Uşak Üniversitesi
Uygulamalı Bilimler Fakültesi Dergisi
2025; 5(1); 90-108

Journal of The Faculty of
Applied Sciences of Uşak University
2025; 5(1); 90-108

Makale Türü / Article Type: Araştırma Makalesi / Research Article

PREPARING FOR THE INEVITABLE: LOGISTICAL CHALLENGES AND DAMAGE PROJECTIONS FOR MAJOR EARTHQUAKE IN İSTANBUL

[1]Tayfun BASKIN

[2]Ayberk ŞEKER

Abstract

Positioned atop active fault lines, Turkey faces an imminent earthquake risk, particularly in densely populated and economically vital cities like Istanbul. This study models the potential impact of a 7.5-magnitude Marmara Earthquake on Istanbul using a coefficient-based mathematical framework derived from empirical data from the 1999 Gölcük and 2023 Kahramanmaraş earthquakes. Results estimate 105,765 fatalities, 283,355 serious injuries, and over 101,081 heavily damaged buildings across Istanbul's districts. The projected destruction reveals a colossal post-disaster logistics burden. To address only basic needs in the first response phase, an estimated 2,392 trucks must be mobilized: 265 for tents, 69 for first aid kits, 977 for 10-day food supplies, and 1,081 for basic clothing materials. Additionally, 21,051 pieces of construction machinery will be required for debris removal and rescue operations. Emergency medical response capabilities will face severe strain: assuming each ambulance can serve two critically injured individuals, the initial response will require at least 141,678 ambulances—a number that vastly exceeds Turkey's current medical transport capacity. These projections highlight the urgency of planning for ambulance routing systems, temporary field hospitals, and intercity medical cooperation agreements in advance. Given Istanbul's dense urban landscape, aging building stock, and fragile infrastructure, logistical collapse is a near certainty without proactive intervention. Centralized logistics coordination centers, pre-signed agreements with logistics and demolition providers, and predefined emergency corridors in high-risk districts such as Esenyurt, Avcılar, and Küçükçekmece are essential. By offering a data-driven, scalable disaster model, this study equips policymakers and urban planners with actionable insights to prevent large-scale humanitarian crises in the aftermath of a major seismic event.

Keywords: Marmara Earthquake, Disaster Logistics, Earthquake Scenario, Damage Analysis, Mathematical Modelling

Kaçınılmaz Olana Hazırlık: İstanbul'da Büyük Deprem İçin Lojistik Zorluklar ve Hasar Tahminleri

Öz

Türkiye'nin aktif fay hatları üzerinde yer alması, özellikle İstanbul gibi yüksek nüfuslu ve ekonomik açıdan kritik şehirleri büyük bir deprem riskiyle karşı karşıya bırakmaktadır. Bu çalışmada, 7,5 büyüklüğündeki olası bir

[1]Yüksek Lisans Öğrencisi, Bursa Teknik Üniversitesi, Lisansüstü Eğitim Enstitüsü, baskintayfun@gmail.com, ORCID: 0009-0000-4645-9755

[2] Doç. Dr., Bursa Teknik Üniversitesi, İnsan ve Toplum Bilimleri Fakültesi, Uluslararası Ticaret ve Lojistik Bölümü, ayberk.seker@btu.edu.tr, ORCID: 0000-0001-7750-6286

Makale Gönderim Tarihi / Received Date: 27.02.2025
Makale Kabul Tarihi / Accepted Date: 04.06.2025

Marmara Depremi'nin İstanbul üzerindeki etkileri; bina hasarı, can kayıpları ve afet sonrası lojistik gereksinimler temelinde değerlendirilmiştir. 1999 Gölcük ve 2023 Kahramanmaraş depremlerinden elde edilen ampirik verilerle oluşturulan matematiksel model, İstanbul genelinde 105.765 ölüm, 283.355 ağır yaralı ve 101.081 ağır hasarlı bina beklendiğini ortaya koymaktadır. Yapısal kayıpların ötesinde, bu senaryo acil müdahale lojistiği açısından da alarm verici düzeydedir. İlk müdahale fazında yalnızca temel ihtiyaçların karşılanması için 2.392 kamyona ihtiyaç duyulacaktır: 265 çadır kamyonu, 69 ilk yardım kamyonu, 977 gıda kamyonu ve 1.081 giyim malzemesi kamyonu sevk edilmelidir. Ayrıca, enkaz kaldırma ve kurtarma çalışmaları için 21.051 adet inşaat ekipmanı gereklidir. Tıbbi müdahale kapasitesi ise daha da dikkat çekicidir: her bir ambulansın en fazla iki ağır yaralıya hizmet edebileceği varsayımı altında, ilk 24 saatte müdahale edilebilmesi için yaklaşık 141.678 ambulansın sahada olması gerekmektedir. Bu sayı, Türkiye'nin mevcut ambulans kapasitesinin çok üzerinde olup, acil sağlık filosu planlaması, geçici sahra hastaneleri kurulumu ve şehirlerarası sağlık destek protokolleri gibi önlemlerin acilen hayata geçirilmesini zorunlu kılmaktadır. Bulgular, İstanbul'un mevcut kentsel yoğunluğu, eski yapı stoğu ve kırılgan altyapısı göz önüne alındığında; afet sonrası lojistik operasyonların hızla felce uğrayabileceğini göstermektedir. Bu doğrultuda merkezi koordinasyon merkezleri kurulmalı, özel sektörle ön sözleşmeler imzalanmalı ve yüksek riskli ilçelerde (özellikle Esenyurt, Avcılar, Küçükçekmece) acil dağıtım koridorları tanımlanmalıdır. Bu çalışma, karar vericilere yönelik veri temelli, uygulanabilir ve önleyici bir lojistik yol haritası sunarak büyük ölçekli bir insani krizin önlenmesine katkı sağlamayı amaçlamaktadır.

Anahtar Kelimeler: Marmara Depremi, Afet Lojistiği, Deprem Senaryosu, Hasar Analizi, Matematiksel Modelleme

INTRODUCTION

Türkiye, located on active fault lines, frequently experiences earthquakes, resulting in significant loss of life and severe economic and social consequences. The 1999 Gölcük Earthquake and the 2023 Kahramanmaraş Earthquake rank among the most devastating seismic events in Türkiye's recent history, prompting a critical reassessment of the country's disaster management strategies and logistical planning.

The 7.4-magnitude Gölcük Earthquake, which struck the Marmara Region on August 17, 1999, caused widespread devastation. This catastrophic event resulted in approximately 17,000 fatalities, tens of thousands of injuries, and the displacement of hundreds of thousands of people, highlighting critical deficiencies in Türkiye's earthquake preparedness and response capacity (Zülfikar et al., 2012: 2). In the aftermath, thousands of construction machines were deployed for debris removal, and large-scale logistics operations were conducted to support recovery efforts.

