes that occurred on February 6, 2024 showed how important the aid from surrounding provinces is. Thus, this study aimed to investigate the issue of identifying the specific locations for DLWs to be created in 16 districts located outside the central area of Ankara. With the DLWs to be opened, it is aimed to quickly deliver aid to the surrounding provinces in case of a disaster. Hence, the study aimed to ascertain the optimal quantity of warehouses to be created in the districts surrounding Ankara, as well as the strategic locations for these facilities, with the primary objective of expediting the distribution of help to nearby provinces.

In the literature, it is seen that maximum coverage, cluster coverage, p-median, p-center models are mostly used in warehouse location selection. This study utilized a mix of the cluster coverage model and p-median models to ascertain the optimal number of DLWs needed in the non-central districts of Ankara, as well as the precise locations for these warehouses. The study consists of four stages. In the first stage of the study, the cluster coverage model was used to determine the minimum number of DLWs that should be opened in the non-central districts of Ankara. In the created model, the coverage distance to serve neighboring districts was taken as 100 km, and the coverage distance to serve neighboring provinces was taken as 300 km and the model was solved. With the solution of the cluster coverage model, it was determined that a minimum of 5 DLWs should be established in sixteen off-center districts of Ankara. The input for the p-median model was the minimal number of warehouses required to cover a cluster of 5 units. In the p-median model, the number of warehouses to be opened was taken as 5, and in the objective function, the distances between warehouses and provinces and districts, as well as the population of the provinces and districts and earthquake risks were taken into account. Based on the calculations, it was concluded that in order to minimize the objective function, it is necessary to open 5 warehouses in the districts of Kalecik, Kızılcahamam, Nallıhan, Polatlı, and Şereflikoçhisar. In addition, the results obtained also determined which provinces and districts would be assigned to the warehouses. In the next stage of the study, the model was solved again by adding the capacity constraint for each warehouse to the p-median model, and it was observed that there were changes in the districts where the warehouses would be opened (Kalecik, Kalecik, Nallıhan, Polatlı, and Şereflikoçhisar) and the provinces and districts assigned to these warehouses. The capacitated p-median model highlights the importance of locating warehouses in close proximity to densely populated cities.

The final phase of the study involved evaluating the efficacy of the p-median and capacitated p-median models by modifying the parameters employed. The model was re-solved by modifying the number of warehouses in the p-median model utilized in the initial stage. It was observed that the objective function value enhanced with an increase in the number of opened warehouses. The second section of the sensitivity analysis focused on evaluating the impact of altering the warehouse capacity and the number of warehouses on the model in the capacitated p - median problem. It has been determined that the increase in warehouse capacity reduces the objective function up to a certain point, and then does not affect the objective function value. Empirical evidence suggests that the objective function tends to improve with an increase in the number of warehouses. However, the ideal outcome is obtained by opening precisely seven DLWs.

In this study, the locations of DLWs to be opened in the non-central districts of Ankara and the locations of the cities and districts to be assigned to the DLWs were tried to be determined. In the study, unlike the literature, the locations of the warehouses to be established in non-central districts were tried to be determined and cluster coverage and p-median and capacitated p-median models were used in location selection. In the study, the costs of opening warehouses and the costs of transporting materials from warehouses to provinces and districts were not taken into account. In future studies, the objective function can be improved by taking these costs into account. In future studies, p-center and maximum coverage models can be used for DLW location selection. Additionally, the effect of traffic in city centers can be included in the model when creating coverage areas. In this study, pre-disaster planning activities are discussed. In future studies, studies on activities during and after disasters can also be addressed.

DECLARATION OF ETHICAL STANDARDS (ETİK STANDARTLARIN BEYANI)

The author of this article declares that the materials and methods they use in their work do not require ethical committee approval and/or legal-specific permission.

Bu makalenin yazarı çalışmalarında kullandıkları materyal ve yöntemlerin etik kurul izni ve/veya yasal-özel bir izin gerektirmediğini beyan ederler.

AUTHORS' CONTRIBUTIONS (YAZARLARIN KATKILARI)

***Beste DESTİCİOĞLU TAŞDEMİR*:** She conducted the experiments, analyzed the results and performed the writing process.

Deneyleri yapmış, sonuçlarını analiz etmiş ve maklenin yazım işlemini gerçekleştirmiştir.

CONFLICT OF INTEREST (ÇIKAR ÇATIŞMASI)

There is no conflict of interest in this study.

Bu çalışmada herhangi bir çıkar çatışması yoktur.

REFERENCES (KAYNAKLAR)

[1] Hoyois, P, Below, R, Scheuren, JM, Guha-Sapir, D. Annual Disaster Statistical Review 2006; Numbers and Trends.

[2] Thomas, AS, Kopczak, LR. From logistics to supply chain management: the path forward in the humanitarian sector. Fritz Institute, 2005; 15(1), 1-15.

[3] Aydın, H, Ayvaz, B, Küçükaşçı, EŞ. Afet yönetiminde lojistik depo seçimi problemi: Maltepe ilçesi örneği. Yaşar Üniversitesi E-Dergisi. 2017; 12: 1-13.

