VULNERABILITY ASSESSMENT WITHIN THE CONTEXT OF RESILIENCE TO EARTHQUAKE HAZARDS: A CASE STUDY OF BAYRAKLI, İZMİR

A Thesis Submitted to
the Graduate School of Engineering and Sciences of
İzmir Institute of Technology
in Partial Fulfillment of the Requirements for the Degree of

MASTER OF SCIENCES

in Urban Planning

by

Helin AYDIN

September 2024

İZMİR

We approve the thesis of **Helin AYDIN**

Examining Committee Members:

Assoc. Prof. Dr. Deniz GERÇEK KURT
Department of City and Regional Planning, İzmir Institute of Technology

Prof. Dr. Mediha Burcu SILAYDIN
Department of City and Regional Planning, Dokuz Eylül University

Assoc. Prof. Dr. Esin ÖZDEMİR ULUTAŞ
Department of City and Regional Planning, İzmir Institute of Technology

24 September 2024

Assoc. Prof. Dr. Deniz GERÇEK KURT
Supervisor, Department of City and Regional Planning, İzmir Institute of Technology

Prof. Dr. Hasan Engin DURAN
Head of Department of City and Regional Planning

Prof. Dr. Mehtap EANES
Dean of the Graduate School of Engineering and Science

To my beloved grandparents and family, for their endless support and love.

ACKNOWLEDGMENTS

I have had the pleasure of receiving unwavering support from many people in the process of achieving my academic goals.

I consider myself lucky to have the chance to work with my dear advisor Assoc. Prof. Dr. Deniz GERÇEK. First, I would like to thank her for accepting me as her student and for her support and patience during the months-long study process. Her commitment to dedicating time and effort to discussions about complex concepts, providing valuable resources, and imparting her knowledge has been a key component in my development as a student. I am grateful for her unwavering commitment to my academic success.

I would also like to express my sincere gratitude to dear Prof. Dr. Yusuf BARAN, the rector of İzmir Institute of Technology, who has never wavered in his support from the moment I started studying at İzmir Institute of Technology until today. I would like to thank my dear professors, Assist. Prof. Dr. Sara BELGE and Prof. Dr. Burak BELGE, who made me interested in academia, whom I see as idols in this field, and who supported me throughout my undergraduate education and the following process.

I would also like to express my sincere gratitude to my esteemed professors Assoc. Prof. Dr. Can Zülfikar, Assist. Prof. Dr. Beyza Şen, Assist. Prof. Dr. Maya Arıkanlı, Assoc. Prof. Dr. Nur Sinem Partigöç and Prof. Dr. Selma Koç, from whom I consulted expert opinions on the thesis method and whose support made invaluable contributions to the study. I would also like to thank my dear professors, Prof. Dr. Mediha Burcu Sılaydın and Assoc. Prof. Dr. Esin Özdemir Ulutaş, who participated in the thesis jury, for their valuable opinions and contributions during the defense.

I am grateful to my dear friends who were with me at every moment during this process, supported me and always listened to me patiently.

Finally, even if words are not enough, I would like to thank my big family, who have supported me endlessly since the beginning of my life and accepted me as I am.

I would like to express my endless gratitude to my beloved grandfather İbrahim Aydın and my grandmother Muhne Aydın, who always supported me throughout my education life and were the biggest factor in me starting my academic journey. I would like to thank my dear uncle Kasım Aydın, who supported me in every aspect throughout my education life. I would like to express my deepest gratitude to my beloved mother and father, Nezahat Aydın and Cengiz Aydın, and my beloved brothers, for their warm and comforting presence and unconditional love. I would like to express my very special gratitude to my sister Şeyma Aydın, who knows me better than anyone else, for always being my biggest support and cheering me up when I needed it.

This thesis, the result of dedicated effort, wouldn't have come to fruition without the unwavering support and assistance I've been fortunate to receive. To all of you, I extend my heartfelt thanks. While I may be the one writing these words, the invaluable support I've received from those around me has been essential to my success.

ABSTRACT

VULNERABILITY ASSESSMENT WITHIN THE CONTEXT OF RESILIENCE TO EARTHQUAKE HAZARDS: A CASE STUDY OF BAYRAKLI, İZMİR

Earthquakes, among all natural hazards, have caused the most devastating consequences for Turkey in its history, with the majority of disaster-related casualties resulting from earthquakes. Besides its historical and economic importance, Bayraklı is a district of İzmir with a high disaster risk potential and a high concentration of building stock that is vulnerable to earthquake hazards. This study aims to assess the earthquake vulnerability of the district and was implemented at the neighborhood scale, covering all neighborhoods of Bayraklı (24 neighborhoods). AHP was conducted to evaluate expert opinions to weigh the vulnerability criteria and determine their importance in earthquake hazards. A comprehensive vulnerability assessment was conducted encompassing three dimensions: physical vulnerability, social vulnerability, and capacity of the built environment. Based on expert evaluations, the relative importance of criteria regarding earthquake vulnerability was revealed. Based on the criterion weights vulnerability maps were created for each main dimension using ArcGIS.. This final stage identified the most vulnerable neighborhoods, which include Çay, Çiçek, Alpaslan, Tepekule Bayraklı, and Muhittin Erener, respectively. The findings of this research have the potential to provide valuable insights for urban planning and strategic efforts aimed at reducing Bayraklı's vulnerability to earthquake hazards.

Keywords: *Vulnerability Assessment, Disaster Risk, Earthquake Hazard, Capacity, Resilience, Analytical Hierarchy Process.*

ÖZ

DEPREM TEHLİKELERİNE KARŞI DİRENÇLİLİK KAPSAMINDA KIRILGANLIK DEĞERLENDİRMESİ: BAYRAKLI, İZMİR ÖRNEĞİ

Depremler, tüm doğal afetler arasında, Türkiye tarihinde en yıkıcı sonuçlara yol açmış olup, afet kaynaklı can kayıplarının çoğunluğu depremlerden kaynaklanmaktadır. Bayraklı, tarihi ve ekonomik öneminin yanı sıra, yüksek afet riski potansiyeline sahip ve deprem tehlikelerine karşı savunmasız yapı stokunun yoğun olduğu İzmir'in ilçelerinden biridir. Bu çalışma, ilçenin deprem tehlikelerine karşı kırılganlığı değerlendirmeyi amaçlamaktadır ve Bayraklı'nın tüm mahallelerini (24 mahalle) kapsayacak şekilde mahalle ölçeğinde uygulanmıştır. Çalışmada kırılganlık kriterlerini ölçmek ve deprem tehlikelerindeki önemlerini belirlemek için uzman görüşlerini değerlendirmek üzere Aanalitik Hiyerarşi Süreci yöntemi kullanılmıştır. Üç boyutu kapsayan kapsamlı bir kırılganlık değerlendirmesi yapılmıştır.: fiziksel kırılganlık, sosyal kırılganlık ve yapılı çevrenin kapasitesi. Uzman değerlendirmelerine dayanarak, kriterlerin deprem tehlikelerine karşı kırılganlık açısından göreceli önemi ortaya çıkarılmıştır. Kriter ağırlıklarına dayanarak, ArcGIS kullanılarak her ana boyut için kırılganlık haritaları oluşturulmuştur. Bu son aşamada sırasıyla Çay, Çiçek, Alpaslan, Tepekule Bayraklı ve Muhittin Erener, olmak üzere en kırılgan mahalleler belirlenmiştir. Bu araştırmanın bulguları, Bayraklı'nın deprem tehlikelerine karşı kırılganlığını azaltmayı amaçlayan kentsel planlama ve stratejik çabalar için değerli içgörüler sağlama potansiyeline sahiptir.

Anahtar Kelimeler: *Kırılganlık Değerlendirmesi, Afet Riski, Deprem Tehlikesi, Kapasite, Dayanıklılık, Analitik Hiyerarşi Süreci*.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF CHARTS

Chart **Page**

LIST OF ABBREVIATIONS

AFAD: Afet ve Acil Durum Yönetimi Başkanlığı (Disaster and Emergency Management Presidency)

AHP: Analytical Hierarchy Process

ANP: Analytical Network Process

CI: Consistency Index

CR: Consistency Ratio

DAUM: Dokuz Eylul University Earthquake Research and Application Center (Dokuz Eylül Üniveristesi Deprem Araştırma ve Uygulama Merkezi)

ELECTRE: ELimination Et Choix Traduisant la REalité

GIS: Geographical Information Sytems

GP: Goal Programming

MADM: Multi-Attribute Decision Making

MCDM: Multi-Criteria Decision Making

METU: Middle East Technical University

MMI: Modified Mercalli Index

MODM: Multi-Objective Decision Making

PROMETHEE: The Preference Ranking Organization METHod for Enrichment of Evaluations

RI: Random Index

SES: Social-Ecological Systems

SEVI model: Spatial Multi-Criteria Social Vulnerability Index

SVI: Social Vulnerability Index

TMMOB: Türk Mühendis ve Mimar Odaları Birliği (Union Of Chambers Of Turkish Engineers And Architects)

TOPSIS: The Technique for Order of Preference by Similarity to Ideal Solution

TURKSTAT: Turkish Statistical Institute

UNDRR: The United Nations Office for Disaster Risk Reduction

UNISDR: United Nations Office for Disaster Risk Reduction

VIKOR: VIseKriterijumska Optimizacija I Kompromisno Resenje

CHAPTER 1

INTRODUCTION

Natural disasters have been a crucial issue for many countries and regions due to their devastating effects throughout human history. Every year, thousands of people around the world lose their lives, people they know, and their homes because of disasters. Natural disasters such as earthquakes, floods, and landslides continue to threaten human existence. It is uncertain when natural disasters will occur and to what extent, particularly earthquakes. Earthquakes have a rapid onset and affect settlements in a very short time, multidimensionally and extremely. The Alpine-Himalayan Earthquake Region is one of the most important earthquake regions in the world. And this earthquake zone covers a wide area from Indonesia to the Atlantic Ocean (Onat, 2022). Many devastating earthquakes have occurred in the seismically active Alpine-Himalayan earthquake zone from past to present. Since Turkey is located in this earthquake zone, approximately 93% of Turkey's territory is considered seismically risky (Onat, 2022). Turkey's territory is involving three major earthquake zones: Northern Anatolian Seismic Zone, Southeastern Anatolian Seismic Zone, and Western Anatolian Seismic Zone (Şahin and Kılınç, 2016). Earthquakes, the most devastating type of disasters that occur in Turkey, cause physical, social, and economic losses (Şahin and Kılınç, 2016). Aegean Region and İzmir are extremely risky in terms of seismicity like many other regions in Turkey. Throughout history, this area has been affected by earthquakes, resulting in loss of life and great destruction (AFAD/IRAP, 2021). Despite having experienced significant earthquakes, the city has become densely populated due to its commercial and touristic potential, favorable natural conditions, and lifestyle. According to various sources, Izmir is an important city that has been able to exist with its urban identity for 8500 years. As of 2023, it is the third-largest city in Turkey, with a population of 4.479.525 (TURKSTAT, 2023). Like other major cities in Turkey, Izmir has been one of the critical destinations for rapid and uncontrolled migration movements since the 1950s. Izmir has gained the status “metropolis” with rapid increase in its population after the 1990s (Karadağ and Mirioğlu, 2012).

On October 30, 2020, an earthquake with a magnitude of Mw = 6.9 (reported as Mw = 6.6 according to AFAD Turkey data) occurred off the coast of Samos Island. It caused serious damage in Izmir, which is approximately 75 km away from the epicenter (Yakut et al., 2021). According to the statement of AFAD (2020) and Izmir Governorship, after the Samos Earthquake, structural damage such as complete collapse, heavy damage, medium damage, and light damage occurred in buildings, especially in Bayraklı and Bornova districts (DAUM, 2020; METU, 2020). In this earthquake, 115 people died and 1035 people were injured (DAUM, 2020). According to Yakut et al. (2021), the heavy damage following the earthquake was concentrated in Bayraklı district, where 166 buildings suffered serious or highest damage. Along with Bayraklı district, Bornova, Konak and Karşıyaka are other districts that suffered relatively serious damage, and these districts are among the most densely populated central regions of Izmir (Yakut et al., 2021). Earthquakes do not only cause physical damage, and assessments should not be considered only from a physical perspective. Earthquakes affect everyone and everything in a community. They not only damage buildings and infrastructure, but, like all other natural disasters, can also destroy economic, cultural, and social activities. Bayraklı district is one of the most important districts of the city with its historical texture, being one of the oldest districts of Izmir, having new urban development areas along with designated urban transformation areas, and its economic vitality with the prestigious multi-storey residences built. The fact that disasters, especially earthquakes, cause physical and social losses brings disaster management and risk reduction efforts to the fore.

Urban areas besides being attractive for various human activities and functions, such as housing needs, economic activities, and recreational facilities, are complex systems that are vulnerable to earthquake hazards due to population size, density, and assets. To assess the vulnerability of such complex systems, 'vulnerability' and 'resilience' are two competing and interrelated concepts that have been widely pronounced in recent years. These concepts are used in various disciplines, especially ecology, engineering, and social-ecological systems. Vulnerability as defined by Smit et al. (2000) is "*the degree to which a system is susceptible to injury, damage, or impairment".* According to Manyena (2006), the term vulnerability is used to describe the state of the environment, or a community being affected by *"hazardous physical phenomena of natural or human-origin"*. A widely accepted view of vulnerability is that it is inversely related to resilience.

Essentially, high vulnerability leads to low resilience and vice versa (Gallopin, 2006). Therefore, the degree of vulnerability of urban areas and societies needs to be assessed to understand disaster risk, and to develop policies to enhance resilience.

Bayraklı district is a region with high disaster risk and vulnerable to earthquake hazards due to the ground conditions of its location and the fact that it is one of the oldest settlements in Izmir. This study focuses on vulnerability assessment, which is one of the most important steps of risk reduction studies and offers an earthquake-related vulnerability assessment method with a multi-criteria decision-making approach, using physical and social parameters for the case of Bayraklı. Vulnerability usually poses spatial variability due to segregation. This thesis study aims to represent the spatial variability of vulnerability across the study area and utilizes administrative borders of the neighborhoods as the smallest statistical unit. The analysis covers all neighborhoods (24 neighborhoods) of Bayraklı district. Three dimensions were utilized in vulnerability assessment for earthquake hazards: social, physical, and capacity of built environment. Although vulnerability studies have been studied in many areas, they have generally focused on one-dimensional studies, whereas in this study, vulnerability to earthquake hazards in three different dimensions was addressed with a more comprehensive approach. Since vulnerability assessments are complex and depend on many different criteria, the Multi-Criteria Decision Making (MCDM) Method was conducted in this study. Analytical Hierarchy Process (AHP), a MCDM method widely used in vulnerability assessment studies due to its flexible structure, was preferred and applied integrated with Geographic Information Systems (GIS).This study comprehensively examines and spatializes the vulnerability to earthquake hazards according to risk profiles in Bayraklı district as case study.

1.1. Problem Definition

Severe earthquakes have occurred in İzmir and its close vicinity in the past, resulting in destructive damage. These earthquakes occurred from the beginning of the 1900s to the present and are called the “Instrumental Period” (MTA, 2005). The magnitude of 13 earthquakes that occurred in İzmir in the last century was greater than 4, and some of the earthquakes caused loss of life and material damage in the region (MTA, 2005). One of the largest earthquakes that occurred in the last century was the Torbalı earthquake (M: 6.5) on March 31, 1927, which affected a very large area and destroyed more than 2,000 houses. Another earthquake with a magnitude of 6.0 occurred in the southern part of İzmir on November 6, 1992 (MTA, 2005). Today, as the population has grown and its density has increased considerably, earthquakes have the potential of devastating impacts. It is unknown when earthquakes will likely occur and how much damage they will cause. For this reason, earthquakes and their possible consequences should be assessed prior to the event. Based on these assessments, measures should be taken to minimize the damage and loss of life that may occur. Although the epicenter of the 30 October Samos earthquake was quite far away from Bayraklı and surrounds, due to ground magnification and ground conditions, the earthquake was felt very strongly in the area and caused great damage (DAUM, 2020). The damage that occurred after the earthquake, especially in Bayraklı district, was evaluated as the ground/structure/building interaction. It was reported that the buildings were not built in accordance with the relevant seismic building codes and the structural/non-structural changes have been made in the building after the construction (DAUM, 2020). The most structural damage during the earthquake occurred in the building stock of Bayraklı districts. The hazard zone is saturated with water, formed of loose alluvial, delta and coastal sediments. Many of the buildings exposed to the hazard are poorly constructed and contain post-occupancy usage errors. The reason why Bayraklı is the district most affected by the earthquake is the ground structure mentioned above. The neighborhoods built on the existing alluviums of the Izmir coast are generally at risk. Since Bayraklı district is built on alluvial ground, it is at greater risk than other districts.

The earthquake risk in big cities exposed to earthquake hazard, such as Izmir, is increasing due to population growth, improper land use and construction, inadequate infrastructure and services, and environmental issues. In past earthquakes, most of the destructions and deaths in urban areas were due to the collapse of buildings with inadequate earthquake resistance or inappropriate site selection. The physical losses that may occur in an earthquake are mainly caused by buildings and infrastructure. The type of structure that is currently widely used in Izmir and is expected to be used intensively in the future is the multi-storey reinforced concrete building. The seismic performance of these types of structures in our country is far below those observed in developed countries (Izmir Earthquake Scenario and Master Plan, 2021). However, in order to carry out a comprehensive earthquake risk analysis, in addition to physical vulnerability rates, the social damage probabilities related to the urban population should also be determined. The loss of life during earthquakes is mostly due to the collapse of structures and, secondarily, secondary disasters caused by earthquakes (Izmir Earthquake Scenario and Master Plan, 2021).

For the study area that is exposed to earthquake hazard it is necessary to assess vulnerability to determine disaster risk, to develop strategies for reducing risk and enhancing resilience. There was a lack of comprehensive studies in the area prior to Samos earthquake, and it is only after the earthquake event that the area is being investigated from diverse aspects, however particularly focused on building performances to earthquake (DAUM, 2020; MTA, 2020). A comprehensive earthquake vulnerability assessment that embodies different dimensions of vulnerability is essential to understand the vulnerability and risk profiles in the study area and to gain a holistic view of earthquake vulnerability. It is also crucial to represent the vulnerability in spatial dimension and detect vulnerable regions if any which is curucial for prioritizing and allocating the limited resources to most vulnerable areas/units.

1.2. Research Questions

This study aims to conduct a comprehensive assessment of Bayraklı district of Izmir by revealing the vulnerability to earthquake hazards and enabling the development of strategies for cities that are less vulnerable to disasters. Evaluating vulnerability in different dimensions is considered to make the assessment more comprehensive. The following research questions will guide this research.

1. How can vulnerability to earthquake hazards be comprehensively assessed in multiple dimensions?
2. Which neighborhoods are most vulnerable to earthquake hazards and should be prioritized as high-risk areas?

These research questions will be addressed through literature review and data analysis in order to reveal which neighborhoods of Bayraklı district are more vulnerable to earthquake hazards and to provide insights and recommendations to policy makers, practitioners and other stakeholders involved in planning and implementation against disaster risks.

1.3. Aim of the Thesis

Based on the research questions, this study underlines that for Bayraklı district, it is necessary to consider and focus on the vulnerability of the region in different dimensions against earthquake hazard. Basically, planning mechanisms should integrate vulnerability assessment methods to understand and reduce the impact of natural disasters and earthquake hazards that occur/may occur. The main purpose of this study is to present a comprehensive earthquake vulnerability assessment for Izmir Bayraklı district. The study aimed to determine the multiple vulnerabilities of neighborhoods against earthquake hazards by considering three dimensions. These three dimensions are physical vulnerability, social vulnerability and the capacity of the built environment. Indicator sets were prepared to analyze and assess each dimension. The main purpose of preparing indicators is to make the dimensions represented and measurable. In this context, it is aimed to determine the weights of the decided indicators and to produce social vulnerability, physical vulnerability and capacity of built environment maps in a GIS environment with MCDM. In this sense, the purpose is to reveal which places are more vulnerable to earthquake hazards by considering the social, physical, and capacity of the built environment dimensions together. The ultimate purpose of this research is to determine the most vulnerable areas to prioritize and focus on against emerging earthquake hazards and to inform the development of the strategies and actions for these areas.

1.4. Scope of the Thesis

This study aims to make an assessment that will help understand vulnerability and determine vulnerability levels at a local scale (neighborhood basis), with an MCDM. Thus, within the scope, it will be possible to identify the neighborhoods with the highest vulnerability level and evaluate the root sources. For this reason, Bayraklı District, where hazard exposure and vulnerability are high, was selected as the study area, and analysis studies were carried out on 24 neighborhoods in the district. The total area of Bayraklı district is 30 km2 (3000 ha). Since vulnerability studies are complex and carried out on many parameters, the Analytical Hierarchy Method, one of the Multi-Criteria Decision-Making Methods, was used in this research. Analyzes were made with the Geographic Information System (GIS) software ArcGIS, which makes it possible to represent spatial dimensions, and many analysis methods integrated for decision support. Vulnerability criteria against earthquake hazards were reviewed in the literature and these criteria and adapted for the study. Social vulnerability, physical vulnerability, and capacity of the built environment as the three dimensions is the main issue addressed in this study. Sub-dimensions of the indicators used for these indicators have been created. Data was requested from relevant institutions/organizations for the prepared indicator sets.

The data was taken from the units of Izmir Metropolitan Municipality and TURKSTAT. Raw data sets received from Izmir Metropolitan Municipality (2023) and TURKSTAT (2019) were arranged to be used to complete the study. The obtained indicators were analyzed at the community level at the neighborhood scale. The accessibility of the data sets developed in the study and used for multiple vulnerability assessment against earthquake hazards may vary depending on countries and regions.

Therefore, not every indicator determined in the study was achieved. Three separate sub-dimensions are discussed for social vulnerability, these are demographics, education level and disadvantaged groups. For physical vulnerability, the average building age, relative position, material of the buildings in the neighborhoods were taken into consideration. For capacity of the built environment, two sub-dimensions and indicators of these dimensions such as distance to critical facilities and distance to assembly areas were discussed. Within the scope of the study, neighborhood-based analyzes were carried out, considering that it would be the most efficient method to determine areas with high vulnerability values at the local level, and it was determined which neighborhoods were vulnerable to earthquake hazards.

1.5. Methodology of the Thesis

The methodology of this study consists of a literature review on risk and components, vulnerability and resilience, vulnerability and dimensions of vulnerability, and the development of an empirical study referring to the theoretical background. In this study, resilience and vulnerability are considered as separate but often interconnected concepts. Concepts were explained and discussed in the literature review. At the same time, the indicators of these concepts were examined and the indicators to be used in the study area were determined. On the other hand, the method to be used for the study was determined and explained within the theoretical framework. After a literature review was conducted in line with the purpose of the thesis, evaluation criteria were determined using these studies. Many indicators have emerged in the light of the literature review. In line with the determined indicators, an indicator set of social vulnerability, physical vulnerability, and capacity of the built environment was created and these data were obtained from relevant institutions/organizations and arrangements were made on the obtained data and made ready for analysis. The data was analyzed using the Analytical Hierarchy Process (AHP) method, one of the MCDM methods, to determine the weights of the criteria. The AHP method is basically based on expert opinion and in this study, experts used values in the range of 1-5 Likert scale. After the scale was used, a series of calculations were made with the given values and the weights of the determined indicators were calculated. Finally, the consistency ratio is checked to show that the calculations are consistent. With the applied method, a vulnerability map was created as a result of analyzing the indicators for the study of 24 neighborhoods of Bayraklı district.

1.6. Limitations

This research aims to explore the assessment of vulnerability to earthquake hazards in Bayraklı using the AHP-GIS integrated approach. However, certain obstacles have been encountered in the research in this area. The main concern is related to the accessibility and usability of the data. Due to the lack of access to a publicly available or scientifically shareable dataset that provides comprehensive details about the economic framework of Bayraklı, certain indicators such as income, race and unemployment rate could not be obtained in the research. Instead, Income data was obtained from the as average income m2/unit price index of rental housing from the official website of Endeksa with a proxy approach. This is one of the major obstacles encountered in the study. However, some of the indicators discussed in the literature could not be accessed. In addition to the income data, data such as the number of household members and the head of household could not be accessed. In physical dimension, indicators such as vertical irregularity, plan irregularity, wall type etc. could not be obtained. Considering the limitations outlined in this research and the assessment framework presented, it is important for the data to be accessible for potential future studies. In order to make a comprehensive assessment of vulnerability to earthquake hazards, it is essential to integrate multiple indicator assessments.

In summary, despite the limitations, the study provides important results and benefits for research and practical applications in the field of assessing vulnerability to earthquake hazards.

1.7. Outline of the Thesis

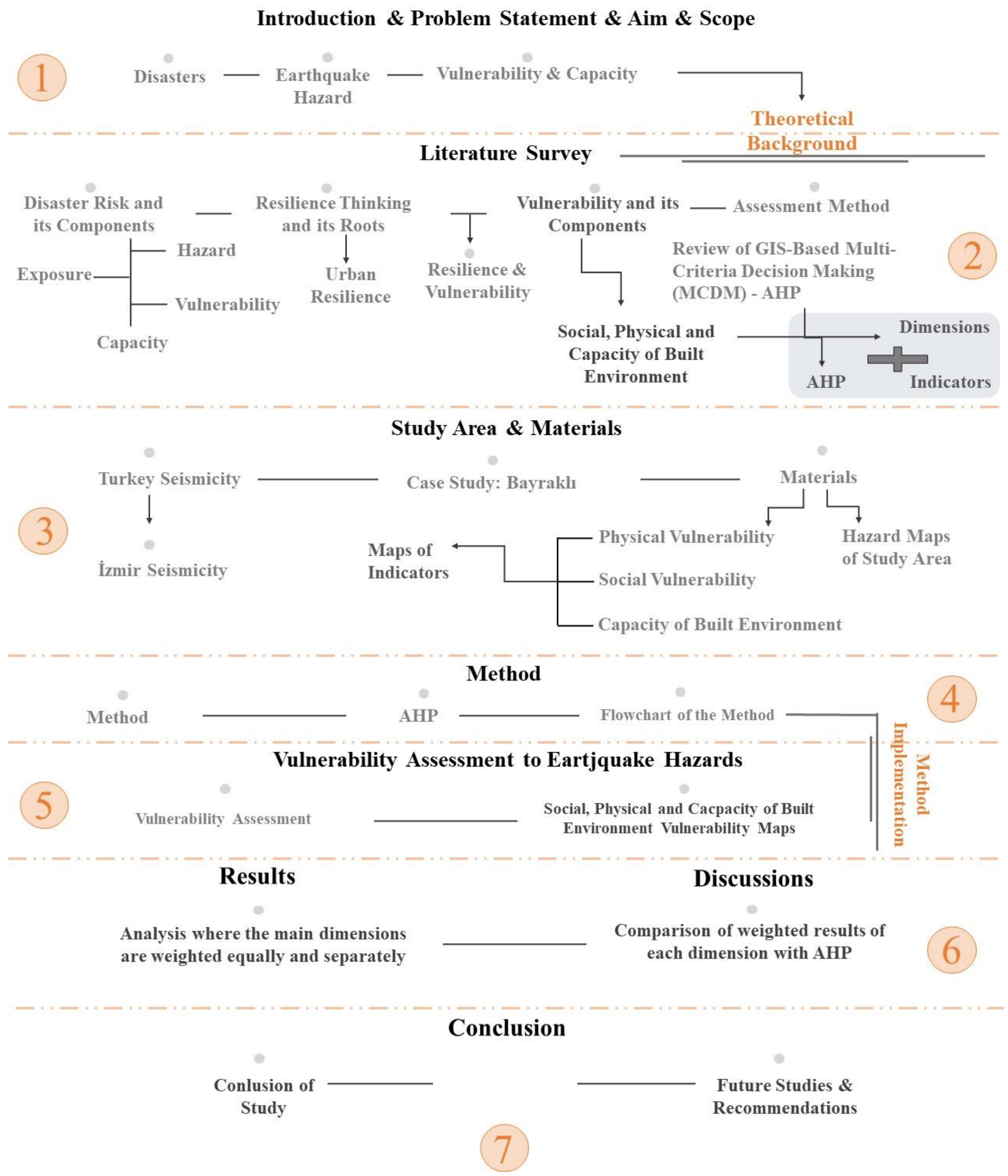

Figure 1: Outline of the Thesis

The organizational structure that constitutes the content of the thesis is explained in sections below.

In the first chapter of the study, which basically consists of seven main chapters, a general explanation of the thesis topic is made, the observed problems are revealed, and the importance of the study is emphasized. In this section, the main problem and research questions, the purpose, scope, and method used of the thesis are also stated.

In the second chapter, a comprehensive investigation of the concepts subject to the research is presented. Literature research on concepts such as disaster, disaster risk, exposure, hazard, and vulnerability, which form the basis of this study, was conducted, the relationships between the concepts were discussed and the relevant models were examined. Subsequently, the relationship between the concepts of vulnerability and resilience is examined. The concept of vulnerability is discussed in a broad framework and its dimensions and selected indicators are explained. At the end of the second chapter, the MCDM-AHP method is discussed and compared with other methods.

In the third chapter, after literature research, the seismicity of Turkey and Izmir is examined, and the characteristics of the study area are mentioned. In this section, the characteristics of the study area and why it was chosen are explained. Then, maps showing the status of the study area were created with the indicator tables used in the thesis.

In the fourth chapter, the method applied to the study area determined in the study, the criteria used, and the analysis studies performed are explained.

In the fifth section, the vulnerability analysis of the study area is explained in detail. By applying the method to the indicators, tables showing their weights were created. As a result, the result maps of all three dimensions were added and explained.

In the sixth chapter, the analysis outputs were evaluated, and the results of the vulnerability study were examined and discussed

In line with the results, the seventh chapter discusses Bayraklı's vulnerability to earthquake hazards.

In the last section, a list of the sources used is given.

CHAPTER 2

LITERATURE REVIEW

2.1. Theoretical Framework

2.1.1. Disaster Risk and Its Components

Disasters happen as a result of a variety of different factors functioning together. These factors are the type of hazards or risks, the degree of exposure of people and the environment, how vulnerable these people and the environment are, and how capable they are to prevent or manage potential harm. Disasters cause great deterioration for people, the environment, and assets. Disasters can occur because of many different types of hazards. They may be natural (e.g. flood, earthquake, landslide, windstorm), or otherwise human-origin. According to Lumen and Yamada (2014), places are affected by disasters and the time duration of these disasters is also an important factor. It may be brought on by sudden events (or shocks) like epidemics, storms, earthquakes, and wars, as well as by the buildup of stressors like protracted drought, degradation of natural resources, unplanned urbanization, and climate change (Lummen and Yamada, 2014). Besides, according to UNISDR (2009) "*Disasters are generally defined as the result of a combination of: exposure to a hazard; current vulnerability conditions; and insufficient capacity or measures to reduce or deal with potential adverse consequences"*. A hazard is *"a process, phenomenon or human activity that can cause loss of life, injury or other health effects, property damage, social and economic disruption, or environmental degradation"* (UNDRR, 2017). Hazards include biological, environmental, geological, hydrometeorological and technological processes and events (UNISDR 2015). For the hazard to turn into a disaster, systems and people must be exposed to the hazard and vulnerability must exist.

The best method for protecting a community's future is to build robust, healthy, resilient communities that can withstand disasters and recover from them. Examining how the concepts relate to one another and how they affect vulnerability is important in this situation. A distinction between the two concepts is necessary because a disaster and a hazard should not be confused. There are linkages and differences among hazards, disasters, and disaster risks. Although these are different terms, they are interrelated. The definitions make it clear that simply having an event happen is insufficient. A natural or human-origin occurrence must cause losses to communities and settlements, be unmanageable with current opportunities and resources, and disrupt or stop human activities for it to qualify as a disaster. (UNISDR, 2009). In simple terms, a disaster is not an event in and of itself, but rather the outcome of an event.

2.1.1.1. Disaster Risk

In the field of natural disasters, risk is interpreted depending on factors such as hazard, exposure, and vulnerability. There are many variations in defining disaster risk, including concepts such as probability, expectation, or the combination of probability and outcome. According to definition of UNISDR (2004), *"disaster risk can be termed as the probability of harmful consequences and expected losses resulting from interactions between natural or human-origin hazards and vulnerable conditions*". Cutter (2009) also defines disaster risk as *"the probability of harm or some type of injury or loss resulting from the hazard event".* In the context of disasters, risk is defined as the outcome of the effects of the possibility of hazard and is a function of the vulnerability of the elements exposed to the hazard (Birkmann, 2007). However, disaster risk cannot be described as a function of a hazard that merely defines the probability of harm, because the elements exposed to a particular hazard also need to be considered (Adger et al. 2005).

In this context, if the disaster risk element is considered for a system (for example, a city), it can be defined on the basis of two different factors: (1) a potentially threat event consisting of its probability, severity, frequency and location, and (2) an element that reveals the vulnerability resulting from the relationship between exposure and the degree of damage of the elements exposed to (UNISDR 2004). While explaining the relationship of the concepts it was mentioned that there should be an exposure situation to examine vulnerability. For this reason, the risk triangle formulation, which considers the exposure, and vulnerability as well came up. The formula was introduced to literature by Crichton

(1999). This formulation emphasizes the dependency of disaster risk on the three components of hazard, exposure, and vulnerability.

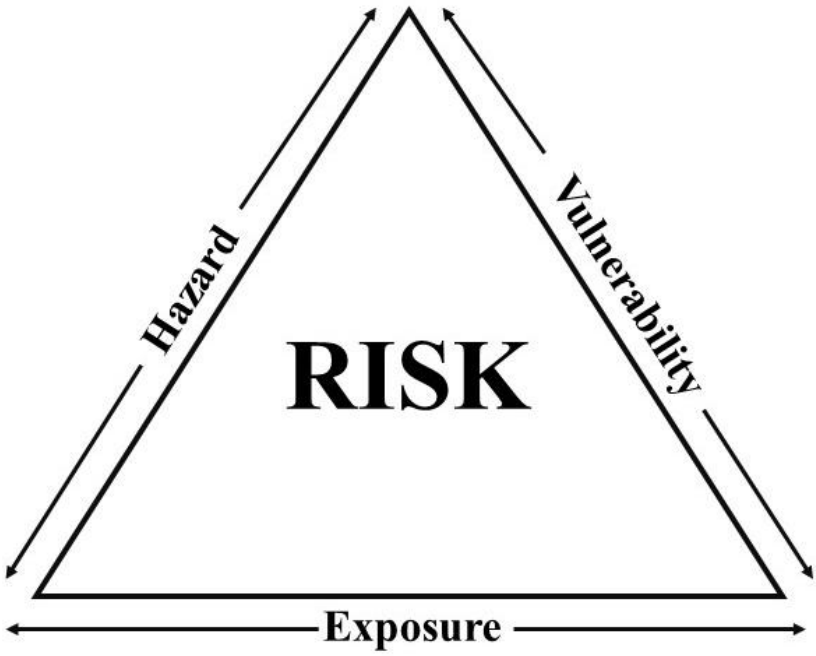

Figure 2: The "Risk Triangle"

(Adapted from Crichton, 1999).

Risk = (1) Hazard × (2) Exposure × (3) Vulnerability (Crichton, 1999).

The equation determines the overall risk by multiplying the hazard exposure and vulnerability. This study examines the risk in the disaster risk context, and three categories are distinguished: hazard, exposure, and vulnerability measures (Davidson and Shah 1997).

It seems that there is a more conventional approach in this basic formula. In Crichton's (1999) formula, it can be seen that there is no concept of 'capacity' when considering disaster risk. According to the UNDRR (2017) definition, disaster risk is *"the potential loss of life, injury, or destruction or damage to assets that may occur to a system, society, or community within a certain period of time, determined probabilistically as a function of hazard, exposure, vulnerability, and capacity"*. In addition to the function of comparing risk between societies and systems, it also has the purpose of determining whether the level of disaster risk is primarily a result of the hazard, exposure, vulnerability and capacity component (Bollin and Hidajat, 2006). Essentially, the conceptual framework of this approach is based on the definitions of disaster risk put forward by

Davidson (1997) and Bollin et al. (2003). As a result, disaster risk has been characterized in terms of four components: hazard, exposure, vulnerability and capacity measures.

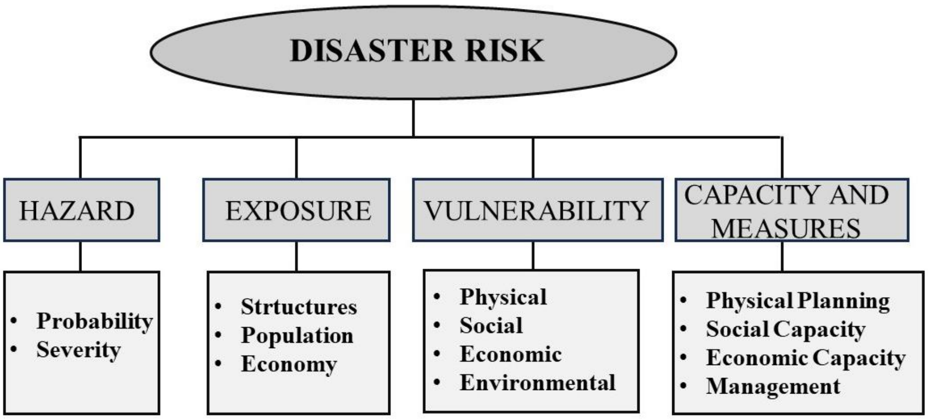

Figure 3: Conceptual framework to identify disaster risk

(Adapted and modified from Davidson and Shah, 1997)

Disaster Risk = (1) Hazard* × *(2) Exposure* × *(3) Vulnerability / (4) Capacity

The term capacity is also referred to as: coping capacity and adaptive capacity. Capacities and measures that seem closely related to what is today defined as coping and adaptation capacities include physical planning, social capacity, economic capacity and management. This scope will naturally affect their immediate and future risk and vulnerability positions, as well as determine their capacity to cope and adapt, and therefore affect their access to capacities and measures (Lummen and Yamada, 2014).

2.1.1.2. Hazard

Hazards can originate from many aspects and situations. ***Hazard (1)*** is defined in a variety of ways: hazard is a natural or artificial event or process that disrupts society's regular operations (Cutter et al., 2009) and has the potential to do damage to people's lives and property with threats the ability to harm individuals and places (Smith 1996, 2007). UNSDR (2015) defined hazards as events that can arise from biological, environmental, geological, hydrometeorological, and technological processes and activities. Wisner et al. (2004) emphasized the interaction of hazards and exposure during the occurrence of disasters: “No hazard, no disaster; no exposure, no disaster”. The degree to which elements at risk are exposed to a certain hazard is described by “exposure” (Lummen and Yamada, 2014).

2.1.1.3. Exposure

Exposure (2) identifies the elements, structures, and populations potentially subject to a particular hazard occurrence and its extents (Bollin et al., 2003a,b). By assessing all structures and elements at risk, disaster managers and community members can predict what is at stake when an event occurs. Generally, it can be said that the smaller the community in a place, the fewer the elements at risk and the smaller the exposure level. On the other hand, as a community grows, so do the elements at risk and the level of exposure (Bollin et al. 2003a, b).

2.1.1.4. Vulnerability

Another important parameter to understand disaster risk is vulnerability. ***Vulnerability (3),*** which indicates the being prone to damage and the susceptibility to a disturbance or stress, stems from the Latin term *“vulnerare”* (to be wounded) (Downing et al. 1997). The term vulnerability covers a wide range of explanations in the existing literature. The notion of vulnerability has been widely used in studies on social-ecological systems, disaster risk reduction, and global environmental/climatic change in recent decades (Lei et al., 2014). Vulnerability is described as the degree to which a system is being damaged or injured. Its components include the system's ability to withstand stressors and external pressures as well as its sensitivity (Adger, 2006). Another important definition was made by Blaikie et al. (1994) *“Vulnerability is the characteristics and states of a person or group that affect their capacity to anticipate the impact of a natural hazard, cope with it, resist and recover from it.”* To conclude, disaster risk is directly related to a combination of hazard, elements exposed, vulnerability of the elements, and inadequate capacities and measures to mitigate the potential negative consequences of the hazard.

2.1.1.5. Capacity

With the addition of the ***capacity (4)*** concept, the definition of disaster risk has transitioned from a dual structure to a multifaceted structure. According to the Sendai Framework (2015), the design and implementation of risk management strategies for disaster risk reduction should be based on a holistic understanding of risk in all its dimensions, including hazard characteristics and the environment, exposure of assets and persons, vulnerability and capacity. Fundamentally, social-ecological systems have coping capabilities determined by internal and external influences. These are capacities to manage, adapt to, and recover from environmental and social disruptions. The capacity concept provided a framework for understanding how complex systems, especially ecological systems, behave and respond dynamically to disturbances and change. The capacity of a system against emerging/possible dangers is divided into two: “adaptive capacity” and “coping capacity”. Turner et al. (2003) distinguishes between adaptive capacity and coping capacity and considers both capacities as components of a system's resilience/vulnerability. The points of convergence of the concepts of vulnerability and resilience are more evident than their points of divergence (Adger, 2006). Essentially, these two concepts have many common areas, such as the stresses and shocks experienced by social-ecological systems, the system's response to these stresses and shocks, and its adaptive capacity (Adger, 2006). The concept of vulnerability has been continuously expanded in many aspects and studies have been carried out in many areas with a more comprehensive approach. Vulnerability relates not only to resilience and adaptive capacity, but also to coping capacity, exposure, and interaction with perturbations and stresses (Turner et al., 2003; Birkmann, 2007).

Basically, coping capacity represents the degree of reducing the effects of changes in processes and structures against hazards that may occur (Manyena, 2006). According to the definition of UNISDR (2002), coping capacity is *“a combination of all the strengths and resources within a community or organization that can reduce the level of risk or reduce the effects of a disaster”*. On the other hand, the concept of adaptive capacity is central to resilience thinking (Gunderson and Holling, 2001). In a more recent usage in the field of climate change, adaptive capacity is defined as *“the ability of a system to adapt to climate change (including climate variability and extremes) to mitigate potential harms, take advantage of opportunities, or cope with climate change”* (IPCC, 2001). According to Smit and Wandel (2006), "coping capacity" is applied to short-term capacity or survival ability, while "adaptive capacity" is used for long-term and more sustainable arrangements.

Consequently, the relationship between disaster risk, hazard, vulnerability, exposure, and capacity is crucial in understanding and handling adverse events. Disasters occur when hazards intersect with exposed and vulnerable elements, resulting in significant damage or loss. Disaster risk, the product of hazard, vulnerability, exposure, and capacity reveals the potential harm from adverse effects. While hazards act as triggers that initiate the chain of events that lead to disasters, vulnerabilities and lack of adaptive capacities reflect the reduced resilience of individuals and communities to such events. Exposure represents the presence and proximity of elements at risk of hazards. Capacity is the knowledge, skills, resources, and abilities that enable systems, individuals, and communities to prevent, prepare for, survive, and recover from disaster risks (Manyena, 2006). The capability to analyze disasters themselves also enables one to demonstrate why they shouldn't be separated from daily life and how the disaster risks associated must be linked to the vulnerability generated for many people by their everyday lives. It is necessary to do a comprehensive evaluation of a location's, community's, or region's disaster risk of certain hazards. Pre-existing population, social, economic, and environmental conditions, and their capacities need to be evaluated, as structures and communities affected by risk factors become more susceptible to greater exposure. As a result, the disaster risk that may occur can be reduced by reducing the vulnerabilities of the society and systems against hazards and increasing the capacity of the systems and societies.

2.1.2. Resilience Thinking: Entry to Urban Planning

The terms "resilience" and "vulnerability" have become widely accepted in the study of natural disasters (Klein et al. 2003). However, the link between them raises a crucial point. Is resilience the exact opposite of vulnerability? Is resilience a vulnerability-related trait? Is it the reverse way around? (Zhou et al., 2010). Furthermore, many vulnerability and resilience researchers have identified possible connections between vulnerability and resilience concepts (Young et al. 2005; Vogel et al. 2007; Miller et al.

2010). The study themes of vulnerability and resilience are distinct yet related (Turner et al. 2003). The points of convergence of the concepts of vulnerability and resilience are more evident than their points of divergence (Adger, 2006).

Essentially, resilience and vulnerability are important concepts for understanding, predicting and managing the effects and consequences of disaster risks. Both concepts produce spatial results as a result of similar approaches, components and methodological approaches applied to these components. This is one of the reasons why resilience is explained contextually together with vulnerability in the study. While disaster resilience assessments address the response to shocks resulting from disasters and the mechanisms that drive this, vulnerability assessments focus on spatial patterns of exposure and resilience. One of the main reasons for the study is improving resilience through vulnerability assessment. Three factors make resilience crucial for the discussion of vulnerability, according to Berkes (2007): (1) it aids in the holistic evaluation of hazards in coupled human-environment systems; (2) it places emphasis on a system's capacity to deal with hazards by absorbing disturbances or adapting to them; and (3) it is forward-looking and aids in the exploration of policy options for coping with uncertainty and future change.

The resilience theory that was previously described has origins in many other disciplines, including physics, ecology, engineering, and more. Resilience thinking recognizes that change and disruption are inherent in systems and seeks to understand how systems can adapt and thrive in the face of challenges. Since its inception in the 1960s and 1970s, resilience research has gone through many phases, as Folke (2006) stated. Resilience was introduced in the 1970s in the context of ecological systems by Canadian ecologist C.S. Holling. Holling's work focused on understanding complex ecological systems and their dynamics. Holling distinguished between two types of resilience concepts. These are ecological resilience and engineering resilience. Holling (1973) described ecological resilience as follows; *"resilience determines the persistence of connections within a system and is a measure of this ability to deal with changes of state variables, driving variables, and parameters and persist."* In engineering resilience, it refers to the ability of a system to return to its original state after a disturbance (Holling, 1996). Gunderson (2000) mentioned that many authors define the term resilience as the time required for the system to return to equilibrium or steady state after a disturbance.

To put it briefly, single-state equilibrium, multiple-state equilibrium, and dynamic non-equilibrium are separated in the literature on resilience (Davoudi et al., 2012; Folke, 2006; Holling, 1996). Frequently, the term "*engineering resilience*" is used to describe single-state equilibrium while the term "*ecological resilience*" refers to multiple-state equilibrium resilience (Holling, 1996). These terms have transformed resilience thinking into a dynamic non-equilibrium known as "*evolutionary resilience*" referred by Davoudi (2012). Evolutionary resilience questions the basic notion of equilibrium and supports the idea that systems themselves may change over time with or without an external disruption and this is referred regarded as *"social-ecological resilience"* by some authors (Davoudi 2012; Folke et al., 2010). This transition can be summed up as follows: Social-ecological resilience and evolutionary resilience refer to a system's ability to evolve and adapt in response to disturbances or changes in its environment. As stated by Tasan-Kok et al., (2013), resilience first appeared in the literature as an ecological term. Second, the concept of system resilience has evolved in the social sciences. Third, the resilience of urban (ecological, social, and economic) systems was studied (Tasan-Kok et al., 2013).

Resilience has also been utilized more frequently in urban area studies over the last few years. The concept of resilience has primarily been adopted by planners from ecology. . The study of resilient cities became a focus of urban planning literature as the emphasis shifted from dealing with environmental hazards to a more all-encompassing strategy that considered the resilience of the urban system as a whole (Tasan-Kok et al., 2013). In response to the environmental threats of changing social and institutional frameworks, the study of resilience in relation to planning began in the late 1990s (Mileti, 1999). As stated by Porter and Davoudi (2012), new ideas have long been assimilated by planning and incorporated into their theories and methods. The main goal is to minimize disruptions, and enhancements to the physical environment and infrastructure were prioritized (Lu and Stead, 2013). It is vital to pay attention to the links between these systems since cities are intricate, dynamic systems nested within a web of socio-ecological systems. When resilience theory is applied to urban planning, social-ecological systems are essentially visible. As an outcome, resilience theory was incorporated into urban planning. A resilient city *is "capable of surviving major shocks without either immediate chaos or permanent damage,"* according to Godschalk (2003). This viewpoint obviously places more value on the resilience of the city than it does on response time.

The ideas of social-ecological resilience have been incorporated into urban planning, including ecological concerns, adaptive governance, participatory methods, and multi-dimensional techniques to improve urban resilience. Urban planning strives to solve the difficulties cities face and create more resilient and sustainable urban settings. Cities need resilience for two reasons: *"(1) it allows for change without a major catastrophe, and (2) it enables residents to adapt and exist in environments free from unusual stresses."* Urban resilience studies in the field of spatial planning have only recently begun, even though the theoretical concept of resilience has been developed for more than forty years. Urban resilience started to come up in discussions about spatial planning in the 1990s. Meerow et al., (2016), defined urban resilience as follows: *"the rapid evolution of urban systems and all socio-ecological and socio-technical networks that comprise them, along with procedures that maintain the required functionality in situations of disturbance or recover quickly, adapt to change, and minimize current or future adaptability."* Urban resilience has described as both the politics of today's battle and survival as well as the actions of a system or a series of collaborations and coordination that will assist politicize the resilient city and urban systems become more resilient with the development of social and physical infrastructure (Deverteuil et al., 2021; Adger, 2020).