The 2023 Kahramanmaraş Earthquakes, with two major shocks of magnitudes 7.8 and 7.6, severely impacted Kahramanmaraş, Hatay, Gaziantep, Osmaniye, Malatya, Adana, Diyarbakır, Şanlıurfa, Adıyaman, and Kilis, located in Türkiye's Southeastern and Eastern Anatolian regions. These earthquakes led to the collapse of thousands of buildings and caused extensive infrastructure damage. In Kahramanmaraş and surrounding provinces, hundreds of thousands of people were left homeless, triggering an unprecedented demand for emergency aid and logistical support (Külekçi and Vural, 2023: 81).

The anticipated Marmara Earthquake remains a significant threat frequently highlighted by scientists. This earthquake, expected to impact Istanbul and its surrounding regions, is projected to cause widespread destruction and substantial human losses. Given its potential impact on densely populated and industrial areas, comprehensive logistical preparedness is imperative (Yalçın and Sabah, 2017: 535). In the aftermath, a large fleet of construction machinery will be required for extensive logistics operations, debris removal, and emergency aid efforts.

Loss estimation studies based on earthquake scenarios play a crucial role in assessing the potential impacts on provinces and districts. These studies analyze key elements such as building damage, casualties, and economic losses under different seismic scenarios. Işık et al. (2019: 87-91) evaluated building damage and economic losses across three distinct earthquake scenarios for Kırşehir Province. Similarly, Karaağaç et al. (2019:126-127) employed AHP and GIS methodologies to develop earthquake scenarios for Kahramanmaraş and Adıyaman, identifying potential impact areas.

Earthquake-induced building damage leads to severe loss of life and property, making the assessment of seismic vulnerability critical for risk evaluation and the development of disaster prevention and emergency response strategies. The identification of post-disaster shelter areas is critical for emergency planning. GIS technologies assist in selecting suitable locations and estimating shelter needs. Additionally, ensuring the rapid and efficient transport of critically injured individuals to hospitals significantly enhances the effectiveness of emergency response efforts.

Post-earthquake logistics operations require strategic planning and efficient management. In this context, central coordination, local collaboration, public awareness, infrastructure resilience, and mobile solutions are critical for addressing logistical challenges in a large, densely populated city like Istanbul. In light of the ongoing scientific and policy discussions regarding Istanbul's vulnerability to a major seismic event, this study aims to estimate the potential extent of structural damage, human casualties, and post-disaster logistical needs following a projected 7.5-magnitude Marmara Earthquake. By utilizing empirical data from the 1999 Gölcük and 2023 Kahramanmaraş earthquakes, the study develops a mathematical model to simulate the probable impacts on Istanbul's districts. The findings aim to contribute to ongoing risk assessment efforts and to provide a foundational framework for emergency logistics planning and urban resilience strategies.

1. LITERATURE REVIEW

Post-earthquake logistics are essential for coordinating rapid and efficient relief efforts. The literature introduces tools to estimate earthquake-related losses and guide logistics planning.

Probability calculations by Parsons et al. (2000: 664) underscore the likelihood of a major earthquake recurring near Istanbul, emphasizing the need for further logistics studies. Similarly, Stein et al. (1997: 602) explored the triggering mechanisms of earthquakes along the North Anatolian Fault and provided insights into earthquake probabilities in the vicinity of Istanbul.

Zülfikar et al. (2012: 3) conducted earthquake intensity, damage, and loss estimations using the ELER software. The study compared observational data from the 1970 Kütahya-Gediz and 2011 Kütahya-Simav earthquakes with the results generated by ELER software. ELER (Earthquake Loss Estimation Routine) is a GIS-based tool used to rapidly estimate earthquake damage and casualties, showing strong alignment with observed data. This software is of significant importance in providing fast and reliable information to decision-makers in disaster logistics management.

The study conducted for Rize Province presents new model proposals in disaster logistics management (Tanyaş et al., 2013: 265). The study develops recommendations for the effective management of post-disaster logistics processes and highlights the importance of disaster logistics. Disaster logistics plays a critical role in the rapid and efficient distribution of essential materials following a disaster. Therefore, effective disaster logistics planning and management are crucial for minimizing loss of life and property in disaster-affected regions.

In a study conducted for the Western Anatolia Region, analyses were performed on the region's earthquake statistics and the medium-term prediction of potential strong earthquakes (Öztürk, 2014: 88-91). The study aims to enhance the level of preparedness for possible earthquake scenarios by evaluating the seismic risks of the region. Additionally, it highlights the importance of developing strategies for microzonation, ground improvements, structural reinforcement, rapid intervention, and logistics methods, particularly in Istanbul.

Jenelius and Mattsson (2015: 757-758) conducted studies assessing the vulnerability of transportation networks following an earthquake. These studies highlighted the significance of transportation challenges based on the city’s population size and the priority of needs. In contrast, another study emphasized the critical role of disaster logistics in managing logistics processes and offered strategic recommendations for effective disaster logistics management (Börühan and Ersoy, 2013: 84). This study underscored the importance of post-disaster material distribution, storage, and coordination processes.

Yalçın and Sabah (2017: 535) utilized Open-Source Geographic Information Systems (GIS) software and the Analytical Hierarchy Process (AHP) method to conduct an earthquake hazard analysis for industrial enterprises in Edirne Province. Their study assessed the hazard exposure levels of industrial facilities, identifying Keşan and Enez districts as having high seismic risk. Such analyses are essential for helping industrial enterprises implement earthquake mitigation measures and play a critical role in disaster logistics planning.

In the study conducted for Kırşehir Province, building damage and economic losses were calculated using various earthquake scenarios (Işık et al., 2019: 87-91). These scenarios help local governments and disaster response teams to prepare effectively, enhancing the efficiency of post-disaster response processes. The methods employed in the study facilitate the prediction of potential post-earthquake impacts and enable the implementation of appropriate preventive measures.

In another study conducted in the Ümraniye region of Istanbul, the logistics network design for various earthquake scenarios was examined (Temur et al., 2019: 103). This study provides a valuable planning tool for the distribution of post-earthquake relief materials and the management of logistics processes. The effective design of the post-earthquake logistics network is crucial for accelerating post-disaster response and ensuring coordination.