[4] Türkiye Cumhuriyeti İçişleri Bakanlığı Afet ve Acil Durum Yönetimi Başkanlığı (AFAD) "Açıklamalı Afet Yönetimi Terimleri Sözlüğü", 2024; https://www.afad.gov.tr/aciklamali-afet-yonetimi-terimleri-sozlugu .

[5] Ergün, M, Korucuk, S, Memiş, S. Sürdürülebilir afet lojistiğine yönelik ideal afet depo yeri seçimi: Giresun ili örneği. Çanakkale Onsekiz Mart Üniversitesi Fen Bilimleri Enstitüsü Dergisi. 2020; 6(1): 144-165.

[6] Barbarosoğlu, G, Arda, Y. A two-stage stochastic programming framework for transportation planning in disaster response. Journal of the operational research society. 2004; 55: 43-53.

[7] Dekle, J, Lavieri, MS, Martin, E, Emir-Farinas, H, Francis, RL. A Florida county locates disaster recovery centers. Interfaces. 2005; 35(2): 133-139.

[8] Hale, T, Moberg, CR. Improving supply chain disaster preparedness: A decision process for secure site location. International journal of physical distribution & logistics management. 2005; 35(3): 195-207.

[9] Gunnec, D, Salman, F. A two-stage multi-criteria stochastic programming model for location of emergency response and distribution centers. In International network optimization conference, 2007; 1-6.

[10] Jia, H, Ordonez, F, Dessouky, MM. Solution approaches for facility location of medical supplies for large-scale emergencies. Computers & industrial engineering. 2007; 52(2): 257-276.

[11] Balcik, B, Beamon, BM. Facility location in humanitarian relief. International Journal of logistics. 2008; 11(2): 101-121.

[12] Mete, HO, Zabinsky, ZB. Stochastic optimization of medical supply location and distribution in disaster management. International journal of production economics. 126(1), (2010). 76-84.

[13] Rawls, CG, Turnquist, MA. Pre-positioning planning for emergency response with service quality constraints. OR spectrum. 2011; 33: 481-498.

[14] Zhu, J, Liu, D, Huang, J, Han, J. Determining storage locations and capacities for emergency response. In The Ninth International Symposium on Operations Research and Its Applications (ISORA'10). 2010; 262-269.

[15] Görmez, N, Köksalan, M, Salman, FS. Locating disaster response facilities in Istanbul. Journal of the operational research society. 2011; 62(7); 1239-1252.

[16] Duran, S, Gutierrez, MA, Keskinocak, P. Pre-positioning of emergency items for CARE international. Interfaces. 2011; 41(3): 223-237.

[17] Döyen, A, Aras, N, Barbarosoğlu, G. A two-echelon stochastic facility location model for humanitarian relief logistics. Optimization Letters. 2012; 6: 1123-1145.

[18] Liu, C, Chen, ZH, Gong, YY. Site selection of emergency material warehouse under fuzzy environment. Journal of Central South University. 2013; 20(6): 1610-1615.

[19] Salman, FS, Yücel, E. Emergency facility location under random network damage: Insights from the Istanbul case. Computers & Operations Research. 2015; 62: 266-281.

[20] Şahin, Y, Altın, FG. Çadırkent yer seçimi problemi için bir atama modeli: Isparta örneği-an assignment model for shelter site selection problem: a case of Isparta. Mehmet Akif Ersoy Üniversitesi Sosyal Bilimler Enstitüsü Dergisi. 2016; 8(16): 323-336.

[21] Iqbal, S, Sardar, MU, Lodhi, FK, Hasan, O. Statistical model checking of relief supply location and distribution in natural disaster management. International Journal of Disaster Risk Reduction, 2018: 31: 1043-1053.

[22] Temur, GT, Turgut, Y, Yılmaz, A, Arslan, Ş, Camcı, A. Deprem sonrası planlamaya yönelik lojistik ağ tasarımı: Ümraniye bölgesinde farklı deprem senaryoları için bir uygulama. Pamukkale Üniversitesi Mühendislik Bilimleri Dergisi. 2019; 25(1): 98-105.

[23] Durdağ, C, Ergenecoşar, S, Kınık, Z, Yılmaz, KK. Afet Bakış Açısıyla Lojistik Depo Yeri Seçimi: İstanbul Beykoz İlçesi Üzerine Bir Uygulama. Beykoz Akademi Dergisi. 2021; 9(1): 98-107.

[24] Soyöz, H, Özyörük, B. Afet Lojistiğinde Üç Aşamalı Karma Tamsayılı Bir Model Önerisi. Journal of Turkish Operations Management. 2021; 5(1): 641-661.

[25] Soyöz, H, Özyörük, B. A Five-Level and Multi-Period Mixed Integer Model Proposal in Disaster Logistics. Available at SSRN 2024; 4557000.

[26] Peker, İ, Korucuk, S, Ulutaş, Ş, Okatan, BS, Yaşar, F. Afet Lojistiği Kapsaminda En Uygun Dağitim Merkez Yerinin AHS-VIKOR Bütünleşik Yöntemi Ile Belirlenmesi: Erzincan İli Örneği. Journal of Management and Economics Research. 2016; 14(1): 82-103.