Quick "response" and "recovery" are key characteristics of a resilient city. It is incredibly difficult to recover from the pre-disturbance condition due to the dynamic complexity of urban systems. Following an interruption, it is preferable to immediately restore vital functions rather than endure protracted delays. For instance, the degree, length, and duration of the effects are strongly influenced by how quickly telecommunications and energy networks recover after a disaster. In summary, the pace of city recovery involves both a quick restoration to the pre-disaster condition and a quick transition to a new operating state. So, to build resilient cities, urban systems must be dynamic.

2.1.3. Vulnerability and Resilience

Turner et al. (2003) state that in studies on vulnerability assessment, resilience is one of the factors contributing to vulnerability, along with exposure and sensitivity. Adger (2000) stated that resilience is a "loose antonym" for vulnerability. Turner et al.'s (2003) definition is similar to Adger's definition because resilience is associated with the capacity to cope with disaster or stress, while vulnerability emerges with exposed elements to stress or disasters. However, as Tyler and Moench (2012) caution, the phrases are frequently employed in a variety of settings "with little consistency or consensus on the definition". According to Watts and Bohle (1993), the connection between the two *"does not rest on a well-developed theory; neither is it associated with widely accepted indicators or measurements."* While resilience is the ability of a system to adapt to change while absorbing disturbance and reorganizing to maintain essentially the same function, structure, identity, and feedback, vulnerability occurs when people or places are exposed to events such as disturbance or shock (Walker et al., 2004; Turner et al., 2003). Resilience is a process that mainly focuses on the stages of in- and post-disaster and works to improve the system's capacity to withstand and recover from hazards while vulnerability concentrates on the state of a system before the disaster (Lei et al., 2014). The relationship between the two is still unclear. According to Engle (2011), adaptive capacity is the link between the ideas of vulnerability and resilience.

In some studies, the basic ideas of vulnerability and resilience within a social-ecological system (SES) have been explored (Folke 2006; Berkes 2007); other studies have attempted to analyze the connection between vulnerability and adaptability (Smit and Wandel 2006). Others have made an effort to explore the connections between vulnerability, resilience, and capacity from the perspective of global change (Gallopin 2006; Vogel et al. 2007). In a coupled human-environment system, there have also been attempts to incorporate the theoretical frameworks of vulnerability and resilience into studies on sustainability (Turner et al. 2003; Turner 2010; Miller et al. 2010; Endfield 2012).

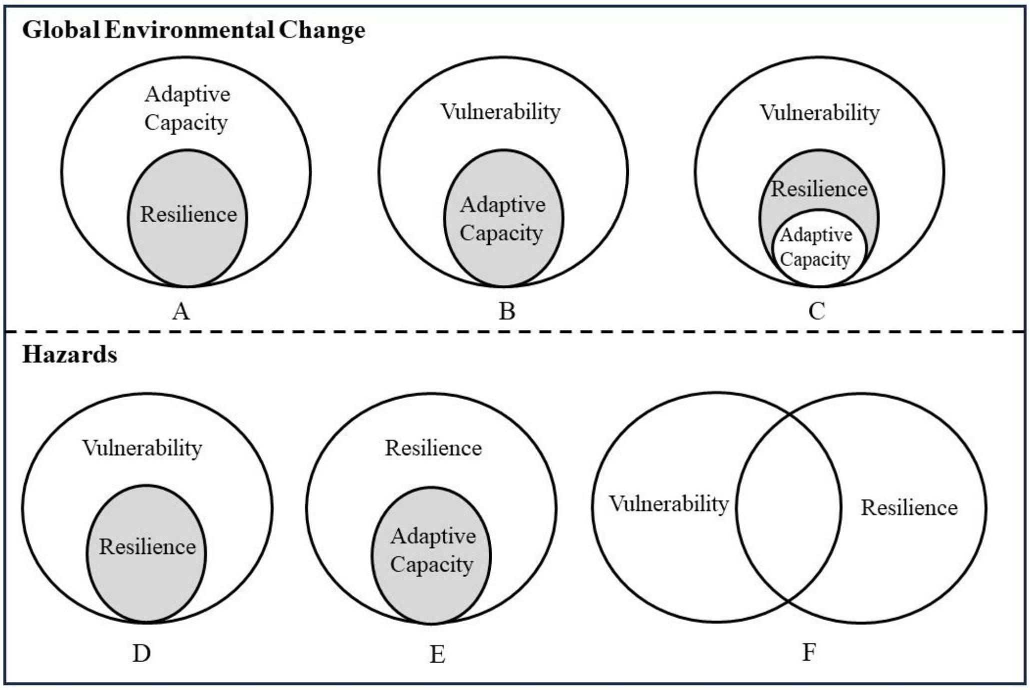

Figure 4: Conceptual linkages between vulnerability, resilience, and adaptive capacity

(Adapted from Cutter et al., 2008)

According to a generally accepted theory of vulnerability, the concepts of resilience and vulnerability are inversely related (Gallopin, 2006). For example, in part D of the figure, when resilience is defined as the ability to return to or cope with a threat event, it is considered a result and is included in vulnerability (Manyena, 2006). In this process, resilience is defined in terms of taking responsibility for continuous learning and making better decisions to improve the capacity to cope with hazards (Cutter et al., 2008). In the diagrams shown in Figure (11), some researchers say that resilience and adaptive capacity are inseparable (A) (Adger, 2006; Folke, 2006), while others see adaptive capacity as a part of vulnerability (B) (Burton et al., 2002; O'Brien et al., 2004). A third perspective sees these concepts as intertwined within a general vulnerability structure, as in (C) (Gallopin, 2006; Turner et al., 2003). According to Cutter et al. (2008), adaptive capacity is an integral feature of the concept of resilience in terms of Global Environmental Change, but adaptive capacity is less important in the Hazard Perspective.

Within the context of natural hazards, the definition of resilience has been revised to mean the ability to survive and cope with a disaster with minimal impact and damage (Berke and Campanella, 2006). Resilience research often focuses on engineering and social systems and includes pre-event measures to prevent hazard-related damage and post-event strategies to help cope with and minimize disaster impacts (Bruneau et al., 2003). In part (D), where vulnerability covers resilience, it is considered a result when resilience is defined as the ability to return to or cope with a dangerous event (Manyena, 2006). However, determining whether resilience is a process, or an outcome is an important step in applying it to the hazard perspective. When comparing the hazard perspective with the global change perspective, hazard researchers often locate adaptive capacity within resilience (E) (Cutter, 2008; Bruneau et al., 2003). Resilience and vulnerability are considered as separate but often interconnected concepts (F). The concept of capacity has long been defined as the ability to confront ecological changes (Holling, 1973), while more recently "adaptive capacity" has been used in connection with the impact of climate change (Parry et al., 2007), as highlighted in definitions of resilience and vulnerability.

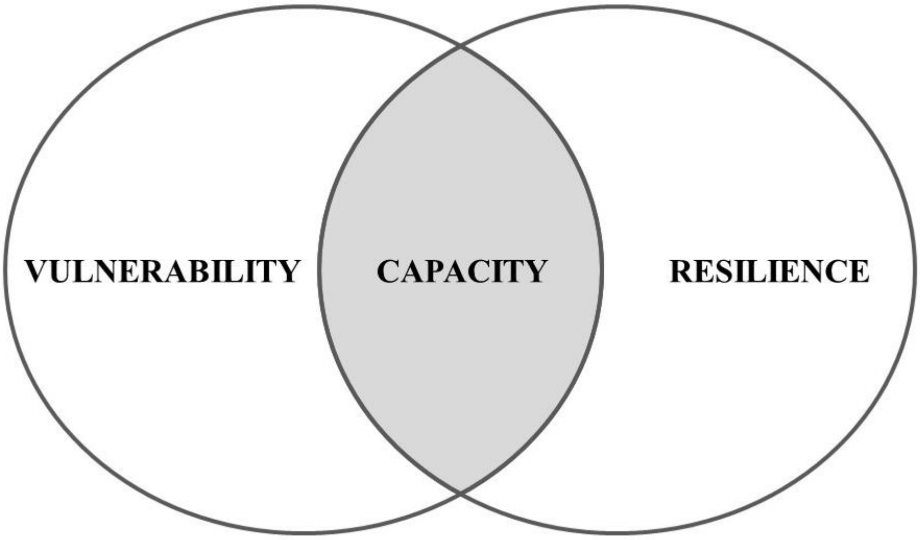

Figure 5: Conceptual linkages between vulnerability, resilience, and capacity prepared by author for the thesis

(Adapted from Cutter et al., 2008)

Although the origins of the terms coping and adaptive capacity are different in the literature, they are similar in terms of both resilience and vulnerability approaches (Cutter et al., 2008). Assessing capacity in the context of vulnerability involves a comprehensive examination of the factors that influence a system's ability to respond effectively to changing conditions and reduce vulnerability to harm or damage while increasing resilience. Through studies such as indicator frameworks, vulnerability assessments, and case studies, experts gain insight into the social, economic, environmental, and institutional dynamics that shape vulnerability, resilience, and capacity. The main aim of these studies is to provide an assessment of the relative vulnerability (and/or relative to capacity) of countries or regions, usually using some type of indicator, scoring, rating, or ranking procedure (Smit and Wandel, 2006). Therefore, surrogate measures of exposure or vulnerability and elements of adaptive capacity are estimated for each system and then combined to create an overall vulnerability "score" (or level or rating) for each system (Adger, 2006). By identifying vulnerabilities, understanding stakeholders' perspectives, and exploring best practices, interventions are developed to increase capacity, and promote resilience, and sustainable development in the face of uncertainty and change.

In conclusion, vulnerability and resilience are closely related ideas that influence how well people, communities, and systems can face and overcome disasters. Vulnerability draws attention to the potential for harm and detrimental effects, which are frequently determined by socioeconomic circumstances and resource accessibility. Resilience, on the other hand, is the ability to adjust, bounce back, and even flourish in the face of difficulties. As a result of the theoretical research stronger resilience can reduce vulnerability, but a lack of resilience can increase it. These two ideas have an inverse connection.

2.1.4. Vulnerability and Its Dimensions

After discussing the vulnerability in related terms, its development and dimensions are discussed in this section. The term vulnerability is defined as the risk factor of a subject or system that is exposed to threats and addresses the fragility of the subject or system (Blaikie et al., 2004; Downing et al., 2005). Many scholars argue that although the idea of vulnerability is associated with various academic topics, vulnerability is mostly socially constructed. (Adger and Kelly, 1999; Cutter et al., 2003). The idea of vulnerability has proven to be a powerful analytical tool to explain the susceptibility to damage, marginality of both social and physical systems, as well as to guide activities through the reduction of risk factors (Adger, 2006). It is imperative to define and measure vulnerability in order to better understand the factors that cause risks to turn into disasters

(Armaş, 2012). Disasters are potentially destructive natural processes and occur when they encounter elements at risk and the corresponding physical, social, built environment and environmental vulnerability (Birkmann, 2006).

The idea of vulnerability has developed into a concept that offers powerful explanations for variations in the severity of harm sustained by natural disasters that manifested for a single person, a community at large, a city, or an entire area (Hufschmidt, 2011). According to Timmermann (1981), who established the statement more than 20 years ago, *"vulnerability is a term of such broad use that it is almost useless for careful description at the present, except as a rhetorical indicator of areas of greatest concern*." According to Liverman (1990), the words *"vulnerability"* and *"marginality," "susceptibility," "adaptability," "fragility,"* and *"risk"* have all been used to describe or quantify vulnerability. Today, vulnerability has been defined, examined, and applied in a variety of ways. This is partly due to the requirement to work within a particular environmental and social context and partly because a variety of disciplines have entered this research field and have brought with them their own ontologies, definitions, and methodologies (Hufschmidt, 2011). Particularly, as the human dimensions of disaster research have gained popularity, the emphasis on vulnerability has gradually shifted from focusing on the physical vulnerability of environmental systems to placing importance on researching the social vulnerability of human society (Lei et al., 2014). Social and physical vulnerability arises from a combination of individual, environmental and systemic factors that can make certain individuals or groups more susceptible to harm or adverse events. For instance, Cutter et al. (2003) highlighted social vulnerability from a natural hazard perspective and presented three key principles in vulnerability research: *"the exposure conditions that make people or places vulnerable to extreme natural events"; "societal resistance or resilience to hazards"* (Kasperson and Kasperson 2001); *"and the integration of potential exposures and societal resilience with a specific focus on particular regions"* (Cutter and Finch 2008).

In general, the definition of vulnerability indicators is vital as the indicator is defined as a variable that is an operational representation of a feature or quality of a system that can provide information about the vulnerability, coping capacity and resilience of a system associated with a hazard of natural origin (Birkmann, 2006). However, the assessment of vulnerability constitutes the most important data in assessing the vulnerability of an element at risk (Birkmann, 2006). The methodology and potential difficulties of defining various indicator categories have been examined in several research studies (e.g., Davidson and Shah, 1997; Bruneau et al., 2003; Birkmann, 2007). As Davidson and Shah (1997) mentioned, vulnerability factors (dimensions) are not separate classes, and there are many interactions and overlaps with contradictions between indicators belonging to different classes. Although there are difficulties in categorizing vulnerability, indicators against earthquake hazards are divided into three main classes: (a) physical indicators such as buildings (including structural elements, occupancy and age factors), (b) social indicators, including demographic information, and socio-economic (Cutter et al., 2003; Adger, 2006) and (c) built environment indicators that relate to the characteristics of systems directly exposed to hazards, i.e. infrastructure and lifelines and the capacity of the built environment, resources, structures, (transport infrastructure, "utility" lifelines and "essential" lifelines) (Mileti, 1999; Messner and Meyer, 2006; Roberts et al., 2009; Balica et al., 2012). Although the indicators are in different classes in the original studies, they refer to the same or very similar aspects (Agliata et al., 2021).

As interdisciplinary approaches have entered the field, vulnerability has shifted its focus from the physical vulnerability and capacity of the environmental systems to the social vulnerability of human society. Understanding physical vulnerability, social vulnerability and capacity of built environment is vital in addressing disaster impacts of hazards, especially the highly destructive ones such as earthquakes. By investigating the interplay of individual, environmental, and systemic factors, efforts can be directed toward reducing harm and enhancing the resilience of vulnerable communities. When evaluating in general, the concept of vulnerability changes over time and turns into broader perspectives, and the concept sets are gradually developing. To reduce the damage caused by hazards, in this chapter, the physical vulnerability, social vulnerability and capacity of built environment dimensions against earthquake hazards are discussed.

2.1.4.1. Physical Vulnerability

When comparing it to earthquake hazards the notion of physical vulnerability becomes a one of the crucial dimensions. Earthquakes offer a special and severe threat to the physical structures in our built environment as well as to the larger environmental context because of their rapid and frequently devastating shocks. While natural disasters will continue to occur, as noted by Dwyer et al. (2004), their ability to turn into a catastrophe or merely a manageable event depends on a variety of elements, including the hazard’s size, the vulnerability of people, political institutions, and the built environment.

Physical vulnerability is the most thoroughly researched part of vulnerability science, because physical vulnerability is more easily measurable than social vulnerability (Notaro et al., 2014). Historically, researchers have done a lot of work to assess and improve physical vulnerability (Douglas, 2007; Carreño et al., 2007) and recent attempts have been made to improve the quantification of social vulnerability (Roberts et al., 2009; Yücemen et al., 2004;). The combination of the vulnerability of exposed elements and the potential for natural hazards to cause damage forms the basis of physical vulnerability (Papathoma-Köhle et al., 2017; Pereira et al., 2020). There is no one or similar methodology for assessing physical vulnerability (Papathoma-Köhle, 2016; Glade and Crozier, 2012 as cited in Leal et al., 2020), and this can be explained by several reasons: (a) the term's lack of a fixed definition, its scope and complexity (Gaume et al., 2009; Fuchs, 2009 as cited in Leal et al., 2020); (b) the complexity and difficulties of using similar methods to assess vulnerability to different natural hazards (such as floods, tsunamis, earthquakes) (Kappes et al., 2012 as cited in Leal et al., 2020); (c) different measurement of factors affecting vulnerability, quantitatively or qualitatively (Fekete, 2009 as cited in Leal et al., 2020); (d) different temporal and spatial scales (national, regional and local) used for vulnerability assessment (Birkmann, 2007; de Moel et al., 2015; Fekete et al., 2010; Marchi et al., 2010 as cited in Leal et al., 2020); (e) lack of data on damage from past disasters (Papathoma-Köhle et al., 2011 as cited in Leal et al., 2020); and (f) reduced data collection time in the field due to the intervention of technical services to restore the infrastructure security and basic functions of cities and the system (Ettinger et al., 2016 as cited in Leal et al., 2020).

Indicator selection gains importance, especially in areas where there is a lack of data, as the characteristics of the elements revealed in vulnerability assessments regarding the physical vulnerability of buildings and the built environment vulnerability are often not considered (Papathoma-Köhle et al., 2019; Malgwi et al., 2020; Fuchs et al., 2019; Cristofari, et al., 2019). Indicators of physical vulnerability of buildings are as follows: occupancy and structural type (Kircher et al., 2006), foundation (type and depth) (Uzielli et al., 2015; Pereria et al., 2020), building environment (i.e. presence of nearby elements)

(Kappes et al., 2012; Singh et al., 2019), number of floors (Stephenson and D'Ayala, 2014; Singh et al., 2019; Agliata et al., 2021), construction material, age (or year of construction) (Silva and Pereria, 2014; Singh et al., 2019), and plan irregularity (Sucuoğlu and Yazgan, 2003; Rajarathnam and Santhakumar, 2015; Joshi et al., 2019). Along with all these indicators, some indicators from the FEMA (2015) report were also added from the title "FEMA Building Type". Maintenance condition, material quality, wall type, mortar type, weak and/or soft story in vertical irregularity indicators are divided into classifications within themselves (FEMA, 2015). And basically, these indicators taken from FEMA (2015) report were created with "rapid visual screening" technique. FEMA P-154 Report, Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook is a report containing the recommended methodology for rapid visual screening of buildings for potential seismic hazards.

With all this, the assessment of the vulnerability of a structure provides an indication of whether a detailed assessment and strengthening is required. Numerous procedures and methods are available in the literature for the physical vulnerability assessment of existing building stock (Khan et al., 2019). These range from the most complex procedures based on finite element analysis of buildings to simpler ones such as the Rapid Visual Secreening procedure based on "sidewalk survey" from the street or inside a building (FEMA, 2015; Khan et al., 2019). Rapid Visual Secreening (RVS) is relatively inexpensive, and a large number of buildings can be surveyed in a limited time. Researchers have developed and used the RVS procedure worldwide for the vulnerability assessment of buildings (Khan et al., 2019). Essentially, this method is based on an observation survey from the street or inside a building, where a trained expert determines the load-resisting system and captures some of the attributes that negatively or positively affect the seismic performance of a structure (FEMA, 2015; Khan et al., 2019). These attributes include vertical irregularity, cracks, wall openings, building height, construction quality, etc

Detailed explanation of these indicators:: structural type includes building type, material, age, and number of floors (Giovinazzi and Lagomarsino, 2004; Kircher et al., 2006; Porter et al., 2008; Duzgun et al., 2011). These indicators are also defined within themselves. Building materials were divided into three categories by Papathoma-Kohle et al., (2007): (a) concrete (most resilient), (b) masonry (medium resilient), and (c) others considered weak materials (least resilient). Building occupancy refers to the type of building use, such as industrial, commercial, or residential. Another indicator is the configuration of the building. Even if the structure is built with high earthquake resistance on its own, if it is built adjacently and there is not enough space between the buildings (Kappes et al., 2012; Stephenson and D'Ayala, 2014) it is anticipated to experience more damage than a detached building due to the impact of collision in an earthquake that may occur (Kreibich et al., 2010).

Structures with different dynamic characters have different oscillation periods during an earthquake. During an earthquake, if these structures are built adjacent to each other and there are not enough joints left between them, they crash into each other and cause severe damage (Kappes et al., 2012; Stephenson and D'Ayala, 2014; Silva and Pereria, 2014). Considering the age of the building, it is seen that it has a wide place and reference in the literature. Observing that construction techniques evolve as science and technology advance, it is assumed that new buildings will be less affected than old ones, because old buildings have completed their expected service life (Singh et al., 2019). Another important reason for the building age is that new buildings are subject to updated earthquake regulations and improved building codes. Experts interpret and use the number of floors differently depending on what building feature and diagnosis they are aiming for (Agliata et al., 2021). However, they think that the number of floors can be a measure of the height of the building or a clue to the depth of the foundation (Singh et al., 2019). Since the depth for the building cannot always be measured easily and directly, the number of floors has been used as a representation for the estimation of foundation depth (Silva and Pereria, 2014). From this perspective, it has been assumed that a one-story building is more prone to destruction by the pressure of unstable materials than a two- or more-story building, which typically has deeper foundations (Pereira et al., 2020; Silva and Pereria, 2014; Singh et al., 2019). It is vital to have access to these areas in case of potential threats. Basically, maintenance of buildings is related to the maintenance and condition of the building. The maintenance of a building is necessary to ensure that all elements of the building are in good condition to fulfill their function (Kappes et al. 2012; FEMA 2015). Especially in hazardous areas, it is important to ensure that the design and construction of a building complies with building codes to assess its vulnerability (Sucuoğlu and Yazgan, 2003; FEMA, 2015). Another indicator is the wall type. Structures with stone walls are more vulnerable because they are not interlocked (Aliabadi et al., 2015). The type of mortar used in conjunction with the wall type is equally important. Walls built using mud as mortar are more vulnerable due to improper bonding (FEMA, 2015; Khan et al., 2019). The presence of a fost or weak stıry occurs when a floor has less strength (less walls or columns) than the floor above or below it, and this causes vulnerability (FEMA, 2015). In the light of all this, the indicators obtained as a result of the literature review examined were collected in a Table (1) to be measured as data.

Table 1: Physical Vulnerability Indicators

Vulnerability Dimensions	Indicators	References
Physical Vulnerability	Building material/type	Aliabadi et al. (2015), Silva and Pereria (2014), Papathoma-Kohle et al. (2007), Stephenson and D'Ayala (2014), Uzielli et al., (2015), Kappes et al. (2012), Papathoma-Kohle (2007, 2016, 2019), Singh et al. (2019)
	Building Age	Sucuoğlu and Yazgan, (2003), Uzielli et al. (2015), Singh et al. (2019), Pereria et al. (2020), Fekete et al. (2010)
	Vertical Irregularity	Sucuoğlu and Yazgan, (2003), Rajarathnam and Santhakumar (2015), FEMA (2015)
	Plan Irregularity	Joshi et al. (2019), Sucuoğlu and Yazgan, (2003), Rajarathnam and Santhakumar (2015)
	Number of Stories	Sucuoğlu and Yazgan, (2003), Silva and Pereria (2014), Papathoma-Kohle et al. (2007), Pereria et al., 2020 Papathoma-Kohle (2007, 2016, 2019), Singh et al. (2019), Kappes et al. (2012), Joshi et al. (2019
	Building Occupancy	Kircher et al. (2006), FEMA (2013a, b).
	Maintenance Condition	Kappes et al. (2012); FEMA (2015); Khan (2019)
	Foundation (type and depth)	(Uzielli et al., 2015; Pereria et al., 2020)
	Construction Quality	FEMA (2015); Sucuoğlu and Yazgan, (2003), Uzielli et al., (2015),
	Wall type	Aliabadi et al. (2015),
	Mortar type	FEMA (2015); Khan (2019)
	Weak and/or Soft Story	FEMA (2015)

Physical vulnerability indicators provide a broad assessment of structural, functional, and operational vulnerabilities and reveal critical vulnerabilities in buildings. Simultaneous examination of building design, compliance with seismic building codes, and maintenance practices reveals physical and structural weaknesses in the city.

2.1.4.2. Social Vulnerability

In general, the possibility of loss is implied by vulnerability to hazards. Depending on the study approach and perspective, vulnerability in the literature on hazards can mean many different things (Dow, 1992; Cutter, 1996, 2001a). The identification of factors that make people vulnerable to extreme natural events, also known as an exposure model (Burton et al., 1993; Anderson, 2000); a measure of social vulnerability to hazards, with the assumption that vulnerability is a social condition (Blaikie et al., 1994 ; Hewitt, 1997) and the fusion of potential exposures and social vulnerability with a focus on particular regions (Kasperson et al., 1995; Cutter et al., 2000) are the three main pillar social vulnerability research. Social vulnerability has been a topic of worry for researchers and policymakers since the 1970s (Badmos et al., 2018). Furthermore, the idea of social vulnerability has developed from the fields of sociology and critical geography, and it attributes vulnerability to the fundamental socioeconomic structure (Biswas, 2023). Vulnerability is described by Cutter (1993) as *"the probability that a group or individual will be exposed to and seriously affected by a hazard."* As Cutter (1993) stated, it is the result of the relationship between hazards of place and communities' social profiles. These approaches briefly address physical and social vulnerability separately and explain how they are integrated together.

The theoretical understanding and quantitative approaches for evaluating vulnerability, and social vulnerability in particular, were significantly advanced by Cutter (1993, 1996, 2009) and Adger (1999, 2000, 2006). The concept's three phases of development have been identified by Cutter et al. (2009). First, the *"political ecology"* method in the works of O'Keefe et al. (1976); second, the *"political economy"* approach by Wisner et al. (2004); and third, the creation of the *"hazard-of-place"* model (Cutter, 1996). *"The political economy approach"* and the *"risk-hazard approach"* are the two classical methods for studying vulnerabilities. Additionally, its main features are consistent with the ‘geocentric’ and ‘anthropocentric’ methods to the study of criticality outlined by Kasperson et al. (1995) as well as the ‘direct’ and ‘adjoint’ techniques to evaluating hazardous impacts highlighted by Parry et al. (1988). The risk-hazard technique can be used to evaluate the threats to certain valuable elements (also known as exposure units) that result from their exposure to hazards of a specific kind and severity (Burton et al., 1978; Kates, 1985). People whose exposure to hazards is mostly governed by their conduct, as dictated by socioeconomic circumstances, find it more challenging to apply the risk-hazard approach (Füssel, 2007).

Social vulnerability has been defined as socioeconomic, institutional, and demographic characteristics of individuals, communities, or systems that reduce their capacity to prepare, respond, and heal from hazard or disaster (Solangaarachchi et al., 2012; Yoon, 2012; Siagian et al., 2014). From a more advanced perspective, social vulnerability can be improved if the nature of the underlying impacts of vulnerable society or people to hazards is understood, and interventions are targeted with the right timing and locations (Collins, 2009). As a result, Sherman et al. (2015) hypothesizes that communities’ vulnerability to hazards depends not just on how often they are exposed to them but also on their socioeconomic and demographic (such as age and gender) features. This causes the demographic and socioeconomic factors of a community to interact with hazards that may be natural but can still lead to disaster (Armaş and Gavriş, 2013). Change in people’s characteristics in relation to disaster consequences determines a situation of advantage or disadvantage. To understand this, the vulnerabilities of people and society must be addressed through social vulnerability measurement. Overall, social vulnerability arises as a result of spatial and social inequalities and is measured using social vulnerability indicators (Cutter et al., 2012).

Before considering social vulnerability measures in more detail, it is important to decide what to evaluate. Over the years, a prevailing consensus has developed on the key factors affecting social vulnerability (Mavhura et al., 2017). The most frequently cited are: *“lack of resources; limited access to political power; connecting with supportive people; weak and physically limited individuals;* (Cutter et al., 2003; Cutter and Finch, 2008; Wisner et al., 2004). Although there are several methods used to evaluate social vulnerability at various systems and dimensions, the indicator-based approach has been widely used in numerous countries to address certain hazards (Armaş and Gavriş, 2013; Chang et al., 2015; Siagian et al., 2014).

Social vulnerability indicators include health, poverty, income, race, age, employment, and housing type (Adger, 2006; Cutter et al, 2003; Kusenbach et al, 2010; Lee, 2014; McEntire, 2012). However, social vulnerability indicators also show exposure of various groups of people (e.g. old, young, women, men, etc.) in an area to natural disasters (Nguyen et al. 2017). A brief description of each indicator and its effects on vulnerability is provided below. A household can have only one person or a group of people living together. The definition of vulnerable households is based on the following indicators: female-headed households, households with disabled and elderly people, household with children-headed, low-income, poor and minority households (Tran et al., 2017). However, there are situations that make families more vulnerable. These are low-quality homes with low education levels, as well as low-income families with limited job skills, who are more socially vulnerable. Another reason for the high social vulnerability is immigration problems. High rates of migration cause service problems in settlements, and in addition, heterogeneous socio-cultural characteristics of the place of migration may aggravate the consequences of social vulnerability (Hejazi et al., 2022). In addition, many migrants do not have equal and favorable economic, social and educational conditions, as a result they are more likely to reside in poor neighborhoods and may therefore be more vulnerable (Hejazi et al., 2022). In all the crisis and disaster cycles that occur, women are more at risk than men. Cutter et al. (2003, 2008, 2012) and Armas and Gavris (2013) on the one hand, said that women are more vulnerable because of lower income and employment rates. Being a female head of households, they may be limited in providing adequate shelter due to their poor social and economic conditions, and these problematic conditions do not allow them to easily change their position in a crisis and take effective measures to protect themselves and their family members (Oswald, 2013; Khani et al., 2017; Dilshad et al., 2019). According to Llorente-Marron et al., (2020) female-headed households are more socially vulnerable than others.

Older adults have higher mortality rates during disasters and are therefore more vulnerable than other groups because of their poor physical condition (e.g. hearing and vision loss), chronic illness, and lack of ability to properly understand stimuli (Daddoust et al., 2018; Maltais et al., 2019; Siagian et al., 2014; Crowley, 2021; Mavhura, 2019a,b). Mortality statistics also support this information (Flanagan et al., 2011) as they have limited abilities in evacuation and response times and cannot perceive warnings in times of hazards (Cecchini et al., 2017; Zhou et al., 2014). Children, like the elderly, are more vulnerable because they have less ability to cope with hazards (Cutter et al., 2003; Flanagan et al., 2011; Mavhura, 2019a,b). Children under the age of five and individuals over 65 are likely to depend on others for safety, financial support, and medical care, making them also likely to be more vulnerable to disasters, according to research by Farin et al., (2017).

The literacy rate of women becomes more important in times of crisis, as women often must take on the responsibility of preparing, restructuring, and caring for other family members in difficult situations (Cutter et al. 2012). Therefore Rabby et al. (2019), states that education, which has a role in empowering women, effectively reduces social vulnerability. Although the relationship between education and vulnerability to disasters is not fully understood, it is generally accepted that it has an impact on vulnerability. People with higher levels of education can better cope with the problems caused by disasters because they have greater access to resources and better understanding of instructions (Wood et al., 2010). Those who are educated are often less vulnerable in post-disaster situations due to greater awareness of rescue information and resources. People's low education limits their ability to understand warning information and their access to rescue information (Mutarrank & Wolfgang, 2014). Education, as represented by literacy rates and high school completion, is often associated with socioeconomic status; people can reach higher awareness with higher educational attainment (Zhou et al., 2014).

Data from the Emergency Events Database (EM-DAT) indicates that when countries are classified by income levels, there are discernible differences in the impacts of disasters, suggesting that economic factors can also be shown to alter vulnerability (UNDRR, 2019). Low-income countries report higher deaths from disaster events, while higher-income countries have lower numbers of people who are badly affected and killed by disasters (Lloyd et al., 2022). The employment rate indicator, similar to the unemployment rate, shows the economic status of households and individuals. The relevance of this indicator to vulnerability is explained as follows: a low employment rate means that residents cannot afford such things as insurance, housing rehabilitation, remodeling, and healthcare (Hejazi et al., 2022).

In addition to women, the elderly, and children, Cutter et al. (2012) argue that physically or mentally disabled people are vulnerable to disaster hazards that may occur. Vulnerable disability groups include people with disabilities such as hearing, speech, vision, mobility, epilepsy, mental disabilities, and other chronic health problems (Mavhura and Manyangadze, 2021). Individuals with disabilities (physical or mental), partial movement and similar restrictions, access to disaster information, and other difficulties in understanding warnings become more vulnerable, similarly, households headed by women or children and the elderly are a more vulnerable group in preparing for disasters and reducing the effects of disasters (Mavhura, 2019b). Groups with disabilities depend on others for their special needs and need to be taken care of during disaster preparedness, response, and recovery (Mavhura and Manyangadze, 2021). The vulnerability of these groups is exacerbated by the large household sizes, the crude birth rate (CBD), and the absence of social protection programs such as retirement, education, and health insurance. When all this is considered, people with disabilities are much more vulnerable to natural disasters (Mavhura & Manyangadze, 2021).

According to Cutter, social vulnerability is fundamentally the product of social inequalities (Cutter et al., 2003). Another characteristic that affects social vulnerability is the characteristics of households and race, immigrants, minority groups and unemployed people. Female-headed households, low-income households, and minority households are defined as relatively more vulnerable than other households (Cutter et al., 2003; Tran et al., 2017). According to Llorente et al (2020), female-headed households are more socially vulnerable than others. One of the biggest reasons for this is that women are economically disadvantaged as heads of households (Cutter et al., 2003; Llorente et al., 2020). Generally, household elders, especially female-headed households, appear to be more vulnerable as they are held responsible for the increasing cost of raising children, economic disadvantage, and the burden of care in disasters (Llorente et al., 2020).

In addition, race is another indicator of social vulnerability as a result of economic and social marginalization, along with lack of access to resources often associated with cultural differences and racial inequalities (Cutter et al., 2003). Another indicator is high immigration rates. High migration rates aggravate the consequences of social fragility in terms of the heterogeneous sociocultural characteristics of the region and lead to service problems in districts and settlements (Cutter et al., 2003; Guadagno, 2016). According to Guadagno (2016), immigrants' limited access to resources, information, and assistance services reduces their ability to cope with disasters, and many immigrants are considered more vulnerable as they lack appropriate social (educational) and economic conditions and are more likely to reside in poor neighborhoods (Garetz and Montz, 2014).

Socioeconomic status is measured by poverty and unemployment rates and is associated with the post-disaster situation as well as the ability to absorb losses (Zhou et al., 2014). Populations with high rates of unemployment and low socioeconomic status do not have sufficient financial resources to purchase supplies in the event of a possible disaster, and they lack access to social assistance plans that can provide this assistance (De Silva and Kawasaki, 2018). Other important indicators are high birth rates and median age. High birth rates have a positive effect while median age has a negative effect (Cutter et al., 2003).

Table 2: Social Vulnerability Indicators

Vulnerability Dimensions	Indicators	References
Social Vulnerability	**Rate of elderly population**	Cutter et al. (2000), Farin et al. (2017), Daddoust et al. (2018), Maltais et al. (2019), Siagian et al. (2014), Crowley (2021), Mavhura (2019a,b), Mavhura and Manyangadze (2021), Alizadeh et al. (2018), Armas (2012)
	Rate of Children Population	Cutter et al. (2000), Cutter et al. (2003), Flanagan et al., (2011), Cutter (2008), Farin et al. (2017), Mavhura (2019a,b), Mavhura and Manyangadze (2021), Alizadeh et al. (2018), Armas (2012)
	Rate of Women Population	Cutter et al. (2003, 2008, 2012), Armas (2012), Armas and Gavris (2013), Mavhura and Manyangadze (2021),
	Average Income	Zhou et al., (2014), (De Silva and Kawasaki, 2018), Cutter et al., (2003, 2008, 2012),
	Literacy rate	Cutter et al. (2012), Rabby et al. (2019), Hejazi et al. (2022), Alizadeh et al. (2018)
	Rate of population with a high school education	Armas and Gavris (2013), Wood et al. (2010), Zhou et al. (2014), Mutarrank & Wolfgang (2014), Martins et al. (2012)
	Rate of population with university education	Armas and Gavris (2013), Wood et al. (2010), Zhou et al. (2014), Mutarrank & Wolfgang (2014), Martins et al. (2012)

(cont. on next page)

Table 2 (Cont.)

Social Vulnerability	**Rate of the population receiving social support**	Produced by the author within the scope of the study
	Rate of patients receiving home care	Produced by the author within the scope of the study
	Rate of disabled person	Mavhura and Manyangadze (2021)
	Rate of Female-Headed Households	Cutter et al., (2003, 2008, 2012), Tran et al., (2017), Llorente et al., (2020)
	Rate of Elderly-Headed Households	Cutter et al., (2003), Mavhura (2019)
	Rate of Children-Headed Households	Cutter et al., (2003), Mavhura (2019)
	Race	Cutter et al., (2003)
	Rate of Immigrants	Cutter et al., (2003), Garetz ve Montz, (2014), Guadagno (2016),
	High Birth Rate	Cutter et al., (2003)
	Median Age	Cutter et al., (2003)
	Unemployment Rate	Zhou et al., (2014), (De Silva and Kawasaki, 2018).

In summary, from a social vulnerability perspective, an assessment is required of both the physical nature of the hazards and the social conditions that contribute to vulnerability. Assessing the spatial dimention of social vulnerability across hazard areas can contribute to identifying the susceptibility of individuals to the combined and cascading effects of hazards, providing better local facilities, and building a safer community. Social vulnerability assessment also helps identify the strengths and weaknesses of communities in the risk management process and highlights their strengths.

2.1.4.3. Capacity of Built Environment

Vulnerability is a function of the transformation and perturbation the system undergoes and the exposure of this system to perturbation, as well as the capacity of the system (Gallopin, 2003). The capacity of built environment is as important as the physical vulnerability of buildings. Shafapourtehrany et al., (2022) stated that the built environment dimension is the most concrete dimension of the urban planning's function of minimizing the earthquake effect. There are several indicators to understand the vulnerability of the built environment. There are the following indicators in the literature: population density (Kamranzad et al., 2020; Yariyan et al., 2020), distance from main roads (No et al., 2020), distance from police stations (Han et al., 2021), distance from hospitals (Han et al., 2021), fuel stations (Hirayama et al., 2018), distance from fire stations (Liu, 2020), distance from faults (Onder et al., 2004), commercial building density (Crowley et al, 2020), residential building density (Bahadouri et al., 2017) building density (Fischer et al., 2002). These criteria have a remarkable effect on reducing or increasing the effects of damage caused by earthquakes. These built environment indicators are also related to capacity. Capacity measurement at city level against hazards was achieved using two different criteria: level of preparedness (expressed as average distance to hospitals, fire stations and police stations); the distance to and accessibility of green and barren areas (considered suitable shelter during hazardous events) (Dwyer et al., 2004; Dayton-Johnson, 2004; Birkmann, 2006).

Along with these environmental characteristics, the population density living there should also be considered. The most vital structural and non-seismic factor that helps assess vulnerability is population density, and living close to a fault can have negative consequences (Hassanzadeh et al., 2013). In addition, rapid population growth, population density, and unequal distribution of resources increase the risk to society (Hassanzadeh et al., 2013). Building density is another important indicator. The increase in dwellings results in minimizing open spaces for escape and circulation, therefore, minimizing densely populated areas and increasing the space for free movement will minimize vulnerability (Cutter et al., 2000). In addition, the collapse of dense buildings during the earthquake blocks the roads and this causes a big problem in the event of a disaster as it blocks transportation (Hosseini et al., 2009). With this indicator, commercial building density is also very vital. Areas with a density of commercial buildings are both an economic and physical necessity and are used as a measure of economic welfare, so despite the economic benefits, the vulnerability during earthquakes increases due to the density of population who trade and make shopping in these centers (Shafapourtehrany et al., 2022). The building density generated by these two indicators plays an important role in vulnerability. The distance or proximity of these buildings from the location(s) with significant tectonic activity plays an important role in the assessment of seismic sensitivity, as it determines the risk of injury and death to persons associated with these buildings during earthquakes (Shapira et al., 2018). In assessing how vulnerable residential and commercial buildings are, it is necessary to know whether the infrastructure of these buildings is capable of withstanding seismic forces, so it can be understood whether these buildings will collapse at the risk of earthquakes (Shapapourtehrany et al., 2022). Due to the increase in building density and improper land use, open spaces have become minimal. As a result, the area of escape and shelter is minimized (Shapapourtehrany et al., 2022).

Another indicator to consider is the distance to critical facilities and structures. Roads, one of the most important features of a city, are very important in carrying out rescue operations such as transporting injured people and delivering goods after an earthquake (Yariyan et al., 2020). Roads and inner-city streets seem to be the main means of moving people and goods in times of disaster and hazard (Yariyan et al., 2020). Analysis of road networks is an important factor, as the level of service plays an important role in mobility when an earthquake occurs (Shafapourtehrany et al., 2022). Police stations are recognized as essential service providers to the community when earthquakes occur. The distance factor from police stations is considered at the level of preparation (Armas, 2012). In order to save as many lives as possible in the event of an earthquake, police need to facilitate urban search and rescue activities appropriately by maintaining social order (Tantala et al., 2008). Critical facilities such as hospitals, fire stations and police stations need to remain operational for post-earthquake response operations (Shapapourtehrany et al., 2022). These facilities are responsible for providing basic services to earthquake victims and quickly recovering the affected area. For this reason, in order for critical facilities to remain operational, buildings must be made fully functional and structurally appropriate. Otherwise, failure to intervene will mean an increase in social and economic losses. (Shapapourtehrany et al., 2022).

The distance to hospitals, schools and other public buildings, the critical facilities, is another important factor. The first day after an earthquake occurs is the most critical day for rescue operations, saving lives and reducing serious injuries, and this indicator is very important for post-earthquake disaster management (Karimzadeh et al., 2014; Han et al., 2021). Reliable access to health services, such as hospitals, decreases vulnerability against earthquake hazards and helps contain post-emergency impact (Han et al., 2021; Shafapourtehrany et al., 2022). Another critical facility is fuel stations. They may not pose a danger under normal conditions, but they cause loss and damage due to their characteristics in the event of a disaster (Shafapourtehrany et al., 2022) Since there are flammable and explosive materials in these critical facilities with the earthquake, the probability of explosion and fire is very high, and in such a case, the risk in the surrounding areas gets worse (Bahadori et al., 2017). Losses caused by earthquakes can often be caused by fire that occurs with seismic events. The severity of fires after an earthquake depends on several factors: the source of the fire, weather conditions, and how susceptible the buildings are to fire (Sarris et al., 2010). While the primary cause of death is the collapse of buildings, the second most common cause of damage is fire (Tantala et al., 2008). Rescue operations can be accelerated if there is access to fire stations, one of the critical facilities (Duzgun et al., 2011).

Considering all these negativities, another important issue is related to open and green areas. The demand of people to live in the city and the dense settlement of buildings expose green areas to the risk of exploitation instead of protecting them (Hogberg-Yilmaz, 2020). In response to this demand, more housing and transportation options are provided to the growing population, while supporting the development of the city, on the other hand, this development has started to pose a threat to green areas (Hogberg Yilmaz, 2020). The scarcity of green and open areas and the difficult and limited access to these areas pose a major problem in the event of an earthquake (Hogberg Yilmaz, 2020). Open lands, parks and green areas in major cities are also strategic areas that strengthen the city's ability to cope with earthquake disasters and other natural disasters. They create open rescue zones in the city that provide shelter and other supplies to people in the event of a disaster (Jabareen, 2013).

Table 3: Capacity of Built Environment Indicators

Vulnerability Dimensions	Indicators	References
Capacity of Built Environment	**Population Density**	Hassanzadeh et al. (2013), Kamranzad et al. (2020), Yariyan et al. (2020)
	Building Density	Fischer et al. (2002), Cutter et al. (2000), Shapira et al. (2018), Shafapourtehrany et al. (2022)
	Residential Building Density	Bahadouri et al. (2017), Hosseini et al. (2009), Shafapourtehrany et al. (2022)
	Commercial Building Density	Crowley et al. (2020), Shafapourtehrany et al. (2022)
	Green Area Per Capita	Dwyer et al. (2004), Dayton-Johnson (2004),
	Distance to Faults	Onder et al. (2004), Alizadeh et al. (2018), Shafapourtehrany et al. (2022)
	Distance to Main Roads	Dwyer et al. (2004), Yariyan et al. (2020), Shafapourtehrany et al. (2022), Hosseini et al. (2009)
	Distance to Police Stations	Dwyer et al. (2004), Dayton-Johnson (2004), Birkmann (2006), Han et al. (2021), Armas (2012), Tantala et al. (2008), Shafapourtehrany et al. (2022)
	Distance to Hospitals	Dwyer et al. (2004), Dayton-Johnson (2004), Birkmann (2006), Karimzadeh et al. (2014), Han et al. (2021), Shafapourtehrany et al. (2022)
	Distance to Fuel Stations	Bahadori et al. (2017), Shafapourtehrany et al. (2022)
	Distance to Fire Stations	Dwyer et al. (2004), Dayton-Johnson (2004), Birkmann (2006), Duzgun et al. (2011), Tantala et al. (2008),
	Distance to and Accessibility of Green and Barren Areas	Dwyer et al. (2004), Dayton-Johnson (2004), Birkmann (2006), Hogberg-Yilmaz (2020),

A comprehensive assessment of the vulnerability of the social, physical, and built environment, guided by a range of indicators, provides a holistic understanding of cities' susceptibility to earthquake hazards. Physical vulnerability indicators provide a broad assessment of structural, functional, and operational vulnerabilities and reveal critical vulnerabilities in buildings, infrastructure, and urban systems. These indicators address not only the structural, functional, and operational weaknesses of buildings and infrastructure but also the socioeconomic factors that shape the city's social vulnerability and the capacity of built environment. Evaluating healthcare accessibility, education levels, income inequality, and vulnerable populations highlights social vulnerabilities that can amplify the impact of seismic events. Simultaneous examination of building design, compliance with seismic building codes, and maintenance practices reveals physical and structural weaknesses in the city. In addition, factors such as the robustness of lifeline and transportation systems, accessibility to emergency services, and interconnectivity of critical infrastructure reveal functional and operational weaknesses of cities. Cities and communities can be more resilient to earthquake hazards by addressing these weaknesses. With these assessments, strategies can be developed, ranging from strengthening the city, structures, and the built environment to strengthening critical infrastructures.

2.2. Analytical Approaches

2.2.1. MCDM in Vulnerability Assessment

The concept of measuring or assessing vulnerability to natural hazards has been widely explored in natural disasters literature. Vulnerability assessment: it is the process of analyzing dimensions such as social vulnerability and physical vulnerability through structure analysis, stakeholder participation, and collection of information and data about a region or community. Physical vulnerability, one of the vulnerability dimensions, is related to indicators of the building level. Additionally, the capacity of built environment was considered as a dimension. On the other hand, social vulnerability is the measure of how vulnerable a community or population is to hazards, with the ability to respond to and recover from the consequences of hazards (Cutter and Finch, 2008). Since the concept of vulnerability cannot be measured directly, some authors have developed methods to measure it. In recent years, studies have begun to measure vulnerability with a series of indicators and indices (Birkmann, 2006). These methods are damage curves and fragility curves (PapathomaKöhle, 2016), and vulnerability indicators (Cutter et al., 2003). Vulnerability and damage curves are specific to the building type in the physical vulnerability dimension and focus on the physical vulnerability of structures to a particular hazard, while ignoring the coping capacity and social vulnerability of the community (Koks et al., 2015). In addition, it is equally important to evaluate a society's ability to recover from disasters and its ability to cope with them.

Consequently, many authors emphasize the need for a holistic understanding of vulnerability by integrating its different dimensions into an overarching framework with indicators (Birkmann et al., 2013; Fuchs et al., 2011). And alternatively, the third method, the indicator-based approach, is a newer method that highlights a multitude of indicators for the assessment of physical vulnerability and, with it, social vulnerability. This method emphasizes the selection of vulnerability indicators, weight assignment, and aggregation to develop the vulnerability index (Bera et al., 2020). Indicator-based methods are transparent and easy to use and understand (Zhang et al., 2017). Earthquake vulnerability indicators are widely used to assess social vulnerability (Fekete, 2009) and physical vulnerability (Kappes et al., 2012), as they do not require detailed data such as damage and fragility curves. Dwyer et al. (2004) used indicators in categories such as security, society, and shelter to measure vulnerability. These indicators are a criterion of physical, structural, and economic factors selected to measure vulnerability. The method they use for this is SVI. Dwyer et al. (2004) used the SVI to measure vulnerability with indicators of socioeconomic status, household, disability, minority status, etc. On the other hand, Armas and Gavris (2013) examined two multi-criteria methods SVI model and spatial multi-criteria social vulnerability index (SEVI model), which combine complex indicators aiming to reveal the social vulnerability of the city of Bucharest in the context of earthquakes. With these methods, statistical results are obtained with a spatial approach. However, most of these applied models are local, require a high level of expertise and are complex. Therefore, an effective, simple and flexible method that can be applied to this field of study is required for multidimensional (in the context of physical vulnerability, social vulnerability and capacity of built environment dimensions) vulnerability assessment against earthquakes. One of the most used methods for vulnerability assessment and analysis is the Analytic Hierarchy Process (AHP) from

MCDM (Fatemi et al., 2016). Multi-criteria assessment model for earthquake vulnerability in Victoria, British Columbia introduced a multi-criteria model to combine physical and social components (Walker et al. 2014). In this study, Walker et al. (2014) examined social and physical vulnerability together, and when examining physical vulnerability, it indicates the distance to hospitals and similar uses. Vulnerability scores form the resulting earthquake vulnerability map. This is a study that includes a more comprehensive vulnerability assessment.