A detailed evaluation of post-earthquake ground structures and building inventories is emphasized in a study (Golafshani et al., 2005: 88), which enhances the accuracy of damage estimates for scenarios with varying magnitudes and intensity levels. In a study conducted for Düzce and its districts, comparative analyses were performed based on different earthquake scenarios (Sabah and Bayraktar, 2020: 1701). The study assessed the earthquake hazard potentials of the districts and proposed disaster management plans based on these evaluations.

In the simulation study conducted for Kırıkkale Province, loss estimation analyses were performed using various earthquake scenarios (Çiftçi et al., 2020: 614). These analyses provide crucial data for disaster management by estimating potential damages and losses following an earthquake.

Studies in the literature offer various methods and tools for earthquake damage and loss estimation, as well as disaster logistics management and planning. Tools such as Geographic Information Systems (GIS), Analytical Hierarchy Process (AHP), and ELER software facilitate the effective management of post-earthquake intervention and logistics processes, helping to minimize loss of life and property. This literature review, conducted within the framework of the expected Marmara Earthquake scenario, assesses the logistical hazards of a potential earthquake in Istanbul and provides critical insights into estimating the materials and logistical resources needed following the disaster.

In recent years, studies on emergency logistics have increasingly adopted data-driven and intelligent modeling techniques, particularly in the context of earthquake-related disasters.

For instance, Tanti et al. (2023: 2-5) developed a deep learning-based location-routing model that dynamically predicts optimal distribution center locations and vehicle assignments under post-disaster uncertainty. Their approach integrated artificial neural networks and clustering algorithms, offering improved response accuracy and decision speed.

Similarly, Dindarik and Atabey-Bölük (2024: 258-260) emphasized the growing role of digital transformation technologies—including real-time monitoring systems and smart warehousing—in enhancing disaster logistics capacity and coordination efficiency.

Kundu et al. (2022: 12-13), in their comprehensive review, called for integrated and intelligent logistics architectures, and proposed a ‘self-organized response system’ model that links transportation and supply chain elements under a unified emergency logistics framework.

These perspectives offer valuable insights for future development of adaptive, resilient, and scalable disaster logistics systems.

This study aims to contribute to the ongoing research on earthquake impact assessment by combining damage estimation with a logistical needs analysis tailored to Istanbul’s demographic and structural characteristics. Rather than focusing solely on hazard mapping or structural vulnerability, the model links estimated building damage and population exposure to quantifiable post-disaster logistics requirements. In doing so, it offers a framework that can support more grounded decision-making in disaster preparedness and response planning, especially in highly urbanized and infrastructure-dependent regions like Istanbul.

2. DATA AND METHODOLOGY

In this study, the potential effects of the expected Marmara Earthquake scenario on Istanbul, a region with dense industry and population, were analyzed using data from the 1999 Gölcük Earthquake and the 2023 Kahramanmaraş Earthquake. The study aimed to estimate post-earthquake damage and losses, assess logistics needs, and calculate the resources required to effectively meet these needs.

For the 1999 Gölcük Earthquake, the report provided by the Kandilli Observatory and Earthquake Research Institute (2022) and the data on damaged houses from Özmen's study (2000) were used. For the 2023 Kahramanmaraş Earthquakes, the data from the Kahramanmaraş and Hatay Earthquakes report (2023) by the Strategy and Budget Presidency of the Republic of Turkey were utilized for modeling.

Table 1. Number of Deaths and Injuries in Gölcük and Kahramanmaraş Earthquakes

Earthquakes	Gölcük	Kahramanmaraş
M_W	7.4	7.6 - 7.7
Number of Dead	18.373	53.537
Number of Injured	48.901	107.204
Heavily Damaged / Destroyed Buildings	66.441	232.632
Moderate damage Buildings	67.242	40.228
Slightly Damaged / No Damage Buildings	80.160	431.421

This table offers empirical mortality and injury data from two of Turkey's most devastating earthquakes, serving as a critical foundation for predictive modeling. The contrast between the 1999 and 2023 events highlights both commonalities and deviations in urban vulnerability patterns. These figures not only validate the magnitude of risk for major population centers like Istanbul but also support the calibration of damage-to-casualty ratios, which are central to realistic future simulations.

The coefficients (Q_1–Q_5) used in the estimation of the expected Marmara Earthquake results were calculated based on proportional relationships derived from the official statistics of the 1999 Gölcük and 2023 Kahramanmaraş earthquakes.

Specifically, the ratios of damaged building categories to the total number of buildings (Q_1 for severely damaged, Q_2 for moderately damaged, and Q_3 for lightly damaged) and casualty rates per severely damaged building (Q_4 for deaths, Q_5 for injuries) were computed separately for each earthquake.

The final coefficients used in the Istanbul modeling were then calculated by averaging the corresponding ratios from both earthquakes to minimize bias from regional variability and to establish a more generalized predictive model. This method aligns with comparative scenario modeling approaches commonly used in disaster impact assessments (Sabah and Bayraktar, 2020: 1699).

As shown in the table above, the following variables were identified: the number of severely damaged/collapsed houses in Gölcük (A), the number of moderately damaged houses (B), the number of slightly damaged/undamaged houses (C), and the total number of houses in the earthquake impact area (D). Similarly, the number of severely damaged/collapsed houses in Kahramanmaraş (E), the number of moderately damaged houses (F), the number of slightly damaged/undamaged houses (G), and the total number of houses in the earthquake impact area (H) were identified. The coefficients derived from these numbers were determined as follows:

X_1: A/D $\quad$ X_2: B/D $\quad$ X_3: C/D

X_4: E/H $\quad$ X_5: F/H $\quad$ X_6: G/H

Similarly, the coefficients used to estimate the number of deaths and injuries were calculated based on the data in Table 1. The number of deaths (I) and injuries (J) in the Gölcük Earthquake were designated, as well as the number of deaths (K) and injuries (L) in the Kahramanmaraş Earthquakes. The coefficients determined from these numbers are as follows:

Y_1: I/A $\quad$ Y_2: J/A $\quad$ Y_3: K/E $\quad$ Y_4: L/E

The number of damaged houses and the number of deaths and injuries in the 1999 Gölcük Earthquake and the 2023 Kahramanmaraş Earthquake were proportionally compared, and the averages of these ratios were calculated. The rates of severely damaged/collapsed, moderately damaged, and lightly damaged houses were determined for both earthquakes, and the potential effects of the expected earthquake in the Marmara region on Istanbul were estimated using these rates. Although the modeling in this study is based on empirical data from the 1999 Gölcük and 2023 Kahramanmaraş earthquakes, it is important to acknowledge that the structural, geological, and urban characteristics of Istanbul differ from those regions. These differences—such as fault dynamics, ground type, and building stock composition—are not limitations but rather contextual boundaries that define the scope of this study. By establishing an average-based coefficient system from two significant seismic events, this model provides a scalable and transferable framework for urban disaster preparedness.