[27] Ofluoglu, A, Birdogan, B, Ar, İM. Multi-criteria decision analysis model for warehouse location in disaster logistics. Journal of Management Marketing and Logistics. 2017; 4(2): 89-106.

[28] Derse, O. Dematel Tabanlı TOPSIS Yöntemi ve Küme Kapsama Modeli İle Afet Lojistiği İçin Depo Yeri Seçimi: Ege Bölgesi Örneği. Kahramanmaraş Sütçü İmam Üniversitesi Mühendislik Bilimleri Dergisi. 2022; 25(4): 702-713.

[29] Tezcan, B, Alakaş, HM, Özcan, E, Eren, T. Afet sonrası geçici depo yeri seçimi ve çok araçlı araç rotalama uygulaması: Kırıkkale ilinde bir uygulama. Politeknik Dergisi. 2021; 26(1): 13-27.

[30] Bayram, B, Eren, T. Çok Kriterli Karar Verme Yöntemleriyle Afet Sonrası Geçici Depo Yeri Seçimi. Acil Yardım ve Afet Bilimi Dergisi. 2023; 3(2): 22-30.

[31] Farahani, RZ, Asgari, N, Heidari, N, Hosseininia, M, Goh, M. Covering problems in facility location: A review. Computers & Industrial Engineering, 2012; 62(1): 368-407.

[32] Toregas, C, Swain, R, ReVelle, C, Bergman, L. The location of emergency service facilities. Operations research. 1971; 19(6): 1363-1373.

[33] Kara, SS, Yurdakul, G. Raylı Sistem İstasyon Yeri Belirleme Problemi İçin Küme Kapsama ve Alternatif Servis Seviyeli P-Medyan Modelleriyle Çözüm Arayışı: Gebze-Darıca Metro Hattı Uygulaması. Dokuz Eylül Üniversitesi Mühendislik Fakültesi Fen ve Mühendislik Dergisi. 2021; 23(69): 845-856.

[34] Keçeci, B, Dengiz, O, Dengiz, B, Sümer, E, Kılıç, A, Ece, Ç, ..., Çiçek, S. AEEE tahmini ve toplama noktalarının belirlenmesi: Çankaya Belediyesi için bir uygulama. Pamukkale Üniversitesi Mühendislik Bilimleri Dergisi. 2017; 24(4): 692-704.

[35] Aktaş, E, Özaydın, Ö, Bozkaya, B, Ülengin, F, Önsel, Ş. Optimizing fire station locations for the Istanbul metropolitan municipality. Interfaces. 2013; 43(3): 240-255.

[36] Bell, JE, Griffis, SE, Cunningham, WA, Eberlan, JA. Location optimization of strategic alert sites for homeland defense. Omega. 2011; 39: 151–158
[37] Sorensen, P, Church, R. Integrating expected coverage and local reliability for emergency medical services location problems. Socio-Economic Planning Sciences. 2010; 44(1): 8-18.
[38] Farahani, RZ, Asgari, N. Combination of MCDM and covering techniques in a hierarchical model for facility location: A case study. European Journal of Operational Research. 2007; 176: 1839–1858.
[39] Erdemir, ET, Batta, R, Spielman, S, Rogerson, PA, Blatt, A, Flanigan, M. Location coverage models with demand originating from nodes and paths: Application to cellular network design. European Journal of Operational Research. 2008; 190(3): 610–632.
[40] Yelbay, B, Birbil, Şİ, Bülbül, K. The set covering problem revisited: an empirical study of the value of dual information. Journal of Industrial and Management Optimization. 2014; 1-22.
[41] Hakimi, SL. Optimum distribution of switching centers in a communication network and some related graph theoretic problems. Operations research. 1965; 13(3): 462-475.
[42] Durak, İ, Yıldız, M. P-Medyan tesis yeri seçim problemi: Bir uygulama. Uluslararası Alanya İşletme Fakültesi Dergisi. 2015; 7(2); 43-64.
[43] Şahin, Y, Hazırcı, M. Geçici İskân Alanlarının Seçimi İçin AHP Temelli P-Medyan Modeli: Burdur Örneği. Mühendislik Bilimleri ve Tasarım Dergisi. 2019; 7(2): 403-417.
[44] Desticioglu, B, Ozyoruk, B. Covid 19 Vaccine Distribution Location Selection Problem: Application of Ankara Province. In International Conference on Management Science and Engineering Management, Cham: Springer International Publishing. 2022; 702-714).
[45] Yao, J, Zhang, X, Murray, AT. Location optimization of urban fire stations: access and service coverage. Comput. Environ. Urban Syst. 2019; 73: 184–190.
[46] Gwalani, H, Tiwari, C, Mikler, AR. Evaluation of heuristics for the p-median problem: Scale and spatial demand distribution. Computers, environment and urban systems. 2021; 88: 101656.
[47] Karayolları Genel Müdürlüğü (KGM), 2024; https://www.kgm.gov.tr/Sayfalar/KGM/SiteTr/Uzakliklar/ilcedenIlceyeMesafe.aspx .