Emerging from the field of operations research, MCDM focuses on creating computational and mathematical tools to help decision-makers evaluate various performance criteria subjectively (Zavadskas et al., 2014; as cited in Mardani et al., 2015). Top of Form Benjamin Franklin created one of the first research papers on multi-criteria decision-making when he released his study on the idea of moral algebra (Taherdoost & Madanchian, 2023). Following that, since the 1950s, several theoretical and empirical scientists have worked on MCDM methods to investigate their capacity for mathematical modeling. This has allowed them to develop a framework that can aid in organizing decision-making problems and producing preferences from alternatives (Zavadskas and Turskis, 2010; Zavadskas et al., 2012 as cited in Mardani et al., 2015; Taherdoost and Madanchian, 2023). This approach considers many quantitative and qualitative parameters that must be set to identify the optimal resolution (Taherdoost and Madanchian, 2023).

MCDM methods are utilized in manifold fields from energy to business, from planning to health areas. As a cerebral, multifaceted process, decision-making is a method for solving problems that seeks to ascertain a desired outcome while considering many factors (Taherdoost & Madanchian, 2023). This process can be either irrational or reasonable, and it can also make use of implicit or explicit assumptions that are impacted by a variety of biological, cultural, physiological, and social factors. Numerous approaches are available for problem-solving, and these approaches can be grouped based on several criteria. It is impossible to guarantee that applying a particular attitude with the same input data would produce the same outcome because each MCDM method has its unique calculating procedure for different options (Zlaugotne et al., 2020). The complexity of a decision-making process can be influenced by all these factors as well as intricacy and risk levels (Taherdoost & Madanchian, 2023). To choose the best decision-making approach for any kind of difficulty, it appears essential to comprehend the decision-making classification. MCDM can be categorized as Fig (6) in the first phase of the general categorization of MCDM approaches. MCDM can be simply categorized by several responses, as stated by Gal (1980; cited in Sabaei et al., 2015) and Korhonen et al. (1992; cited in Sabaei et al., 2015). The categories are 1- *"innumerable when the admissible answers are infinite",* and 2- *"numerable when the admissible answers are finite"*. According to Edwards and Barron (1994; as cited in Sabaei et al., 2015), all MCDM techniques can be broadly divided into two categories, which 1-(MADM): multi-attribute decision-making (MADM) and 2- (MODM) multi-objective decision-making. MADM or MODM: One of the most widely used approaches divides the criteria into two categories: (1) *"attributes"* and (2) *"objectives"*. In addition, Hwang and Yoon (1981; cited in Mardani et al., 2015) separated MCDM situations into two primary groups according to the range of possibilities. Consequently, (MODM) multi-objective decision-making and (MADM) multi-attribute decision-making are the two broad subcategories into which MCDM problems fall. There are two further names for the sub-groups: numerable (having finite admissible answers) and innumerable (having infinite admissible answers) (Taherdoost & Madanchian, 2023)

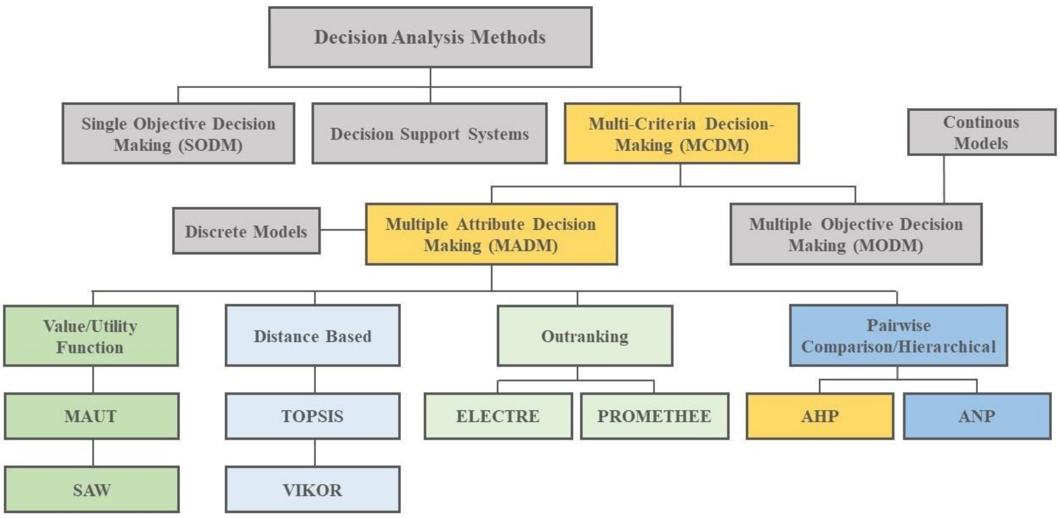

Figure 6: Method Decision Tree

(Adapted and prepared by the author from Hosseinzadeh et al., 2020)

MODM: MODM, often called continuous issues of decision-making, is concerned with continuous decision spaces that have an absolute number of possibilities. The solution to the decision-making problem is here thought to be a viable zone, or the place where the alternatives lie. There hasn't been a clear-cut solution selected for this optimization challenge (Taherdoost & Madanchian, 2023). Criteria are goals of these kinds, and attributes are implicit. Here, decision-makers engage extensively, and there is a high degree of clarity on limitations despite the lack of a precise aim and option (Taherdoost & Madanchian, 2023).

MADM: Discrete problems, another name for MADM, focus on issues with clearly defined, finite-number choice possibilities. It's an evaluation problem where the answer is selected from a limited set of options (Taherdoost & Madanchian, 2023). Goals, characteristics (which serve as criteria), and options are evident in these forms of MCDM; however, the constraints are not evident, and the decision-makers' degree of interaction is constrained (Taherdoost & Madanchian, 2023).

The choice options in the DM technique are chosen based on their qualities. Numerous MCDM methods and strategies have been put forth over time; they vary in terms of their theoretical underpinnings, the questions they raise, and the kinds of outcomes they produce. DMs in MADM choose, categorize, order, or prioritize a limited set of options before determining which is the outstanding option. Pairwise comparison, outranking, and distance-based approaches are the three primary methods used in MADM (Azhar et al., 2021). Pairwise comparison primarily entails evaluating and contrasting the relative weights of multiple criteria using a basic scale. Analytical Hierarchy Process (AHP) and Analytical Network Process (ANP) are frequently used in pairwise comparisons (Azhar et al., 2021). In addition, outranking techniques generate many options and determine whether one is more dominant than another (Kangas et al., 2001; as cited in Azhar et al., 2021). These methods work notably well when there is conflicting or insufficient information (Penadés-Plà et al., 2016; as cited in Azhar et al., 2021). The Preference Ranking Organization METHod for Enrichment of Evaluations (PROMETHEE) and ELimination Et Choix Traduisant la REalité (ELECTRE) are two examples of outranking techniques (Brans et al., 2015; cited in Azhar et al., 2021). By evaluating a solution's distance from the ideal point, distance-based techniques determine which solution is best: the one that is closest to the ideal point. The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) and VIseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) are two well-known distance-based methods (Hwang and Yoon 1981; as cited in Azhar et al., 2021). In the meantime, scenarios with several DMs and an endless array of options are handled by MODM. This method involves specialists selecting from a range of options only at the very end of the procedure (Azhar et al., 2021). Among the popular MODM techniques are Genetic Algorithm (GA) (Bharathi et al., 2017; Ma et al., 2018; as cited in Azhar et al., 2021) and Goal Programming (GP) (Tamiz et al., 1998; Özcan et al., 2017).

The following can be listed as studies in which AHP was applied; Ahadnejad (2011) tried to assess the social vulnerability of Zanjan City to earthquakes by using GIS analytical capabilities and the AHP method, one of the MCDM approaches. In another study, Ahadnejad (2009) measured susceptibility to urban earthquakes in a GIS system using the analytic hierarchy process (AHP). Servi (2004) prepared the earthquake risk map using a multi-criteria decision-making method based on mathematics and spatial information systems. Again, using a combination of MCDM approach and GIS, Keping et al. (2001) made a vulnerability analysis for natural disasters. As can be seen, different methods are currently used to assess the vulnerability of cities to earthquakes. Basically, in this research, Saaty's AHP, which is a multi-criteria mathematical evaluation method, was used in the decision-making process. One of the biggest reasons for this is that, because of combining the AHP method, which is one of the MCDM approaches, and GIS analysis, the earthquake vulnerability assessment of cities is made with higher accuracy.

2.2.2. Analytical Hierarchy Process

One of the most known multi-criteria decision-making methods (MCDM) is the Analytic Hierarchy Process (AHP). The oldest reference that was found belongs to Saaty’s works (Saaty, 1980). Besides, AHP has been inspired by several previous discoveries. As defined by Forman and Gass (2001), the Analytic Hierarchy Process (AHP) is a methodology for measurement, synthesis, and structuring. Numerous problem-solving cases have seen the use of the AHP, including forecasting, resource allocation, and competitive alternative selection in multi-objective environments (Forman and Gass, 2001). Geographic Information Systems (GIS) technologies are frequently preferred in making these and similar decisions, planning studies and multi-criteria analyses. The AHP method is widely applied in the analysis of multi-criteria problems. The weights of the criteria are determined according to comprehensive professional opinions and Saaty's fundamental scale (Chang and Chao, 2012). In an MCDM problem, the weight of each criterion represents the relative importance of those criteria (Saaty 1980, 1990, 2008).

AHP decision steps;

1. Defining the problem & objective of problem
2. Decomposition of the problem in a systematic hierarchy structure: Similar to a decision tree, different criteria are located at different levels. The problem is the most basic level, below this the key elements are determined, and below that the sub-criteria are determined. Depending on the problem structure, 3-4 different levels can be produced. As a general rule, the hierarchy develops from the general (upper levels) to the specific (lower levels), or from the uncertain or uncontrollable (upper levels) to the more precise or controllable (lower levels).
3. The pairwise comparison method is applied: Each group in the hierarchy forms a matrix. For n criteria, n(n-1)/2 pairwise comparisons are made. To compare the elements in this group, a survey containing a 9-point scale created by Saaty is usually applied, asking experts or decision makers which one is more important or effective
4. Relative weights are calculated for the component at each level of the hierarchy: These weights can be normalized to 1 or as a percentage in rows or columns, and the eigenvalue or geometric mean method can be used.
5. Consistency measurement is made. The consistency ratio should not be greater than 0.1.
6. Relative weights are used in different calculations in problem solving, depending on the decision maker's scenarios.

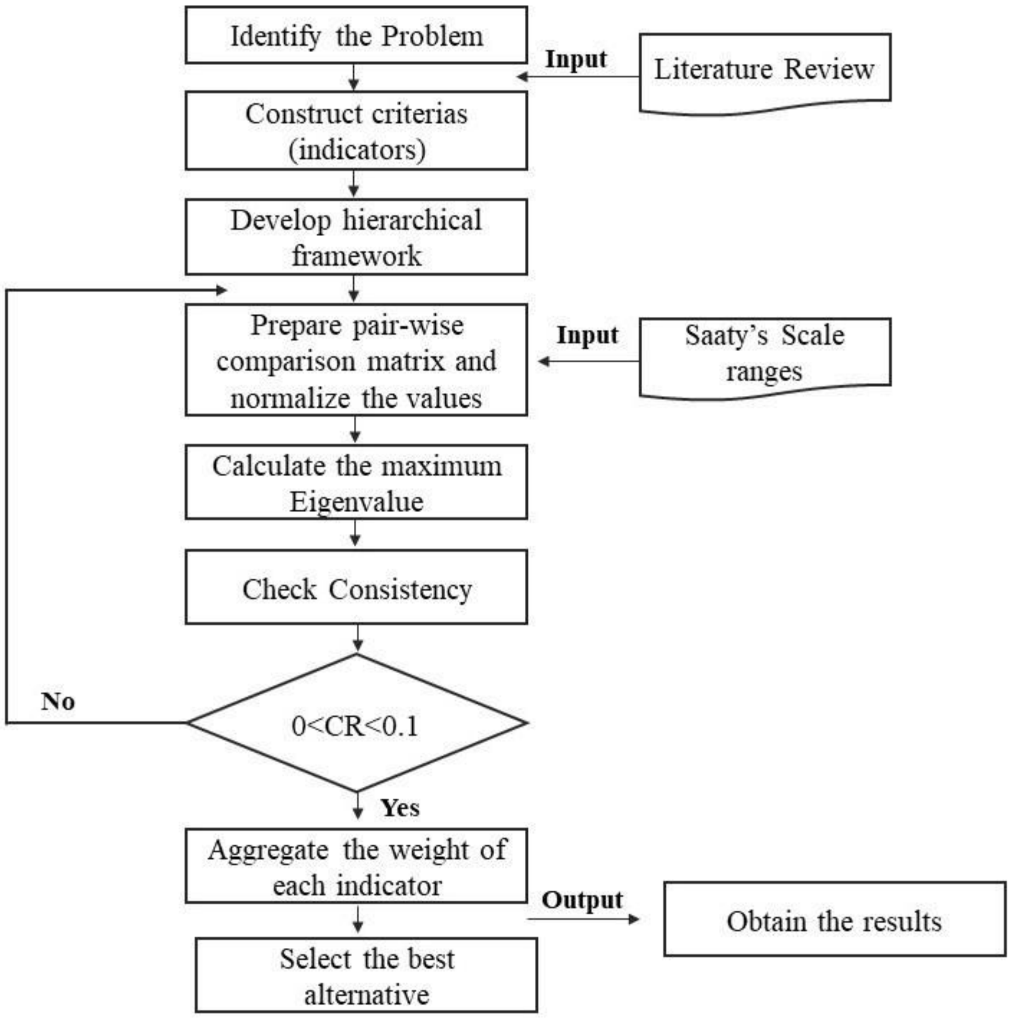

Figure 7: Flowchart of the method

(Adapted and modified by author from Saaty, 2008; 2012; Azhar et al., 2021)

One benefit of using AHP is that it allows for a hierarchical structure of the criteria, which helps users focus more intently on criteria and sub-criteria while allocating the weights (Ishizaka and Labib, 2011). Hierarchical structuring of criteria, an important feature of AHP, was first proposed by Miller in his doctoral thesis in 1966 (Ishizaka and Labib, 2011). The main use of AHP with this hierarchical configuration is the solution of selection problems in a multi-criteria environment. In summary, the AHP method involves a natural, pairwise comparison of goals and alternatives (Forman and Gass, 2001).

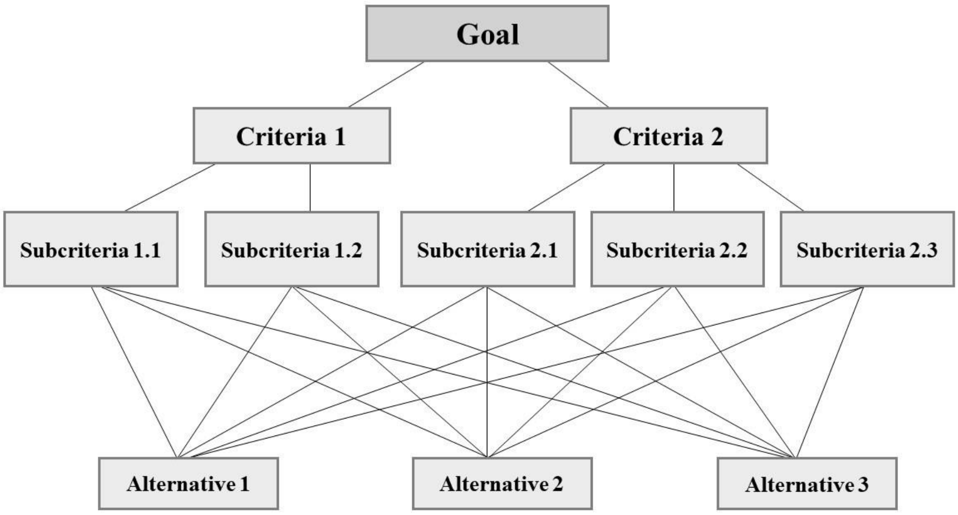

Figure 8: Hierarchical Decision Tree

(Adapted and modified by author from Saaty, 2008, 2012)

Transforming individual preferences into "ratio-scale" weights that are combined into linear additive weights for relevant alternatives forms the basis of the AHP method. And these resulting weights are used to rank the alternatives, then help the decision maker (DM) make a choice or predict the outcome of the problem (Forman and Gass, 2001). Unlike methods that use interval scales, AHP uses a ratio scale that does not require any units in comparison. With this, pairwise comparison matrices are created. Pairwise comparison matrices can be created by comparing middle and lower-level elements with higher level elements. Essentially, the pairwise comparison technique plays an important role in assessing the relative weights and importance levels of different criteria. Once the pairwise comparison matrices are created, *"the fundamental scale"* is used to evaluate the weight of the criteria (Azhar et al., 2021). There is a need for a number scale that shows how many times more important or dominant an element is than another in terms of the criterion or feature being compared (Saaty, 2008). The fundamental scale is used to make this comparison. (Saaty, 2008; 2012). With this basic 9-point numerical scale, AHP can simplify a complex system into a series of pairwise comparisons (Noble and Sanchez 1993; Mendoza and Prabhu 2000; Gomontean et al. 2008; as cited in Chang and Chao, 2012). The values in Saaty's basic importance scale used in pairwise comparison can be handled as follows; the value of 1 represents that both criteria are equally important, the value of 5 represents that one criterion is very important compared to the other criteria, and the value of 9 represents extreme important than the other criteria (Zlaugotne et al., 2020). In other words, the weights of the indicators given using the importance scale reveal the dominance and importance of each element compared to other indicators. As can be seen, this step is important because a different structure may lead to a different final ranking. In the AHP method, the pairwise comparison matrix created by evaluating the importance of the criterion relative to the other criterion is shown in Figure (9).

Intensity of importance on an absolute scale	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance of one over another	Experience and judgment strongly favor one activity over another
5	Essential or strong importance	Experience and judgment strongly favor one activity over another
7	Very strong importance	An activity is strongly favored and its dominance demonstrated in practice
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation
2,4,6,8	Intermediate values between the two adjacent judgments	When compromise is needed

Figure 9: The fundamental scale

(Adapted by author from Saaty, 1987 & Saaty and Vargas, 2012)

A pairwise comparison matrix was created by giving the weights in Saaty's fundamental scale. Assuming that the number of criteria in the pairwise comparison matrix is n, “n(n-1)/2” comparisons are made. The elements of the created pairwise comparison matrix obey the “reciprocal” rule. For example, while the importance of the first criterion relative to the second criterion takes the value 8, the importance of the second criterion relative to the first criterion is 1/8, the inverse of 8 (Saaty, 1987).

Once all the pairwise comparison matrices are created according to the rules mentioned above, the weight vector is calculated. The weight vector is calculated according to the eigenvector procedure of Saaty (1980, 2012). Calculating the weight vector involves two basic steps: First, normalizing the pairwise comparison matrix; The second is to calculate the weights from the normalized values (Saaty and Vargas, 2012).

Then, the pairwise comparison matrix is analyzed to calculate the weights of each criterion using the Eigenvector method. Eigenvector is a weight vector that expresses the relative importance of each criterion (Saaty, 2008; Saaty and Vargas, 2012). However, a mathematical algorithm is used to normalize and detect the corresponding significance of each matrix. The relative weights are obtained where the maximum eigenvalue (λmax) corresponds to the right eigenvector (w).

The λmax value is used to analyze whether the comparison between criteria is consistent. The λmax value serves as a basic coefficient in calculating the Consistency Ratio (CR) (Alizadeh et al., 2018). The consistency of the analysis is achieved by calculating the consistency ratio (CR) developed by Saaty (2000). To calculate CR, the Consistency Index (CI) must first be calculated. The most important issue for factor weighting in AHP is the consistency between decisions and weights. Verifying the consistency of judgments is fundamentally very important. Consistent judgments are required for the correct application of AHP to multi-criteria decision-making problems (Chang and Chao, 2012In fact, to evaluate the consistency of the evaluation when applying the AHP method, the consistency ratio (CR) is calculated by dividing the consistency index (CI) by the random index (RI) (Saaty 1987; 2008; Chang and Chao, 2012; Azhar et al., 2021). And as the result, the CR rate should be less than 10%. If this percentage value is exceeded, the procedure must be repeated to achieve consistency (Azhar et al., 2021). In this context, the Consistency Rate (CR) is obtained by dividing the Consistency Index (CI) by the Random Index (RI). RI is the coefficient value obtained from the pairwise comparison matrix randomly determined by Saaty (1980) (Saaty and Vargas, 2012). RI takes the values in the table depending on the number of compared criteria (n).

RI values depend on the number of criteria compared. As the number of criteria increases, RI values also increase. The CR value must be less than 0.1, that is, consistent. If the CR value exceeds 0.1, the pairwise comparison matrix becomes inconsistent and decisions in the pairwise comparison matrix must be reconsidered (Saaty, 1987; Saaty and Vargas, 2012). Details and formulas about the method are given in Chapter 4. The final stage of solving the problem is to make a composite weighting that will cover all levels. Ultimately, a comprehensive evaluation of each alternative is achieved by calculating the result of the weight given to each criterion and the corresponding score of the alternative according to that criterion, and then summing the results obtained.

CHAPTER 3

STUDY AREA & MATERIALS

3.1. Turkey’s Seismicity

The sudden vibrations that occur due to fractures in the earth's crust and spread in waves, shaking the environments they pass through, are called earthquakes (AFAD, 2019). Earthquakes are divided into two groups: tectonic and volcanic earthquakes. Earthquakes that occur as a result of the movement of plates within the earth's crust are called tectonic earthquakes. 90% of earthquakes that occur in the world are classified as tectonic earthquakes (AFAD, 2019). Turkey is located on the Alpine-Himalayan earthquake belt, which has fault lines that can produce devastating effects and large magnitude earthquakes due to its geographical structure (Aral and Tunç, 2021). The Alpine-Himalayan Earthquake Belt, one of the most important earthquake belts in the world, covers a large area from Indonesia to the Atlantic Ocean. In the seismically active Alpine-Himalayan seismic belt, many destructive earthquakes have occurred from the past to the present and continue to come. Turkey is also located within this seismic belt, and therefore, approximately 93% of Turkey's lands are seismically risky (Onat, 2022). The lands of our country are surrounded by three major earthquake belts, namely the North Anatolian Earthquake Belt, the Southeastern Anatolian Earthquake Belt, and the Western Anatolian Earthquake Belt (Şahin and Kılınç, 2016).

Turkey is a country located within the most active fault zones on earth and is always exposed to the danger and risk of major earthquakes. When the earthquake zone map of Turkey is taken as a basis, it is seen that 96% of the country's land is located within the zones with varying degrees of earthquake risk and 98% of the population lives in these zones. 66% of these regions are within 1st and 2nd degree earthquake zones, in other words, active fault zones (Gökçe et al., 2008). The Earthquake Map of Turkey, where these lines, which carry active seismic risk and are the cause of earthquakes in Turkey, are also clearly seen, is shown in the Figure (10).

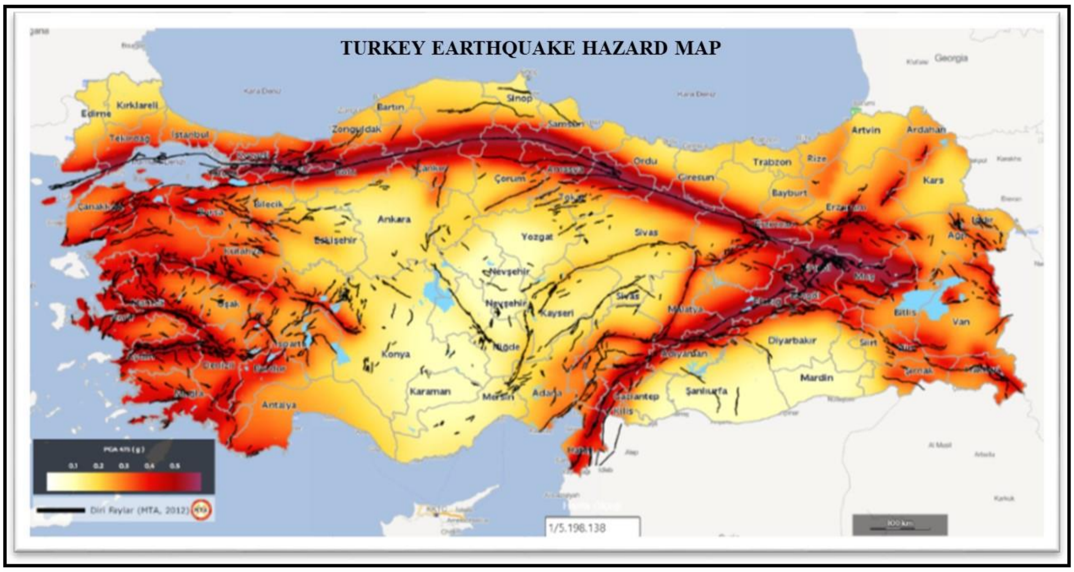

Figure 10: Turkey Earthquake Hazard Map

(Source: AFAD, 2024)

3.2. İzmir's Seismicity

Located in the Aegean region, İzmir is in the Mediterranean Earthquake Belt, which was formed as a result of the collision of the Eurasian, African and Arabian plates. The fault lines in İzmir are seismically active and continue to move, and as a result, tectonic earthquakes occur in the region. Active faults in this region can produce earthquakes between 4 and 8 magnitudes (Usta, 2016). Although the number of active faults in İzmir is high, earthquakes in the region are also caused by these faults. As a result of fault lines longer than 30 km, earthquakes larger than 6.5 occur. Fault lines in İzmir province are longer than 10 km, that is, if the faults break, earthquakes greater than 6 may occur in the region (Emre et al., 2005).

A significant portion of earthquakes occur as a result of tectonic activities. The seismicity of regions with different tectonic features also varies. It is important to define all these faults that have the potential to produce earthquakes in İzmir and its immediate vicinity and that may have a destructive effect on our city in more detail; to determine earthquake hazards, risks and effects; and to reduce the earthquake risk of İzmir. Since İzmir and its immediate vicinity are a region where many civilizations have ruled in historical times, there are many historical earthquake records for the region before the beginning of the instrumental period, which is accepted as 1900. The records reveal that most settlements in Bayraklı and its immediate vicinity were affected by many earthquakes in the historical period (TMMOB, 2020). The fault lines in İzmir and the earthquakes that occurred from 1900 to 2024 are shown in the Figure (11).

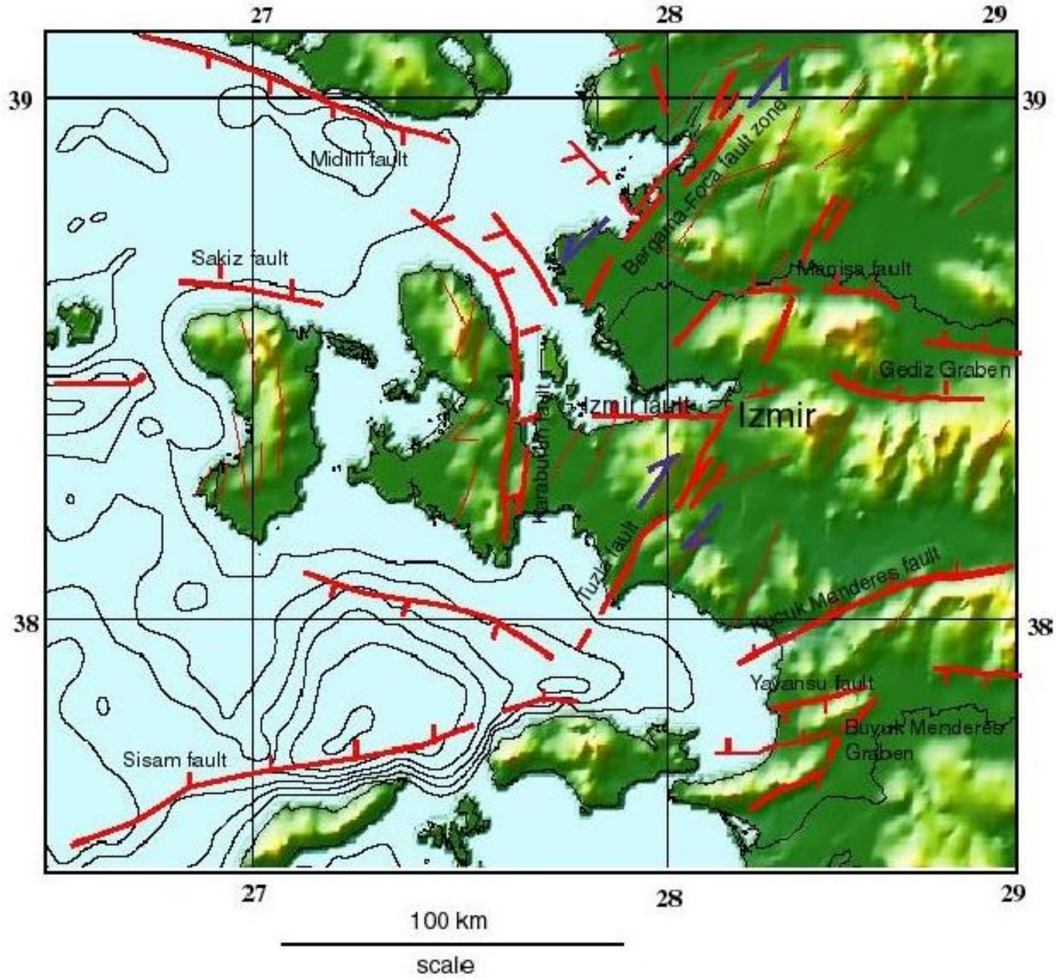

Figure 11: İzmir Fault Lines

(Source: İzmir Metropolitan Municipality, 2018)

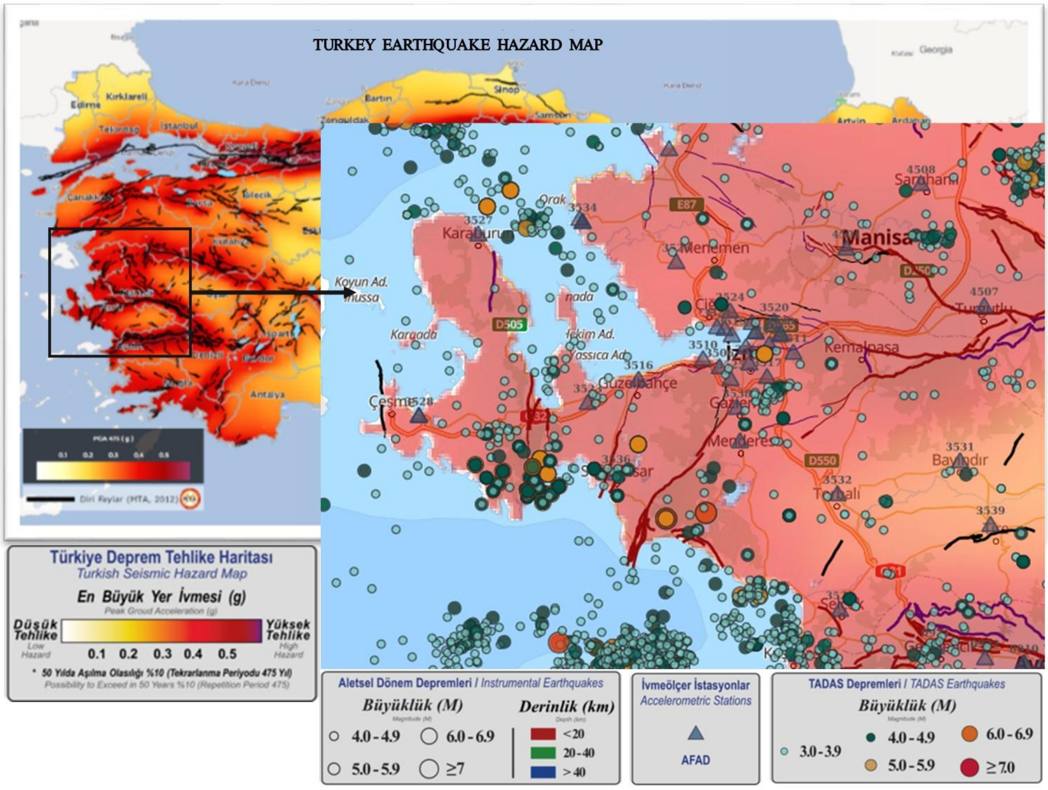

Figure 12: Historical earthquakes around Izmir (1900-2024)

(Source: AFAD, 2024a)

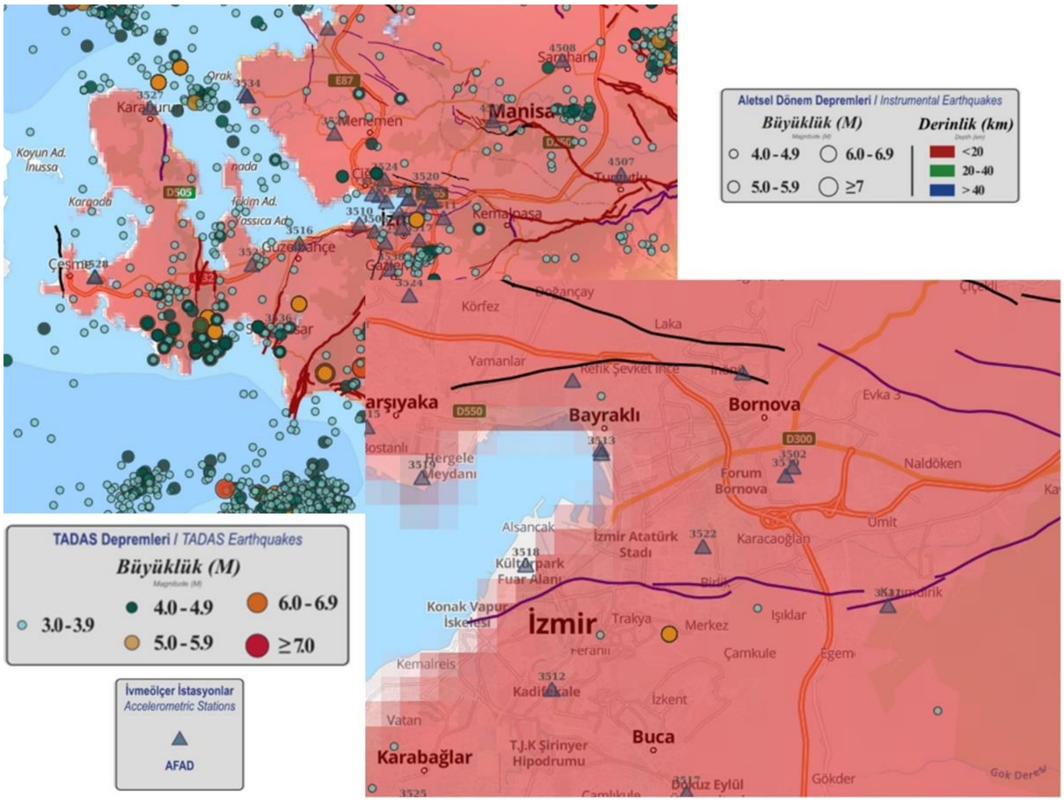

Figure 13: Historical earthquakes around Izmir/Bayraklı (1900-2024)

(Source: AFAD, 2024a)

3.3. Case Study: Bayraklı

Bayraklı, which was selected as the study area, is a district of İzmir province. Karşıyaka is in the northwest and north of the district, Bornova is in the east and south, Konak is in the southwest, and İzmir Gulf is in the west. Located in the Aegean Region, İzmir is located around İzmir Bay in the west of the Anatolian Peninsula, surrounded by the Aegean Sea in the west, Balıkesir in the north, Manisa in the east and Aydın in the south, at an altitude of 2 m. (6.56 ft) is a port city. İzmir is the 3rd largest city in Turkey in terms of geographical area and is the 3rd most populous city after Istanbul and Ankara. According to TURKSTAT results, the population of İzmir Province was 3,793,353 people in 2007, while it is 4,394,694 people as of 2020. (TURKSTAT between 2007-2020) While the population of İzmir was 4,279,677 in 2017, it is expected to reach 4,580,076 people in 2023. With a population of 4,479,525 people (TURKSTAT, 2023), the province of Izmir ranks 3rd in Turkey after Istanbul and Ankara. The population density (number of people per square kilometer) is 366 people/km2, ranking 1st in the Aegean Region and 3rd in Turkey (AFAD/IRAP, 2021). Izmir is one of the most important cities of Turkey. It has functioned as a busy trade center throughout its history. By the 1990s, people migrated from Eastern and Southeastern Anatolia because of the concern for their safety due to terror and disasters. At that time, İzmir was listed in the first ten cities to migrate to (Eğilmez, 2010).

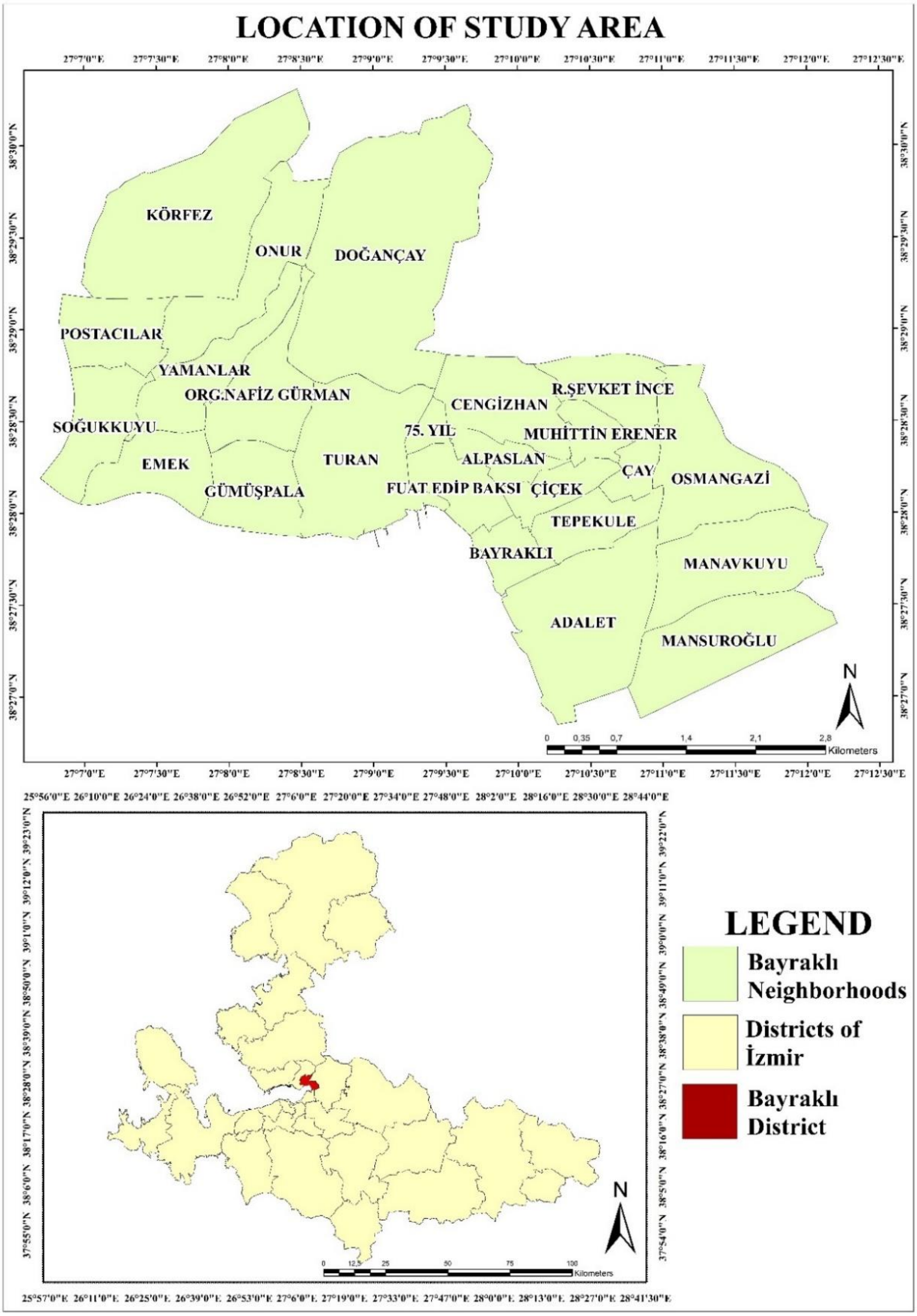

Figure 14: İzmir Province Map and the Location of Study Area

(Prepared by author in ArcGIS, 2024)

Bayraklı is located at a point where the southern and northern parts of İzmir connect to each other. Bayraklı was one of the districts of İzmir that witnessed a great part of migration. Bayraklı was separated from Karşıyaka District in 2008 and became a district of İzmir. Bayraklı is surrounded by Karşıyaka on the west, Bornova on the east, and Konak on the south. The district has an important historical value due to being the earliest settlement in İzmir (Akurgal, 1983). The earliest settlement is Smyrna (Tepekule Tumulus), and the first research started by the Bayraklı excavations to examine the site from 1050 BC to 300 BC (Akurgal, 1983). Bayraklı, one of the central districts of İzmir, has undergone significant urban planning development throughout time. The district has grown quickly, especially in terms of infrastructure for residential and commercial properties (Karadağ and Mirioğlu, 2012). A part of Bayraklı, which has been developing as a squatter housing area, is remarkable in terms of being one of the largest squatter housing districts of Izmir (Karadağ and Mirioğlu, 2012).

On October 30, 2020, at 14:51, an earthquake of magnitude Mw=6.6 (according to AFAD data and Mw=6.9 according to Boğaziçi University Kandilli Observatory and Earthquake Research Institute data) occurred, with the epicenter off the Aegean Sea, approximately 10 km north of Samos, and caused significant damage in İzmir which is located approximately 75 km's from the epicenter (Yakut et al., 2021; AFAD, 2020; TMMOB, 2020). The main shock is 23.38 km away from Doğanbey Payamlı village of Seferihisar district of İzmir province, which is the closest settlement to the earthquake. After the Samos Earthquake, especially in Bornova and Bayraklı districts, structural damage such as complete collapse, heavy damage, moderate damage, and light damage occurred in derelict buildings, 115 people lost their lives and 1035 people were injured, reported by the Izmir Governor's Office and AFAD (DAUM, 2020). The most structural damage during the earthquake occurred in the buildings in Bayraklı district, which are saturated with water, built on loose alluvial, delta and coastal sediments, poorly constructed and containing post-occupancy usage errors (MTA, 2020).

The neighborhoods built on the existing alluviums on the coast of Izmir are generally at risk. Bayraklı, one of the central districts of Izmir, is one of the regions that has recently experienced significant physical changes and has been subject to intense zoning decisions. These changes are especially evident in the new city center and surrounding residential areas, which developed in the region integrated with the coast in the west of the district. The old squatters (gecekondu) on the northern slopes remain with unresolved infrastructure and transportation problems. As a result of the reports written by institutions and universities (AFAD, 2020; DAUM, 2020; MTA, 2020), examination of the Izmir Earthquake Master Plan and analysis maps, it is seen that Bayraklı, one of the central districts of Izmir, was more affected by the 2020 Samos earthquake zone. Bayraklı is the district most affected by the earthquake because the ground structure and buildings were built before 2000 and the necessary precautions were not taken in terms of quality and construction (Gürbuz et al., 2020).

3.4. Materials

After determining the dimensions of vulnerability from the theoretical framework, indicator sets were created for each dimension. Later, maps of these indicators were created and Bayraklı's current situation per indicator was revealed.

The main purpose of the thesis is to determine how vulnerable Bayraklı neighborhoods are by considering the indicators under the three dimensions of vulnerability: physical, social and the capacity of the built environment. In the study, factors such as soil structure, elevation, slope, liquefaction probability were examined but were not involved in the vulnerability assessment analysis. Drawing from the conceptual framework of Disaster Risk outlined in the literature survey, hazard is a component of Disaaster Risk. As this study is focused on vulnerability, that is a component of Disaster Risk as well, it is important to consider hazards in the overall assessment of Disaster Risk, though not specifically in the assessment of vulnerability. As explained in the definition of the study area, it is known that the ground conditions of Bayraklı district are poor. One of the biggest reasons for not taking these factors into consideration is that since these conditions cannot be intervened, it is possible to see how much the results differ when these factors are not included in the analysis. It was observed that the neighborhoods most affected by the October 30 Samos earthquake were Bayraklı, Manavkuyu and Mansuroğlu. It is known that one of the biggest effects in this situation is the ground conditions and liquefaction. However, as a result of not adding natural factors to the analysis in this study, it was revealed which neighborhoods of Bayraklı district were vulnerable to earthquake hazards in three dimensions of vulnerability. For all these reasons, these factors were discussed under the title of hazard map.

3.4.1. Hazard Maps

Bayraklı, the district of Izmir most affected and damaged by the earthquake, is one of the riskiest districts in terms of many parameters. Liquefaction possibility, soil classes, and fault maps were overlayed and created to evaluate them in terms of earthquake hazards. Also, the maps of geology and MMI values were shown in this study. The earthquake characteristics that will affect the structures during earthquakes are significantly affected by the ground conditions in the regions where these structures are located. For this reason, determining the effect of ground layers is an important step in studies carried out to predict the damages that may occur in buildings (Izmir Earthquake Scenario and Earthquake Master Plan).

According to the data obtained, the intensity of the earthquake was calculated as MMI (Modified Mercalli Index) VII in the intensity map created using the Earthquake Preliminary Damage Estimation System (AFAD-RED) in the settlement closest to the epicenter of the earthquake (DAUM, 2020). Intensity distribution maps are used to quickly determine relative and maximum ground shaking levels. MMI values were calculated using the empirical equation proposed by Bilal and Askan (2014) and the maximum ground speed (MYH) values recorded at stations less than 100 km away from the epicenter (METU, 2020). In the report prepared by the Middle East Technical University, in the map prepared based on the work of Bilal and Askan (2014), it is seen that the MMI values calculated for most parts of the region are V and VI, and the largest MMI value is the VII value calculated for the Bayraklı region.