The data-driven approach enables preliminary estimation of damage and logistics needs, especially in areas where Istanbul-specific micro-level data may not yet be accessible. Future studies can benefit from this foundation by integrating more localized parameters, such as detailed soil amplification maps, real-time urban growth models, and updated structural inventories. In this sense, the methodology presented here is not an endpoint, but a modular framework adaptable to more granular datasets as they become available.

Based on these rates, the following coefficients were defined: the coefficient of severely damaged/collapsed houses (Q_1), the coefficient of moderately damaged houses (Q_2), the coefficient of slightly damaged/undamaged houses (Q_3), the coefficient of the number of deaths (Q_4), and the coefficient of the number of injuries (Q_5).

$$Q_1: (X_1 + X_4)/2 \qquad Q_2: (X_2 + X_5)/2 \qquad Q_3: (X_3 + X_6)/2$$

$$Q_4: (Y_1 + Y_3)/2 \qquad Q_5: (Y_2 + Y_4)/2$$

As a result of these operations, the coefficients used in the modeling are as follows:

Table 2. Calculated Coefficients

Symbol	Coefficients
$\boldsymbol{Q_1}$	0,321
$\boldsymbol{Q_2}$	0,186
$\boldsymbol{Q_3}$	0,494
$\boldsymbol{Q_4}$	0,253
$\boldsymbol{Q_5}$	0,598

The coefficient set derived from the 1999 and 2023 earthquakes provides a scalable, quantitative foundation for disaster simulation in high-risk urban areas. Notably, the ratios of 0.253 deaths and 0.598 injuries per severely damaged building serve as predictive tools for future planning. These metrics allow authorities to transition from reactive crisis management to evidence-based pre-disaster logistics planning, ensuring that resources are proportionally allocated to projected outcomes.

An earthquake of a magnitude capable of significantly affecting Istanbul and the Marmara Region is expected along the North Anatolian Fault Line, one of the world's most active fault lines (Görür, 2020: 25). Based on this expectation, for the estimations in the Istanbul earthquake scenario, the proximity of the Istanbul districts to the North Anatolian Fault Line was measured in kilometers, with Avcılar, the closest district, selected as the epicenter. The M_w magnitude was determined to be 7.5.

3. FINDINGS

To determine the intensity that the districts of Istanbul will experience in the expected Marmara Earthquake scenario, an assessment was made using the Richter scale (Richter, 1958: 353). The Richter scale quantifies earthquake magnitude, while the Modified Mercalli Intensity (MMI) scale (Spence et al., 1989: 59) qualitatively describes their effects.

The distances of the districts of Istanbul from the epicenter and the corresponding MMI intensities for these distances were determined, and the effects of these intensities on the districts were analyzed. The expected damage rates and losses in the districts, based on their intensity levels, were evaluated by comparing them with data from the 1999 Gölcük and 2023 Kahramanmaraş earthquakes. Intensity levels (e.g., IX-X, VIII-IX, VII-VIII) were assigned to each district, and these levels were used to estimate the potential building damage and losses in the districts following the earthquake. This approach enabled the application of the

Q_1, Q_2, Q_3, Q_4, and Q_5 coefficients according to the expected intensity level of each district, allowing for the estimation of post-earthquake logistics needs. These calculations, made using the Richter scale and the MMI scale, contributed to modeling earthquake scenarios realistically and in accordance with local conditions.

Table 3. Richter Magnitude and Earthquake Effects

Intensity	Information
I - II	Not felt by people
II - III	Felt little by people
III - IV	Ceiling lights swing
IV - V	Walls crack
V - VI	Furniture moves
VI - VII	Some buildings collapse
VII - VIII	Many buildings destroyed
VIII - Up	Total destruction of buildings, roads and bridges

Categorizing structural damage levels is essential for linking physical damage to functional disruption. For instance, buildings labeled as “heavily damaged” are not only structurally unsafe but also uninhabitable, necessitating immediate shelter solutions. This classification directly informs supply chain modeling, such as determining how many tents, hygiene kits, and relocation transport units are needed within each damage band. It also supports insurance estimation, post-disaster zoning, and debris management prioritization.

Table 4 below presents the expected intensity levels that the districts of Istanbul will experience in the anticipated Marmara Earthquake scenario, based on their distance from the earthquake epicenter. These intensity levels were determined by evaluating both the Richter Magnitude Scale and the Mercalli Modified Intensity (MMI) Scale together.

Table 4. Severity Scales of Districts Based on Distance from the Epicenter

Districts	Intensity	Districts	Intensity
Avcılar	IX - X	Kağıthane	V - VI
Büyükçekmece	VIII - IX	Eyüp	V
Beylikdüzü	VIII - IX	Bayrampaşa	V
Silivri	VIII - IX	Gaziosmanpaşa	V
Esenyurt	VII - VIII	Bağcılar	V
Küçükçekmece	VII - VIII	Güngören	V
Bakırköy	VII	Bahçelievler	V
Zeytinburnu	VII	Sultangazi	V
Fatih	VII	Arnavutköy	IV - V
Beyoğlu	VII	Başakşehir	IV - V
Eminönü	VII	Esenler	IV - V
Üsküdar	VII	Çatalca	IV - V
Kadıköy	VII	Şile	IV
Kartal	VI - VII	Sancaktepe	IV
Maltepe	VI - VII	Çekmeköy	IV
Pendik	VI - VII	Ataşehir	IV
Tuzla	VI	Ümraniye	IV
Sarıyer	VI	Sultanbeyli	IV
Şişli	V - VI	Beykoz	IV
Beşiktaş	V - VI		

The Richter Scale is a logarithmic scale used to measure earthquake magnitude and quantify seismic energy, whereas the Mercalli Modified Intensity (MMI) Scale qualitatively assesses an earthquake's impact on people, structures, and the environment. By utilizing both scales together, the local effects of the expected earthquake on Istanbul's districts were evaluated.

This spatial intensity analysis reveals a west-east vulnerability gradient. Districts on the western coast such as Avcılar, Büyükçekmece, and Beylikdüzü are projected to face seismic intensities of IX–X, corresponding to nearly total structural collapse and ground deformation. These findings necessitate the urgent development of emergency evacuation routes, reinforced communication hubs, and on-site rescue equipment staging zones in these areas. Moreover, eastern districts, though experiencing lower intensities, should be designated as logistical fallback points for resource storage and mobilization.

The intensity levels presented in the table were calculated based on the distance of each district from the modeled earthquake epicenter. Districts closer to the epicenter (e.g., Avcılar, Büyükçekmece, and Beylikdüzü) are expected to experience very high intensity levels (IX–X), while more distant districts (e.g., Şile, Beykoz, and Çekmeköy) are anticipated to experience lower intensity levels (IV–V).

While this study primarily utilizes the distance from the epicenter to estimate intensity levels in Istanbul districts, it is important to acknowledge that seismic impact is also significantly influenced by additional factors such as soil liquefaction potential, local geological conditions, and structural typologies.

Due to data availability constraints, such variables were not directly integrated into the model. However, it is recognized that areas with soft soil composition (e.g., alluvial basins) or high liquefaction potential could experience disproportionately higher damage compared to areas with stable rock formations, even at equal distances from the epicenter.

Similarly, variations in building typologies—such as height, material quality, and adherence to seismic codes—also play a crucial role in actual damage levels. Future modeling efforts could be enhanced by incorporating microzonation maps, ground shaking amplification factors, and detailed structural inventories using GIS-based multi-criteria analysis.

Thus, while the current model provides a generalized and scalable framework, its outputs should be interpreted in light of these unmodeled local risk amplifiers. Additionally, data from the 1999 Gölcük and 2023 Kahramanmaraş Earthquakes were incorporated to enhance the predictive accuracy of the intensity calculations. This approach provides a critical foundation for estimating the potential damage rates in Istanbul's districts following the earthquake.

Damage estimates for buildings in Istanbul were made based on their construction years (İstanbul Metropolitan Municipality, 2017) and incorporated into the modeling. Buildings were classified into three main categories according to their construction periods: pre-1980, 1980–2000, and post-2000. These categories were established by considering the construction standards and building quality of different periods.

Buildings constructed before 1980 generally used older construction technologies and materials. Due to insufficient seismic regulations at the time, these buildings have low earthquake resistance, making them more prone to severe damage and collapse. Buildings constructed between 1980 and 2000 utilized improved construction techniques and materials compared to pre-1980 structures. However, as seismic regulations were still evolving, their earthquake resistance remains inadequate. In contrast, buildings constructed after 2000 were built in accordance with more advanced seismic regulations and higher construction standards, providing greater earthquake resistance and reducing the likelihood of severe damage.

Table 5. Population of Istanbul Districts

Districts	Population	Districts	Population
Adalar	16.325	Gaziosmanpaşa	483.830
Arnavutköy	336.062	Güngören	269.944
Ataşehir	416.529	Kadıköy	467.919
Avcılar	437.221	Kağıthane	445.672
Bağcılar	719.071	Kartal	475.042
Bahçelievler	567.848	Küçükçekmece	792.030
Bakırköy	220.476	Maltepe	523.137
Başakşehir	509.915	Pendik	743.774
Bayrampaşa	268.850	Sancaktepe	492.804
Beşiktaş	169.022	Sarıyer	344.250
Beykoz	245.647	Silivri	221.723
Beylikdüzü	409.347	Sultanbeyli	360.702
Beyoğlu	218.589	Sultangazi	532.802
Büyükçekmece	276.572	Şile	48.537
Çatalca	80.007	Şişli	264.736
Çekmeköy	299.806	Tuzla	293.604
Esenler	427.901	Ümraniye	723.760
Esenyurt	978.007	Üsküdar	517.348
Eyüpsultan	420.194	Zeytinburnu	280.896
Fatih	356.025		

The projected breakdown of building damage—ranging from light to complete collapse—underscores the scale of humanitarian displacement that will occur. The expected 101,081 heavily damaged buildings imply that hundreds of thousands will be left without shelter, triggering long-term housing crises in addition to short-term logistics challenges. This data must feed into real-estate risk assessments, modular shelter procurement plans, and strategic relocation policies post-disaster.

For pre-1980 buildings, very high intensity (X, IX) is expected to cause extensive destruction of all structures and significant loss of life. High intensity (VIII) is likely to result in substantial building collapses, severe injuries, and high mortality rates. Moderate intensity (VII) is expected to cause widespread structural damage and moderate injuries. Low intensity (VI and below) is anticipated to lead to minor structural damage and limited injuries.

For buildings constructed between 1980 and 2000, very high-intensity earthquakes (X, IX) are expected to cause significant structural collapse and substantial casualties. High-intensity earthquakes (VIII, VII) are likely to result in moderate structural damage and a high number of injuries. Low-intensity earthquakes (VI and below) are anticipated to cause minor structural damage and minimal injuries.

In buildings constructed after 2000, a very high-intensity earthquake (X) is expected to cause the collapse of a small number of structures, resulting in moderate casualties. In high-intensity earthquakes (IX, VIII, VII), minor structural damage and low injury rates are anticipated. In low-intensity earthquakes (VI and below), minimal structural damage and very few injuries are expected. By modeling a magnitude 7.5 earthquake centered in the Marmara region, using coefficients derived from previous earthquake data and the specified constraints, the following conclusions were reached for Istanbul.

Table 6. Modeling Results for Istanbul Districts in the Possible Marmara Earthquake

Districts	Death Toll	Seriously Wounded	Slightly Wounded	Heavily Damaged / Demolished Buildings	Moderate Damage Buildings	Llight Damage Buildings
Avcılar	9.788	23.080	5.328	8.321	4.823	12.789
Büyükçekmece	8.501	23.080	4.629	8.222	4.768	12649
Beylikdüzü	8.499	23.075	4.628	8.221	4.768	12.649
Silivri	8.499	23.075	4.628	8.221	4.768	12.649
Esenyurt	14.000	37.973	7.615	13.528	7.847	20.817
Küçükçekmece	14.000	37.973	7.615	13.528	7.847	20.817
Bakırköy	4.382	11.878	2.382	4.235	2.457	6520
Zeytinburnu	4.382	11.878	2.382	4.235	2.457	6520
Fatih	8.764	23.756	4.764	8.470	4.914	13.040
Beyoğlu	4.382	11.878	2.382	4.235	2.457	6520
Üsküdar	4.382	11.878	2.382	4.235	2.457	6520
Kadıköy	4.382	11.878	2.382	4.235	2.457	6520
Kartal	2.521	6.832	1.370	2.435	1.412	3750
Maltepe	2.521	6.832	1.370	2.435	1.412	3750
Pendik	2.521	6.832	1.370	2.435	1.412	3750
Tuzla	1.229	3.331	668	1.187	689	1.829
Sarıyer	1.229	3.331	668	1.187	689	1.829
Şişli	426	1.153	231	411	239	635
Beşiktaş	426	1.153	231	411	239	635
Kağıthane	426	1.153	231	411	239	635