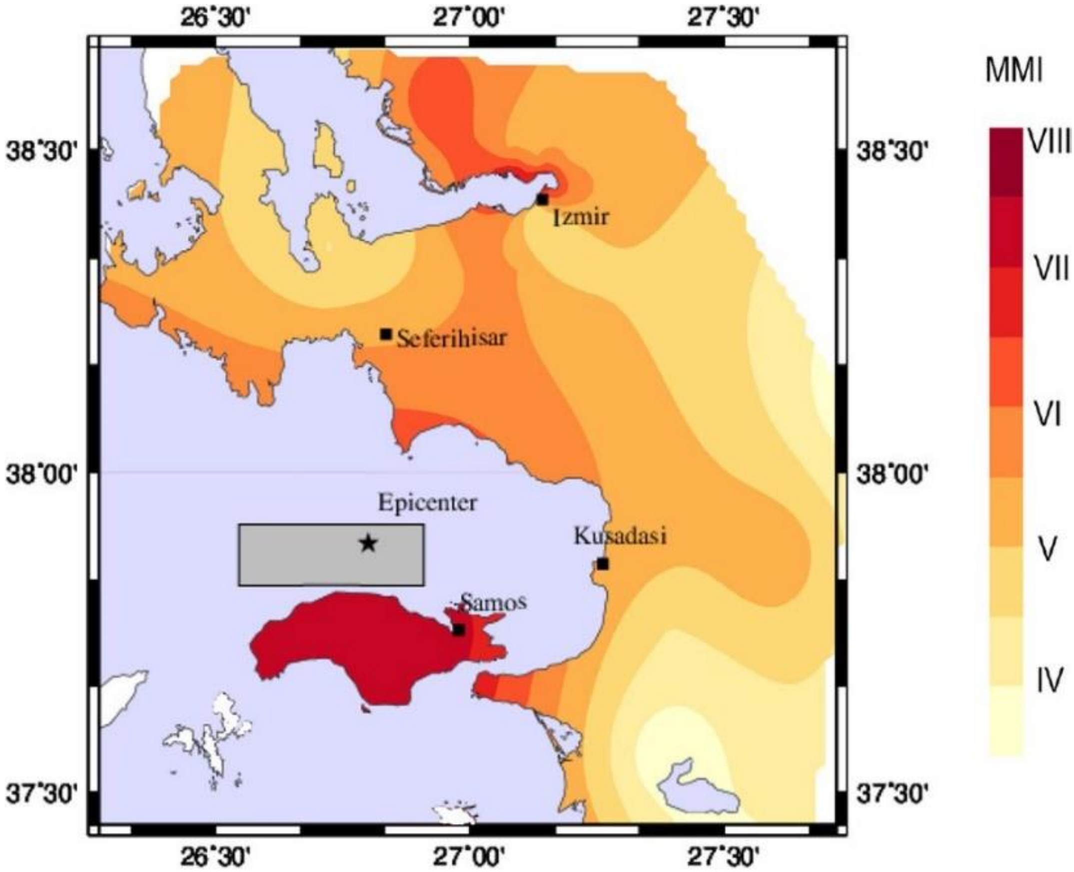

Figure 15: Modified Mercalli Intensity (MMI) map for the 30 October 2020, M7.0 Samos earthquake

(Source: Askan et al., 2021)

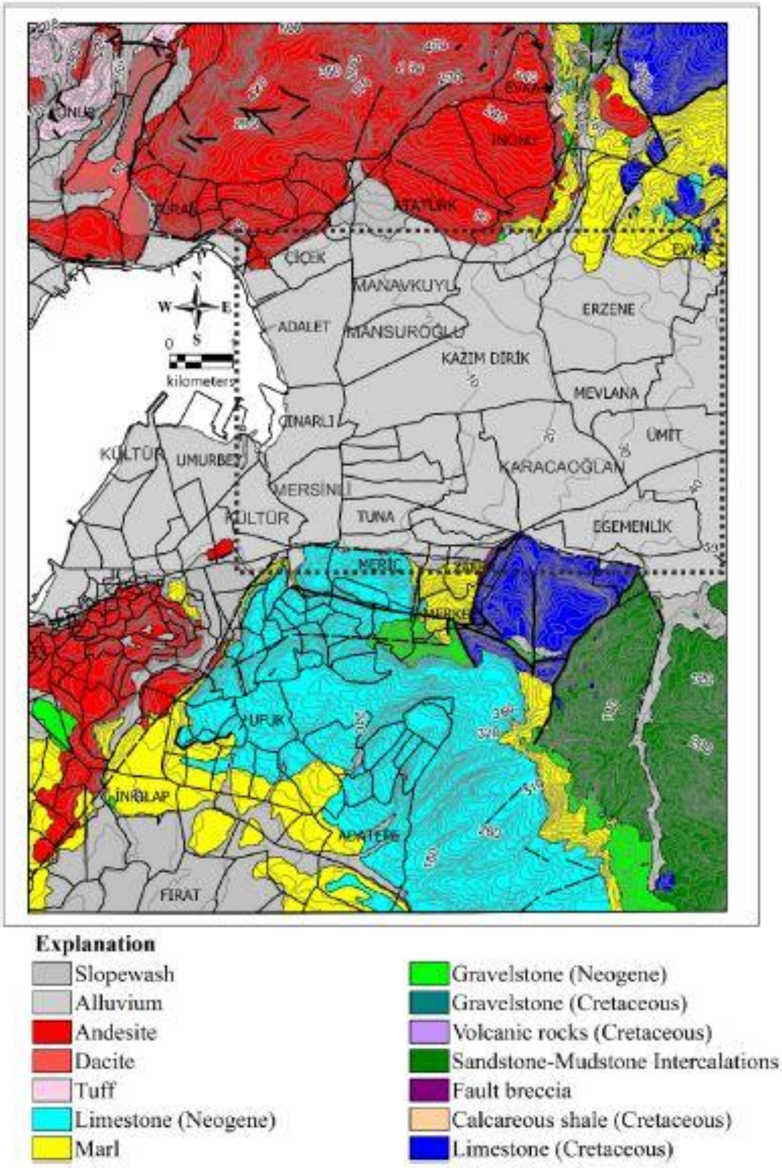

Figure 16: Local geology of the Bornova Plain

(Source: Kıncal, 2005; as cited in Nuhoglu et al., 2021).

Alluvial deposits are seen in the stream beds of Bornova Plain and its surroundings. Alluviums are mostly found in the Bayraklı, Bornova and Konak districts of the Bornova Plain. There are alluvial plains around the Gulf of Izmir, which develop on the same terrestrial fills (Kıncal, 2005; as cited in Nuhoglu et al., 2021). Due to the hydro-geomorphological characteristics of the rivers, different soils were formed in the basin, and this caused the accumulation of alluvial geomaterials in the Bornova Plain. There are three mountain streams passing through Bornova and ending in Izmir Bay (Kıncal, 2005; as cited in Nuhoglu et al., 2021). The most structural damage during the earthquake occurred in the buildings in Bayraklı district, which are saturated with water, built on loose alluvial, delta and coastal sediments, poorly constructed and containing post-occupancy usage errors (MTA, 2020).

The effect of ground layers varies depending on the type of ground layers, their thickness and groundwater level. Increasing pore water pressures during earthquakes in sand layers where the groundwater level is close to the surface, in other words saturated with water, leads to a phenomenon defined as liquefaction. One of the important ground damages caused by earthquakes is liquefaction. Liquefaction is the loss of the bearing feature of the ground by increasing the pore water pressures in the ground due to any dynamic effect (Izmir Earthquake Scenario and Earthquake Master Plan). The values in Figure (?), which were digitized from the Izmir Earthquake Scenario and Earthquake Master Plan of the Izmir Metropolitan Municipality, were divided into regions in terms of liquefaction probability by defining the liquefaction probability as high, moderate, and low. The other hazard indicator is the soil classification. Soil classification indicator is one of the natural/environmental indicators. In this classification, ZA class represents the best ground (DBYBHY, 2007; TBDY, 2018). Although ZF class soil represents the worst soil class in this ranking, it is obligatory to carry out some special analyzes and use ground motion spectra for this soil class (DBYBHY, 2007).

Local Soil Class	Soil Type
ZA	Solid, hard rocks
ZB	Slightly weathered, medium-solid rocks
ZC	Very dense layers of sand, gravel and hard clay or weathered, weak rocks with many cracks
ZD	Medium-tight sand, gravel or very solid clay layers
ZE	Layers of loose sand, gravel or soft-solid clay
ZF	Soils that require site-specific research and evaluation: • Soils at risk of collapse and potential collapse under the influence of an earthquake (liquefiable soils, highly sensitive clays, collapsible weakly cemented soils, etc.), • Peat and/or clays with high organic content, with a total thickness of more than 3 meters, • High plasticity (PI > 50) clays with a total thickness of more than 8 meters, • Very thick (> 35 m) soft or medium stiff clays.

Figure 17: Soil Classification

(Adapted and modified by author from TBDY, 2018)

Essentially, the local soil class generally depends on the type and thickness of the soil layer closest to the structure. Soil classification is made based on various features and criteria and helps determine the ground conditions in the area where the structures will be built (TBDY, 2018). Distance to faults plays an important role in a place's vulnerability to earthquakes. The further the structures are from the faults, the lower the vulnerability and therefore the higher the resilience (Shapapourtehrany et al., 2022). Distance to faults is a critical issue in building design and planning in areas vulnerable to earthquake hazards, and areas vulnerable to earthquakes should be avoided to prevent these negative effects of earthquakes (Önder et al., 2004).

According to AFAD (2020) records, 16 buildings were destroyed in the Samos Earthquake. Most of the collapsed buildings were located on loose sediments. This caused the earthquake waves to grow towards the ground (Uzelli et al., 2020). There was serious damage and loss of life in the region. The same region was also affected by devastating earthquakes in historical periods (Uzelli et al., 2020). In addition, inadequate and unqualified construction practices and post-occupancy usage errors can be listed among other important causes of structural damage (DAUM, 2020). Most of the collapsed buildings, especially the Doğanlar and Rızabey apartments in Bayraklı district, were located approximately 60 m above sea level, approximately 4-5 km away from the coast, but on loose ground (MTA, 2020). On the other hand, there are buildings with very high floors built on coastal sediments, right next to the beach, with modern construction techniques (pile foundation, earthquake isolator, etc.) (MTA, 2020). No structural damage occurred in multi-storey buildings built using modern construction techniques (MTA, 2020). The map showing the faults, liquefaction probability, soil classes and structures affected by the October 30 Samos earthquake reveals the earthquake hazard status of Bayraklı district.

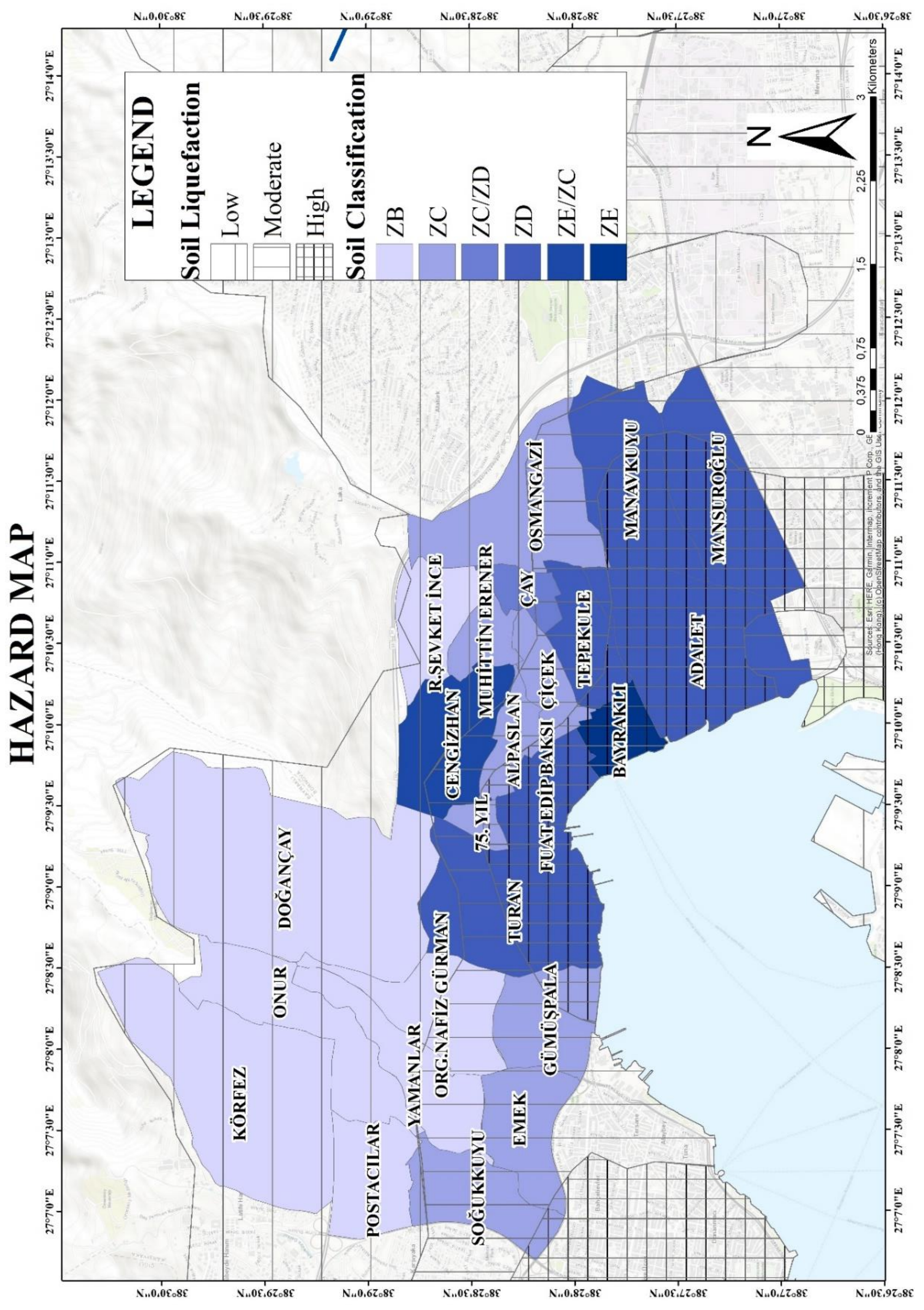

Figure 18: Soil Liquefaction and Classification

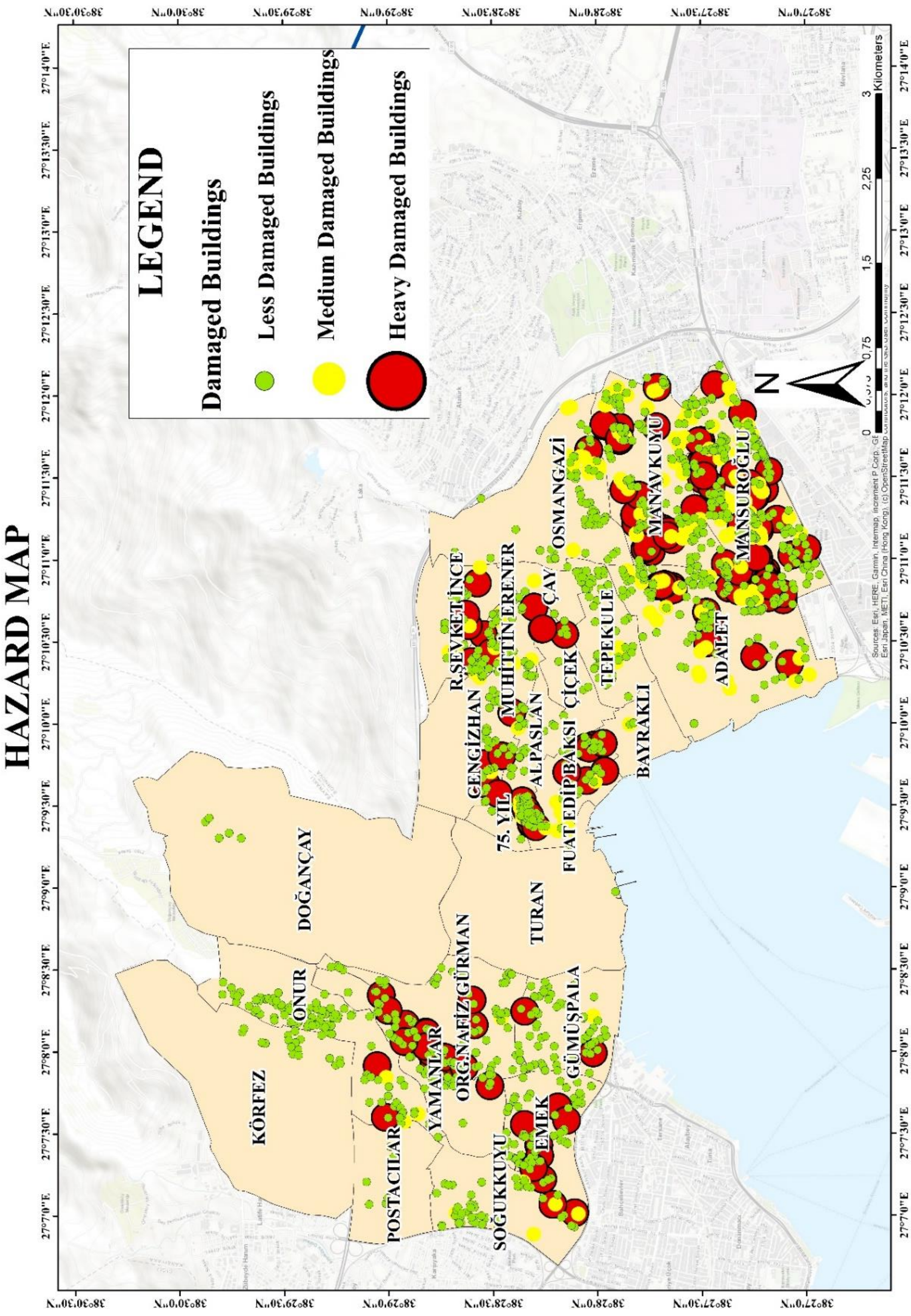

Figure 19: Damaged Buildings

The map was prepared at a scale of 1/25000. The map formed by the blue color scale at the bottom is the map with soil classes. Liquefaction probability is added to the map, and the liquefaction probability is divided into three separate classes. In the second map shows the point data of the buildings most affected and destroyed by the earthquake. The neighborhoods where severely and moderately damaged buildings are most common are Mansuroğlu, Manavkuyu and Fuat Edip Baksı neighborhoods, where the soil class is poor (ZC, ZD, ZE) and the probability of liquefaction is high.

3.4.2. Physical Vulnerability

Compared to earthquake hazards, the concept of physical vulnerability becomes a particularly important dimension. In this section, indicators of the extent of physical vulnerability are mapped and show the current situation of Bayraklı. Under the headings of building age, building material and building configuration, reinforced concrete buildings, masonry buildings, attached buildings, detached buildings, corner adjacent buildings and average building age are mapped separately. Some of the indicators given in the literature could not be obtained from institutions. These indicators are vertical irregularity, plan irregularity, wall type etc. According to the indicator table, the data was obtained from the "building identity data" created by Izmir Metropolitan Municipality for Bayraklı district. Raw data were analyzed according to the scope of the study. The raw data obtained from the institution is neighborhood-based. These data were prepared on a neighborhood basis and the numbers were proportioned accordingly. These data were classified in ArcGIS environment after being proportioned in Excel. "Natural breaks" were used in the classification and each indicator was mapped separately. Some of the indicators given in the literature could not be obtained.

Table 4: Physical Vulnerability Indicators

(Source: İzmir Metropolitan Municipality, 2023 (prepared by author))

Vulnerability Dimensions	Sub-Dimensions	Indicators
Physical Vulnerability	Building material/type	Distribution of Reinforced Concrete Buildings (%)
		Distribution of Masonry Buildings (%)
	Building Configuration	Distribution of Attached Buildings (%)
		Distribution of Detached Buildings (%)
		Distribution of Corner Adjacent Buildings (%)
	Building Age	Distribution of Average Building Age (%)

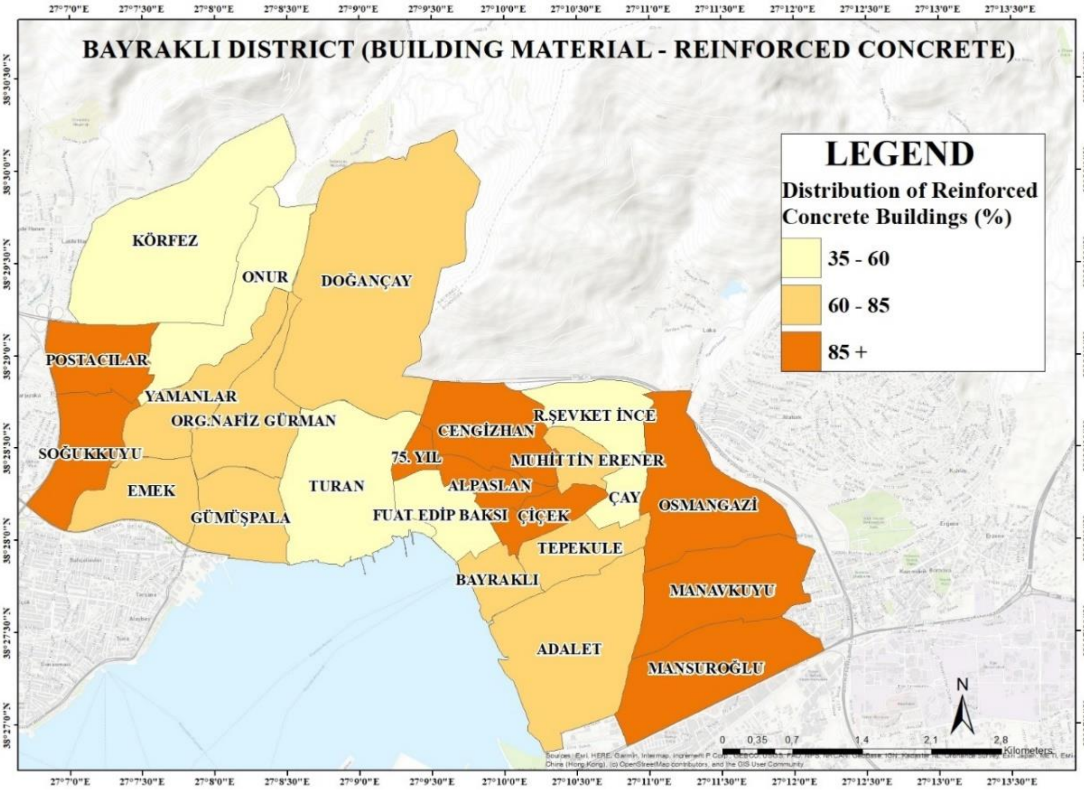

Figure 20: Distribution of Reinforced Concrete Buildings (%)

According to Papathoma-Kohle et al., (2007), reinforced concrete structures are more resilient than masonry structures. The neighborhoods with the least amount of reinforced concrete are the most vulnerable neighborhoods. These neighborhoods are Çay, Turan, Onur, Fuat Edip Baksi, Körfez, R. Şevket İnce.

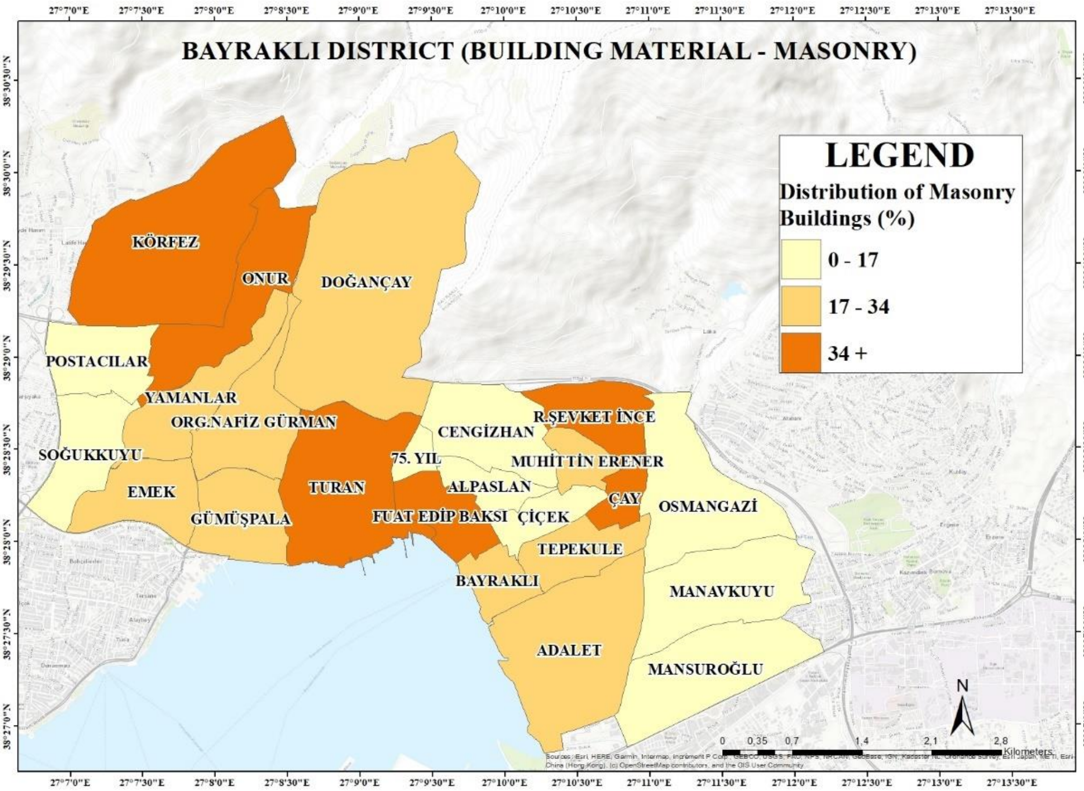

Figure 21: Distribution of Masonry Buildings (%)

The neighborhoods where the buildings with masonry materials are most concentrated are Körfez, Turan, Onur, Fuat Edip Baksi, Çayand R. Şevket İnce neighborhoods. It can be seen that the most vulnerable neighborhoods are the same as the previous map. More than 34% of these neighborhoods consist of masonry buildings.

Building configuration is another important indicator of physical vulnerability. As explained in the previous section, the fact that structures have different dynamic characters causes them to have different oscillation periods during an earthquake. As can be seen in Figure (22) the neighborhoods where the buildings are concentrated in a separate order are Körfez, Doğançay and 75. Yıl. These neighborhoods are considered as least vulnerable. More than 52% of these neighborhoods consist of detached buildings.

The neighborhoods where the buildings with adjacent corners are most concentrated are Postacılar, Yamanlar, Emek, Gümüşpala, Cengizhan, Muhittin Erener, R. Şevket İnce, Çiçek, Çay, Tepekule, Osmangazi and Adalet neighborhoods. These neighborhoods are vulnerable compared to previous neighborhoods. More than 52% of these neighborhoods consist of corner adjacent buildings.

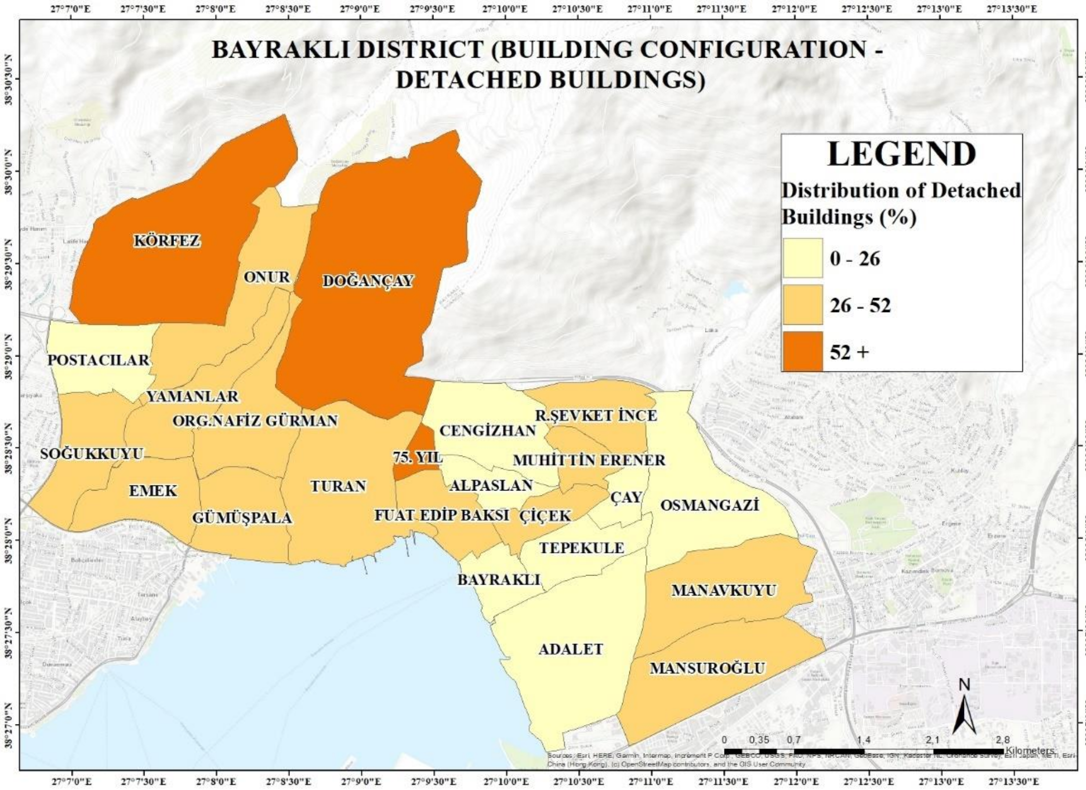

Figure 22: Distribution of Detached Buildings (%)

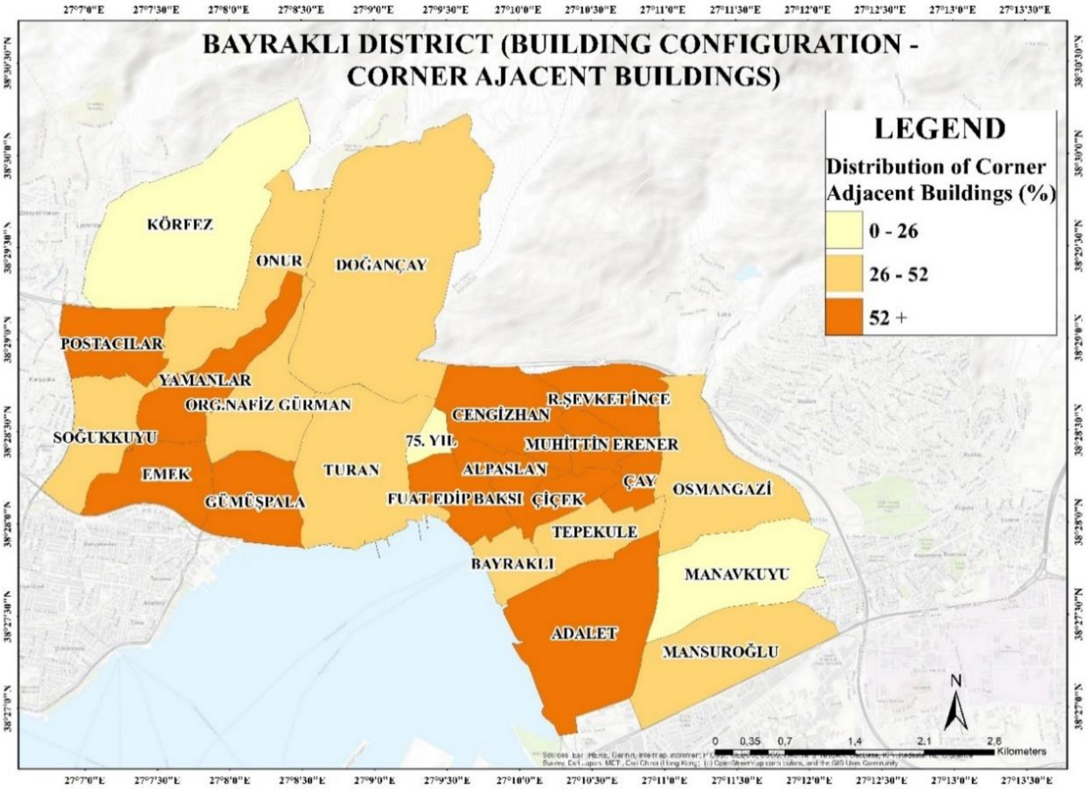

Figure 23:Distribution of Corner Adjacent Order Buildings (%)

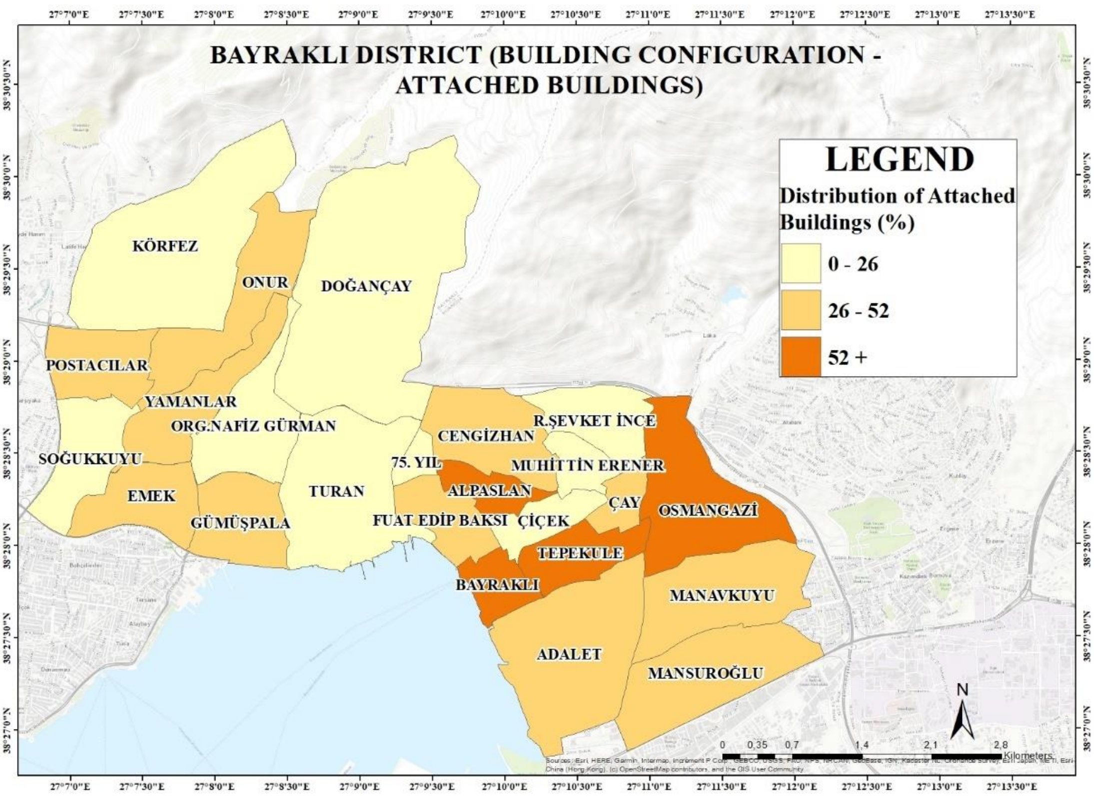

Figure 24: Distribution of Attached Order Buildings (%)

The neighborhoods where the buildings with attached buildings are most concentrated are Tepekule, Alpaslan, Osmangazi and Bayraklı. These neighborhoods are the most vulnerable and more than 52% of these neighborhoods consist of attached buildings.

Considering the ***building age,*** it is seen that it has a wide place and reference in the literature. In general, the effect of building age on earthquake vulnerability is twofold: (a) deterioration of construction materials occur with higher building ages, and (b) more recently constructed buildings are more frequently subject to improved building codes (Cochrane and Schaad, 1992; Bommer et al., 2002).

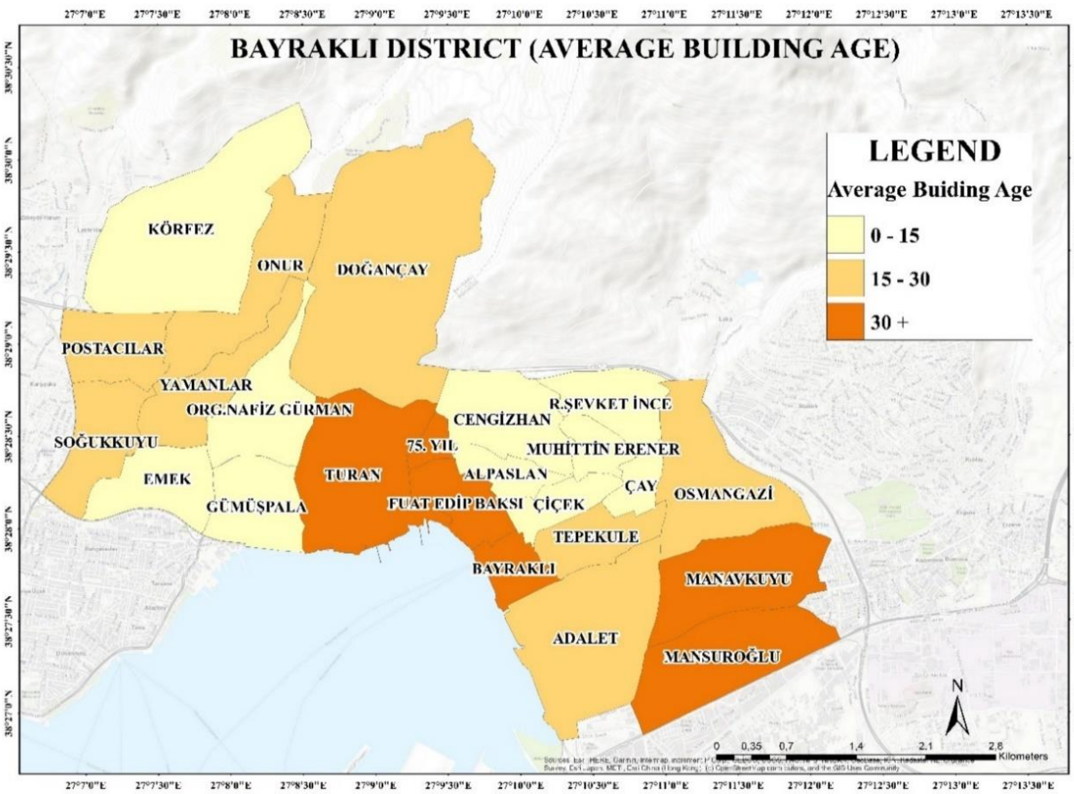

Figure 25: Average Building Age

The oldest buildings are concentrated in Turan, 75. Yıl, Bayraklı, Manavkuyu and Mansuroğlu neighborhoods. And although these buildings are more than 30 years old, most of them were built before the 2007 Türkiye Building Earthquake Code.

The physical vulnerability analysis for Bayraklı district in Izmir reveals several critical deficiencies that affect the district's vulnerability to earthquake hazards. The analysis not only helps to reveal the physical vulnerability of the district, but also enables the identification of priority neighborhoods for emergency response and rescue operations. In this context, it is possible to see which neighborhoods of the district are physically fragile with the indicators examined. In this section, the raw forms of the physical fragility indicator data of the neighborhoods of Bayraklı District are mapped and the average building age, building configuration and building materials are evaluated.

3.4.3. Social Vulnerability

Social vulnerability is one of the critical dimensions of earthquake hazards. In this section, indicators of the extent of physical vulnerability are mapped and show the current situation of Bayraklı. Under the headings of demography and socioeconomic elderly population, the children population, female population, average income, literacy rate, university graduates, disabled population, population receiving social support, and patients receiving home care indicators are mapped separately. Some of the indicators given in the literature could not be obtained from institutions. These indicators are the unemployment rate, immigrant rate, race, etc. According to the indicator table, the data was obtained from the Izmir Metropolitan Municipality (2024) and TURKSTAT (2019) for the Bayraklı district. Raw data were analyzed according to the scope of the study. The raw data obtained from the institution is neighborhood-based. These data were prepared on a neighborhood basis and the numbers were proportioned accordingly. These data were classified in the ArcGIS environment after being proportioned in Excel. "Natural breaks" were used in the classification and each indicator was mapped separately. Some of the indicators given in the literature could not be obtained. Average income data is calculated from m^2/ unit price from ENDEKSA website, and m^2/unit price was used as a proxy indicator in place of income. Considering all this, the indicators obtained as a result of the literature review were collected in the Table (5) to be measured as data.

Table 5: Social Vulnerability Indicators

(Source: TURKSTAT, 2019; İzmir Metropolitan Municipality, 2023 (prepared by author))

Vulnerability Dimensions	Sub-Dimension	Indicators
Social Vulnerability	**Demography**	Percentage of elderly people >65 in Total Population
		Percentage of children <5 in total population
		Percentage of Women Population in Total Population
	Socioeconomic	Literacy rate
		Average Income
		Percentage of population with university education in total population
		Percentage of the population receiving social support in the total population
		Percentage of the number of patients receiving home care in the total population
		Percentage of disabled person in the total population

One of the most important factors causing vulnerability is the demographical vulnerable groups in settlements, consisting of women, the elderly, and children. It is generally accepted that women are the most vulnerable then men. Women are in a much more vulnerable situation than other groups due to their low educational qualifications, the obstacles they face in integrating into the labor market, and difficulties in accessing resources as a reflection of social inequality. In this respect, while being a woman is a cause of vulnerability, especially in developing societies, a much more vulnerable picture can emerge when poverty conditions are added to this. The difficulties experienced by women after the 2020 Izmir earthquake, especially poor women's weakness due to insufficient access to resources, increased workload in temporary shelters and decreased mobility, have revealed their increasing vulnerability. Another group that is vulnerable to threats is children and the elderly, who are at both ends of the spectrum. The social vulnerability indicators map below was created from the raw data.

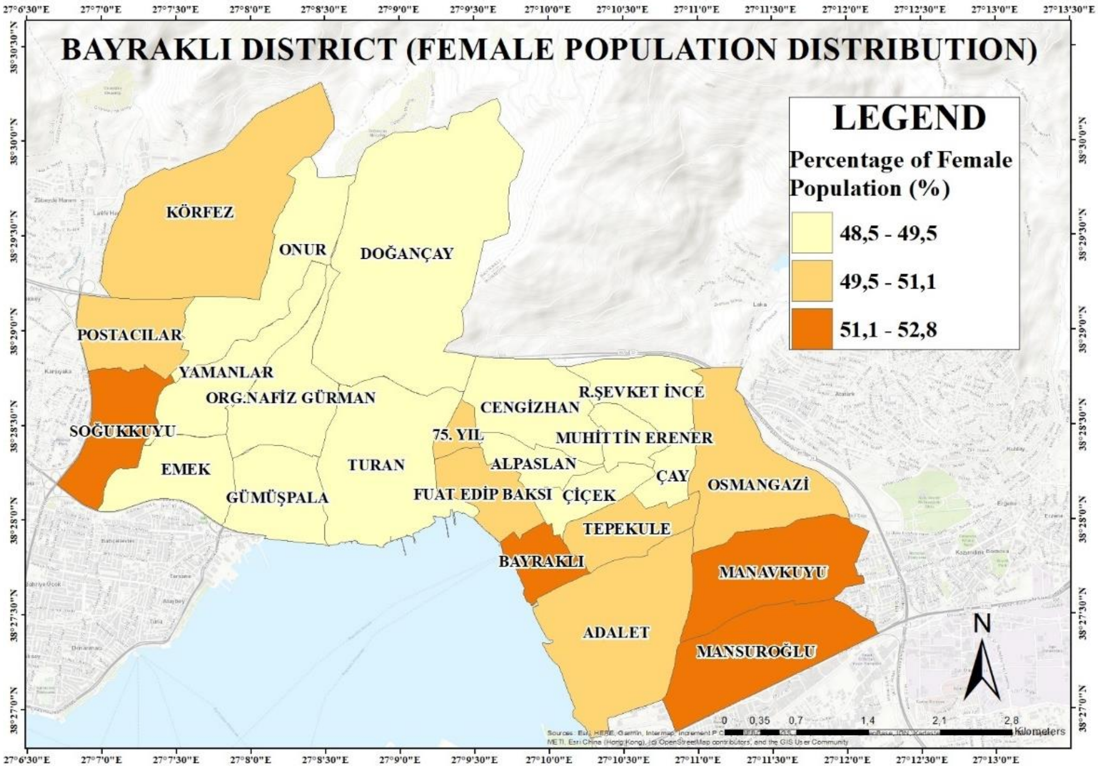

Figure 26: Distribution of Female Population (%)

This map created as a result of the analysis made based on neighborhoods in Bayraklı District, more than 51% of the population of Mansuroğlu, Soğukkuyu, Manavkuyu and Bayraklı neighborhoods is female.

In the map in figure (28) it is seen that the older population density is in Mansuroğlu, Manavkuyu, and Bayraklı neighborhoods. More than 10% of the population of these neighborhoods is elderly.

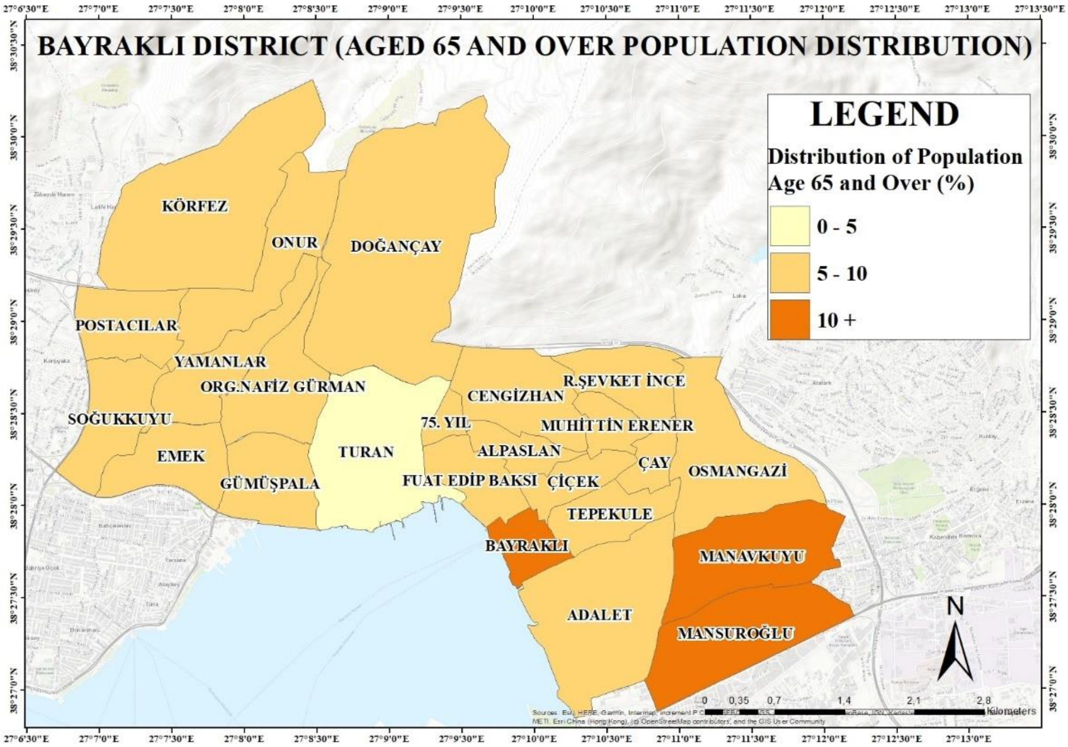

Figure 27: Distribution of Population Age 65 and Over (%)

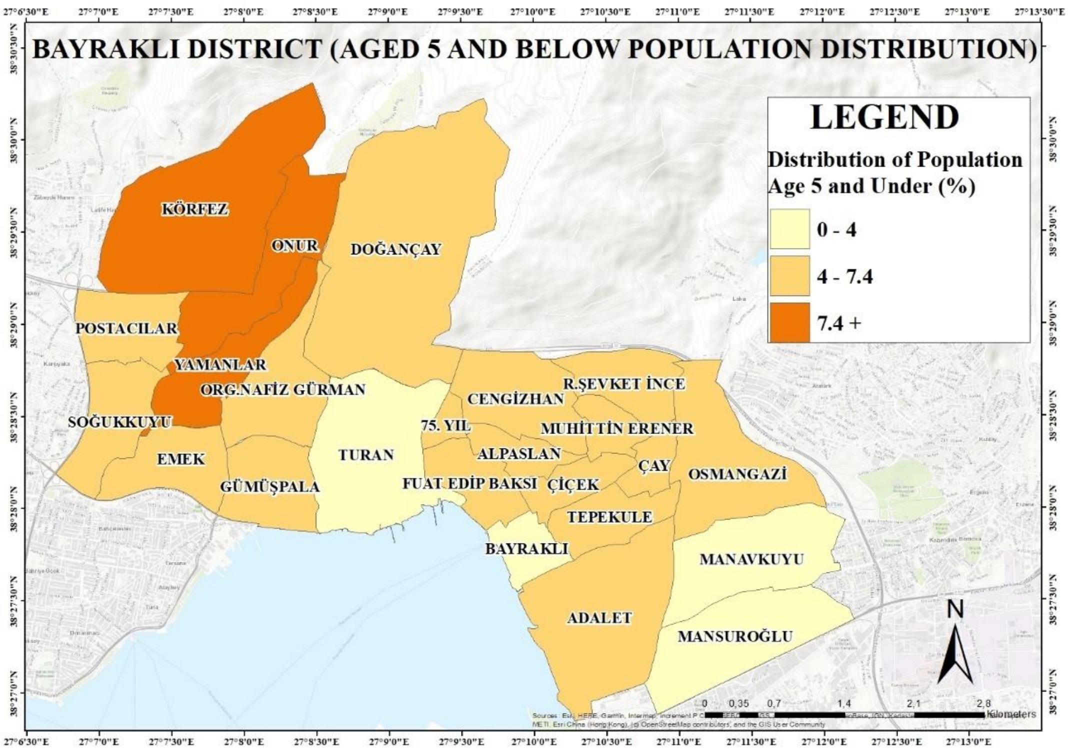

Figure 28: Distribution of Population Age 5 and Under (%)

Another map shows the distribution of children under the age of 5. The neighborhoods where the group of children aged 5 and under is most concentrated are Körfez, Onur, and Yamanlar, Postacılar, Org. Nafiz Gürman, Emek, Gümüşpala, Cengizhan, Muhittin Erener, R. Şevket İnce and Adalet neighborhoods. More than 7.4% of the population of these neighborhoods consists of children.