Eyüp	57	154	31	55	32	85
Bayrampaşa	57	154	31	55	32	85
Gaziosmanpaşa	57	154	31	55	32	85
Bağcılar	57	154	31	55	32	85
Güngören	57	154	31	55	32	85
Bahçelievler	57	154	31	55	32	85
Sultangazi	57	154	31	55	32	85
Arnavutköy	23	61	12	21	12	32
Başakşehir	23	61	12	21	12	32
Esenler	23	61	12	21	12	32
Çatalca	23	61	12	21	12	32
Şile	2	2	1	2	1	3
Sancaktepe	2	2	1	2	1	3
Çekmeköy	2	2	1	2	1	3
Ataşehir	2	2	1	2	1	3
Ümraniye	2	2	1	2	1	3
Sultanbeyli	2	2	1	2	1	3
Beykoz	2	2	1	2	1	3
İstanbul (Toplam)	105.765	283.355	57.528	101.081	58.630	155.567

The model's projections uncover a staggering reality: over 105,000 lives could be lost and nearly 300,000 people severely injured in a single seismic event. Districts such as Esenyurt, Avcılar, and Küçükçekmece—marked by high population density and pre-2000 buildings—represent critical vulnerability zones, accounting for nearly 30% of total expected fatalities. These results underscore the urgent necessity for structural audits, seismic retrofitting, and the creation of rapid deployment logistics corridors in these districts. Without such measures, Istanbul's emergency response could be overwhelmed within hours of the disaster.

The estimated number of deaths and injuries in each district was determined based on the population density in buildings expected to sustain damage. The total district population was analyzed in relation to household size and building occupancy rates to estimate the number of residents in affected structures. Mortality and injury figures were then calculated by correlating these population estimates with the proportions of severely, moderately, and lightly damaged buildings. The results are presented in Table 6.

This method considered local factors such as building structures, population density, and proximity to the epicenter, offering a more realistic estimate of potential losses in the expected Marmara Earthquake scenario in Istanbul. The modeling process was designed to ensure that the results were both consistent and grounded in scientific principles. In this context, estimates for the number of deaths, severe injuries, minor injuries, and damaged buildings were calculated for each district.

In obtaining the table, an example from the Avcılar district at the top can be used. First, the coefficients specified in Table 2 were multiplied by the total number of buildings in the district to estimate the building damage for the simulated earthquake in the district. The death and injury rates were estimated based on the population living in severely damaged/collapsed buildings. The minor injury rate was taken as 0.1, separate from the Q4 and Q5 coefficients. In calculating the number of deaths, the formula used was: (number of severely damaged buildings * population per building) * Q4. Additionally, the number of moderately damaged buildings was incorporated into the calculation for severe injuries, while the number of slightly damaged buildings was included in the minor injury formulation. The population per building was calculated by dividing the total population of the district by the total number of buildings. The final death toll was determined by multiplying the estimated number of severely damaged or collapsed buildings by Q4. The same formula was applied to each district, using the same calculations and coefficients. The results obtained for Istanbul are presented in Table 6.

In terms of disaster logistics, determining the resources required after an earthquake is not only possible but also critical once the number of people and buildings affected by the earthquake is established. In this study, the quantities of tents, first aid supplies, food, clothing materials, and necessary construction equipment needed after an earthquake were calculated. For instance, the number of trucks required for transporting 4-person tents, the number of trucks needed for first aid supplies, the number of trucks required for meeting daily food needs, and the distribution of clothing materials were determined.

The capacity of an average truck is calculated as 15 tons and 40 cubic meters. The capacity of an average 4-person tent is 7.5 kg and 0.04 cubic meters; the average first aid kit for one person is 1.5 kg and 0.006 cubic meters; the average daily food kit weighs 2 kg and occupies 0.015 cubic meters; the average clothing kit for one person weighs 2 kg and occupies 0.03 cubic meters.

Table 7. Number of Trucks & Ambulances Required in the First Response Phase after an Earthquake

Material Type	Number of Trucks & Ambulances Required
4 Person Tent	265
First Aid Supplies	69
10 Days of Food Supplies	977
Basic Clothing Supplies	1.081
Ambulance for Seriously Wounded People	141.678
Total	144.070

The size of Istanbul's logistics needs following the expected Marmara Earthquake, as indicated by the data in Table 7, clearly demonstrates the level of organization required to address the devastating effects of the disaster. To meet the basic needs of thousands of people affected by the earthquake, a logistics plan involving 2,392 trucks is required in the first phase of intervention alone. This number highlights the urgency and effectiveness with which materials must be delivered to increase the chances of survival for those in the region.

The types of materials provided are essential for ensuring survival after an earthquake. For instance, 265 trucks are needed to transport 4-person tents for those affected. These tents are not only crucial for shelter but also vital for the safety and privacy of disaster victims. Similarly, the requirement of 69 trucks to transport first aid supplies for treating the injured underscores that these logistics operations are directly aimed at saving lives. Additionally, 977 trucks are necessary to transport 10 days' worth of food supplies to meet the nutritional needs of people in the disaster area. Food supplies are critical for maintaining the energy and health of disaster victims. Furthermore, the need for 1,081 trucks to distribute basic clothing items highlights the importance of protecting disaster victims, especially under harsh weather conditions.

Furthermore, the projected figure of 283,355 severely injured individuals introduces a critical strain on emergency medical logistics. Assuming that each ambulance can serve two severely injured patients, the first response phase would require approximately 141,678 ambulances to effectively triage and transport patients. This demand far exceeds current operational capacity, underscoring the urgent need for pre-positioned ambulance fleets, temporary field hospitals, and intercity medical support agreements to be integrated into national disaster response frameworks.

The estimated need for 2,392 trucks in the immediate response phase lays bare the operational scale of the challenge. Each of these vehicles represents the difference between survival and prolonged suffering for thousands. The delivery of 10-day food supplies alone demands nearly 1,000 trucks, while the distribution of tents and first-aid kits must begin within the first 24 hours to prevent a secondary humanitarian crisis. Any disruption—be it due to damaged roads, fuel shortages, or coordination failure—may leave tens of thousands exposed to hunger, injury, and exposure. These figures call for pre-disaster logistics simulations, stockpiling near high-risk zones, and a real-time dispatch command center to manage flow under duress.

Together, the truck and ambulance requirements highlight that disaster logistics is not merely about supply volume—it is about timing, prioritization, and seamless coordination across sectors. Without an integrated logistics framework, even the most resource-rich responses may falter under the pressure of scale, fragmentation, and infrastructure failure.

In addition, approximately 18.000 pieces of construction vehicles were deployed to 272,860 damaged buildings during the Kahramanmaraş earthquakes. Public observations indicated that the amount of construction equipment was insufficient considering the number of damaged buildings. Based on these observations, it is estimated that at least 21,051 pieces of construction vehicles will be needed in Istanbul for the expected Marmara earthquake. This estimate is derived by calculating that the ratio of damaged buildings to construction equipment during the Kahramanmaraş earthquakes should be at least doubled.

CONCLUSION AND POLICY RECOMMENDATIONS

Earthquakes are devastating natural disasters that result in both loss of life and extensive property damage. The collapse of buildings, damage to infrastructure, and disruption of basic services severely impact living conditions in the affected areas. Earthquakes, particularly in densely populated regions, lead to high casualty rates and numerous injuries. For a rapid and effective relief process after an earthquake, it is crucial that the necessary resources are delivered to the disaster area accurately and promptly. In this context, disaster logistics plays a pivotal role in the efficient management and distribution of essential supplies.

Turkey is a country that is frequently exposed to earthquakes due to its location along active fault lines. The North Anatolian Fault Line (NAF), one of the most dangerous fault lines in the country, poses a significant threat, particularly to Istanbul and its surrounding areas (Görür, 2020: 25). This fault line has been responsible for numerous major earthquakes throughout history, resulting in substantial loss of life and property. Therefore, earthquake awareness and preparedness are of critical importance. In a densely populated and economically vital city like Istanbul, a potential major earthquake disaster could have severe consequences.

In this study, the potential damage and losses caused by the anticipated Marmara Earthquake scenario in Istanbul were estimated using data from the 1999 Gölcük Earthquake and the 2023 Kahramanmaraş Earthquake. The impact of earthquake intensities on buildings constructed during different periods in Istanbul, as well as the subsequent logistic requirements resulting from these effects, were examined in detail.

The modeling conducted based on the coefficients derived from the data and the defined constraints indicates that significant damage and losses will occur following an anticipated earthquake in Istanbul. As a result of this modeling, the data presented in Table 6 were obtained. According to these results, the earthquake scenario with a magnitude of 7.5 and an epicenter in Avcılar, Istanbul predicts the following: 105.765 fatalities, 283.355 individuals with serious injuries, 57.528 individuals with minor injuries; the collapse and/or severe damage of 101.081 buildings, moderate damage to 58.630 buildings, and minor damage to 155.567 buildings.

These results, when compared with data from the 1999 Gölcük and 2023 Kahramanmaraş earthquakes, suggest that the levels of life and property loss in Istanbul could be similar to or exceed those observed in these previous events. Istanbul must improve structural resilience and enforce seismic standards to mitigate expected earthquake risks.

In addition, the number of people who may be left without shelter and in need of basic necessities was calculated based on the number of fatalities, injuries, and damaged buildings. The number of trucks required to provide aid during the first intervention phase after the earthquake was estimated. Accordingly, 265 trucks for tents, 69 trucks for first aid supplies, 977 trucks for food supplies, and 1.081 trucks for basic clothing supplies were projected. Furthermore, it was concluded that at least 21.051 pieces of construction vehicles would be needed in the initial phase to remove debris and rescue the severely injured.

The findings highlight the scale of post-earthquake logistics requirements and reinforce the need for rapid, well-coordinated emergency response strategies. Unlike the Kahramanmaraş earthquakes, which affected a broad geographic area, a potential earthquake in Istanbul suggests that transportation and communication challenges could lead to significant chaos due to the region's narrow geography, high population density, and complex infrastructure.

A central coordination center should be established, with all logistics processes managed from this center to effectively carry out post-earthquake logistics operations. Given the estimated need for

2,392 trucks and 21,051 units of construction equipment, this center should be equipped with a centralized digital inventory system and real-time vehicle tracking infrastructure. Pre-contracts with national logistics providers and heavy equipment suppliers must be signed in advance. These agreements should be legally framed and budgeted within one year by the Disaster and Emergency Management Authority (AFAD) and Istanbul Metropolitan Municipality.

Cooperation with local governments, civil society organizations, and the private sector should be fostered to expedite logistics efforts. For instance, the study estimates over 100,000 severely damaged buildings, requiring immediate removal. Partnerships with private demolition firms should be formalized regionally, with contractual clauses detailing availability within 24–48 hours after the disaster. These firms should participate in annual disaster simulations as part of a certification process.

In the disaster of transportation infrastructure collapse, alternative routes and even temporary bridges should be planned. Districts like Avcılar, Beylikdüzü, and Küçükçekmece — which are closest to the projected epicenter and face the highest destruction risk — must have pre-approved logistics corridors. A specific timeline (within two years) should be set for the retrofitting or structural strengthening of at least five major arterial roads connecting these districts to logistics hubs such as Hadımköy and Tuzla.

Early warning systems should be implemented in coastal areas to address tsunami risks, and logistics planning in these regions should account for this threat. Üsküdar and Kadıköy, with high coastal density and population, should be prioritized in the first wave of tsunami-focused early warning system installations. These systems should be linked directly to the logistics coordination center for immediate decision-making. Budget allocations can be planned in annual municipal investment programs.

Earthquake preparedness education and training on how to respond during an earthquake should be prioritized across Turkey, and particularly in Istanbul. The study's fatality projections highlight the importance of household-level resilience. Therefore, an annual city-wide earthquake preparedness drill should be made mandatory in districts with more than 500,000 residents (e.g., Esenyurt, Küçükçekmece). This can be coordinated through schools, community centers, and workplaces with standardized training materials supported by local government funding.

As a result, this study provides crucial data on the estimation of potential damage and losses for the expected Marmara Earthquake scenario in Istanbul, as well as the identification of post-earthquake logistics needs. With this data, the aim is to contribute to more effective and realistic post-earthquake intervention and logistics planning. The rapid and efficient execution of post-earthquake logistics operations is essential to minimize loss of life and injuries. Therefore, disaster logistics planning and management should be an integral part of the earthquake preparedness process. In particular, decision-makers responsible for public welfare must be acutely aware of the risks facing Istanbul and the Marmara Region, and should take preventive measures based on the modeling results derived from the available data.

STATEMENT OF RESEARCH AND PUBLICATION ETHICS

The method used in the study does not require ethics committee approval.

DECLARATION OF SUPPORT

This study was not supported by any person or organization.

CONFLICT OF INTEREST STATEMENT

There is no conflict of interest between the authors.

REFERENCES

Boruhan G., and Ersoy P., 2013. The Importance of disaster logistics in terms of logistic processes. *Finance, Politics and Economic Reviews,* 50(578), 75–86.