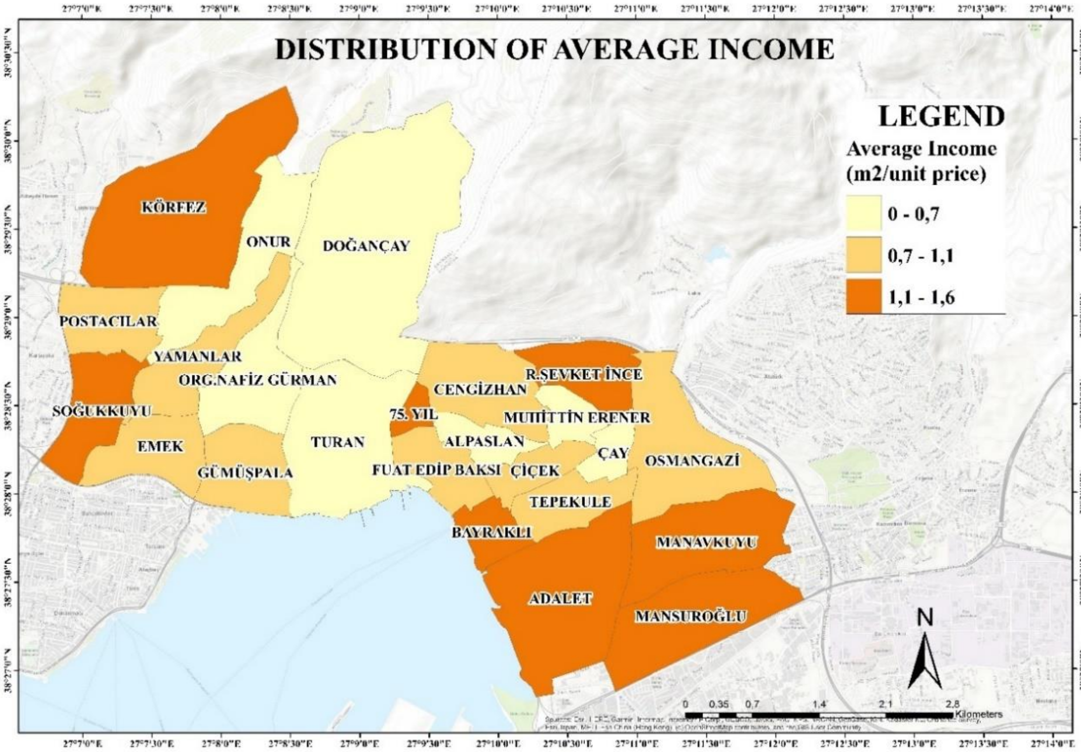

Figure 29: Distribution of Income Levels

The average income indicator was taken from the ENDEKSA website and is a proxy data calculated according to the m^2/unit price and average rental value of each neighborhood. It was then divided by the average rental value of Bayraklı and the rate of each neighborhood was calculated. The neighborhoods with the lowest income distribution are Onur, Doğançay, Org. Nafiz Gürman, Turan, Alpaslan, Çay and Muhittin Erener neighborhoods.

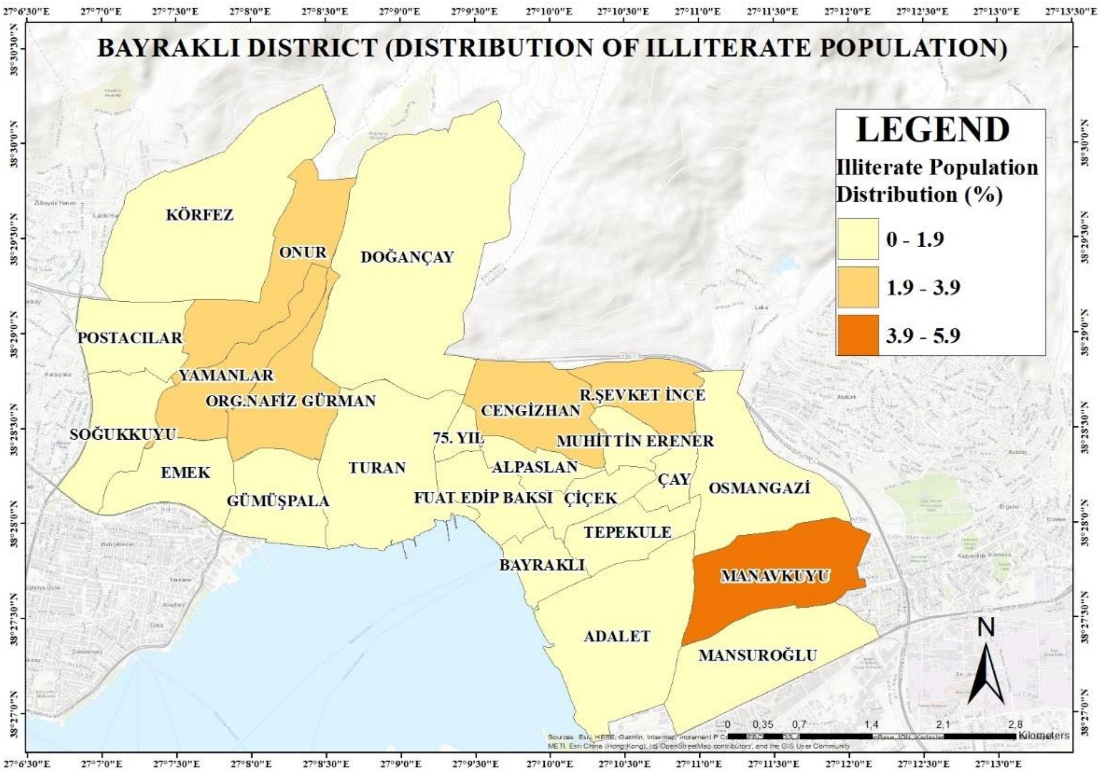

Figure 30: Distribution of Literacy Rate (%)

Although the relationship between education and vulnerability to disasters is not fully understood, it is generally accepted that it has an impact on vulnerability. It is seen that the illiterate segment is mostly concentrated in the Manavkuyu neighborhood. In other neighborhoods, there is a more homogeneous distribution.

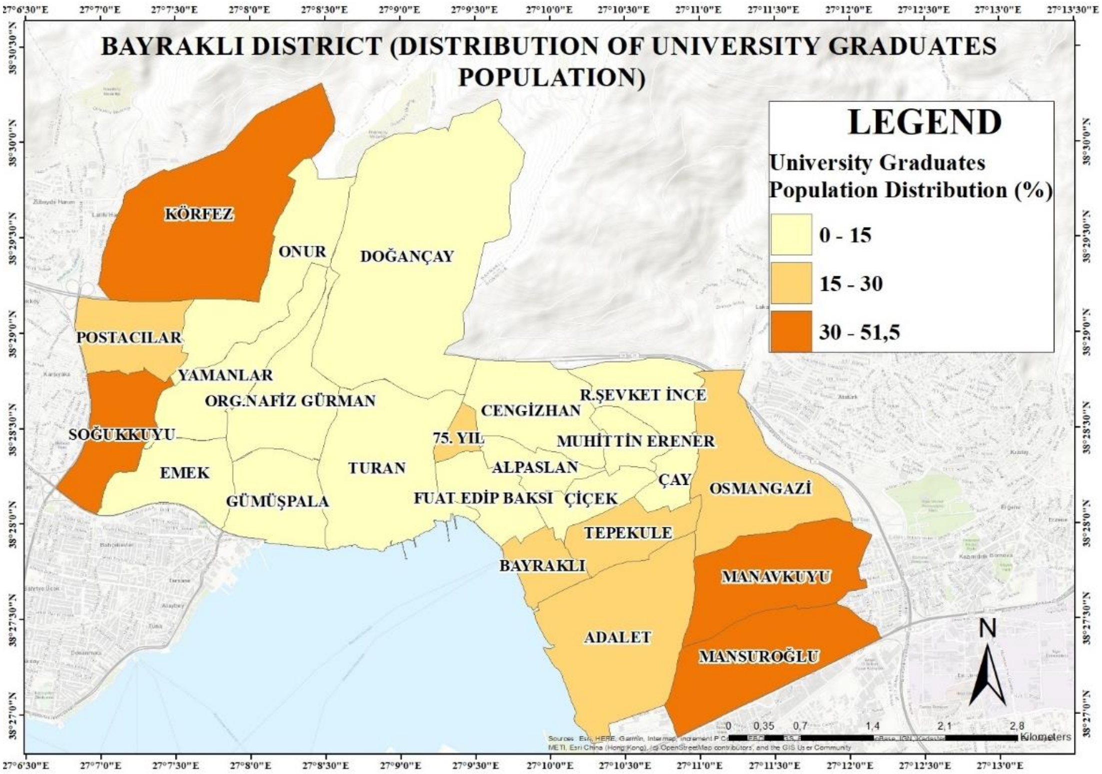

Figure 31: Distribution of College or Faculty Graduates (%)

The neighborhoods where the population distribution of college or faculty graduates is most concentrated are Körfez and Mansuroğlu neighborhoods. And the rate of university graduates in these neighborhoods is between 30% and 51.5%.

Individuals with disabilities (physical or mental) who are among the ***disadvantaged groups*** are considered as a vulnerable group because they have partial mobility and similar restrictions, difficulty accessing disaster information and understanding warnings (Mavhura, 2019b). Disadvantaged groups include individuals with disabilities, individuals receiving social assistance support, and home care patients.

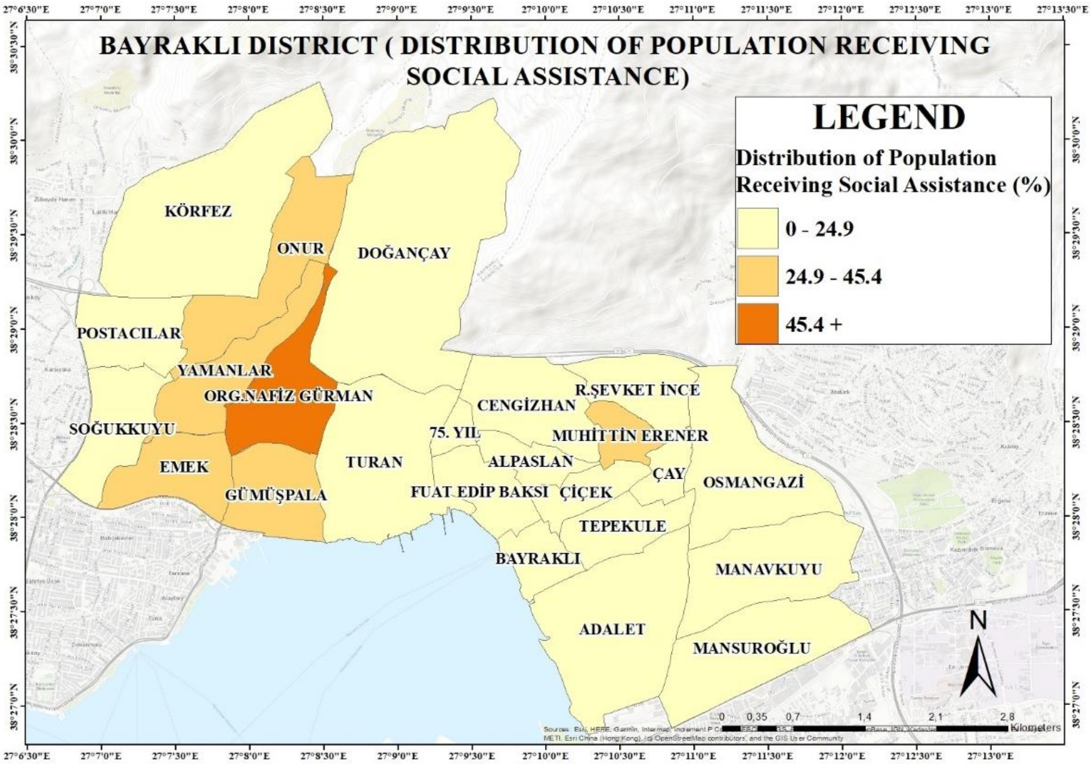

Figure 32:Distribution of Population Receiving Social Assistance (%)

Another indicator of social vulnerability is those who receive social assistance. Org. Nafiz Gürman, Onur, Yamanlar and Emek neighborhoods receive social assistance which is seen as the most vulnerable neighborhood based on this indicator. More than 45.4% of Org. Nafiz Gürman neighborhood receives social assistance support.

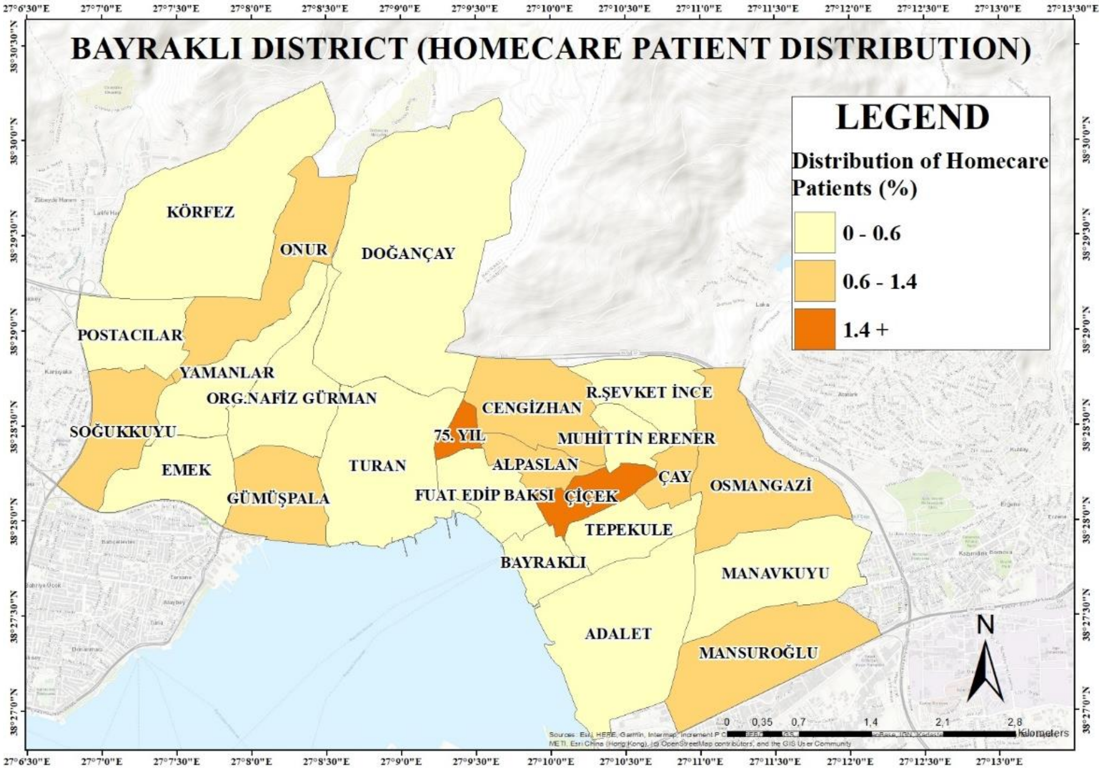

Figure 33: Distribution of Home Care Patient (%)

Homecare patients in figure (34) are also included in thie vulnerable groups. These groups are among the vulnerable groups due to their social limitations. These groups, which are mostly unable to support themselves, are also in need of economic social assistance.

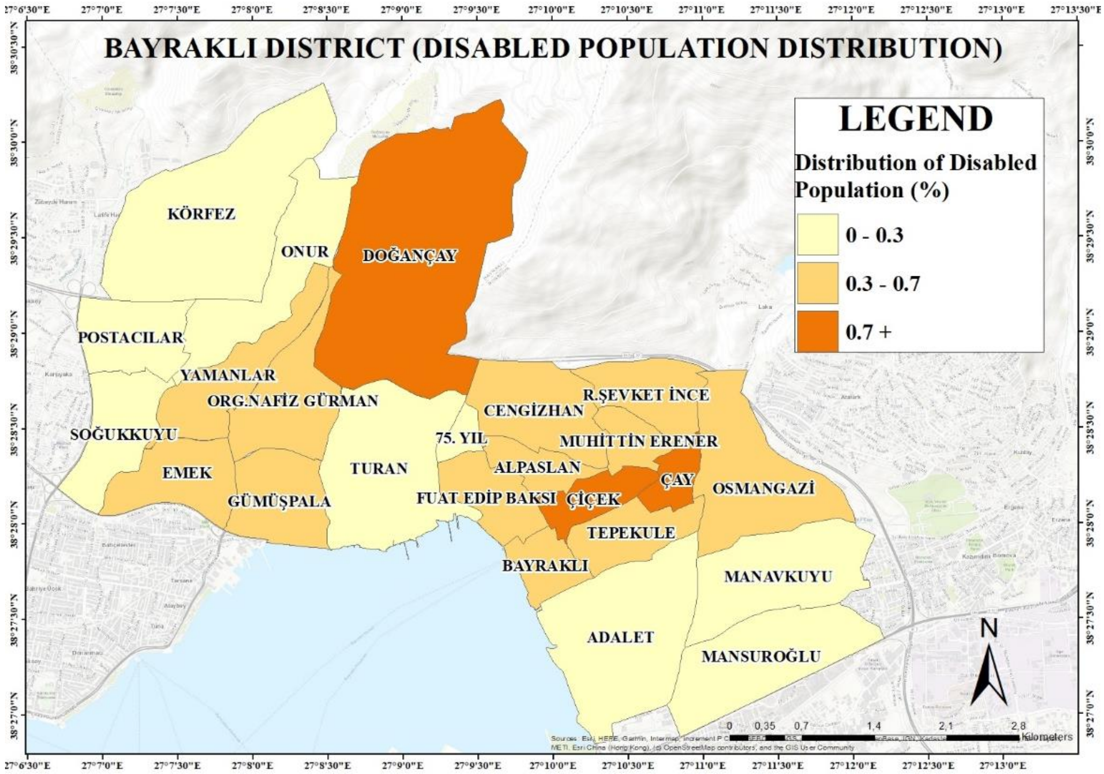

Figure 34: Distribution of Disabled Population (%)

The neighborhoods with the highest concentration of disabled individuals are Çiçek, Çay and Doğançay neighborhoods.

With the indicators examined within this framework, it can be seen which aspects of society are vulnerable. In this section, the raw forms of social vulnerability indicator data of Bayraklı District neighborhoods were mapped, and education level, demographic data and social situation were assessed. The social vulnerability analysis for Bayraklı district in Izmir reveals several critical deficiencies that affect the district's vulnerability to earthquake hazards. The analysis not only enables the determination of priority neighborhoods for emergency response and rescue operations, but also reveals the social vulnerability of the district.

3.4.4. Capacity of Built Environment

In this study, capacity was provided in the intersecting space, building upon the similar overlapping structure presented by Cutter et al. (2008). According to Birkmann et al. (2009), coping capacity encompasses actions and strategies implemented in existing systems/environments, while adaptive capacity is associated with longer-term strategic actions that may require change in these systems/environments. In light of these conceptualizations, this study examines "capacity" more comprehensively, considering coping capacity as an immediate response in the assessment of vulnerability to earthquake hazards and adaptive capacity as preparation for future earthquake hazards.The capacity of built environment is as important as the physical vulnerability of buildings. Shafapourtehrany et al., (2022) stated that the built environment dimension is the most concrete dimension of the urban planning's function of minimizing the earthquake effect. There are several indicators to understand the vulnerability of the built environment.

Table 6: Capacity of Built Environment Indicators

(Source: İzmir Metropolitan Municipality, 2024 (prepared by author))

<table>
<tr><th>Vulnerability Dimensions</th><th>Sub-Dimension</th><th>Indicators</th></tr>
<tr><td rowspan="9">Capacity of Built Environment</td><td rowspan="3">Density</td><td>Building Density</td></tr>
<tr><td>Population Density</td></tr>
<tr><td>Green Area Per Capita</td></tr>
<tr><td rowspan="6">Accesibility of Critical Facilities</td><td>Distance to Main Roads</td></tr>
<tr><td>Distance to Police Stations</td></tr>
<tr><td>Distance to Hospitals</td></tr>
<tr><td>Distance to Fuel Stations</td></tr>
<tr><td>Distance to Fire Stations</td></tr>
<tr><td>Distance Disaster and Emergency Assembly Areas</td></tr>
</table>

In this section of the study, the adequacy of open and green areas and accessibility to these areas, building density, population density and critical facilities accessibility are explored. The concept of accessibility discussed above is an important type of analysis used in many scientific fields such as transportation planning, urban planning and geography. Accessibility has been defined in various ways and has therefore acquired various meanings (Geurs and Van Wee, 2004). Accessibility is generally defined *"as being able to go from one location to another in the shortest time, at an appropriate speed, comfortably, safely and without harming the environment"* (PTALS, 2010 as cited in Gerçek and Güven, 2016). The accessibility of these components is of vital importance during an earthquake. It is important to be able to reach these points on foot. The spatial adequacy and accessibility criteria of open and green areas related to population, population density and building density are discussed under the subheading "density". Service area analysis, which is a sub-function of network analysis, is used to determine the areas that can reach point, linear or polygonal objects belonging to a certain unit or units within a certain distance and/or time through the available transportation network (ArcGIS Resource Center, 2024). ArcGIS-based network analysis service areas tool was used to access critical facilities. Using the "service area" tool from the ArcGIS based "network analysis", the accessibility status of these critical facilities in the study area was determined. When calculating the service area, a 500-meter walking distance was used, and these areas were divided into neighborhood areas to create a ratio. The amount of green space per person (neighborhood-based) was calculated using open green space digital data bases and population data from TURKSTAT (2019). Green space service areas in neighborhoods were determined from the digital databases. The total population and population density of the neighborhoods were determined using population data from TURKSTAT. Then, these areas were associated with population and accessibility, and the status of the neighborhoods defined by administrative boundaries was revealed.

Firstly, a map of the population density indicator was created. The ***population density*** living there, as well as the physical and environmental characteristics, should also be considered. One of the most vital non-structural and non-seismic factors of vulnerability to earthquake hazards is population density, and living near a fault in places with the highest population density has negative consequences (Hassanzadeh et al., 2013). In addition, population density and rapid population growth, as well as unequal distribution of resources, increase the risk for society (Hassanzadeh et al., 2013).

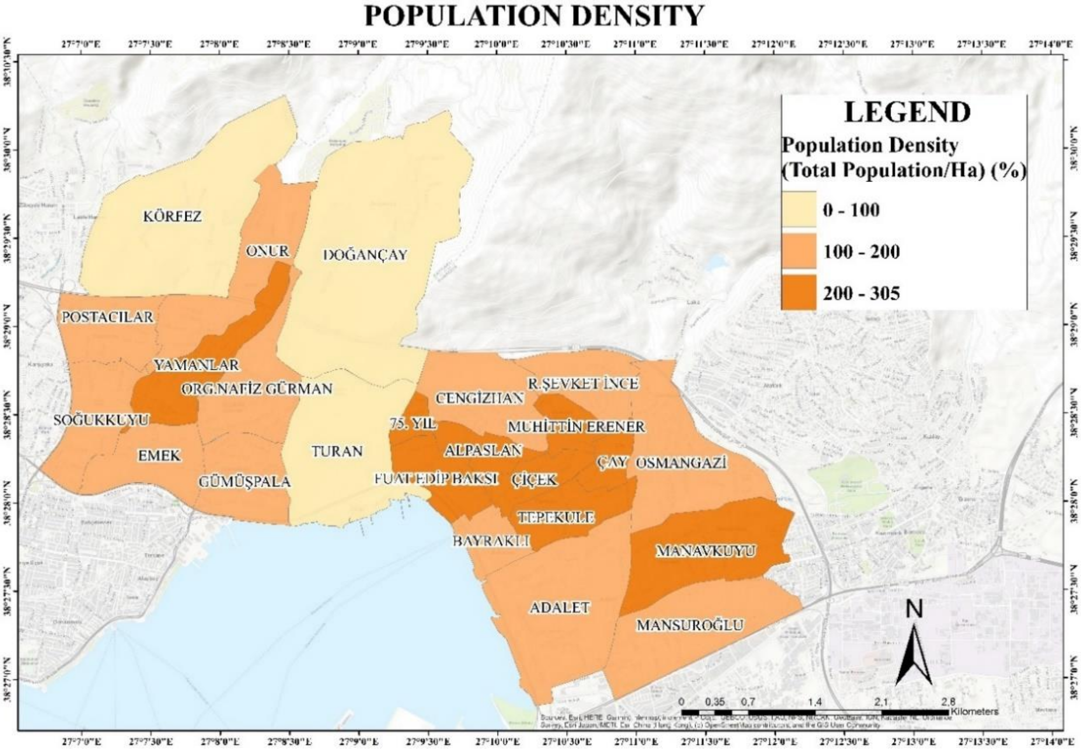

Figure 35: Distribution of Population Density (%)

The neighborhoods with the highest population density are Yamanlar, Alpaslan, Çay, Muhittin Erener, TepekuleÇiçek, Fuat Edip Baksi, and Manavkuyu neighborhoods.

Building density is another important indicator. The increase in dwellings results in minimizing open spaces for escape and circulation, therefore, minimizing densely populated areas and increasing the space for free movement will minimize vulnerability (Cutter et al., 2000). In addition, the collapse of dense buildings during the earthquake blocks the roads and this causes a big problem in the event of a disaster as it blocks transportation (Hosseini et al., 2009).

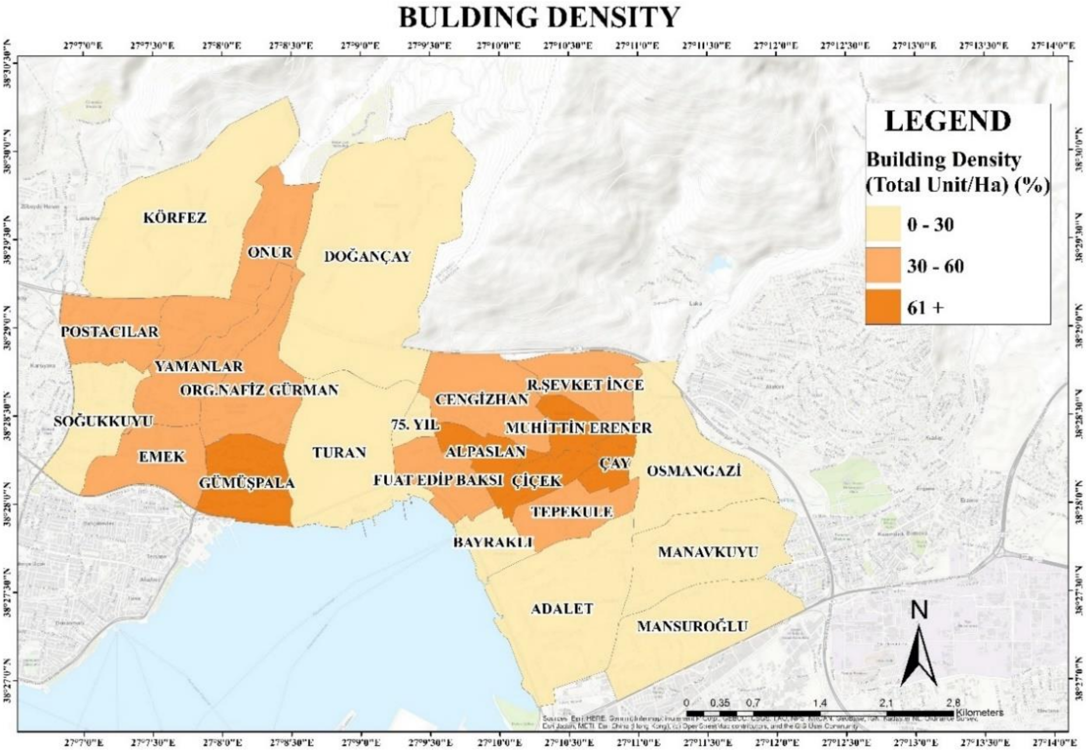

Figure 36: Distribution of Building Density (%)

The neighborhoods with the highest building density are Gümüşpala, Alpaslan, Muhittin Erener, Çay and Çiçek neighborhoods.

Analysis of ***road networks*** is an important factor, as the level of service plays an important role in mobility when an earthquake occurs (Shafapourtehrany et al., 2022).

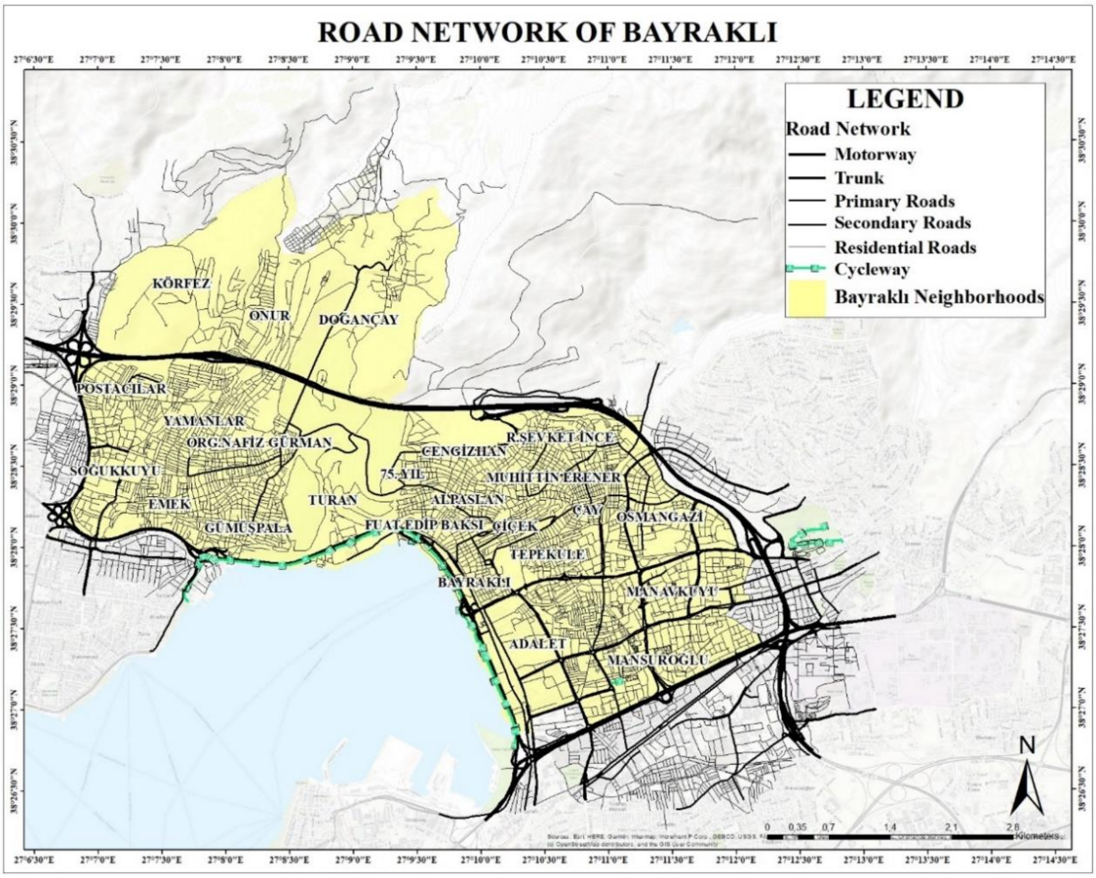

Figure 37: Road Network of Bayraklı

A map was created by considering the hierarchy in the road network of Izmir. In addition, this road network was used as a base for the service area analysis, which is a tool of network analysis used for this section.

Since ***police stations*** are one of the critical facilities, they are important for search, rescue, and assistance after the earthquake. There are a total of 5 police stations in Yamanlar, Gümüşpala, Bayraklı, Tepekule and Mansuroğlu neighborhoods.

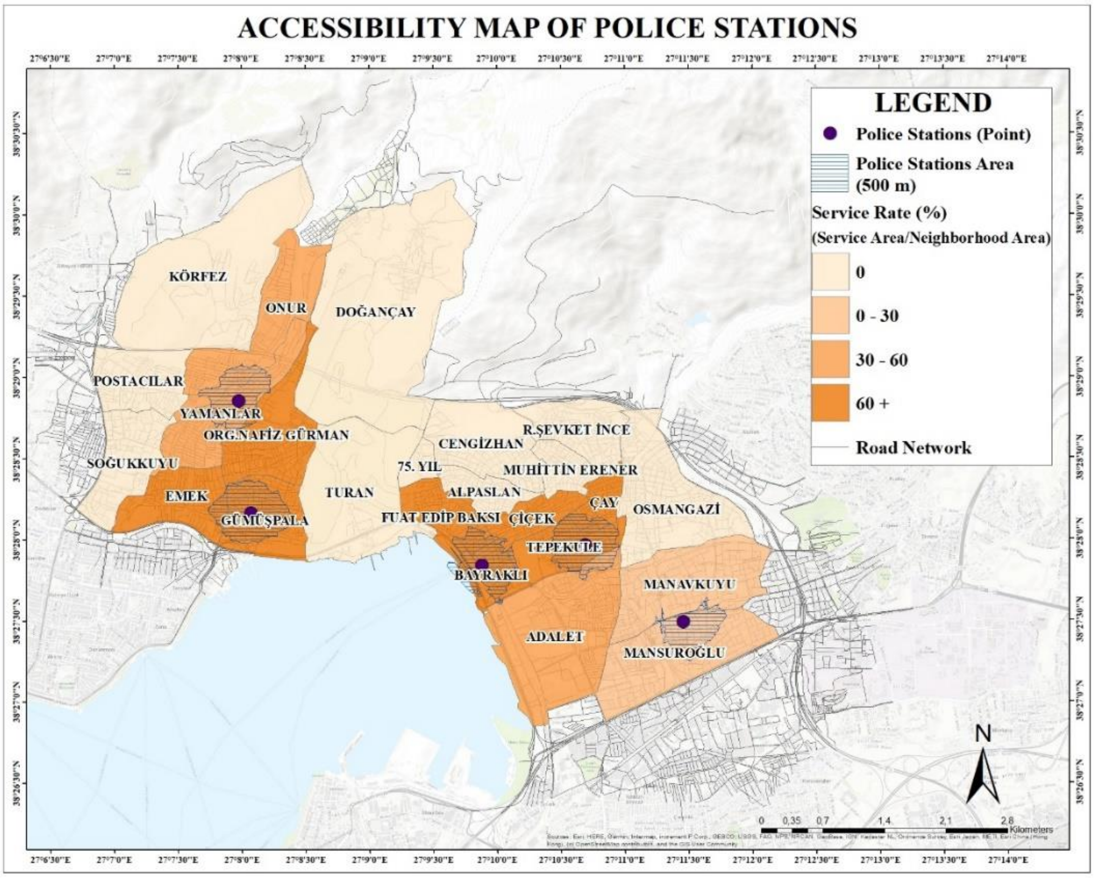

Figure 38: Distribution of Police Stations

When calculating access to critical facilities, when looking at the ratio of 500-meter accessibility areas to neighborhood areas, the neighborhoods that receive the most service are Gümüşpala, Emek, Tepekule, Bayraklı, Çay, Çiçek, Fuat Edip Baksi neighborhoods.

Distance to hospitals, one of the most critical facilities, is another important factor. Reliable access to health services, such as hospitals, decreases vulnerability against earthquake hazards and helps contain post-emergency impact (Han et al., 2021; Shafapourtehrany et al., 2022).

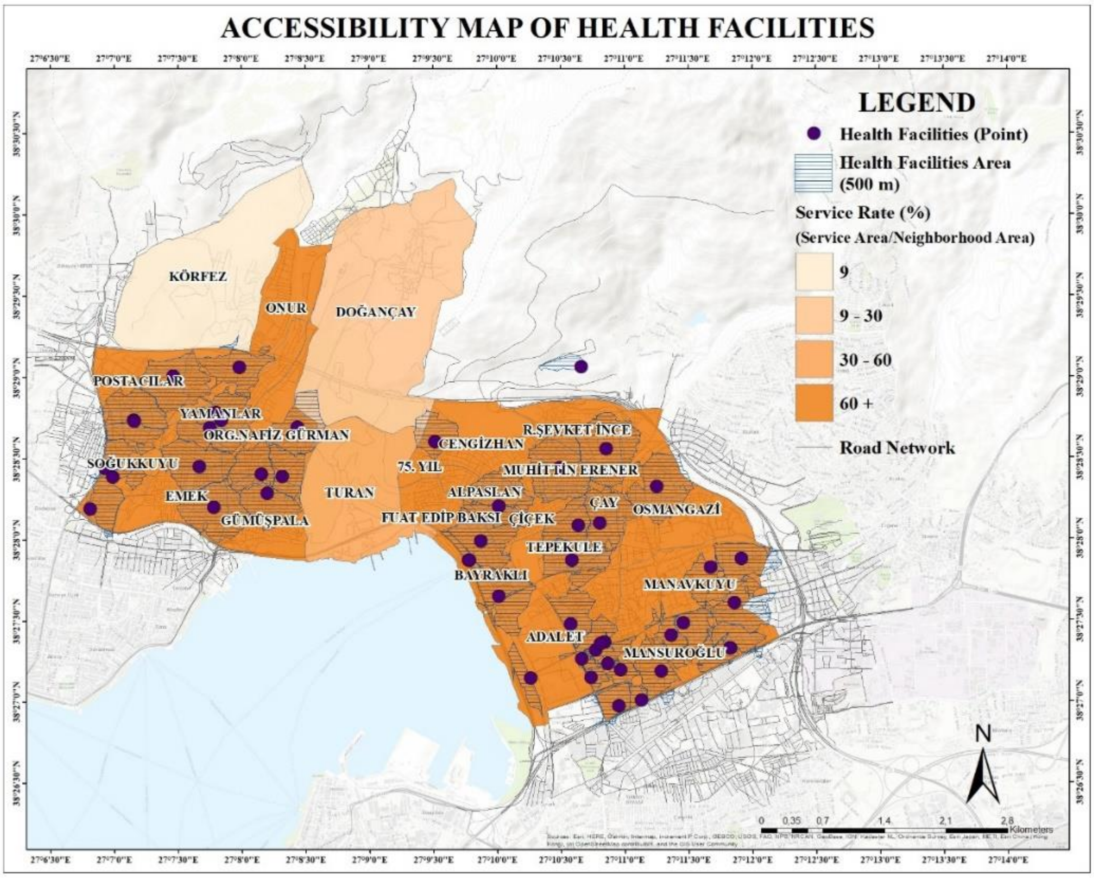

Figure 39: Distribution of Health Facilities

There are no health facilities in Körfez Turan and Doğançay neighborhoods. In addition, Körfez neighborhood receives a total of 9% service, followed by Doğançay and Turan neighborhoods, which are the neighborhoods that receive the least service.

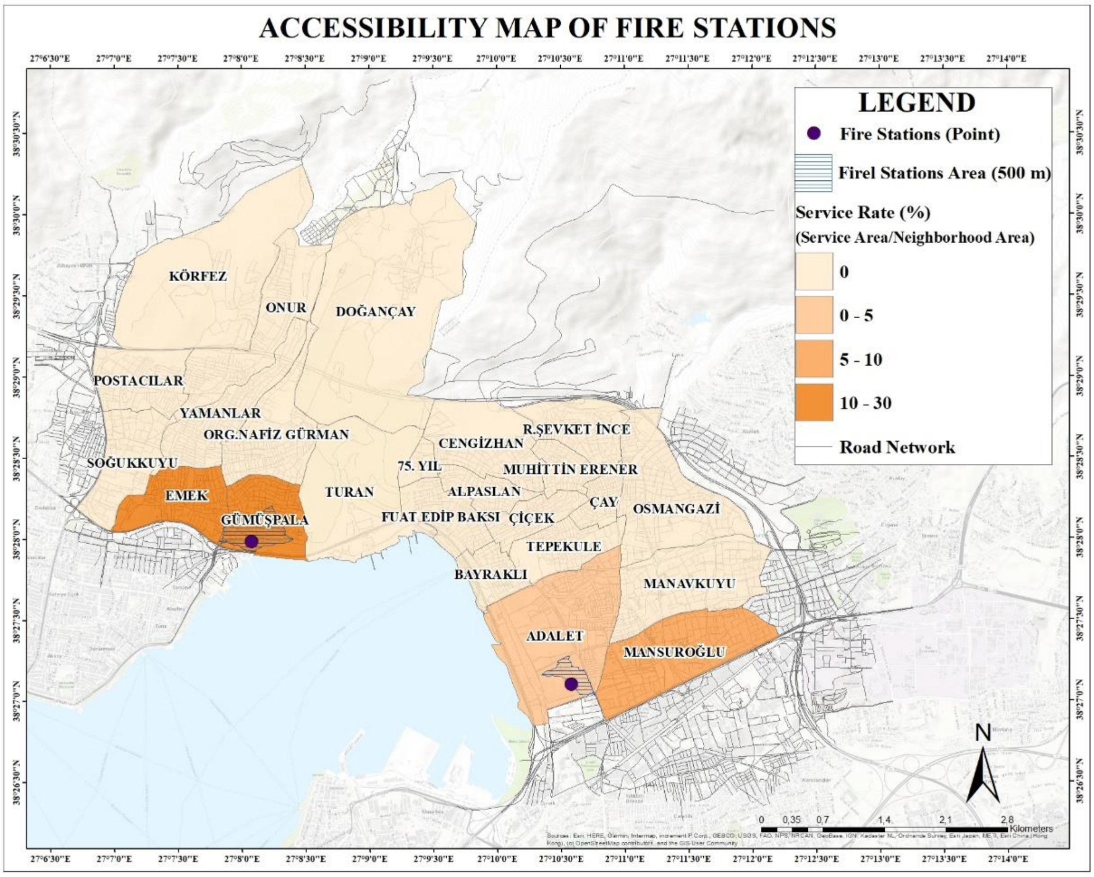

Figure 40: Distribution of Fire Stations

Fire stations are another critical facility and must remain operational for post-earthquake response operations (Shapapourtehrany et al., 2022). It seems that fire stations are in only two neighborhoods. The analysis applied to police stations and hospitals is also valid for fire stations. As seen on the map, the neighborhoods that receive the most service are Emek and Gümüşpala neighborhoods.

Another critical facility is ***fuel stations.*** They may not pose a threat under normal conditions, but during a disaster, the probability of explosion and fire is very high, and in such a case, the risk in the environment worsens (Bahadori et al., 2017) and because of these features, they can cause loss and damage (Shafapourtehrany et al., 2022).

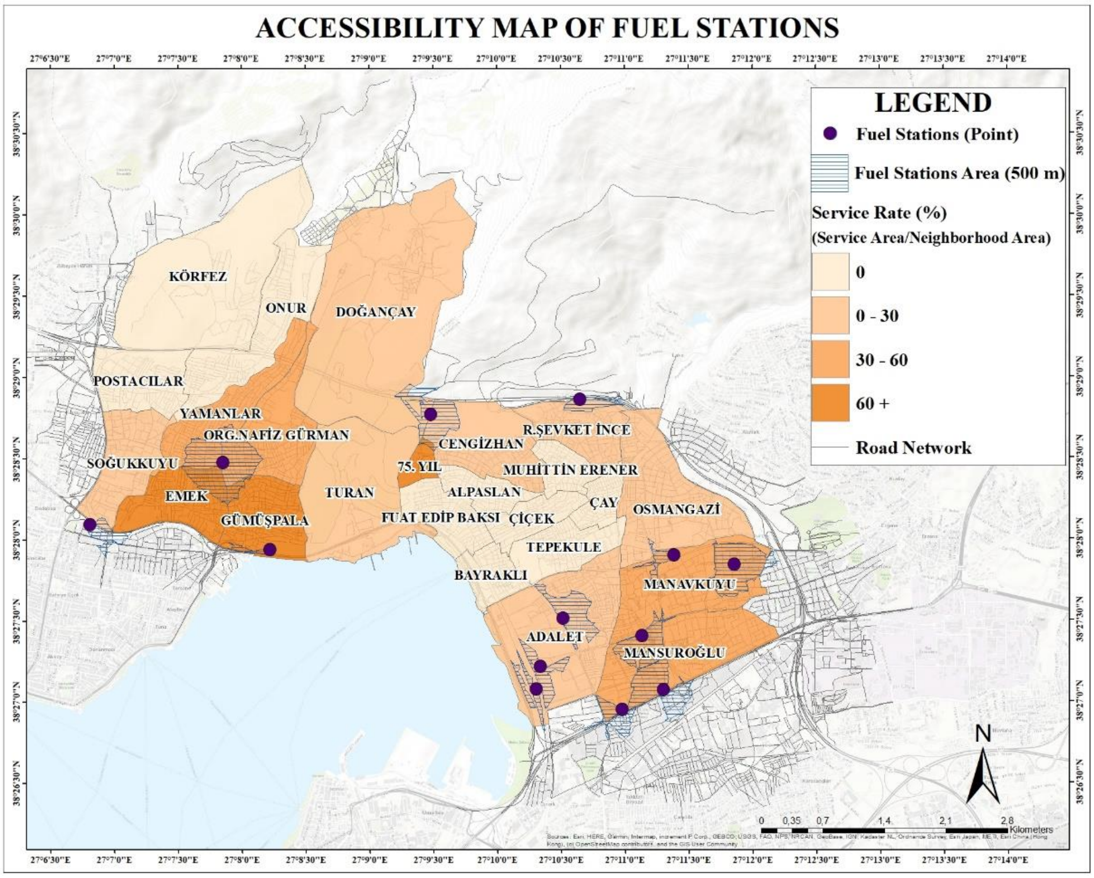

Figure 41: Distribution of Fuel Stations

When considering a natural disaster such as an earthquake, another important issue concerns ***open, green spaces and assembly areas***. People's demand to live in cities and intense construction expose green areas to the risk of exploitation instead of protecting them (Hogberg-Yılmaz, 2020). The scarcity of green and disaster gathering areas and the difficult and limited access to these areas pose a major problem in the event of an earthquake (Hogberg Yılmaz, 2020). Open spaces, parks and green areas in big cities are also strategic areas that strengthen the city's ability to cope with earthquakes and other natural disasters. They create open rescue zones in the city that provide shelter and other supplies to people in the event of a disaster (Jabareen, 2013). It is vital to be able to access these areas against possible threats.