Ciftci, S., Cakirer, Z., and Sakalli, U. (2020). Creating earthquake scenario with simulation study and analysis of loss prediction in Kırıkkale province. *International Journal of Engineering Research and Development*, 12(2), 603-617.

Dindarik, N., & Atabey, A. (2024). Future of Earthquake-Based Disaster Logistics and Futuristic Approaches. *Journal of Social Sciences And Education*, 7(2), 257-278. https://doi.org/10.53047/josse.1536068

Golafshani, A. A., Bakhshi, A., and Tabeshpour, M. R. (2005). Vulnerability and damage analysis of existing buildings.

Görür, N. (2020). *Türkiye'de deprem*. 1. Baskı. İstanbul: Doğan Egmont Yayıncılık ve Yapımcılık, 87-95.

Isik, E., Sagir, C., Tozlu, Z., and Ustaoglu, U. S. (2019). Loss estimation for Kırşehir province according to different earthquake scenarios. *Journal of Natural Hazards and Environment*, 5 (2), 80-93. https://doi.org/10.21324/dacd.432592

Istanbul Metropolitan Municipality (2017), Mahalle bazlı bina sayıları. Access Address: https://data.ibb.gov.tr/tr/dataset/mahalle-bazli-bina-analiz-verisi

Jenelius, E., and Mattsson, L. G. (2015). Road network vulnerability analysis of area-covering disruptions: A grid-based approach with case study. *Transportmetrica A: Transport Science*, 11(9), 746–760. https://doi.org/10.1016/j.tra.2012.02.003

Kandilli Observatory and Earthquake Research Institute (2022), Kocaeli earthquake. Access Address: https://web.archive.org/web/20220120015250/, http://www.koeri.boun.edu.tr/depremmuh/eqspecials/kocaeli/earthquake1.htm

Karaagac, D., Karaman, H., and Aktug, B. (2019). Investigation of disasters in Kahramanmaras and Adiyaman provinces and determination of suitable settlement locations with spatial analysis techniques. *Turkish Journal of Earthquake Research*, 1(2), 123-133.

Kulekci, G., and Vural, A. (2023). Strengthening of highway tunnels following earthquakes in Kahramanmaras province: An examination of underground voids and earthquake effects. *AS-Proceedings*, 1(1), 79-82.

Kundu, T., Sheu, J. B., & Kuo, H. T. (2022). Emergency logistics management—Review and propositions for future research. *Transportation research part E: logistics and transportation review*, 164, 102789. https://doi.org/10.1016/j.tre.2022.102789

Özmen, B. (2000). İzmit körfezi depremi'nin hasar durumu (rakamsal verilerle). Türkiye Deprem Vakfı: İstanbul.

Ozturk, S. (2014). A study on earthquake statistics and the forecasting for the ıntermediate-term locations of possible strong earthquakes for the Western Anatolian region of Turkey. *Gumushane University Journal of Science and Technology Institute*, 4(1), 75-93. https://doi.org/10.17714/gufbed.2014.04.006

Parsons, T., Toda, S., Stein, R.S., Barka, A.A., and Dieterich, J.H. (2000). Heightened odds of large earthquakes near Istanbul: An interaction-based probability calculation. *Science*, 288(5466), 661-664. https://doi.org/10.1126/science.288.5466.661

Richter, C. F. (1958). Elementary Seismology, 338-375.

Sabah, L., and Bayraktar, H. (2020). Comparative analysis of Düzce central and districts according to earthquake scenarios. *Düzce University Journal of Science & Technology*, 8(2), 1695-1705. https://doi.org/10.29130/dubited.574013

Spence, W., Sipkin, S. A., and Choy, G. L. (1989). Measuring the size of an earthquake. *Earthquake Information Bulletin (USGS)*, 21(1), 58-63.

Stein, R. S., Barka, A. A., and Dieterich, J. H. (1997). Progressive failure on the North Anatolian fault since 1939 by earthquake stress triggering. *Geophysical Journal International*, 128(3), 594-604. https://doi.org/10.1111/j.1365-246X.1997.tb05321.x

Tanti, L., Efendi, S., Lydia, M. S., & Mawengkang, H. (2023). A decision-making model to determine dynamic facility locations for a disaster logistic planning problem using deep learning. *Algorithms*, 16(10), 468. https://doi.org/10.3390/a16100468

Tanyaş, M., Günalay, Y., Aksoy, L., and Küçük, B. (2013). Afet lojistik yönetiminde Rize iline yönelik yeni model önerisi. II. Rize Kalkınma Sempozyumu Bildiriler Kitabı, 256-268, Rize, Access Adress: https://www.researchgate.net/profile/Aziz-Karakaya/publication/271965855_RIZE_ILINDE_KIVI_BITKILERINDE_GORULEN_HASTALIKLAR/links/5b5db013aca272a2d6735ed0/RIZE-ILINDE-KIVI-BITKILERINDE-GOeRUeLEN-HASTALIKLAR.pdf#page=254.

Temur, G. T., Turgut, Y., Yilmaz, A., Arslan, S., and Camci, A. (2019). Logistic network design for post-earthquake planning: A case study for Ümraniye district under different earthquake scenarios. *Pamukkale University Journal of Engineering Sciences,* 25(1), 98-105. https://doi.org/10.5505/pajes.2018.11736

Türkiye Cumhuriyeti Cumhurbaşkanlığı (2023). Kahramanmaraş ve Hatay depremleri raporu. Strateji ve Bütçe Başkanlığı: Ankara. Access Adress: https://www.sbb.gov.tr/wp-content/uploads/2023/03/2023-Kahramanmaras-ve-Hatay-Depremleri-Raporu.pdf

Türkiye İstatistik Kurumu (TÜİK) (2022), Adrese Dayalı Nüfus Kayıt Sistemi Sonuçları. Access Adress: https://data.tuik.gov.tr/Bulten/Index?p=49685

Yalcin, C., and Sabah, L. (2017). Analysis of the earthquake hazard of Edirne ındustry enterprises by using open source geographic ınformation systems (GIS) and analytic hierarchy process (AHP) method. *Düzce University Journal of Science & Technology*, 5(2), 524-537.

Zulfikar, O., Zulfikar, C., and Alcik, H. (2012). Earthquake intensity, damage and casualty estimation by ELER. 1. Yerbilimleri Sempozyumu Süleyman Demirel Üniversitesi, Isparta, Türkiye, Access Adress: https://www.researchgate.net/publication/329840333_ELER_Yazilimi_ile_Deprem_Siddeti_Hasar_ve_Kayip_Tahmini-Earthquake_Intensity_Damage_and_Casualty_Estimation_by_ELER.