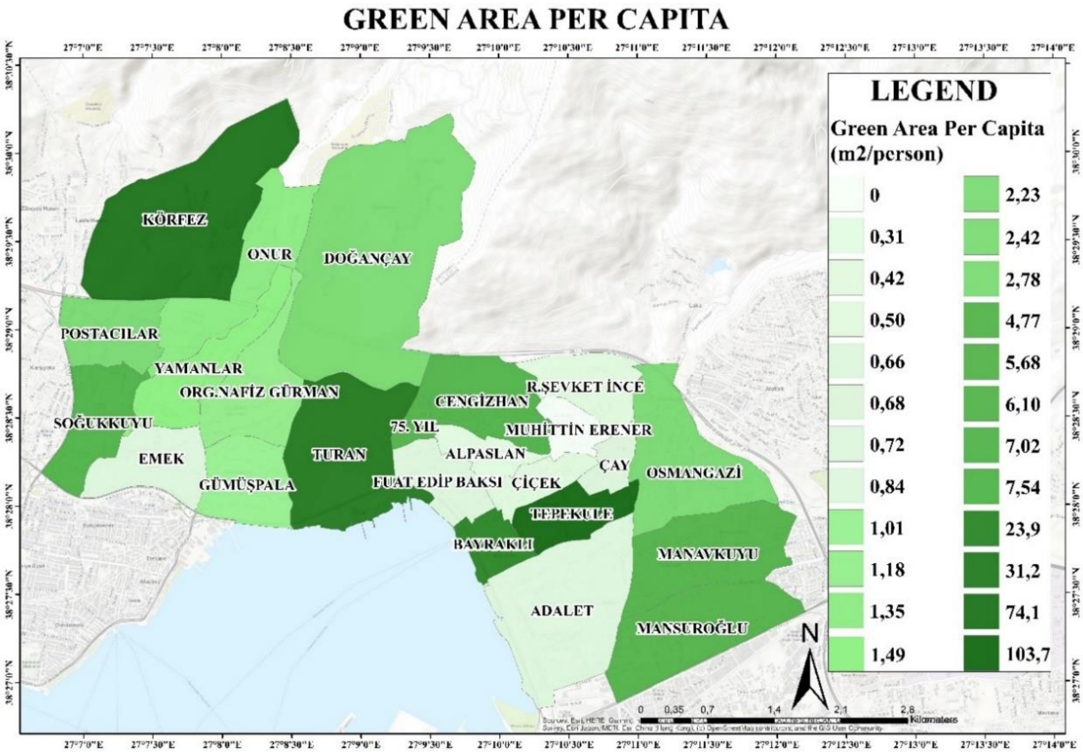

Figure 42: Adequacy of Green Areas

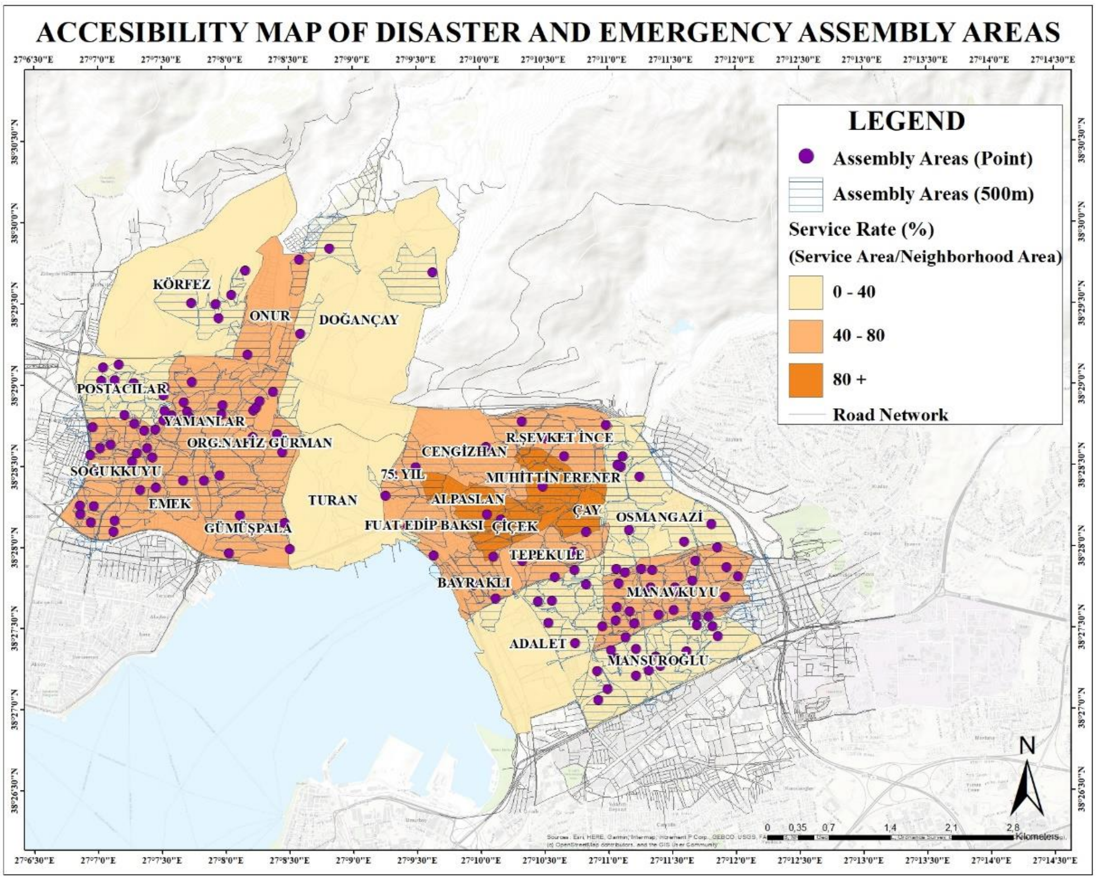

Figure 43: Accesibility to Disaster and Emergency Assembly Areas

In the map created by dividing the service area of disaster and emergency assembly areas by the neighborhood area, the neighborhoods that receive the least service are Körfez, Doğançay, Turan, Adalet, Mansuroğlu, Osmangazi and Postacılar. In the green area adequacy map, which is calculated by dividing green areas by population, the green area adequacy of the maps with the lightest colors is critically low. These neighborhoods are Muhittin Erener, Alpaslan, Çiçek, Çay, Adalet, Fuat Edip Baksi and Emek neighborhoods. It is seen that the green area per person in these areas is less than the required 10 m^2/person. Considering that Bayraklı district is one of the districts with the highest earthquake risk, the distribution of green areas is critically low. Thus, it is seen that disaster and emergency assembly areas are few in Körfez and Doğançay neighborhoods.

The service area analysis for Bayraklı district in Izmir reveals several critical deficiencies that affect the district's vulnerability to earthquake hazards. The analysis highlights a significant lack of green spaces, which are important not only for environmental and recreational purposes but also for providing vital open spaces for emergency response and rescue operations. The current distribution of green spaces does not meet recommended urban planning standards, potentially complicating efforts to manage post-earthquake relief and rescue efforts. In addition, the analysis identifies issues related to the availability and accessibility of assembly areas. These areas are crucial for organizing evacuation procedures and providing temporary shelter for residents in emergencies. The limited number and suboptimal distribution of these assembly areas can hinder efficient evacuation processes.

Access to critical facilities such as hospitals, fire stations, etc. is another important dimension. The analysis reveals that some parts of Bayraklı district face difficulties in quickly accessing these essential services. In the event of a major earthquake, delays in accessing medical care, fire response, and other critical services could significantly impact the region’s ability to manage casualties and implement effective disaster management strategies. Overall, the findings highlight the urgent need for improvements in the provision and strategic positioning of green spaces, gathering areas, and critical facilities. Addressing these issues is vital to increasing the Bayraklı region’s preparedness and resilience to earthquake hazards, enabling a more effective response to emergencies, and supporting a rapid and organized recovery.

CHAPTER 4

METHOD

4.1. Method

Decision makers (DMs) need to solve problems methodically, accurately, and consistently in numerous disciplines while adhering to their preferences. One of the most accurate approaches to decision-making is Multi-Criteria Decision Making (MCDM), also known as Multi-Criteria Decision Analysis (MCDA) (Aruldoss et al., 2013; Velasquez and Hester, 2013; as cited in Taherdoost and Madanchian, 2023). Multi-criteria decision making includes widely applied methods of decision analysis, which enable selection among alternatives, grouping or ranking of alternatives by evaluating more than one decision criterion (Saaty and Vargas, 2012).

MCDM was used as the decision-making method in this study because it is an analytical process used to evaluate complex decisions involving multiple criteria. The most important advantage of the multiple criteria methods is their capability to address the problems that are marked by different conflicting interests. Using these techniques, actors can solve problems that it is not possible to solve using broad optimization models. MCDM techniques and approaches are being employed increasingly for the evaluation of alternatives and comparative analysis. Considering that there are many options available in assessing vulnerability to earthquake hazards, AHP, one of the MCDM techniques, was used in this study. One of the main reasons why AHP was chosen as the method in this study is that it combines various vulnerability dimensions and provides a comprehensive evaluation framework in the context of vulnerability assessment against earthquake hazards. In this process, multiple indicators, often working together, are identified and analyzed to determine the overall vulnerability of an area and community. In this study, vulnerability to earthquake hazards is categorized into three basic dimensions: physical vulnerability, social vulnerability and lack of capacity of built environment.

The physical vulnerability dimension used in this study focuses on the vulnerability of buildings to earthquake hazard in Bayraklı neighborhoods. Indicators used when analyzing the vulnerability for the physical dimension include the age of buildings, building material, building configuration and building density. Assessing physical vulnerability is helpful in determining which areas are most at risk in the event of structural collapse during or after an earthquake.

Social vulnerability examines the demographic and social factors that affect a community's capacity to prepare for, respond to, and recover from an earthquake. Key indicators include the proportion of the elderly, children and women within the neighborhood population, because these groups are generally considered more vulnerable in disaster scenarios. The education factor also plays a critical role. In addition to these two criteria, socially disadvantaged groups were also considered.

Capacity of built environment assesses the ability of the built environment to withstand and recover from earthquake impacts. This dimension includes the availability and accessibility of critical infrastructures such as hospitals, emergency services, transportation networks, and utilities. By evaluating this dimension in the study, it is shown which areas of the built environment are at risk during earthquake hazards. A number of indicators have been selected to assess the capacity of built environment.

In this study, Analytical Hierarchy Process (AHP), which is a multi-criteria evaluation method, was applied for the Vulnerability Assessment for Earthquake Hazards. The research method consists of three main stages. The first stage includes determining the criteria and data preparation, the second stage involves applying the AHP method in the context of expert opinions, and the last stage involves performing aggregation operation with the help of the ArcGIS program using the obtained weights. AHP allows decision makers to assign a relative priority to each factor through pairwise comparison. GIS techniques that enable the combination of criteria obtained from different sources, were used in order to support vulnerability assessment.

4.2. Analytical Hierarchy Process

In earthquake vulnerability assessment, physical or social dimensions have mostly been studied separately. In this study, physical, social and capacity of built environment are included in determining the vulnerability levels of urban areas. The selection of dimensions was determined based on the purpose of the study, theoretical frameworks, literature, and availability of data. The first stage of the AHP is the hierarchical structuring of the decision problem. At this stage, the problem, vulnerability herein, is divided into dimensions and relevant indicators representing the dimensions.

In this study, vulnerability assessment encompasses three dimensions; (1) physical vulnerability, (2) social vulnerability and (3) capacity of built environment. These dimensions are represented with indicators.

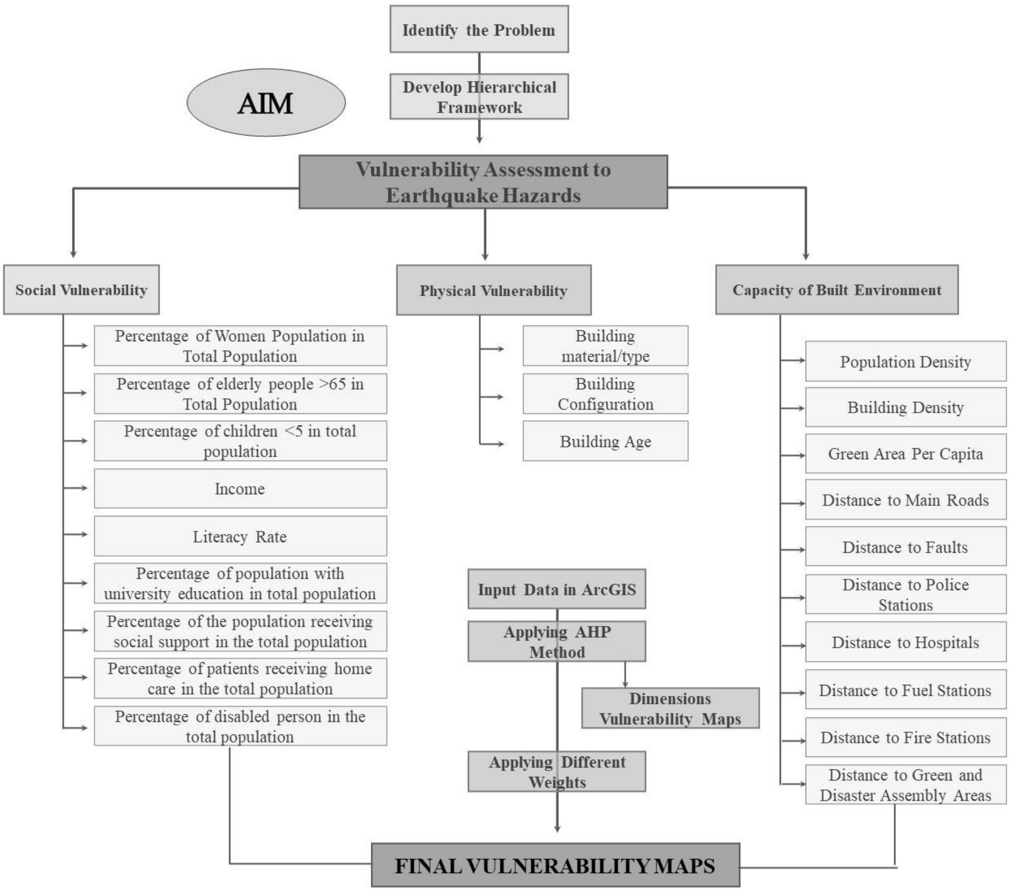

Figure 44: Flowchart of the methodology

After creating the indicator tables, the data set was normalized. The values were normalized in the range of 0-1 and 1-0 using the "Min-Max" normalization formulas. The reason for using two different normalization formulas is that some indicators have a negative effect on the degree of fragility while other indicators have a positive effect.

$$x_n = \frac{x - min\ (x)}{\max(x) - \min(x)} \quad \text{formula (1)}$$

$$x_n = \frac{\max(x) - x}{\max(x) - \min(x)} \quad \text{formula (2)}$$

After creating neighborhood-level tables of normalized values, the AHP method was applied to measure vulnerability.

The AHP model consists of 3 basic parts:

1. Hierarchy structure is created according to main dimensions and sub-dimensions
2. Pairwise comparisons of the dimensions are made and the weight of each is determined according to expert opinion.
3. Consistency of decisions is checked

After the hierarchical structure was established in the first stage of the AHP process, pairwise comparison questionnaires containing these indicators were developed (see Appendix A). In order to obtain important and reliable feedback from the selected experts during this process, the questionnaires were organized in a systematic and consistent design. The AHP process included a critical expert selection phase that required careful identification of appropriate individuals with the necessary competence in the field of vulnerability assessment. The contributing experts were carefully selected to represent a wide range of professional backgrounds and perspectives in order to provide comprehensive and complete assessments. In this context, the prepared pairwise comparison surveys were shared with urban planners and Expert opinions were taken to determine their weights in the pairwise comparison matrices, "1-5" scale based on importance was used by the experts when determining the order of importance among the criteria. The reason for using the importance scale between "1-5" instead of Saaty's "1-9" fundamental scale in the method is that the sensitivity rate is high when used in cases where the indicator sets are crowded with values between 1-9. The 1-5 importance scale was used so that decision makers can interpret more easily and produce more consistent results. After that pairwise comparison matrices were created as a result of surveys using expert opinions.

A pairwise comparison matrix was created by giving the weights. Assuming that the number of criteria in the pairwise comparison matrix is n, "n(n-1)/2" comparisons are made. The elements of the created pairwise comparison matrix obey the "reciprocal" rule. For example, while the importance of the first criterion relative to the second criterion takes the value 5, the importance of the second criterion relative to the first criterion is 1/5, the inverse of 5 (equation 1.1) (Saaty, 1987).

A

	A1	A2	A3	…	A*n*
A1	*1*	a_{12}	a_{13}	…	a_{1n}
A2	a_{21}	*1*	a_{23}	…	a_{2n}
A3	a_{31}	a_{32}	*1*	…	a_{3n}
⋮	⋮	⋮	⋮	…	⋮
A*n*	a_{n1}	a_{n2}	a_{n3}	…	*1*

Figure 45: An n-dimensional pairwise comparison matrix

(Adapted and modified by author from Saaty, 1987 & Saaty and Vargas, 2012)

$$a_{ij} = \frac{1}{a_{ji}} \qquad (1.1)$$

aij is the pairwise comparison value of the ith criterion and the jth criterion, and the aji value is obtained from 1/aij. This property is called the correspondence property. Once all the pairwise comparison matrices are created according to the rules mentioned above, the weight vector is calculated. The weight vector is calculated according to the eigenvector procedure of Saaty (1980, 2012). Calculating the weight vector involves two basic steps: First, normalizing the pairwise comparison matrix; the second is to calculate the weights from the normalized values (Saaty and Vargas, 2012).

The elements of each column in the pairwise comparison matrix is divided by the total value of that column. A normalized pairwise comparison matrix is obtained, where the sum of the values in each column is 1. This gives A'=[aij']nxn where the sum of the values in each column is equal to 1 (A' =Normalized Pairwise Comparison Matrix, aij'=normalized aij). The normalization process is done for all elements (i,j=1,2,3,…,n) in that column and is obtained with equation 1.2. (Saaty and Vargas, 2012).

$$a_{ij}' = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}} \quad (1.2)$$

After obtaining the A' (normalized) matrix, the arithmetic mean of the elements in each row is taken and the weight vector "*wi*" (also eigenvector) is obtained. The weight vector is calculated with equation 1.3 below for all elements (i=1,2,3,…,n) in that row.

$$w_i = \frac{\sum_{j=1}^{n} a_{ij}'}{n} \quad (1.3)$$

Then, the pairwise comparison matrix is analyzed to calculate the weights of each indicator using the Eigenvector method. An eigenvector is a weight vector that expresses the relative importance of each indicator (Saaty, 2008; Saaty and Vargas, 2012). The relative weights are obtained via Equation (1.5) where the maximum eigenvalue (λmax) corresponds to the right eigenvector (wi). After calculating the Eigenvector (representing the weight of each indicator), the analysis was continued to find the λmax value. The λmax value is obtained by multiplying the weight vector with the pairwise comparison matrix (each indicator value in the row is multiplied by its own weight, this is done for each indicator, then all values in the row are summed). According to Saaty (1980), the following equality exists between the weight vector and the pairwise comparison matrix A (Saaty, 2008; Saaty and Vargas, 2012). λmax equal to the product of the values in matrix A and wi.:

$$A \times wi = \lambda_{max} \quad (1.5)$$

With this formula, the eigenvalue of each indicator was found. Then, in order to find the largest eigenvalue, the eigenvalue of each indicator was divided by the eigenvector value and the average of all indicators was taken to find the largest eigenvalue, namely λmax.

The λmax value is used to analyze whether the comparison between criteria is consistent. The λmax value serves as a basic coefficient in calculating the Consistency Ratio (CR) (Alizadeh et al.,2018). The consistency of the analysis is achieved by calculating the consistency ratio (CR) developed by Saaty (2000). To calculate CR, the

Consistency Index (CI) must first be calculated (Equation 1.6). The most important issue for factor weighting in AHP is the consistency between decisions and weights. Verifying the consistency of judgments is fundamentally very important. Consistent judgments are required for the correct application of AHP to multi-criteria decision-making problems (Chang and Chao, 2012). In fact, to evaluate the consistency of the evaluation when applying the AHP method, the consistency ratio (CR) is calculated by dividing the consistency index (CI) by the random index (RI) (Saaty 1987; 2008; Chang and Chao, 2012; Azhar et al., 2021). And as the result, the CR rate should be less than 10%. If this percentage value is exceeded, the procedure must be repeated to achieve consistency (Azhar et al., 2021).

$$CI = \frac{\lambda_{\max - n}}{n-1} \quad (1.6)$$

According to Saaty (1980, 1987, 1991), n refers to the number of criteria. In addition, the closer the λmax value is to the n value, the more consistent the comparisons are (Saaty and Vargas, 2012). In this context, the Consistency Rate (CR) is obtained by dividing the Consistency Index (CI) by the Random Index (RI) (Equation 1.7). RI is the coefficient value obtained from the pairwise comparison matrix randomly determined by Saaty (1980) (Saaty and Vargas, 2012). RI takes the values in the table depending on the number of compared criteria (n).

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0	0	0,58	0,90	1,12	1,24	1,32	1,41	1,45	1,49	1,51	1,48	1,56	1,57	1,59

Figure 46: Average Random Index values based on 15 criteria numbers

(Adapted and modified by author from Saaty, 1987; Saaty and Vargas, 2012)

$$CR = \frac{CI}{RI} \quad (1.7)$$

RI values depend on the number of criteria compared. As the number of criteria increases, RI values also increase. The CR value must be less than 0.1, that is, consistent. If the CR value exceeds 0.1, the pairwise comparison matrix becomes inconsistent and decisions in the pairwise comparison matrix must be reconsidered (Saaty, 1987; Saaty and Vargas, 2012).

The final stage of solving the problem is to make a composite weighting that will cover all levels. Ultimately, a comprehensive evaluation of each alternative is achieved by calculating the result of the weight given to each criterion and the corresponding score of the alternative according to that criterion, and then summing the results obtained. The above-mentioned task is accomplished using Equation 1.8:

Final Vulnerability Assessment to Earthquake Hazards Score (1.8):

$$\sum_{i=1}^{n} Wi \times Ri$$

Here n is the number of indicators, Wi is the final weight of each factor and Ri is the ranking of the main dimensions.

In summary, after determining the criteria, creating the hierarchical structure and determining the weights, a series of spatial analyzes must be carried out on the data. In the final stage of solving the problem, a composite weighting was made to cover all levels. Then, a comprehensive evaluation of each alternative was made by calculating the result of the weight given to each criterion and the corresponding score of the alternative according to that criterion and summing the results obtained. To carry out these analyzes collectively, a basic model was created using ArcGIS in the Geographic Information Systems (GIS) environment.

CHAPTER 5

VULNERABILITY ASSESSMENT TO EARTHQUAKE HAZARDS

5.1. Earthquake Vulnerability Assessment of Bayraklı

In this study, a multi-dimensional vulnerability analysis of Bayraklı district of Izmir against earthquake hazards was conducted, and ways to make cities more resistant to earthquakes, which are an unpreventable natural phenomenon, were examined. Although earthquakes are an unpreventable natural phenomenon, disasters are preventable events; from this perspective, when the phenomenon of earthquakes is examined, the importance of vulnerability assessment against earthquake hazards becomes apparent.

In İzmir, a seismically active region of Turkey, understanding and mitigating earthquake hazards requires a multifaceted approach that addresses the unique vulnerabilities of the city. This chapter introduces a comprehensive vulnerability assessment framework specifically designed for this study area that uses the Analytical Hierarchy Process (AHP) method to assess the vulnerability of Bayraklı district of İzmir to earthquake hazards along three primary dimensions: physical vulnerability , social vulnerability, and lack of built environment capacity. The physical dimension assesses the structural integrity of buildings, identifying vulnerabilities that could lead to significant damage or failure during an earthquake. The social dimension assesses community factors such as disadvantaged groups, socioeconomic status, and demographics that affect the ability of the population to prepare for, respond to, and recover from seismic events. The capacity of the built environment examines the density, capacity and accessibility of existing infrastructure, including emergency services, transportation networks, and public service systems for sufficiency and accessibility, during and after an earthquake. This framework facilitates a systematic and weighted analysis of these dimensions using the AHP, while prioritizing vulnerabilities to earthquake hazards. In this chapter, separate analyses of the three dimensions considered for vulnerability were made and the results are shown.

Then, a series of analyses are started through Geographic Information Systems. Based on the weights resulting from the pairwise comparison matrices, the entire physical vulnerability map was created with ArcGIS in the Geographic Information Systems (GIS) environment to perform these analyses collectively. After the final weights were transferred to ArcGIS, class breaks were used to determine the vulnerability levels. There are 7 different class breaks in ArcGIS. These are "natural breaks (jenks)", "defined interval", "manual interval", "quantile", "equal interval", "geometrical interval" and "standard deviation". For example, the natural breaks (jenks) method is based on natural groupings found in the data and can be used for unequally distributed data (Gerçek and Güven, 2023; ArcGIS Data Classification Methods n.d.). Since natural breaks are essentially data-specific classifications, they are not useful for comparing multiple maps created from different underlying information (ArcGIS Data Classification Methods n.d.). The quantile method can be used for evenly distributed data and since the data is generally grouped in equal numbers in each class, the resulting map can be misleading (Gerçek and Güven, 2023; ArcGIS Data Classification Methods n.d.). For such reasons, the most appropriate class break was used in the study as "standard deviation".

Basically, Standard Deviation indicates how much an attribute value is separated from the mean and is more reliable in identifying the highest vulnerability cases, as other methods may include values that are undesirably close to the mean in these separated classes (ArcGIS Data Classification Methods n.d.; Gerçek and Güven, 2023). In ArcGIS, the mean and standard deviation are calculated automatically. Class breaks are created with equal intervals of values that are a ratio of the standard deviation; typically one-half, one-third, or one-fourth intervals, using mean values and standard deviations from the mean (ArcGIS Data Classification Methods n.d.). According to Gerçek and Güven (2023); *"Standard deviation classes are obtained by subtracting or adding a certain standard deviation (e.g., 0.5, 1, 1.5) from the mean of the dataset, which can allow the results to be compared to a future state of the same study area or to another study area given the same dataset"*. Based on the Standard Deviation classification, six categories were defined in the study (Capacity of the Built Environment has 5 class): High Vulnerability (> 1.5 Std Dev.), High-Medium Vulnerability (0.5–1.5 Std. Dev.), Medium

Vulnerability (- 0.5 to 0.5 Std. Dev.), Medium-Low Vulnerability (- 1.5 to - 0.5 Std. Dev.), Low Vulnerability (< - 1.5 to -2.5 Std. Dev.), and Lowest Vulnerability (<-2.5 Std Dev.).

5.1.1. Physical Vulnerability Assessment

Ensuring the safety of human life is the most fundamental element in the event of a possible earthquake. Although many criteria affect the damage caused by an earthquake, the main factor causing people to die or get injured is buildings that were built without engineering services or that have reached the end of their lifespan. The risk that buildings will take in the event of a possible earthquake must be determined and precautions must be taken as soon as possible. The study Building Identity Data, which Izmir Metropolitan Municipality carried out for the Bayraklı district, which was selected as a pilot after the October 30 Samos earthquake, aimed to determine the risk levels under headings such as building material (reinforced concrete and masonry buildings), building age, and building configurations. In the thesis, appropriate indicators were selected and analyzed from the study conducted for building identity data.

Table 7: Data Type and Source

DATA	DATA SOURCE	INSTITUTION
Building Material	Building Identity Data	İzmir Metropolitan Municipality
Building Configuration	Building Identity Data	İzmir Metropolitan Municipality
Building Age	Building Identity Data	İzmir Metropolitan Municipality

In this section after determining the criteria, creating the hierarchical structure and determining the weights are completed, a series of spatial analyses need to be performed on the data. Tables with percentage distribution and normalized data of indicators were created to form the basis for the ‘Physical Vulnerability’ map. In this step of the study, all indicator values were normalized and made ready to use the weights from the AHP analysis.

Table 8: Physical Vulnerability Indicators Ratio Values (%)

NEIGHBORHOODS	Detached Buildings (%)	Corner Adjacent Buildings (%)	Attached Buildings (%)	Reinforced Concrete Buildings (%)	Masonry Buildings (%)	Average Building Age (Numeric)
75. YIL	86.36	13.64	0.00	100.00	0.00	28
ADALET	17.22	48.09	34.69	68.46	31.54	17
ALPASLAN	9.54	46.33	44.13	83.20	16.80	11
BAYRAKLI	11.13	37.50	51.37	77.41	22.59	31
CENGİZHAN	21.85	46.12	32.03	85.62	14.38	12
ÇAY	26.30	45.95	27.75	58.96	41.04	13
ÇİÇEK	40.06	48.41	11.53	84.49	15.51	10
DOĞANÇAY	67.45	30.04	2.52	65.17	34.83	25
EMEK	34.06	46.82	19.12	66.26	33.74	15
FUAT EDİP BAKSI	31.23	46.45	22.33	61.23	38.77	26
GÜMÜŞPALA	30.74	50.10	19.16	72.69	27.31	11
KÖRFEZ	76.92	15.38	7.69	58.54	41.46	12
MANAVKUYU	48.55	21.97	29.47	89.34	10.66	30
MANSUROĞLU	32.35	37.70	29.95	96.92	3.08	29
MUHİTTİN ERENER	34.04	51.21	14.75	70.80	29.20	8
ONUR	42.13	37.15	20.72	62.14	37.86	19
ORG.NAFİZ GÜRMAN	48.72	38.73	12.55	65.48	34.52	15
OSMANGAZİ	16.44	40.62	42.94	92.81	7.19	25
POSTACILAR	20.30	45.57	34.13	94.71	5.29	19
R.ŞEVKET İNCE	36.71	50.13	13.16	57.91	42.09	8
SOĞUKKUYU	52.03	31.44	16.53	84.28	15.72	21
TEPEKULE	9.01	40.52	50.46	73.97	26.03	21
TURAN	50.00	36.84	13.16	36.84	63.16	31
YAMANLAR	35.42	42.30	22.28	77.47	22.53	21

Table 9: Physical Vulnerability Indicators Normalised Values (%)

NEIGHBORHOODS	N_ Detached Buildings (%)	N_ Corner Adjacent Buildings (%)	N_ Attached Buildings (%)	N_ Reinforced Concrete Buildings (%)	N_ Masonry Buildings (%)	N_ Average Building Age (Numeric)
75. YIL	1.00	0.00	0.00	1.00	0.00	1
ADALET	0.11	0.92	0.68	0.50	0.50	0
ALPASLAN	0.01	0.87	0.86	0.73	0.27	0
BAYRAKLI	0.03	0.64	1.00	0.64	0.36	1
CENGİZHAN	0.17	0.86	0.62	0.77	0.23	0
ÇAY	0.22	0.86	0.54	0.35	0.65	0
ÇİÇEK	0.40	0.93	0.22	0.75	0.25	0
DOĞANÇAY	0.76	0.44	0.05	0.45	0.55	1
EMEK	0.32	0.88	0.37	0.47	0.53	0
FUAT EDİP BAKSI	0.29	0.87	0.43	0.39	0.61	1
GÜMÜŞPALA	0.28	0.97	0.37	0.57	0.43	0
KÖRFEZ	0.88	0.05	0.15	0.34	0.66	0
MANAVKUYU	0.51	0.22	0.57	0.83	0.17	1
MANSUROĞLU	0.30	0.64	0.58	0.95	0.05	1
MUHİTTİN ERENER	0.32	1.00	0.29	0.54	0.46	0
ONUR	0.43	0.63	0.40	0.40	0.60	0
ORG.NAFİZ GÜRMAN	0.51	0.67	0.24	0.45	0.55	0
OSMANGAZİ	0.10	0.72	0.84	0.89	0.11	1
POSTACILAR	0.15	0.85	0.66	0.92	0.08	0
R.ŞEVKET İNCE	0.36	0.97	0.26	0.33	0.67	0
SOĞUKKUYU	0.56	0.47	0.32	0.75	0.25	1
TEPEKULE	0.00	0.72	0.98	0.59	0.41	1
TURAN	0.53	0.62	0.26	0.00	1.00	1
YAMANLAR	0.34	0.76	0.43	0.64	0.36	1

In the next step of the study, pairwise comparisons were made for the physical vulnerability map. Weights were determined for three sub-dimensions in the survey with expert opinions. Expert1 holds a PhD in civil engineering and has expertise in earthquake engineering and risk analysis. Currently a member of the civil engineering department. evaluated the criteria of physical vulnerability by structured pairwise comparisons. A "1-5" importance scale was used when making pairwise comparisons. The reason for using the importance scale between 1-5 instead of Saaty's 1-9 scale in the method is that the sensitivity rate is high when used in cases where the indicator sets are crowded with values between 1-9. The 1-5 importance scale was used so that decision makers can produce more consistent results.

Table 10: Comparison Matrix for Physical Vulnerability Indicators

Indicators	Building Material	Building Configuration	Building Age
Building Material	**1**	**1**	**4**
Building Configuration	**1**	**1**	**4**
Building Age	**0.25**	**0.25**	**1**
	λmax = 3.00	**CI = 0.00**	**CR = 0.00**

Comparisons and weights were calculated with the help of experts (Table 10). Then, the matrix was normalized, and the weights emerged.

Table 11: Normalised Values and Final Weigts

Indicators	Building Material	Building Configuration	Building Age	Final Weights
Building Material	**0.44**	**0.44**	**0.44**	**0.444**
Building Configuration	**0.44**	**0.44**	**0.44**	**0.444**
Building Age	**0.11**	**0.11**	**0.11**	**0.111**
λmax = 3.00		**CI = 0.00**	**CR = 0.00**	

While AHP calculates the weights according to the given rankings in the pairwise comparison, it also calculates the consistency of the given rankings. This process is called estimation of the consistency ratio. It is seen that the consistency ratio is 0.00. The matrix is considered to be consistent, and the final weights and normalized values are multiplied.

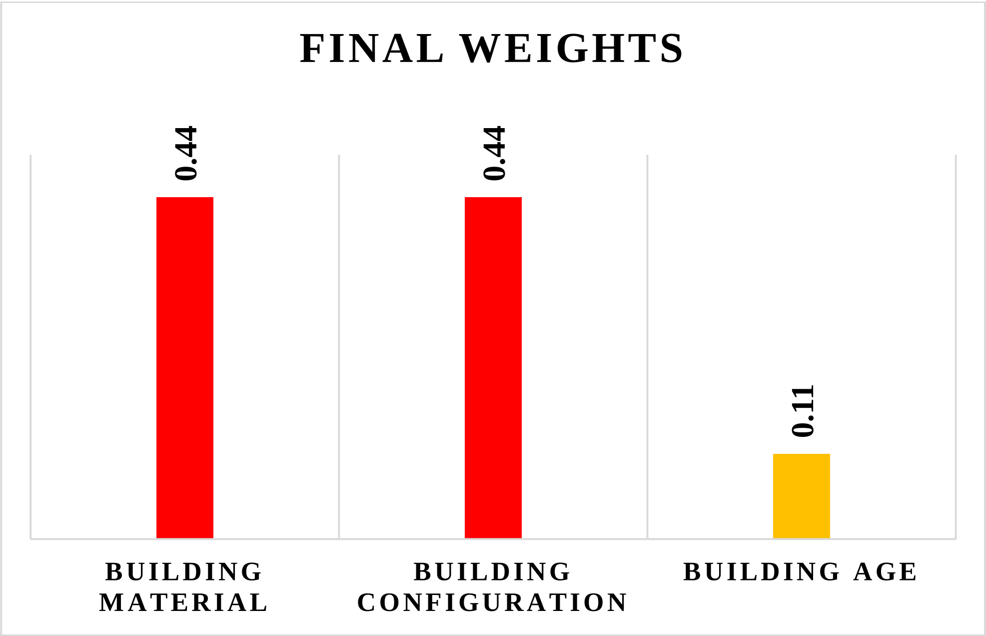

Chart 1: Physical Vulnerability Indicators Final Weight Chart

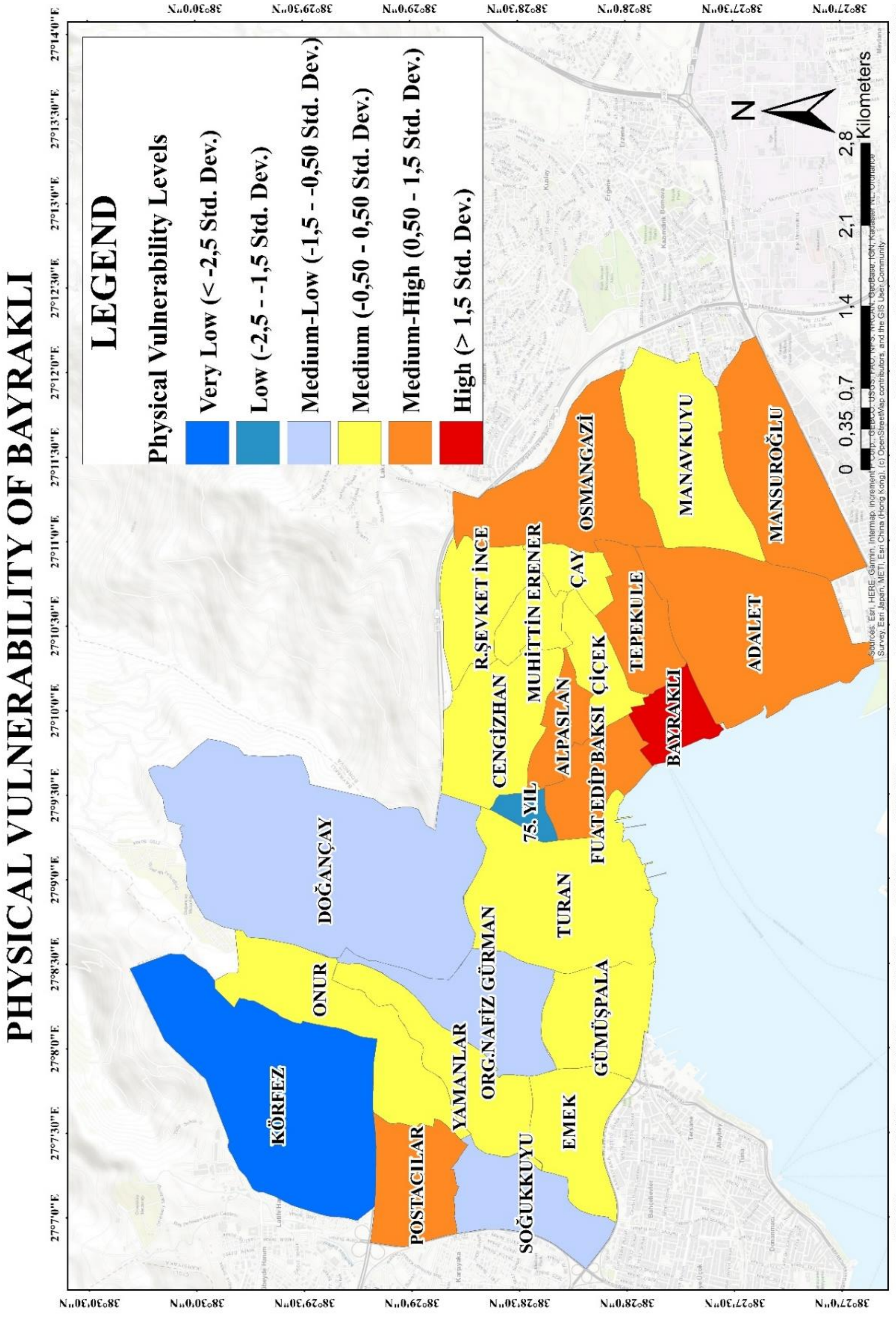

Figure 47: Physical Vulnerability of Bayraklı

For the physical dimension, neighborhood-based analyses were performed using the weights obtained by experts using AHP, and the analyses were spatialized. It is seen that the criteria with the highest importance in terms of physical vulnerability to earthquake hazards are building material and building configuration. The weight value of these two indicators is 0.444 and these indicators for the physical vulnerability distribution on the basis of neighborhoods obtained as a result of the analysis are important (Figure 47).

When looking at the overall Bayraklı district, it is known that its historical features and texture come to the fore. After all, the district has a texture that contains many different structures. This situation also affects the building quality and earthquake risk in the area. While preparing the vulnerability map, the final weights of the indicators were multiplied with the indicator values on the basis of neighborhoods, and finally the final weights of all three indicators were added.

The most vulnerable neighborhood is Bayraklı and 2.13% of the population lives in Bayraklı. When the vulnerability distribution is examined in the light of this information, it is seen that 7 out of 24 neighborhoods are at a medium-high level of physical vulnerability, and the population in these neighborhoods constitutes 39.38% of the total population. Very low and low vulnerable neighborhoods are 75. Yıl and Körfez neighborhoods. where 2.73% of the population lives. The remaining 55.76% of the population lives in medium-low and medium vulnerable neighborhoods. The biggest reason why the area has such a high vulnerability potential is that the building construction type, building configuration and building age in the area show a risky distribution. When looking at the types of building construction. It is seen that there are no steel structures that can be considered as the most earthquake-resistant type. and reinforced concrete structures are at 76%. On the other hand, the rate of masonry structures, which have a higher potential for earthquake damage, is 26%.

5.1.2. Social Vulnerability Assessment

It is not possible to easily define the concept of social vulnerability and draw its boundaries. Moreover, the fact that it cannot be completely quantified may cause the evaluations to be limited. In order to be able to associate the indicators related to the conceptual model with the harm reduction studies, indicators should be developed effectively. In order to explain social vulnerability, indicators such as female population, elderly population over 65 years of age, child population under 5 years of age,illiterate population, university graduate population, income, patient population receiving home care support, disabled individuals and population distribution receiving social support were used. Indicator sets for disadvantaged groups were taken from raw data and created by the author.

In the thesis, appropriate indicators were selected and analyzed from the institutions TURKSTAT (2019) and İzmir Metropolitan Municipality (2024).

Table 12: Data Type and Source

DATA	DATA SOURCE	INSTITUTION
Female Population	Excel Table	TURKSTAT (2019)
Population of 65 year and Over	Excel Table	TURKSTAT (2019)
Population of 5 year and Below	Excel Table	TURKSTAT (2019)
Income	Excel Table	Endeksa (2024)
Illiterate Population	Excel Table	TURKSTAT (2019)
Population of University Graduates	Excel Table	TURKSTAT (2019)
Population of Home Care Patients	Website	İzmir Metropolitan Municipality
Population of Disabled Individuals	Website	İzmir Metropolitan Municipality
Population of Receiving Social Support	Website	İzmir Metropolitan Municipality

Tables with percentage distribution and normalized data of indicators were created to form the basis for the 'Social Vulnerability' map. In this step of the study, all indicator values were normalized and made ready to use the weights from the AHP analysis.

Table 13: Social Vulnerability Indicators Values

NEIGHBORHOODS	Female Population (%)	Population of 65 year and Over (%)	Population of 5 year and Below (%)	Average Income (unit price/m2)	Illiterate Population (%)	Population of University Graduates (%)	Population of Home Care Patients (%)	Population of Disabled Individuals (%)	Population of Receiving Social Support (%)
75. YIL	51.10	8.40	6.30	145 ₺/m2	0.00	26.30	4.10	0.30	5.10
ADALET	49.80	7.40	7.00	220 ₺/m2	0.90	21.10	0.30	0.30	18.40
ALPASLAN	49.20	9.20	5.80	116 ₺/m2	1.40	7.70	0.80	0.70	22.10
BAYRAKLI	52.30	13.00	4.90	162 ₺/m2	0.50	18.60	0.60	0.60	11.70
CENGİZHAN	49.40	8.50	6.90	122 ₺/m2	2.20	6.20	0.80	0.60	24.40
ÇAY	49.50	9.60	6.30	103 ₺/m2	1.10	8.60	0.80	1.00	19.60
ÇİÇEK	49.40	10.20	5.20	123 ₺/m2	1.30	9.40	2.40	1.00	21.70
DOĞANÇAY	49.00	10.30	6.50	72 ₺/m2	0.00	6.90	0.50	1.20	24.90
EMEK	49.10	10.10	6.80	139 ₺/m2	1.90	8.80	0.50	0.40	41.00
FUAT EDİP BAKSI	50.10	10.00	5.80	166 ₺/m2	0.90	12.10	0.40	0.50	16.00
GÜMÜŞPALA	49.10	10.20	6.70	138 ₺/m2	1.40	10.10	1.40	0.60	33.50
KÖRFEZ	50.40	6.50	9.30	181 ₺/m2	0.00	42.10	0.00	0.10	11.40
MANAVKUYU	52.80	14.10	4.40	157 ₺/m2	5.90	33.70	0.50	0.20	6.60
MANSUROĞLU	52.60	12.80	4.30	196 ₺/m2	0.20	51.50	1.10	0.20	7.40
MUHİTTİN ERENER	49.40	9.30	6.90	114 ₺/m2	1.90	6.50	0.60	0.40	37.40
ONUR	48.60	5.30	9.00	97 ₺/m2	2.60	7.20	0.90	0.30	45.40
ORG.NAFİZ GÜRMAN	48.40	8.80	7.40	82 ₺/m2	2.90	6.50	0.40	0.70	124.40
OSMANGAZİ	51.00	8.80	6.40	139 ₺/m2	0.70	22.40	0.70	0.40	9.80
POSTACILAR	50.10	7.00	7.40	134 ₺/m2	1.10	15.50	0.10	0.20	16.60
R.ŞEVKET İNCE	49.10	8.50	7.30	164 ₺/m2	2.60	6.60	0.40	0.50	22.10
SOĞUKKUYU	52.20	9.60	6.30	159 ₺/m2	0.40	30.40	0.80	0.20	7.50
TEPEKULE	50.40	9.60	5.80	152 ₺/m2	0.80	16.20	0.40	0.60	13.80
TURAN	49.20	1.20	1.10	0.00	0.00	14.70	0.00	0.00	1.90
YAMANLAR	48.90	7.30	8.10	129 ₺/m2	2.40	9.20	0.60	0.40	41.80

Table 14: Social Vulnerability Indicators Normalised Values

NEIGHBORHOODS	N_Female Population (%)	N_Population of 65 year and Over (%)	N_Population of 5 year and Below (%)	N_Average Income (%)	N_Illiterate Population (%)	N_Population of University Graduates (%)	N_Population of Home Care Patients (%)	N_Population of Disabled Individuals (%)	N_Population of Receiving Social Support (%)
75. YIL	0.614	0.558	0.634	1.460	0.000	0.556	1.000	0.250	0.026
ADALET	0.318	0.481	0.720	1.680	0.153	0.671	0.073	0.250	0.135
ALPASLAN	0.182	0.620	0.573	0.694	0.237	0.967	0.195	0.583	0.165
BAYRAKLI	0.886	0.915	0.463	1.236	0.085	0.726	0.146	0.500	0.080
CENGİZHAN	0.227	0.566	0.707	0.778	0.373	1.000	0.195	0.500	0.184
ÇAY	0.250	0.651	0.634	0.718	0.186	0.947	0.195	0.833	0.144
ÇİÇEK	0.227	0.698	0.500	0.760	0.220	0.929	0.585	0.833	0.162
DOĞANÇAY	0.136	0.705	0.659	0.486	0.000	0.985	0.122	1.000	0.188
EMEK	0.159	0.690	0.695	0.861	0.322	0.943	0.122	0.333	0.319
FUAT EDİP BAKSI	0.386	0.682	0.573	1.182	0.153	0.870	0.098	0.417	0.115
GÜMÜŞPALA	0.159	0.698	0.683	0.861	0.237	0.914	0.341	0.500	0.258
KÖRFEZ	0.455	0.411	1.000	1.649	0.000	0.208	0.000	0.083	0.078
MANAVKUYU	1.000	1.000	0.402	1.335	1.000	0.393	0.122	0.167	0.038
MANSUROĞLU	0.955	0.899	0.390	1.519	0.034	0.000	0.268	0.167	0.045
MUHİTTİN ERENER	0.227	0.628	0.707	0.633	0.322	0.993	0.146	0.333	0.290
ONUR	0.045	0.318	0.963	0.690	0.441	0.978	0.220	0.250	0.355
ORG.NAFİZ GÜRMAN	0.000	0.589	0.768	0.554	0.492	0.993	0.098	0.583	1.000
OSMANGAZİ	0.591	0.589	0.646	1.081	0.119	0.642	0.171	0.333	0.064
POSTACILAR	0.386	0.450	0.768	1.130	0.186	0.795	0.024	0.167	0.120
R.ŞEVKET İNCE	0.159	0.566	0.756	1.293	0.441	0.991	0.098	0.417	0.165
SOĞUKKUYU	0.864	0.651	0.634	1.489	0.068	0.466	0.195	0.167	0.046
TEPEKULE	0.455	0.651	0.573	1.083	0.136	0.779	0.098	0.500	0.097
TURAN	0.182	0.000	0.000	0.000	0.000	0.812	0.000	0.000	0.000
YAMANLAR	0.114	0.473	0.854	0.828	0.407	0.934	0.146	0.333	0.326

In the next step of the study, pairwise comparisons were made for the social vulnerability map. Weights were determined for three sub-dimensions in the survey with expert opinions. A 1-5 importance scale was used when making pairwise comparisons. Expert2 holds a PhD in Sociology and specializes in social sciences and urbanism and urban sociology. She currently works within the Izmir Metropolitan Municipality. Exepert 2 assessed social vulnerability through structured pairwise comparisons.

Table 15: Comparison Matrix for Social Vulnerability Indicators

Indicators	Female Population	Population of 65 year and Over	Population of 5 year and Below	Income	Illiterate Population	Population of University Graduates	Population of Home Care Patients	Population of Disabled Individuals	Population of Receiving Social Support
Female Population	**1**	**0.50**	**0.20**	**0.25**	**0.33**	**3**	**0.20**	**0.20**	**0.25**
Population of 65 year and Over	**2**	**1**	**0.20**	**0.33**	**0.33**	**3**	**0.25**	**0.25**	**0.25**
Population of 5 year and Below	**5**	**5**	**1**	**4**	**4**	**4**	**4**	**4**	**4**
Average Income	**4**	**3**	**0.25**	**1**	**1**	**3**	**0.33**	**0.33**	**0.33**
Illiterate Population	**3**	**3**	**0.25**	**1**	**1**	**3**	**0.25**	**0.25**	**0.25**
Population of University Graduates	**0.33**	**0.33**	**0.25**	**0.33**	**0.33**	**1**	**0.25**	**0.25**	**0.25**
Population of Home Care Patients	**5**	**4**	**0.25**	**3**	**4**	**4**	**1**	**0.33**	**1**
Population of Disabled Individuals	**5**	**4**	**0.25**	**3**	**4**	**4**	**3**	**1**	**4**
Population of Receiving Social Support	**4**	**4**	**0.25**	**3**	**4**	**4**	**1**	**0.25**	**1**
	λmax=10.129				**CI=0.141**			**CR=0.097**	

Comparisons and weights were calculated with the help of experts. Then, the matrix was normalized, and the weights emerged.

Table 16: Normalised Values and Final Weigts of Social Vulnerability Indicators

Indicators	Female Population	Population of 65 year and Over	Population of 5 year and Below	Income	Illiterate Population	Population of University Graduates	Population of Home Care Patients	Population of Disabled Individuals	Population of Receiving Social Support	**Final Weights**
Female Population	**0**	**0.02**	**0.07**	**0.02**	**0.02**	**0**	**0.02**	**0.03**	**0.02**	**0.037**
Population of 65 year and Over	**0**	**0**	**0.07**	**0.02**	**0.02**	**0**	**0.02**	**0.04**	**0.02**	**0.045**
Population of 5 year and Below	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0.293**
Income	**0**	**0**	**0.09**	**0**	**0**	**0**	**0.03**	**0.05**	**0.03**	**0.075**
Illiterate Population	**0**	**0**	**0.09**	**0**	**0**	**0**	**0.02**	**0.04**	**0.02**	**0.068**
Population of University Graduates	**0.01**	**0.01**	**0.09**	**0.02**	**0.02**	**0**	**0.02**	**0.04**	**0.02**	**0.030**
Population of Home Care Patients	**0**	**0**	**0.09**	**0**	**0**	**0**	**0**	**0.05**	**0**	**0.132**
Population of Disabled Individuals	**0**	**0**	**0.09**	**0**	**0**	**0**	**0**	**0**	**0**	**0.194**
Population of Receiving Social Support	**0**	**0**	**0.09**	**0**	**0**	**0**	**0**	**0.04**	**0**	**0.127**
		λmax=10.129				**CI=0.141**			**CR=0.097**	

While AHP calculates the weights according to the given rankings in the pairwise comparison, it also calculates the consistency of the given rankings. This process is called estimation of the consistency ratio. It is seen that the consistency ratio is 0.097. The matrix is considered to be consistent, and the final weights and normalized values are multiplied.

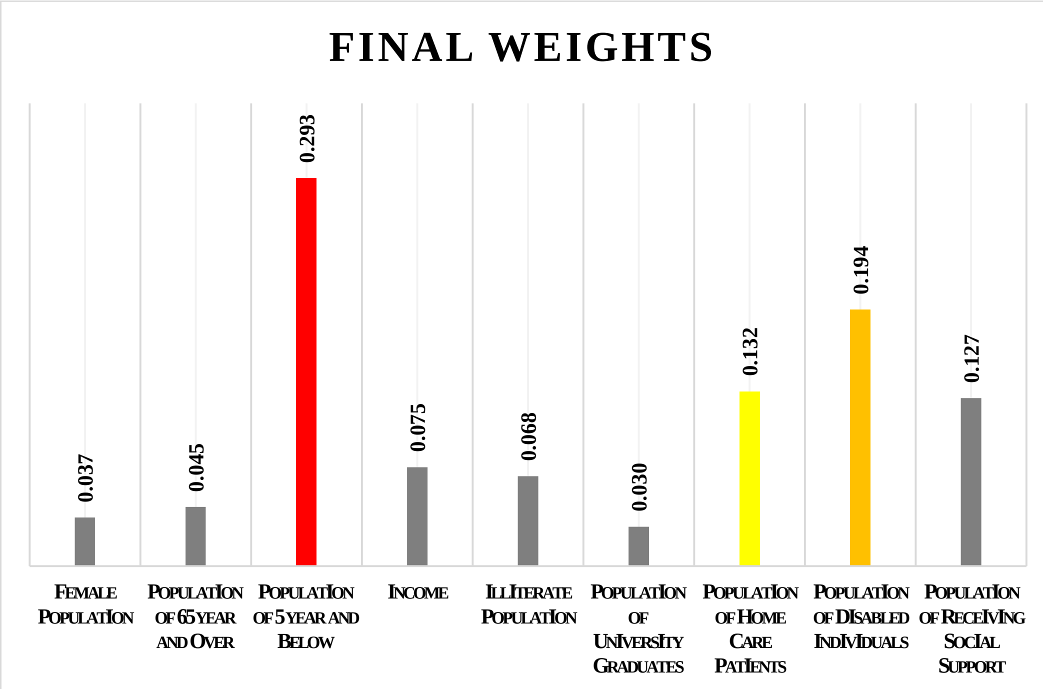

Chart 2: Social Vulnerability Indicators Final Weight Chart

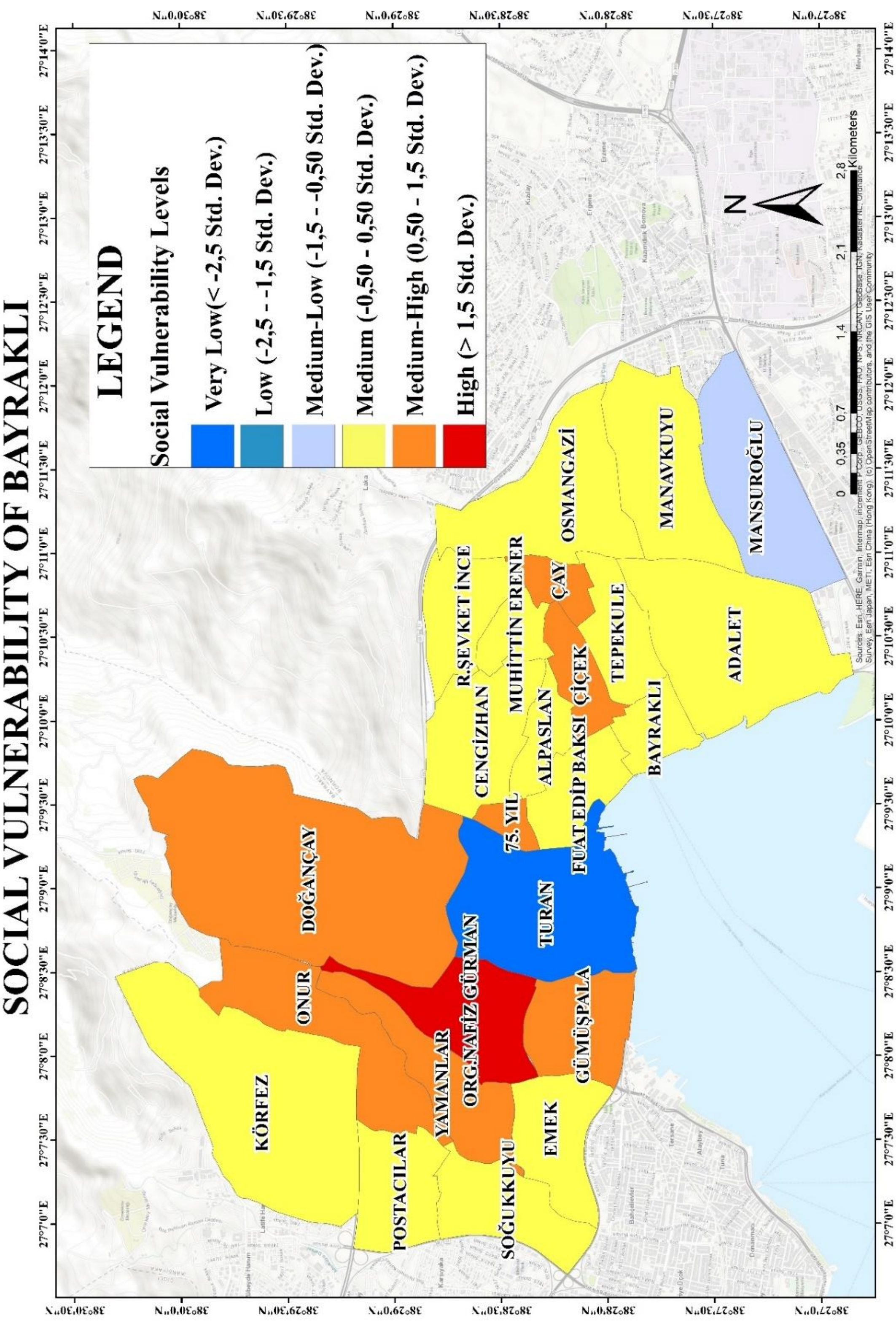

Figure 48: Social Vulnerability Map of Bayraklı

For the social dimension, neighborhood-based analyses were performed using the weights obtained by experts using AHP, and the analyses were spatialized. It is seen that the criterion with the highest importance in terms of social vulnerability to earthquake hazards is population of 5 years and below. The weight value of this indicator is 0.293, and this indicator is composed of disabled individuals with a weight value of 0.194, and patients receiving home care support with 0.132, and therefore, the neighborhood-based social vulnerability distribution obtained as a result of the analysis is important (Figure 48).

When the Bayraklı district is examined in general, it is seen that the majority of the district consists of 'gecekondus'. This situation also affects the earthquake risk. While preparing the vulnerability map, the final weights of the indicators were multiplied by the neighborhood-based indicator values, and finally the final weights of all three indicators were added.

The most vulnerable neighborhood is Org. Nafiz Gürman. where 4.69% of the population lives. When the vulnerability distribution is examined in the light of this information, it is seen that 7 out of 24 neighborhoods are at a medium-high social vulnerability level, and the population in these neighborhoods constitutes 23.37% of the total population. 8.59% of the population lives in areas with low and very low vulnerability levels. The remaining 63.35% of the region lives in neighborhoods with moderate vulnerability. The biggest reason why the district has such a high vulnerability potential is that people receiving social support, people receiving home care support and disadvantaged population groups in the region show a risky distribution.

5.1.3. Capacity of Built Environment Assessment

One of the most important criteria in terms of earthquake vulnerability is accessibility to uses such as hospitals and green areas. The distribution of critical facilities, which is determined as another most important criterion in terms of earthquake vulnerability, is quite important in urban and densely populated areas. The distribution of these uses, which are directly affected by land use decisions, becomes especially important during and after an earthquake. The distribution of these areas is of vital importance for rapid evacuation and first response operations after an earthquake.

In addition, uses such as open green areas are also suitable for use as temporary shelter areas and escape points. In line with the AHP results, a map of vulnerability levels obtained on a neighborhood basis was created as a result of the analysis of infrastructure facilities, urban uses and population density. In line with the data obtained from the Izmir Metropolitan Municipality Geographic Information Systems unit, it was aimed to determine the risk vulnerability level under the density and capacity headings.

Table 17: Data Type and Source

DATA	DATA TYPE	INSTITUTION
Building Density	Vector	İzmir Metropolitan Municipality
Population Density	Vector	İzmir Metropolitan Municipality
Adequacy of Green Areas	Vector	İzmir Metropolitan Municipality
Distance to Main Roads	Vector	İzmir Metropolitan Municipality
Distance to Police Stations	Vector	İzmir Metropolitan Municipality
Distance to Hospitals	Vector	İzmir Metropolitan Municipality
Distance to Fuel Stations	Vector	İzmir Metropolitan Municipality
Distance to Fire Stations	Vector	İzmir Metropolitan Municipality
Distance Disaster and Emergency Assembly Areas	Vector	İzmir Metropolitan Municipality

In this section after determining the criteria, creating the hierarchical structure and determining the weights are completed, a series of spatial analyses need to be performed on the data. Indicator such as fire stations and fuel stations created by the author on ArcGIS.

ArcGIS-based network analysis service areas tool was used to access critical facilities. Using the “service area” tool from the ArcGIS based “network analysis”, the accessibility status of these critical facilities in the study area was determined. When calculating the service area, a 500-meter walking distance was used, and these areas were divided into neighborhood areas to create a ratio. The amount of green space per person (neighborhood-based) was calculated using open green space digital data bases and population data from TURKSTAT (TUIK). Green space service areas in neighborhoods were determined from the digital databases. The total population and population density of the neighborhoods were determined using population data from TURKSTAT.

Tables with percentage distribution and normalized data of indicators were created to form the basis for the ‘Capacity of Built Environment’ map. In this step of the study. all indicator values were normalized and made ready to use the weights from the AHP analysis

Table 18: Capacity of Built Environment Indicators Values

NEIGHBORHOODS	Building Density (Number of Buildings/HA)	Population Density (Population/HA)	Green Area Per Capita (m2/person)	Distance to Main Roads (500m Service Area / Neighborhood Area)	Distance to Police Stations (500m Service Area/ Neighborhood Area)	Distance to Hospitals (500m Service Area/ Neighborhood Area)	Distance to Fuel Stations (500m Service Area/ Neighborhood Area)	Distance to Fire Stations (500m Service Area/ Neighborhood Area)	Distance to Disaster and Emergency Assembly Areas (500m Service Area/ Neighborhood Area)
75. YIL	6.0	231	5.68	1.96	0.00	1.20	1.69	0.00	2.53
ADALET	17.0	107	0.85	0.46	0.41	0.73	0.19	0.05	0.81
ALPASLAN	85.0	262	0.31	4.77	0.00	4.29	0.00	0.00	3.70
BAYRAKLI	28.0	180	23.93	0.83	1.05	1.77	0.00	0.00	1.74
CENGİZHAN	41.0	129	7.03	1.63	0.00	0.84	0.25	0.00	1.50
ÇAY	85.0	305	0.68	2.97	1.56	5.01	0.00	0.00	3.94
ÇİÇEK	80.0	248	0.51	5.32	2.00	3.92	0.00	0.00	3.51
DOĞANÇAY	3.0	6	2.42	0.15	0.00	0.13	0.07	0.00	0.35
EMEK	58.0	168	0.72	1.16	0.63	1.20	0.78	0.32	1.58
FUAT EDİP BAKSI	51.0	218	0.67	2.16	0.69	1.27	0.00	0.00	2.22
GÜMÜŞPALA	63.0	200	1.01	1.12	0.61	1.26	0.66	0.31	1.41
KÖRFEZ	2.0	20	74.17	0.15	0.00	0.10	0.00	0.00	0.32
MANAVKUYU	12.0	246	4.78	0.20	0.22	0.86	0.41	0.00	1.41
MANSUROĞLU	13.0	196	6.11	0.12	0.21	1.01	0.41	0.08	1.12
MUHİTTİN ERENER	85.0	279	0.00	3.70	0.00	3.74	0.00	0.00	3.78
ONUR	37.0	139	1.35	0.54	0.32	0.83	0.00	0.00	1.32
ORG.NAFİZ GÜRMAN	53.0	161	1.18	1.29	0.92	1.91	0.53	0.00	1.53
OSMANGAZİ	25.0	189	2.79	0.60	0.00	0.76	0.03	0.00	1.08
POSTACILAR	31.0	179	2.24	0.55	0.00	0.81	0.00	0.00	1.16
R.ŞEVKET İNCE	58.0	185	0.43	2.01	0.00	1.28	0.11	0.00	1.56
SOĞUKKUYU	9.0	152	7.54	0.81	0.00	1.33	0.11	0.00	1.31
TEPEKULE	42.0	272	103.75	2.52	1.38	2.36	0.00	0.00	1.85
TURAN	0.0	1	31.26	0.45	0.00	0.37	0.14	0.00	0.39
YAMANLAR	56.0	213	1.50	1.25	0.44	1.61	0.58	0.00	2.39

Table 19: Capacity of the Built Environment Indicators Normalised Values

NEIGHBORHOODS	N_Building Density (Number of Buildings/HA)	N_Population Density (Population/ HA)	N_ Green Area Per Capita (m2/person)	N_Distance to Main Roads (500m Service Area / Neighborhood Area)	N_Distance to Police Stations (500m Service Area/ Neighborhood Area)	N_Distance to Hospitals (500m Service Area/ Neighborhood Area)	N_Distance to Fuel Stations (500m Service Area/ Neighborhood Area)	N_Distance to Fire Stations (500m Service Area/ Neighborhood Area)	N_Distance to Disaster and Emergency Assembly Areas (500m Service Area/ Neighborhood Area)
75. YIL	0.071	0.757	0.055	0.354	0.000	0.225	1.000	0.000	0.610
ADALET	0.200	0.349	0.008	0.066	0.206	0.130	0.111	0.165	0.136
ALPASLAN	1.000	0.859	0.003	0.893	0.000	0.854	0.000	0.000	0.933
BAYRAKLI	0.329	0.589	0.231	0.136	0.522	0.340	0.000	0.000	0.393
CENGİZHAN	0.482	0.421	0.068	0.291	0.000	0.151	0.148	0.000	0.327
ÇAY	1.000	1.000	0.007	0.547	0.781	1.000	0.000	0.000	1.000
ÇİÇEK	0.941	0.813	0.005	1.000	1.000	0.779	0.000	0.000	0.882
DOĞANÇAY	0.035	0.016	0.023	0.007	0.000	0.007	0.039	0.000	0.008
EMEK	0.682	0.549	0.007	0.200	0.315	0.224	0.460	1.000	0.348
FUAT EDİP BAKSI	0.600	0.714	0.006	0.392	0.345	0.239	0.000	0.000	0.525
GÜMÜŞPALA	0.741	0.655	0.010	0.193	0.305	0.238	0.392	0.968	0.301
KÖRFEZ	0.024	0.063	0.715	0.006	0.000	0.000	0.000	0.000	0.000
MANAVKUYU	0.141	0.806	0.046	0.016	0.110	0.155	0.242	0.000	0.302
MANSUROĞLU	0.153	0.641	0.059	0.000	0.106	0.185	0.245	0.235	0.222
MUHİTTİN ERENER	1.000	0.914	0.000	0.687	0.000	0.742	0.000	0.000	0.955
ONUR	0.435	0.454	0.013	0.082	0.161	0.150	0.000	0.000	0.276
ORG.NAFİZ GÜRMAN	0.624	0.526	0.011	0.226	0.460	0.369	0.317	0.000	0.335
OSMANGAZİ	0.294	0.618	0.027	0.092	0.000	0.136	0.020	0.000	0.211
POSTACILAR	0.365	0.586	0.022	0.082	0.000	0.146	0.000	0.000	0.232
R.ŞEVKET İNCE	0.682	0.605	0.004	0.364	0.000	0.241	0.064	0.000	0.343
SOĞUKKUYU	0.106	0.497	0.073	0.133	0.000	0.251	0.067	0.000	0.275
TEPEKULE	0.494	0.891	1.000	0.461	0.691	0.460	0.000	0.000	0.424
TURAN	0.000	0.000	0.301	0.064	0.000	0.056	0.084	0.000	0.019
YAMANLAR	0.659	0.697	0.014	0.218	0.222	0.309	0.345	0.000	0.572

In the next step of the study, pairwise comparisons were made for the capacity of built environment map. Weights were determined for two sub-dimensions in the survey with expert opinions. A 1-5 importance scale was used when making pairwise comparisons. Expert 3 holds a PhD in urban planning and is an expert in social sciences, geography and urban morphology. She is currently a member of the Department of Urban Planning at KTU, where she evaluated the capacity of built environment criteria through structured pairwise comparisons.

Table 20: Comparison Matrix for Capacity of the Built Environment Indicators

Indicators	Building Density	Population Density	Green Area Per Capita	Distance to Main Roads	Distance to Police Stations	Distance to Hospitals	Distance to Fuel Stations	Distance to Fire Stations	Distance Green and Assembly Areas
Building Density	**1**	**0.25**	**0.50**	**0.33**	**2**	**0.25**	**2**	**0.25**	**0.33**
Population Density	**4**	**1**	**1**	**2**	**2**	**1**	**3**	**0.50**	**1**
Green Area Per Capita	**2**	**1**	**1**	**0.50**	**2**	**0.33**	**2**	**1**	**2**
Distance to Main Roads	**3**	**0.50**	**2**	**1**	**3**	**0.50**	**3**	**2**	**2**
Distance to Police Stations	**0.50**	**0.50**	**0.50**	**0.33**	**1**	**0.33**	**2**	**1**	**1**
Distance to Hospitals	**4**	**1**	**3**	**2**	**3**	**1**	**3**	**1**	**2**
Distance to Fuel Stations	**0.50**	**0.33**	**0.50**	**0.33**	**0.50**	**0.33**	**1**	**0.50**	**0.50**
Distance to Fire Stations	**4**	**2**	**1**	**0.50**	**1**	**1**	**2**	**1**	**2**
Distance Green and Assembly Areas	**3**	**1**	**0.50**	**0.50**	**1**	**0.50**	**2**	**0.50**	**1**
	λmax=9.691			**CI=0.086**				**CR=0.060**	

Table 21: Normalised Values and Final Weigts of Capacity of Built Environmen Indicators

Indicators	Building Density	Population Density	Green Area Per Capita	Distance to Main Roads	Distance to Police Stations	Distance to Hospitals	Distance to Fuel Stations	Distance to Fire Stations	Distance Green and Assembly Areas	**Final Weights**
Building Density	**0.05**	**0.03**	**0.05**	**0.04**	**0.13**	**0.05**	**0.10**	**0.03**	**0.03**	**0.057**
Population Density	**0.18**	**0.13**	**0.10**	**0.27**	**0.13**	**0.19**	**0.15**	**0.06**	**0.08**	**0.144**
Green Area Per Capita	**0.09**	**0.13**	**0.10**	**0.07**	**0.13**	**0.06**	**0.10**	**0.13**	**0.17**	**0.109**
Distance to Main Roads	**0.14**	**0.07**	**0.20**	**0.13**	**0.19**	**0.10**	**0.15**	**0.26**	**0.17**	**0.156**
Distance to Police Stations	**0.02**	**0.07**	**0.05**	**0.04**	**0.06**	**0.06**	**0.10**	**0.13**	**0.08**	**0.069**
Distance to Hospitals	**0.18**	**0.13**	**0.30**	**0.27**	**0.19**	**0.19**	**0.15**	**0.13**	**0.17**	**0.190**
Distance to Fuel Stations	**0.02**	**0.04**	**0.05**	**0.04**	**0.03**	**0.06**	**0.05**	**0.06**	**0.04**	**0.046**
Distance to Fire Stations	**0.18**	**0.26**	**0.10**	**0.07**	**0.06**	**0.19**	**0.10**	**0.13**	**0.17**	**0.141**
Distance Green and Assembly Areas	**0.14**	**0.13**	**0.05**	**0.07**	**0.06**	**0.10**	**0.10**	**0.06**	**0.08**	**0.088**
	λmax=9.691			**CI=0.086**			**CR=0.060**			

While AHP calculates the weights according to the given rankings in the pairwise comparison, it also calculates the consistency of the given rankings. This process is called estimation of the consistency ratio. It is seen that the consistency ratio is 0.060. The matrix is considered to be consistent, and the final weights and normalized values are multiplied.

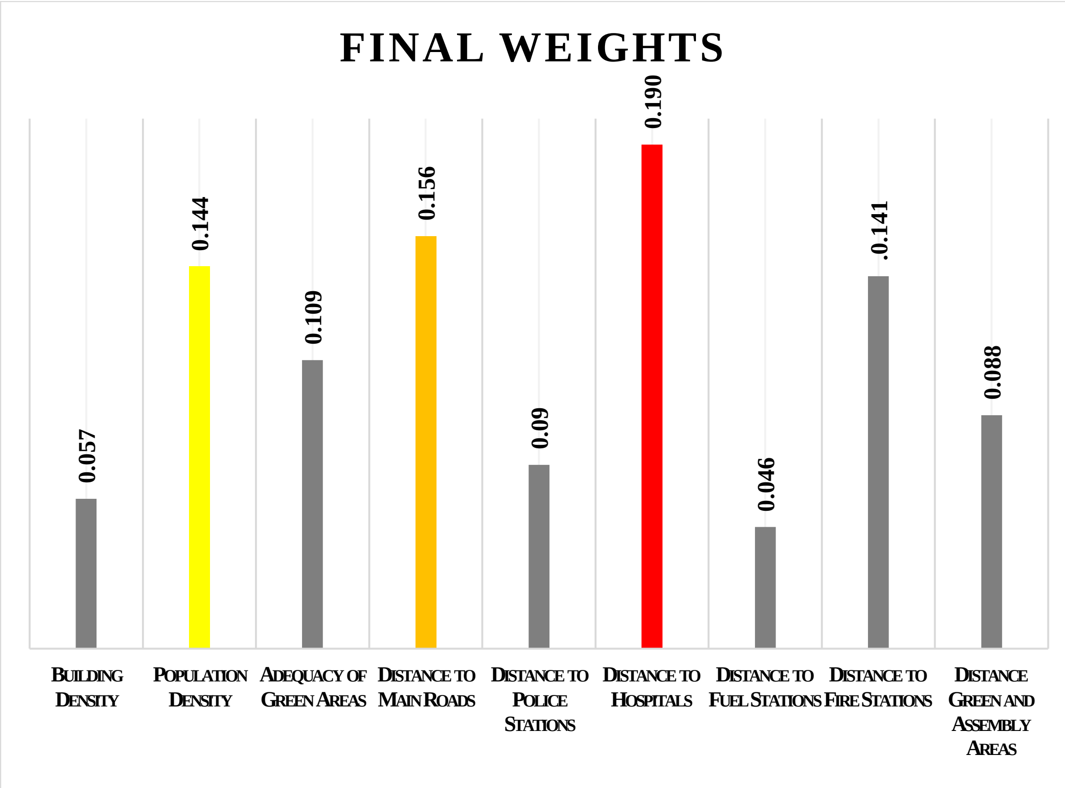

Chart 3: Capacity of Built Environment Indicators Final Weight Chart

Then, a series of analyses are started through Geographic Information Systems. Based on the weights resulting from the pairwise comparison matrices, the entire physical vulnerability map was created with ArcGIS in the Geographic Information Systems (GIS) environment to perform these analyses collectively.

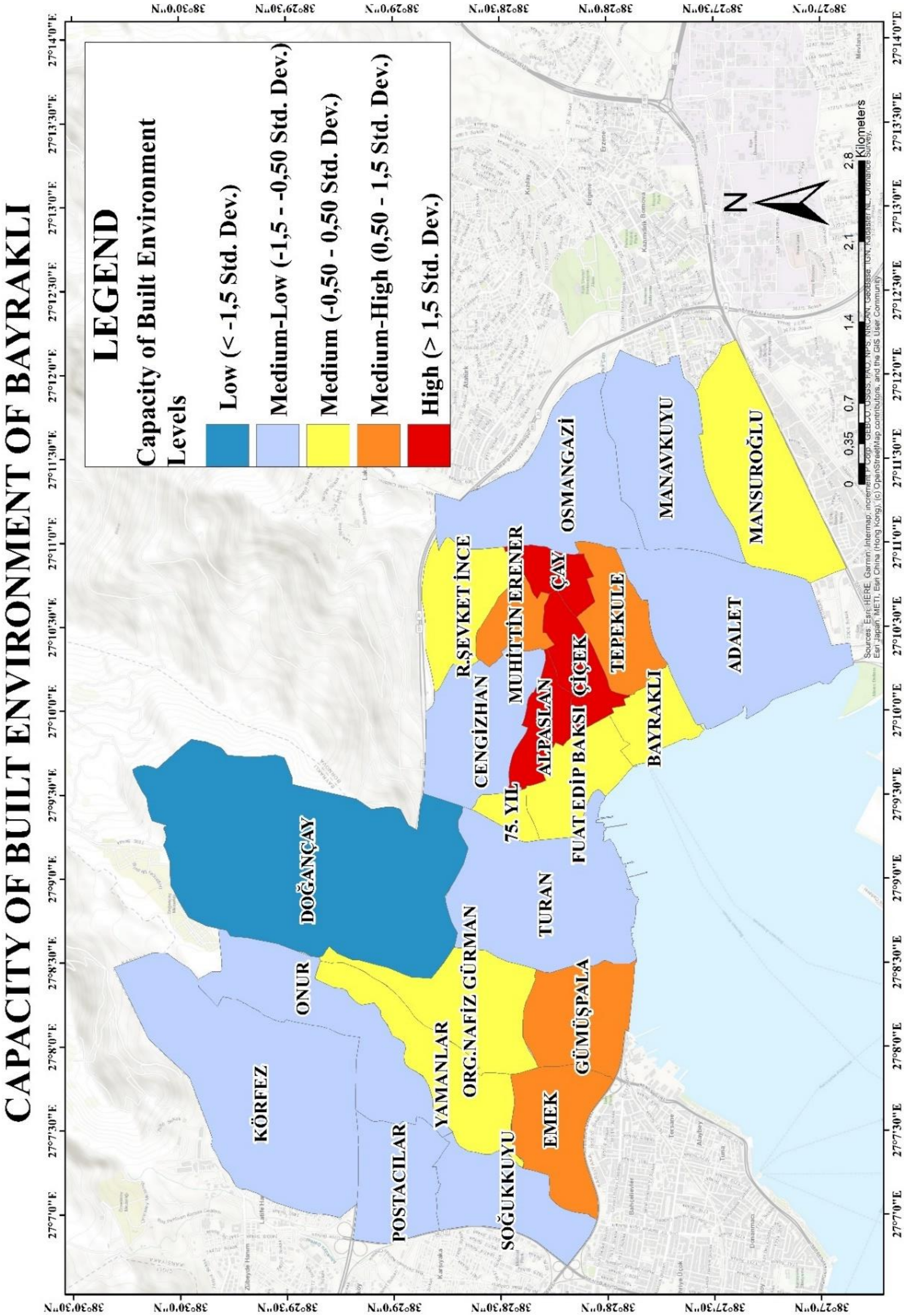

Figure 49: Capacity of Built Environment Map of Bayraklı

For the capacity of built environment dimension, neighborhood-based analyses were performed using the weights obtained by experts using AHP, and the analyses were spatialized. It is seen that the criteria with the highest importance in terms of capacity of built environment for earthquake hazards are distance to hospitals, distance to main roads and population density. The weight values of these three indicators are 0.190, 0.156 and 0.144. These indicators for the capacity of built environment distribution on the basis of neighborhoods obtained as a result of the analysis are important (Figure 49).

The distribution of these uses, which are directly affected by land use decisions, becomes especially important during and after an earthquake. The distribution of these areas is of vital importance for the rapid completion of post-earthquake evacuations and first aid operations. In addition, uses such as open green areas are also suitable for temporary shelters and escape points.

Looking at the distribution, while 1 neighborhood has a low vulnerability level, 3 neighborhoods have a high vulnerability level, and 4 neighborhoods have a medium-high level vulnerability. The population in these neighborhoods with high vulnerability rates constitutes 8.48% of the district population. The population of neighborhoods with medium-high vulnerability levels constitutes 16.55% of the district population. In other words, it is thought that 25.03% of the total population will have problems accessing relatively urban services/critical facilities.

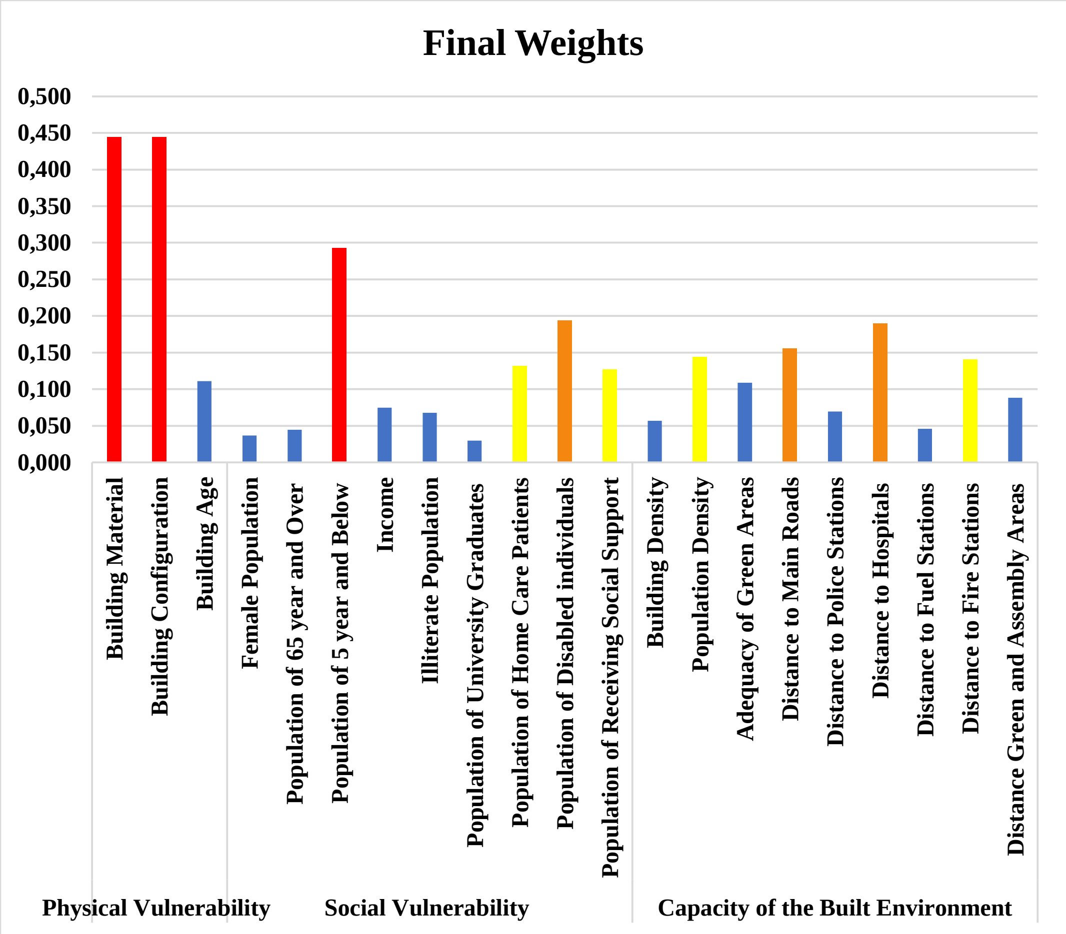

Chart 4: Indicators Final Weight Chart

Chart 4 shows the final weights of the indicators of all main dimensions. As can be seen in the chart, the most dominant indicators are in the physical vulnerability dimension. These indicators are followed by disabled individuals, population receiving social assistance and patients receiving home care support in the social dimension. In the Capacity of the built environment dimension, the indicators of distance to hospitals and roads come to the fore.

CHAPTER 6

RESULTS

As a result of the applied method, evaluations were made for three main vulnerability criteria for the physical dimension, according to the condition of the buildings, for the social dimension, according to the demography, education and disadvantaged groups, and for the capacity of the built environment, according to access to critical urban service. In the last stage, general vulnerability levels consisting of the combination of these three main criteria were reached. For the last stage an analysis was performed, and four separate result maps were created.

The indicator weights of the three main dimensions examined in the study were calculated on a neighborhood basis and maps showing the vulnerability levels of all three dimensions were created. The levels of vulnerability of three dimensions shown in Table (22).

Table 22: Vulnerability Levels of Bayraklı

VULNERABILITY LEVELS OF BAYRAKLI			
NEIGHBORHOODS	**Physical Vulnerability**	**Social Vulnerability**	**Capacity of the Built Environment**
75. YIL	0,986	0,499	0,317
ADALET	1,243	0,425	0,152
ALPASLAN	1,231	0,438	0,565
BAYRAKLI	1,294	0,418	0,286
CENGİZHAN	1,199	0,477	0,205
ÇAY	1,190	0,503	0,620
ÇİÇEK	1,144	0,522	0,622
DOĞANÇAY	1,078	0,514	0,012
EMEK	1,180	0,450	0,407
FUAT EDİP BAKSI	1,240	0,410	0,315
GÜMÜŞPALA	1,181	0,494	0,415
KÖRFEZ	0,941	0,434	0,089
MANAVKUYU	1,132	0,392	0,207
MANSUROĞLU	1,224	0,333	0,214
MUHİTTİN ERENER	1,160	0,444	0,521
ONUR	1,145	0,511	0,168
ORG.NAFİZ GÜRMAN	1,112	0,592	0,294
OSMANGAZİ	1,260	0,408	0,169
POSTACILAR	1,235	0,397	0,169
R.ŞEVKET İNCE	1,149	0,484	0,262
SOĞUKKUYU	1,108	0,395	0,181
TEPEKULE	1,262	0,417	0,510
TURAN	1,179	0,031	0,059
YAMANLAR	1,191	0,493	0,314

LEGEND
Red = High Vulnerability
Orange = Medium-High Vulnerability
Yellow = Medium Vulnerability
Light Blue = Medium-Low Vulnerability
Blue = Low Vulnerability
Dark Blue = Very Low Vulnerability

A table of the three dimensions of vulnerability examined in the study was created. Table (22) shows the level of vulnerability of neighborhoods based on the three dimensions examined. Bayraklı neighborhood is the most vulnerable neighborhood in terms of physical vulnerability, while it is moderately vulnerable in terms of social vulnerability and capacity of built environment dimensions. The vulnerability weight is given next to each labe l in the table. In Chart (4), a graph is created showing the severity ranges in which neighborhoods are vulnerable to damage on a three-dimensional basis.

Org. Nafiz Gürman neighborhood is the most vulnerable neighborhood in terms of social vulnerability, while it is medium-low in terms of physical vulnerability and moderately vulnerable in terms of capacity of built environment. In terms of Capacity of built environment, three neighborhoods are seen to be vulnerable. These neighborhoods are Alpaslan, Çay and Çiçek. While Alpaslan neighborhood is a medium-high vulnerable neighborhood in terms of physical vulnerability, it is a medium vulnerable neighborhood in terms of social vulnerability. While Çay and Çiçek neighborhoods are medium vulnerable in terms of physical vulnerability, they are medium-high vulnerable in terms of social vulnerability. When looking at the Table (22) it is seen that there is a more homogeneous distribution in terms of medium vulnerability in the neighborhoods.

The indicator with the highest importance in terms of physical vulnerability to earthquake hazards are building material and building configuration. The weight value of these two indicators is 0.444 and these indicators for the physical vulnerability distribution on the basis of neighborhoods obtained as a result of the analysis are important (see Figure 48). The indicators with the highest importance in terms of social vulnerability to earthquake hazards is population of 5 years and below. The weight value of this indicator is 0.293, and this indicator is composed of disabled individuals with a weight value of 0.194, and patients receiving home care support with 0.132, and therefore, the neighborhood-based social vulnerability distribution obtained as a result of the analysis is important (see Figure 48). It is seen that the criteria with the highest importance in terms of capacity of built environment for earthquake hazards are distance to hospitals, distance to main roads and population density. The weight values of these three indicators are 0.190, 0.156 and 0.144. These indicators for the capacity of built environment distribution on the basis of neighborhoods obtained as a result of the analysis are important (see Figure 49).

In the maps and tables created, no weights were given to the main dimensions. The final weights emerged from the weights of the indicators and were calculated for three dimensions. In this section of the thesis, three different weights were determined for the main dimensions and analyses were made with those weights.

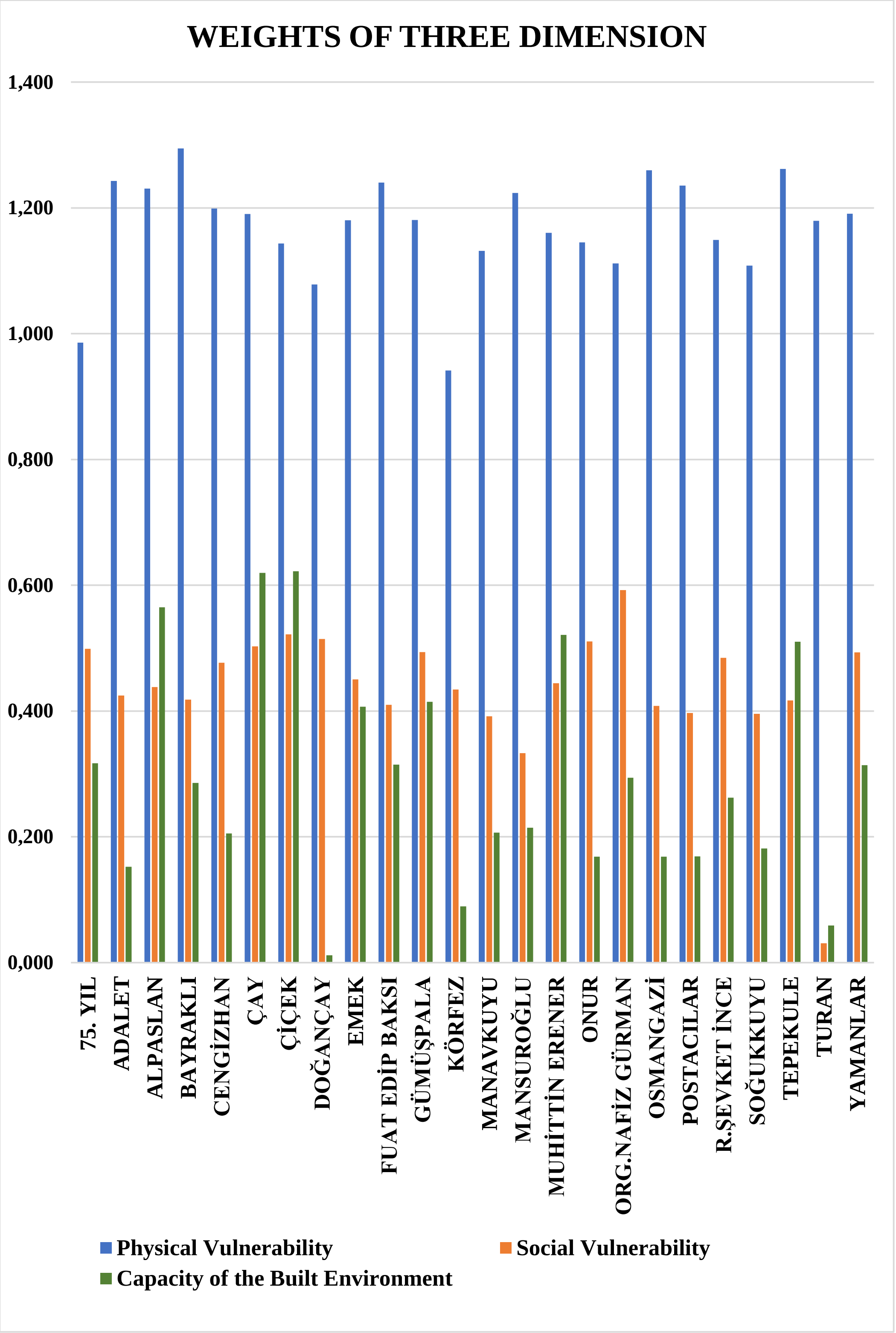

Chart 5: Three Main Dimension Indicators Final Weight Chart on Neighborhood Basis

In line with the purpose of the study, the AHP method was applied to determine the vulnerability levels of three different dimensions. However, a comparison matrix was not created for the three main dimensions, instead a series of analysis was performed. The fundamental question in performing the analysis is: Would the results of the study change if we used different weights? In line with this question, analyses were conducted in four different ways by applying the AHP method. One of the key benefits of these analysis is that it can help distinguish the extent to which vulnerability models are influenced by parameters. Essentially, this analysis provides metrics for assessing the relative importance of different methods.

After the separate vulnerability maps were created, the weights given to the main dimensions were multiplied by the weights of the indicators to reach the general weight values and maps with four different general vulnerability levels on a neighborhood basis were created. With the results of this analysis, Bayraklı's vulnerability level was considered in four separate analyses. First, a general vulnerability map was created in which the weights of the three main dimensions were taken equally.

6.1. Equal Weighted Results of Dimensions

In the first analysis, a map created from the weight of all three dimensions was taken equally and multiplied by the indicator weights of each dimension. Then, each dimension was collected on a neighborhood basis and the first overall vulnerability map was created. The degree of equal weight considered is distributed among three dimensions (totaling 1). The weight of each dimension considered is (0.33).

Table 23: Equal Weighted Overall Vulnerability Weights

	EQUAL WEIGHTS (0.33)			
NEIGHBORHOODS	**Physical Vulnerability**	**Social Vulnerability**	**Capacity of Built Environment**	**TOTAL WEIGHTS**
75. YIL	0.329	0.166	0.106	0.200
ADALET	0.414	0.142	0.051	0.202
ALPASLAN	0.410	0.146	0.188	0.248
BAYRAKLI	0.431	0.139	0.095	0.222
CENGİZHAN	0.400	0.159	0.068	0.209
ÇAY	0.397	0.168	0.207	0.257
ÇİÇEK	0.381	0.174	0.207	0.254
DOĞANÇAY	0.359	0.171	0.004	0.178
EMEK	0.393	0.150	0.136	0.226
FUAT EDİP BAKSI	0.413	0.137	0.105	0.218
GÜMÜŞPALA	0.394	0.165	0.138	0.232
KÖRFEZ	0.314	0.145	0.030	0.163
MANAVKUYU	0.377	0.131	0.069	0.192
MANSUROĞLU	0.408	0.111	0.071	0.197
MUHİTTİN ERENER	0.387	0.148	0.174	0.236
ONUR	0.382	0.170	0.056	0.203
ORG.NAFİZ GÜRMAN	0.371	0.197	0.098	0.222
OSMANGAZİ	0.420	0.136	0.056	0.204
POSTACILAR	0.412	0.132	0.056	0.200
R.ŞEVKET İNCE	0.383	0.161	0.087	0.211
SOĞUKKUYU	0.369	0.132	0.060	0.187
TEPEKULE	0.421	0.139	0.170	0.243
TURAN	0.393	0.010	0.020	0.141
YAMANLAR	0.397	0.164	0.105	0.222

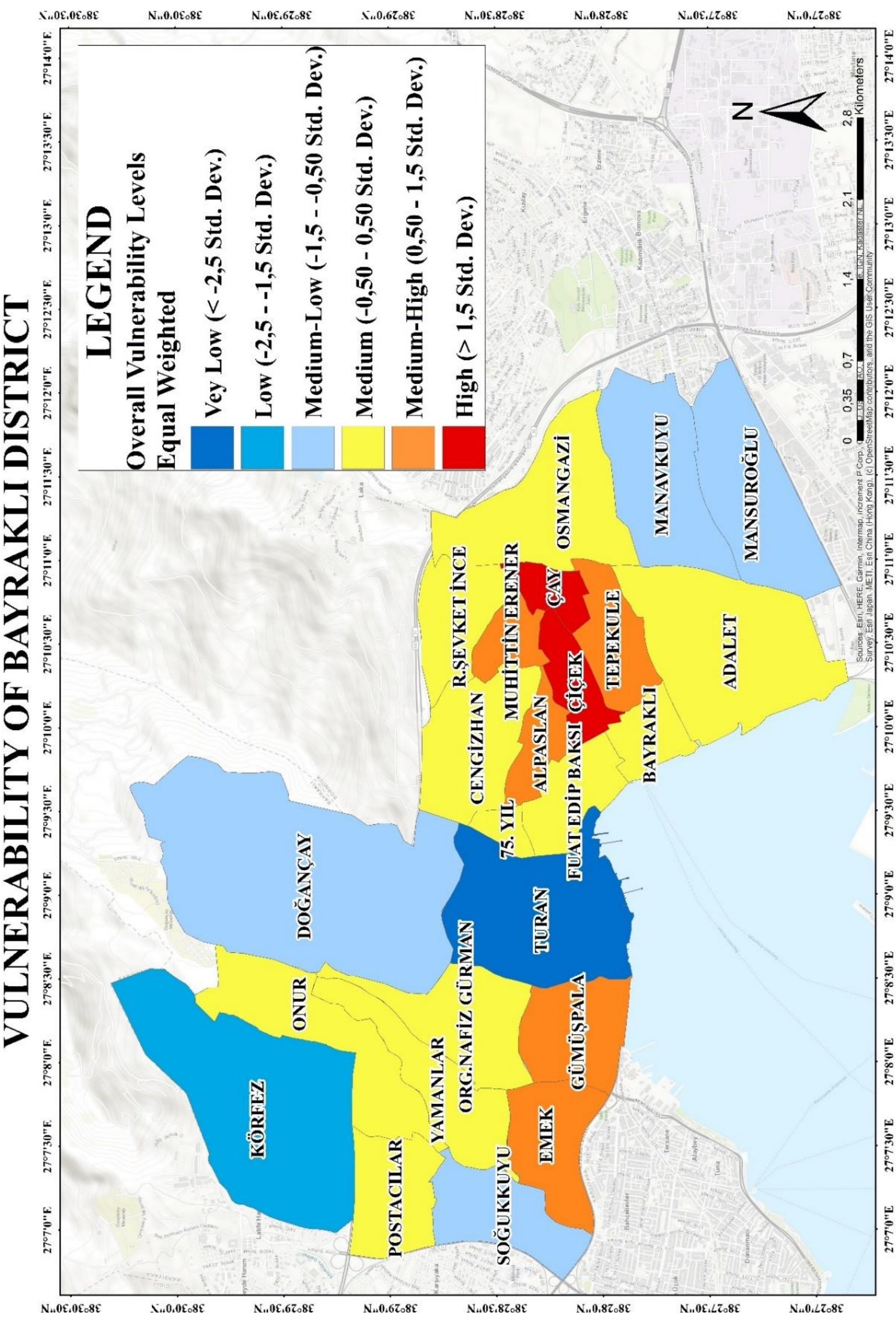

Figure 50: Equal Weighted Overall Vulnerability Map of Bayraklı

After multiplying the indicator weights and the equally weighted values of the three dimensions (0.33) and averaging them on a neighborhood basis,the resulting map in figure (50) emerged. As a result of the dimensions accepted as equally weighted, it is seen that the dimension that has the most impact on the vulnerability level of the neighborhoods is the physical vulnerability dimension (see Figure 57).

The equal-weighted analysis shows that the most vulnerable neighborhoods are, the Çay and Çiçek neighborhoods. These neighborhoods constitute 5.7% of Bayraklı's total population. The neighborhoods with medium-high vulnerability levels are Alpaslan, Emek, Gümüşpala, Muhittin Erener and Tepekule. These neighborhoods constitute 19.32% of Bayraklı's total population. 49.99% of the population lives in neighborhoods with a medium vulnerability level.

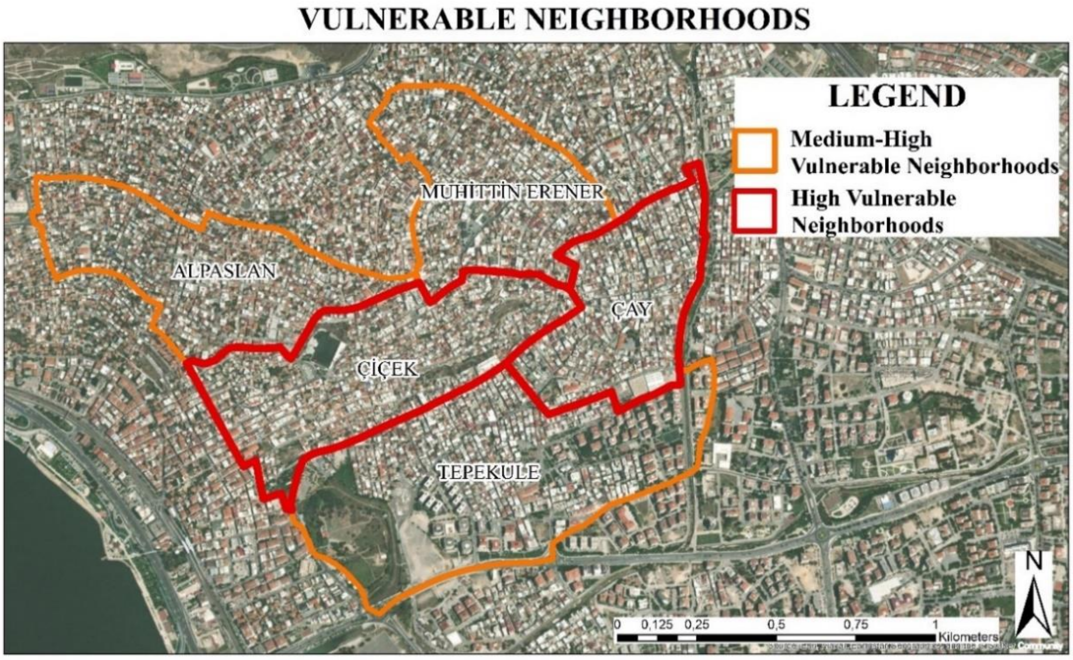

Figure 51: High and Medium-HighVulnerable Neighborhoods

The results obtained with equal weighted analysis show that the most vulnerable neighborhoods are Çay and Çiçek neighborhoods. Although these two neighborhoods are the oldest settlements, they are “gecekondu” areas. When Çay and Çiçek neighborhoods are examined in terms of physical vulnerability, they are neighborhoods with old-style buildings, a high density of masonry buildings, and a high density of corner adjacent buildings (see Figures 21, 22, and 23). In terms of the social vulnerability dimension, no migration data could be obtained, but these two neighborhoods are old settlements that receive high migration. Çay and Çiçek neighborhoods have the lowest average income value and the highest number of disabled individuals and home care patients (see Figures 30, 34, and 35). When looking at the capacity of the built environment, it is seen that there is a dense population and a high density of buildings (see Figures 36 and 37). It is seen that the amount of green space per person is quite low; the amount of green space per person in Çay neighborhood is 0.7 m2, while the amount of green space per person in Çiçek neighborhood is 0.5 m2.

Figure 52: Medium-HighVulnerable Neighborhoods

These two neighborhoods are followed by Emek, Gümüşpala, Alpaslan, Muhittin Erener and Tepekule neighborhoods with medium-high vulnerability. These neighborhoods also have the same typology as Çay and Çiçek neighborhoods. In terms of physical vulnerability, most of the buildings are corner adjacent buildings (see Figure 23). In terms of social vulnerability, the distribution of the elderly and children population is between 5% and 10%, and the average income values are medium and low. In addition, the rate of the population receiving social assistance is between 24% and 45% in Emek, Gümüşpala, and Muhittin Erener (see Figures 28, 29, 30, and 33). When looking at the capacity of the built environment dimension, it is seen that the population and building density are high (see Figures 36 and 37). In addition, the amount of green space per person is 0.7 m^2 in the Emek neighborhood, 1 m^2 in Gümüşpala, 0 in Muhittin Erener, and 0.3 m^2 in the Alpaslan neighborhood.

6.2. Results with Physical Dimension as a Major Factor

For the second analysis, the physical vulnerability dimension was considered the major factor, and its weight was given as (0.50). The other two dimensions, social vulnerability and the capacity of the built environment, were considered as equal weights (0.25). The aim is to weigh each dimension separately and to see to what extent the vulnerability of the neighborhood's changes in the final product.

After multiplying the indicator weights and the values of the three dimensions and summing them on a neighborhood basis, the resulting map in Figure (54) emerged. The weight of the physical vulnerability dimension is kept higher than the weight of the other two dimensions.

Table 24: Weight Results of Physical Vulnerability as a Major Factor

	Physical Vulnerability as a Major Factor (0.50)			
NEIGHBORHOODS	**Physical Vulnerability**	**Social Vulnerability**	**Capacity of Built Environment**	**TOTAL WEIGHTS**
75. YIL	0.493	0.125	0.079	0.697
ADALET	0.621	0.106	0.038	0.766
ALPASLAN	0.615	0.110	0.141	0.866
BAYRAKLI	0.647	0.105	0.071	0.823
CENGİZHAN	0.599	0.119	0.051	0.770
ÇAY	0.595	0.126	0.155	0.876
ÇİÇEK	0.572	0.130	0.156	0.858
DOĞANÇAY	0.539	0.129	0.003	0.671
EMEK	0.590	0.112	0.102	0.804
FUAT EDİP BAKSI	0.620	0.102	0.079	0.801
GÜMÜŞPALA	0.590	0.123	0.104	0.818
KÖRFEZ	0.471	0.109	0.022	0.601
MANAVKUYU	0.566	0.098	0.052	0.715
MANSUROĞLU	0.612	0.083	0.054	0.749
MUHİTTİN ERENER	0.580	0.111	0.130	0.821
ONUR	0.573	0.128	0.042	0.742
ORG.NAFİZ GÜRMAN	0.556	0.148	0.073	0.777
OSMANGAZİ	0.630	0.102	0.042	0.774
POSTACILAR	0.618	0.099	0.042	0.759
R.ŞEVKET İNCE	0.575	0.121	0.066	0.761
SOĞUKKUYU	0.554	0.099	0.045	0.698
TEPEKULE	0.631	0.104	0.128	0.863
TURAN	0.590	0.008	0.015	0.612
YAMANLAR	0.595	0.123	0.078	0.797

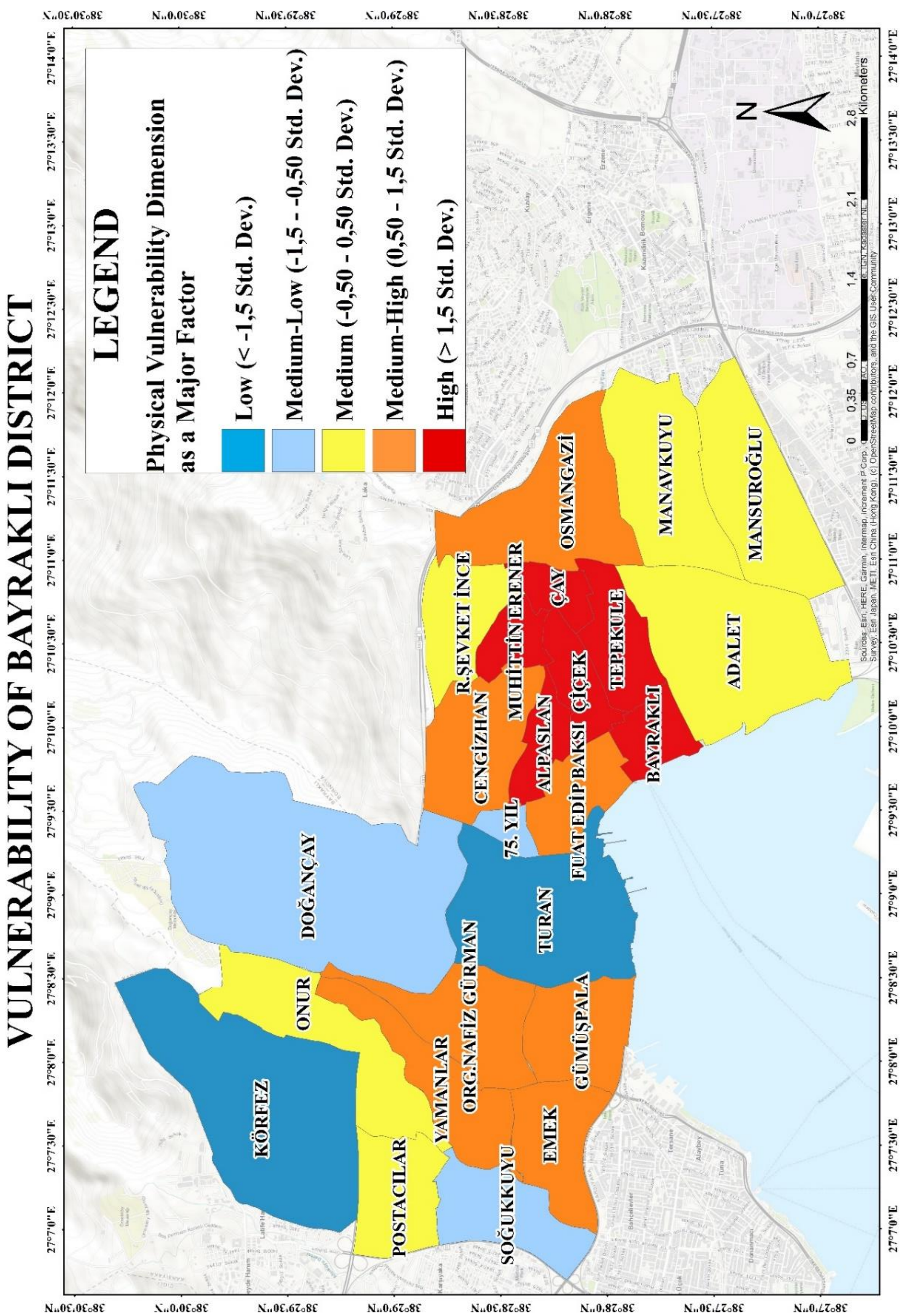

Figure 53: Results with Physical Dimension as a Major Factor

In this section, physical vulnerability is considered as the main factor and its weight is determined as (0.50). The other two dimensions are kept equal, and their weights are (0.25). After the indicator weights and the weighted values of the three dimensions are multiplied and added up on a neighborhood basis, the map in Figure (54) emerges.

The second analysis shows that the most vulnerable neighborhoods are Alpaslan, Bayraklı, Çay, Çiçek, Muhittin Erener and Tepekule. These neighborhoods constitute 23.19% of Bayraklı's total population. The neighborhoods with medium-high vulnerability levels are Osmangazi, Cengizhan, Fuat Edip Baksi, Emek, Gümüşpala, Org. Nafiz Gürman and Yamanlar. These neighborhoods constitute 35.90% of Bayraklı's total population.

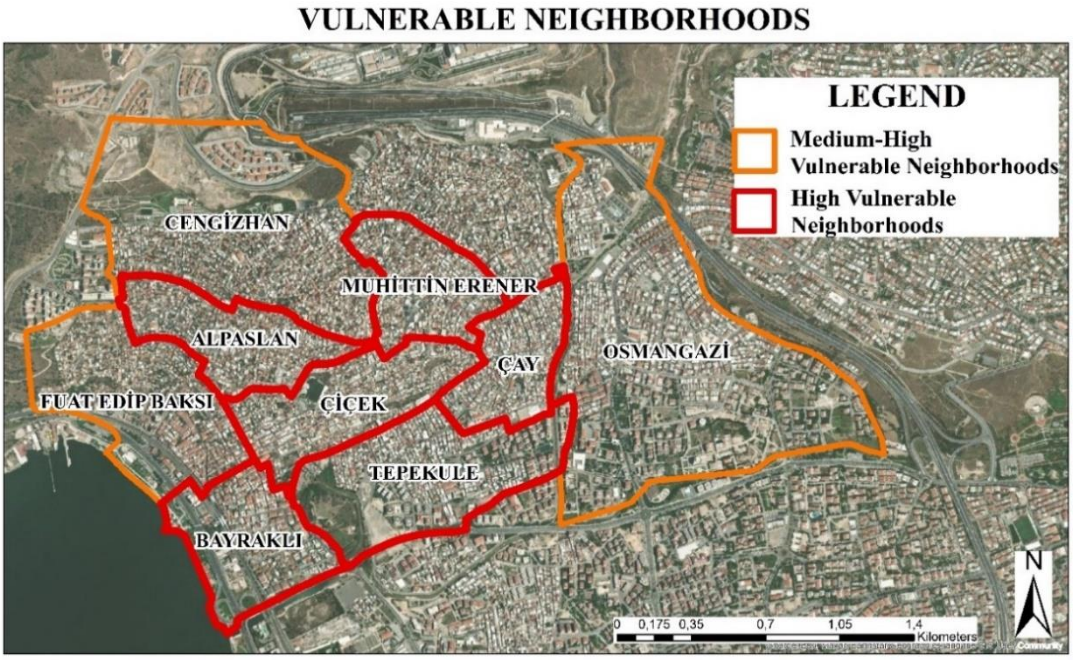

Figure 54: High and Medium-HighVulnerable Neighborhoods when Physical Vulnerability as the Major Factor

The results obtained with physical dimension as a major factor analysis show that the most vulnerable neighborhoods are Çay, Çiçek Alpaslan, Bayraklı, Muhittin Erener and Tepekule neighborhoods. These neighborhoods are the oldest settlements which they called “gecekondu” areas. When these neighborhoods are examined in terms of physical vulnerability, they are neighborhoods with old-style buildings, and a high density of corner adjacent and attached buildings (see Figures 23 and 24). In terms of the social vulnerability dimension, no migration data could be obtained, but these neighborhoods are old settlements that receive high migration. These neighborhoods are also the two neighborhoods with the lowest average income value and have the highest number of disabled individuals and home care patients (see Figures 30, 34, and 35). When looking at the capacity of the built environment, it is seen that there is a dense population and a high density of buildings (see Figures 36 and 37). Thus, it is seen that the amount of green space per person is quite low; the amount of green space per person in Çay neighborhood is 0.7 m^2, while the amount of green space per person in Çiçek neighborhood is 0.5 m^2, 0 in Muhittin Erener, 0.3 m^2 in the Alpaslan neighborhood.

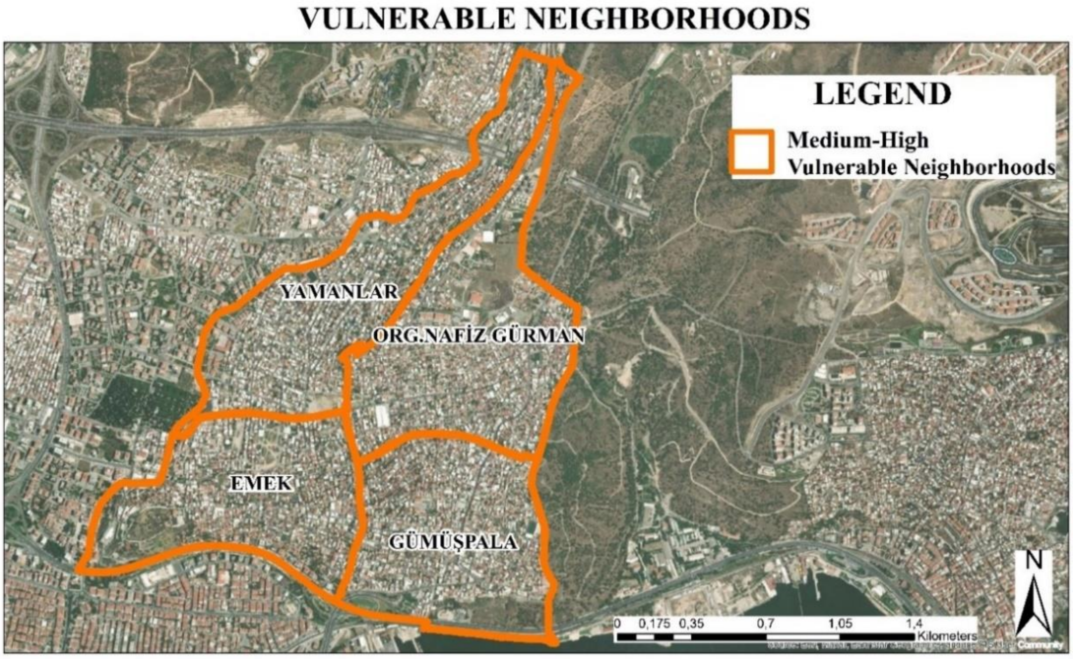

Figure 55: Medium-HighVulnerable Neighborhoods when Physical Vulnerability as the Major Factor

These neighborhoods are followed by Osmangazi, Cengizhan, Fuat Edip Baksi, Emek, Gümüşpala, Org. Nafiz Gürman and Yamanlar with medium-high vulnerability level. These neighborhoods also have the same typology as highly vulnerable neighborhoods. In terms of physical vulnerability, most of the buildings are corner adjacent buildings (see Figure 23). In terms of social vulnerability, the average income values are medium and low, in these neighborhoods, the number of university graduates is around 15%, and more than 45% of those receiving social assistance are in the Org.

Nafiz Gürman neighborhood. In addition, the rate of the population receiving social assistance is between 24% and 45% in Emek, Gümüşpala (see Figures 28, 29, 30, and 33). When lookin at the capacity of the built environment dimension, it is seen that the population and building density are high (see Figures 36 and 37). In addition, the amount of green space per person is 0.7 m^2 in the Emek neighborhood, 1,2 m^2 in Org. Nafiz Gürman neighborhood, 1,5 m^2 in Yamanlar neighborhood, 2,8 m^2 in Osmangazi neighborhood, 7 m^2 in Cengizhan neighborhood, 0,7 m^2 in Fuat Edip Baksi neighborhood and 1 m^2 in Gümüşpala neighborhood.

When the physical dimension was selected as the major factor and given a higher weight than the other two dimensions, it was seen that the number of vulnerable neighborhoods was higher than the number of vulnerable neighborhoods when equal weights were given. Some of the biggest reasons for this are that most of the neighborhoods are “gecekondu”. The old and weak structure of the buildings, their adjacent layout and the fact that most of the buildings are not built in accordance with earthquake regulations. When physical vulnerability is considered as the major factor, the increase occurred not only in the most vulnerable neighborhoods but also in the number of medium-high vulnerable neighborhoods. While calculating the dimensions with different weights does not generally affect the change in low and very low vulnerability neighborhoods, the situation is the opposite in medium, medium-high and high vulnerability levels.

6.3. Results with Social Dimension as a Major Factor

For the third analysis, the social vulnerability dimension was considered the main factor and its weight was given as (0.50). The other two dimensions, physical vulnerability and the capacity of the built environment, were considered as equal weights (0.25). The aim is to weigh each dimension separately and to see to what extent the vulnerability of the neighborhood’s changes in the final product.

Table 25: Weight Results of Social Vulnerability as a Major Factor

	Social Vulnerability as a Major Factor (0.50)			
NEIGHBORHOODS	**Physical Vulnerability**	**Social Vulnerability**	**Capacity of Built Environment**	**TOTAL WEIGHTS**
75. YIL	0.246	0.249	0.079	0.575
ADALET	0.311	0.212	0.038	0.561
ALPASLAN	0.308	0.219	0.141	0.668
BAYRAKLI	0.324	0.209	0.071	0.604
CENGİZHAN	0.300	0.238	0.051	0.589
ÇAY	0.298	0.251	0.155	0.704
ÇİÇEK	0.286	0.261	0.156	0.702
DOĞANÇAY	0.270	0.257	0.003	0.530
EMEK	0.295	0.225	0.102	0.622
FUAT EDİP BAKSI	0.310	0.205	0.079	0.594
GÜMÜŞPALA	0.295	0.247	0.104	0.646
KÖRFEZ	0.235	0.217	0.022	0.475
MANAVKUYU	0.283	0.196	0.052	0.530
MANSUROĞLU	0.306	0.167	0.054	0.526
MUHİTTİN ERENER	0.290	0.222	0.130	0.642
ONUR	0.286	0.255	0.042	0.584
ORG.NAFİZ GÜRMAN	0.278	0.296	0.073	0.648
OSMANGAZİ	0.315	0.204	0.042	0.561
POSTACILAR	0.309	0.198	0.042	0.549
R.ŞEVKET İNCE	0.287	0.242	0.066	0.595
SOĞUKKUYU	0.277	0.198	0.045	0.520
TEPEKULE	0.315	0.208	0.128	0.651
TURAN	0.295	0.015	0.015	0.325
YAMANLAR	0.298	0.247	0.078	0.623

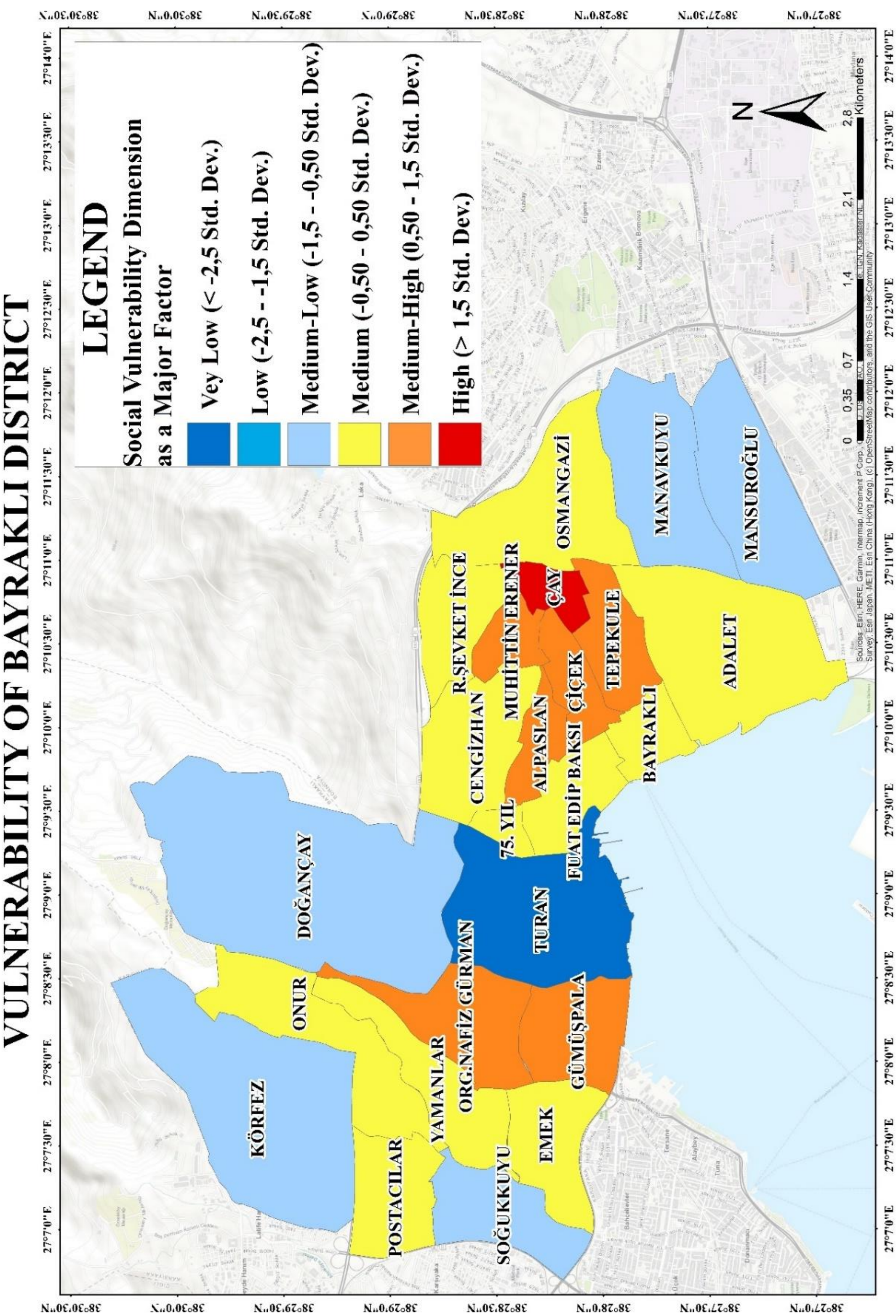

Figure 56: Results with Social Dimension as a Major Factor

In this section, social vulnerability is considered as the main factor and its weight is determined as (0.50). The other two dimensions are kept equal, and their weights are (0.25). After the indicator weights and the weighted values of the three dimensions are multiplied and added up on a neighborhood basis, the map in Figure (56) emerges.

The third analysis shows that the most vulnerable neighborhoods is Çay neighborood. Çay neighborhood constitute 2.53% of Bayraklı's total population. The neighborhoods with medium-high vulnerability levels are Alpaslan, Çiçek, Muhittin Erener, Gümüşpala, Org. Nafiz Gürman and Tepekule. These neighborhoods constitute 23,21% of Bayraklı's total population.

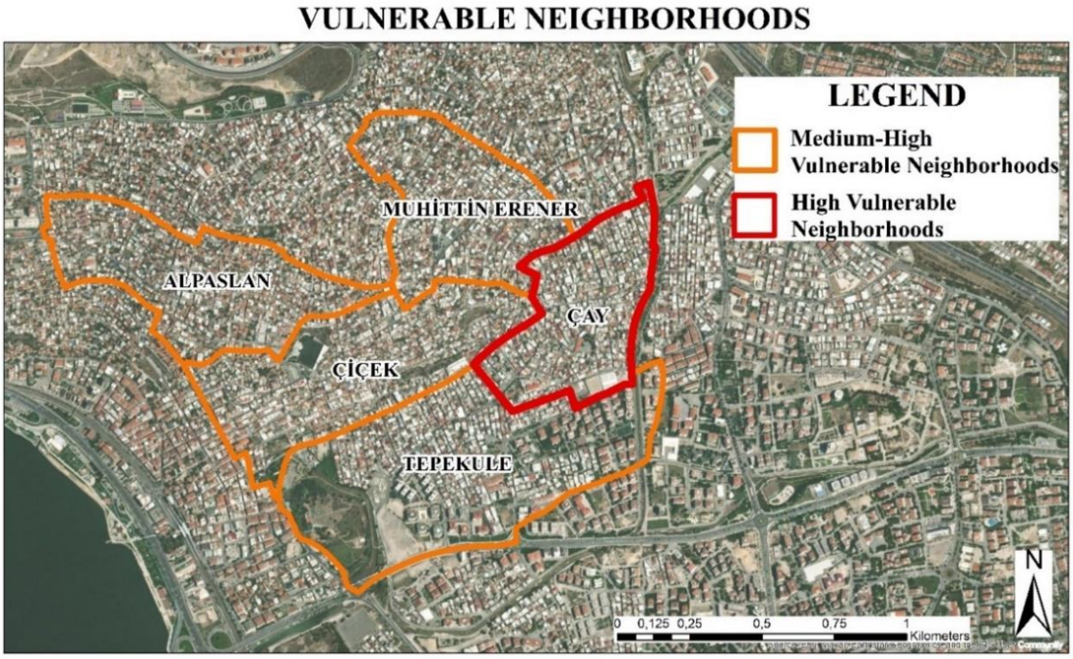

Figure 57: High and Medium-HighVulnerable Neighborhoods when Social Vulnerability as the Major Factor

The result obtained with social dimension as a major factor analysis shows that the most vulnerable neighborhood is Çay. This neighborhood is one of the oldest settlements which they called "gecekondu" areas. When this neighborhood is examined in terms of physical vulnerability there is a high density of masonry buildings and also in terms of building configuration corner adjacent and attached buildings are highly dense in this neighborhood (see Figures 23 and 24). In terms of the social vulnerability dimension, no migration data could be obtained, but this neighborhood is one of the old settlements that receive high migration. This neighborhood has a low average income value and has a high number of disabled individuals and home care patients (see Figures 30, 34, and 35). When looking at the capacity of the built environment, it is seen that there is a dense population and a high density of buildings (see Figures 36 and 37). Thus, it is seen that the amount of green space per person is quite low; the amount of green space per person in Çay neighborhood is 0.7 m2.

Figure 58: Medium-HighVulnerable Neighborhoods when Social Vulnerability as the Major Factor

This neighborhood is followed by Alpaslam, Çiçek, Gümüşpala, Muhittin Erener, Tepekule and Org. Nafiz Gürman with medium-high vulnerability levels. These neighborhoods also have the same typology as highly vulnerable neighborhoods. Regarding physical vulnerability, most of the buildings are corner adjacent (see Figure 23). In terms of social vulnerability, the average income values are medium and low, in these neighborhoods, the number of university graduates is around 15%, and more than 45% of those receiving social assistance are in the Org. Nafiz Gürman neighborhood. In addition, the rate of the population receiving social assistance is between 24% and 45% in Gümüşpala (see Figures 28, 29, 30, and 33). When looking at the capacity of the built environment dimension, it is seen that the population and building density are high (see Figures 36 and 37). In addition, the amount of green space per person is 0.3 m2 in the Alpaslan neighborhood and 1,2 m2 in Org. Nafiz Gürman neighborhood, 0,5 m2 in the Çiçek neighborhood, 0 m2 in the Muhittin Erener neighborhood, and 1 m2 in the Gümüşpala neighborhood.

When the social dimension is selected as the main factor and given a higher weight than the other two dimensions, it is seen that the number of vulnerable neighborhoods is lower than the number of vulnerable neighborhoods given equal weight and where the physical dimension is the major factor. Basically, this result is seen to be lower than expected. When the map of the social vulnerability dimension is examined (see Figure 56), it is seen that the most vulnerable neighborhood is Org. Nafiz Gürman, while Çay neighborhood is at the medium-high vulnerability level. The reasons for this change in the social dimension may be due to the fact that the indicator rates are not distributed homogeneously and are clustered in a certain place. While factors such as high migration rates, low average income, clustering of the population receiving social assistance, and distribution of patients receiving home care affect the change in the results, it is also seen that the change in the weight of the social dimension has an effect. When social vulnerability is considered as the major factor, the increase and change occurred not only in the number of medium-high vulnerable neighborhoods but also in the number of medium-vulnerable neighborhoods. While calculating the dimensions with different weights does not generally affect the change in low and very low vulnerable neighborhoods, the situation is exactly the opposite in medium, medium-high and high vulnerability levels.

6.4. Results with Capacity of Built Environment Dimension as a Major Factor

For the fourth analysis, the capacity of built environment dimension was considered as the main factor and its weight was given as (0.50). The other two dimensions, physical vulnerability and social vulnerability, were considered as equal weights (0.25). The aim is to weigh each dimension separately and to see to what extent the vulnerability of the neighborhood's changes in the final product.

Table 26: Weight Results of Capacity of Built Environment as a Major Factor

	Capacity of Built Environment as a Major Factor (0.50)			
NEIGHBORHOODS	**Physical Vulnerability**	**Social Vulnerability**	**Capacity of Built Environment**	**TOTAL WEIGHTS**
75. YIL	0.246	0.125	0.158	0.529
ADALET	0.311	0.106	0.076	0.493
ALPASLAN	0.308	0.110	0.282	0.700
BAYRAKLI	0.324	0.105	0.143	0.571
CENGİZHAN	0.300	0.119	0.103	0.521
ÇAY	0.298	0.126	0.310	0.733
ÇİÇEK	0.286	0.130	0.311	0.727
DOĞANÇAY	0.270	0.129	0.006	0.404
EMEK	0.295	0.112	0.203	0.611
FUAT EDİP BAKSI	0.310	0.102	0.157	0.570
GÜMÜŞPALA	0.295	0.123	0.207	0.626
KÖRFEZ	0.235	0.109	0.045	0.388
MANAVKUYU	0.283	0.098	0.103	0.484
MANSUROĞLU	0.306	0.083	0.107	0.496
MUHİTTİN ERENER	0.290	0.111	0.261	0.662
ONUR	0.286	0.128	0.084	0.498
ORG.NAFİZ GÜRMAN	0.278	0.148	0.147	0.573
OSMANGAZİ	0.315	0.102	0.084	0.501
POSTACILAR	0.309	0.099	0.084	0.492
R.ŞEVKET İNCE	0.287	0.121	0.131	0.539
SOĞUKKUYU	0.277	0.099	0.091	0.467
TEPEKULE	0.315	0.104	0.255	0.675
TURAN	0.295	0.008	0.029	0.332
YAMANLAR	0.298	0.123	0.157	0.578

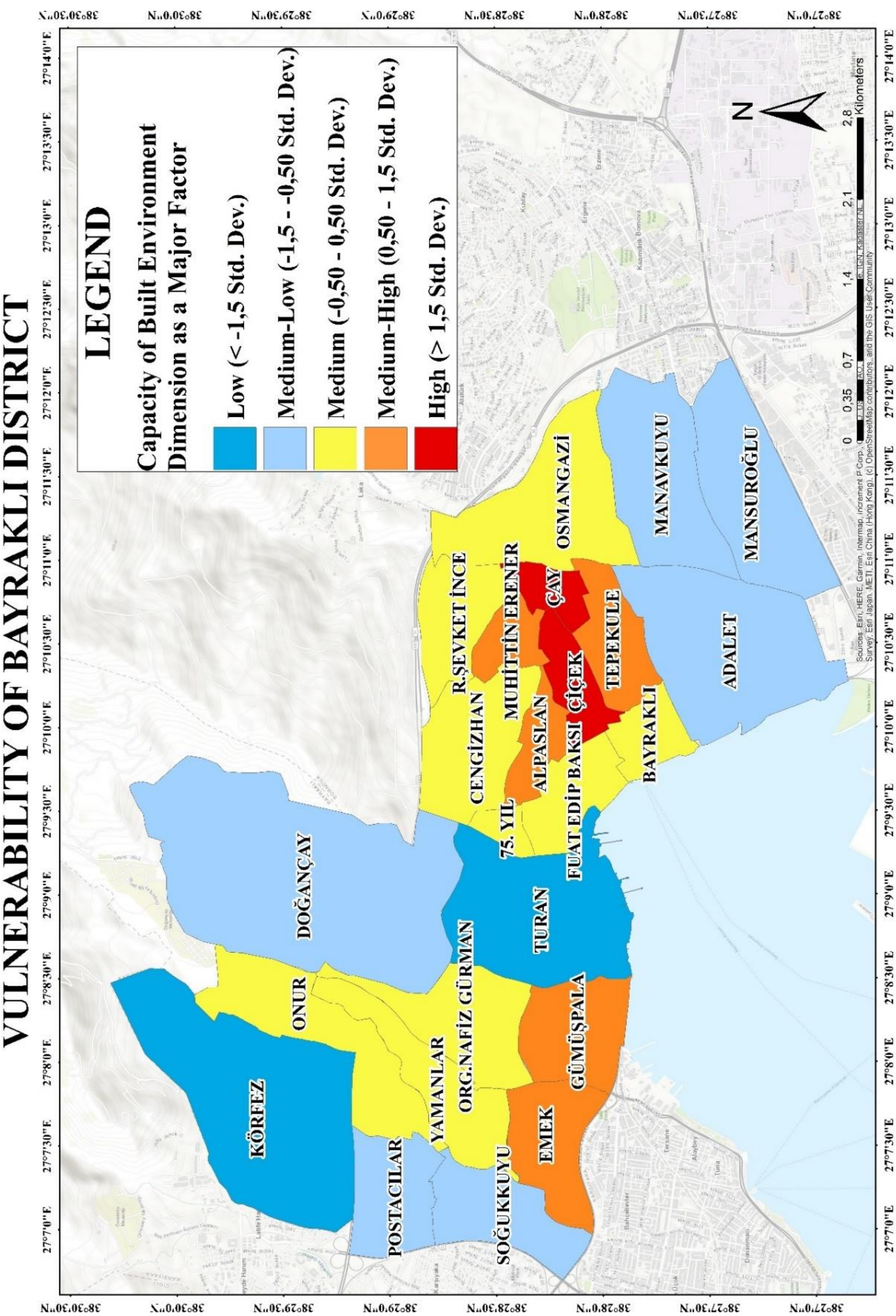

Figure 59: Results with Capacity of Built Environment Dimension as a Major Factor

In this section, capacity of built environment is considered as the main factor and its weight is determined as (0.50). The other two dimensions are kept equal, and their weights are (0.25). After the indicator weights and the weighted values of the three dimensions are multiplied and added up on a neighborhood basis, the map in Figure (64) emerges.

The most vulnerable neighborhoods are, the Çay and Çiçek neighborhoods. These neighborhoods constitute 5.7% of Bayraklı's total population. The neighborhoods with medium-high vulnerability levels are Alpaslan, Emek, Gümüşpala, Muhittin Erener and Tepekule. These neighborhoods constitute 19.32% of Bayraklı's total population. 49.99% of the population lives in neighborhoods with a medium vulnerability level.

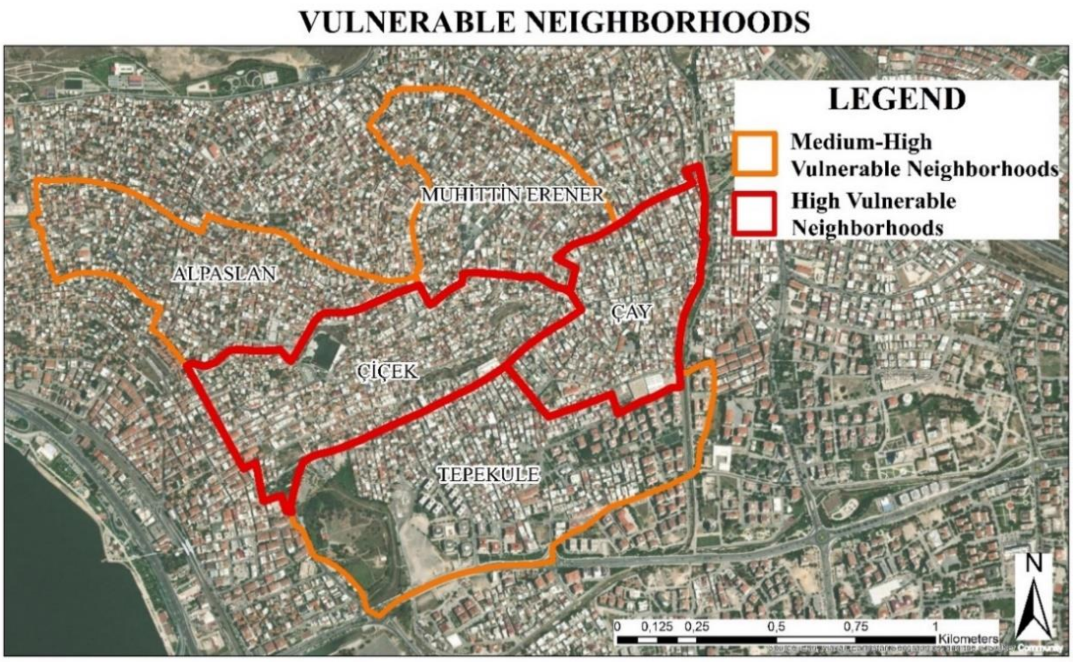

Figure 60: High and Medium-HighVulnerable Neighborhoods

The result obtained with the capacity of built environment dimension as a major factor analysis shows that the most vulnerable neighborhoods are Çay and Çiçek neighborhoods. Although these two neighborhoods are the oldest settlements, they are “gecekondu” areas. It is seen that the results where the capacity of the built environment dimension is the major factor, and the equal-weighted results are almost the same (see Figures 50 and 57). There is only a classification difference. While six classifications were created in the equal-weighted results, there are five classes in the result where the capacity of the built environment dimension is the major factor. One of the reasons for this is thought to be the distribution shape of the data. When Çay and Çiçek neighborhoods are examined in terms of physical vulnerability, they are neighborhoods with old-style buildings, a high density of masonry buildings, and a high density of corner adjacent buildings (see Figures 21, 22, and 23).

In terms of the social vulnerability dimension, no migration data could be obtained, but these two neighborhoods are old settlements that receive high migration. Çay and Çiçek neighborhoods have the lowest average income value and the highest number of disabled individuals and home care patients (see Figures 30, 34, and 35). When looking at the capacity of the built environment, it is seen that there is a dense population and a high density of buildings (see Figures 36 and 37). It is seen that the amount of green space per person is quite low; the amount of green space per person in Çay neighborhood is 0.7 m2, while the amount of green space per person in Çiçek neighborhood is 0.5 m2. When the capacity of the built environment dimension considered in the final analysis is compared with the dimension where the physical dimension is considered as the major factor, it is seen that there is a decrease in the number of vulnerable neighborhoods. However, it is seen that the number of medium-high vulnerable neighborhoods is the same (see Figures 54 and 57). When the capacity of the built environment dimension considered in the final analysis is compared with the dimension where the social vulnerability dimension is considered as the major factor, the number of vulnerable neighborhoods is one in the social dimension and two in the capacity of the built environment. However, the number of medium-high vulnerable neighborhoods is the same (see Figures 53 and 57).

Figure 61: Medium-HighVulnerable Neighborhoods

These two neighborhoods are followed by Emek, Gümüşpala, Alpaslan, Muhittin Erener, and Tepekule neighborhoods with medium-high vulnerability. These neighborhoods also have the same typology as Çay and Çiçek neighborhoods. Regarding the physical vulnerability dimension, most of the buildings are corner adjacent buildings (see Figure 23). Regarding social vulnerability, the distribution of the elderly and children population is between 5% and 10%, and the average income values are medium and low. In addition, the rate of the population receiving social assistance is between 24% and 45% in Emek, Gümüşpala, and Muhittin Erener (see Figures 28, 29, 30, and 33). Regarding the capacity of the built environment dimension, it is seen that the population and building density are high (see Figures 36 and 37). In addition, the amount of green space per person is 0.7 m2 in the Emek neighborhood, 1 m2 in Gümüşpala, 0 in Muhittin Erener, and 0.3 m2 in the Alpaslan neighborhood.

6.5. Final Results

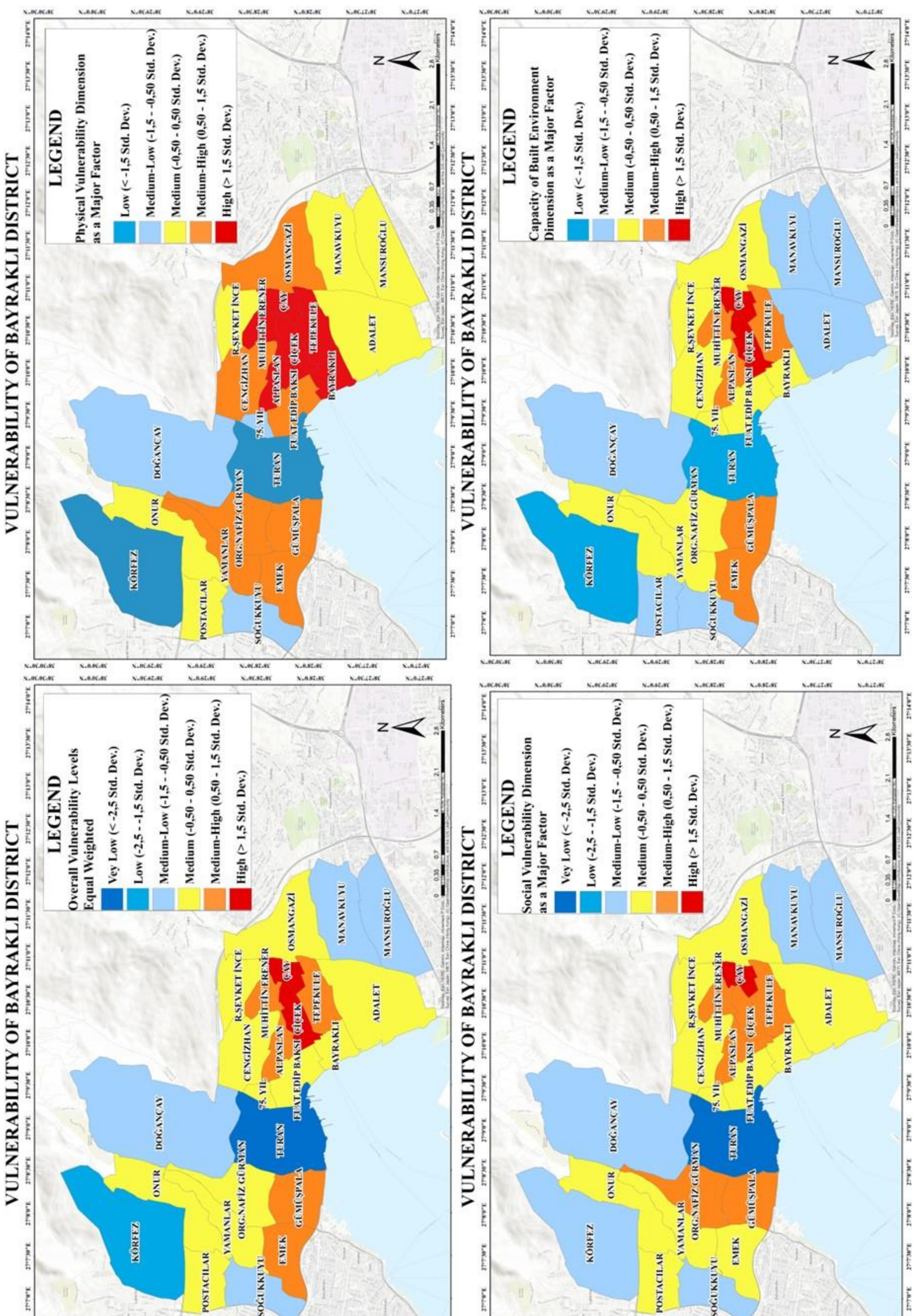

Figure 62: Comparison of Final Result Maps

Table 27: Final Vulnerability Levels of Bayraklı

	VULNERABILITY LEVELS OF BAYRAKLI			
NEIGHBORHOODS	**Equal Weighted Results**	**Physical Vulnerability as Major Factor**	**Social Vulnerabilityas Major Factor**	**Capacity of the Built Environment as Major Factor**
75. YIL	0,200	0,697	0,575	0,529
ADALET	0,202	0,766	0,561	0,493
ALPASLAN	0,248	0,866	0,668	0,700
BAYRAKLI	0,222	0,823	0,604	0,571
CENGİZHAN	0,209	0,770	0,589	0,521
ÇAY	0,257	0,876	0,704	0,733
ÇİÇEK	0,254	0,858	0,702	0,727
DOĞANÇAY	0,178	0,671	0,530	0,404
EMEK	0,226	0,804	0,622	0,611
FUAT EDİP BAKSI	0,218	0,801	0,594	0,570
GÜMÜŞPALA	0,232	0,818	0,646	0,626
KÖRFEZ	0,163	0,601	0,475	0,388
MANAVKUYU	0,192	0,715	0,530	0,484
MANSUROĞLU	0,197	0,749	0,526	0,496
MUHİTTİN ERENER	0,236	0,821	0,642	0,662
ONUR	0,203	0,742	0,584	0,498
ORG.NAFİZ GÜRMAN	0,222	0,777	0,648	0,573
OSMANGAZİ	0,204	0,774	0,561	0,501
POSTACILAR	0,200	0,759	0,549	0,492
R.ŞEVKET İNCE	0,211	0,761	0,595	0,539
SOĞUKKUYU	0,187	0,698	0,520	0,467
TEPEKULE	0,243	0,863	0,651	0,675
TURAN	0,141	0,612	0,325	0,332
YAMANLAR	0,222	0,797	0,623	0,578

LEGEND
Red = High Vulnerability
Orange = Medium-High Vulnerability
Yellow = Medium Vulnerability
Light Blue = Medium-Low Vulnerability
Blue = Low Vulnerability
Dark Blue = Very Low Vulnerability

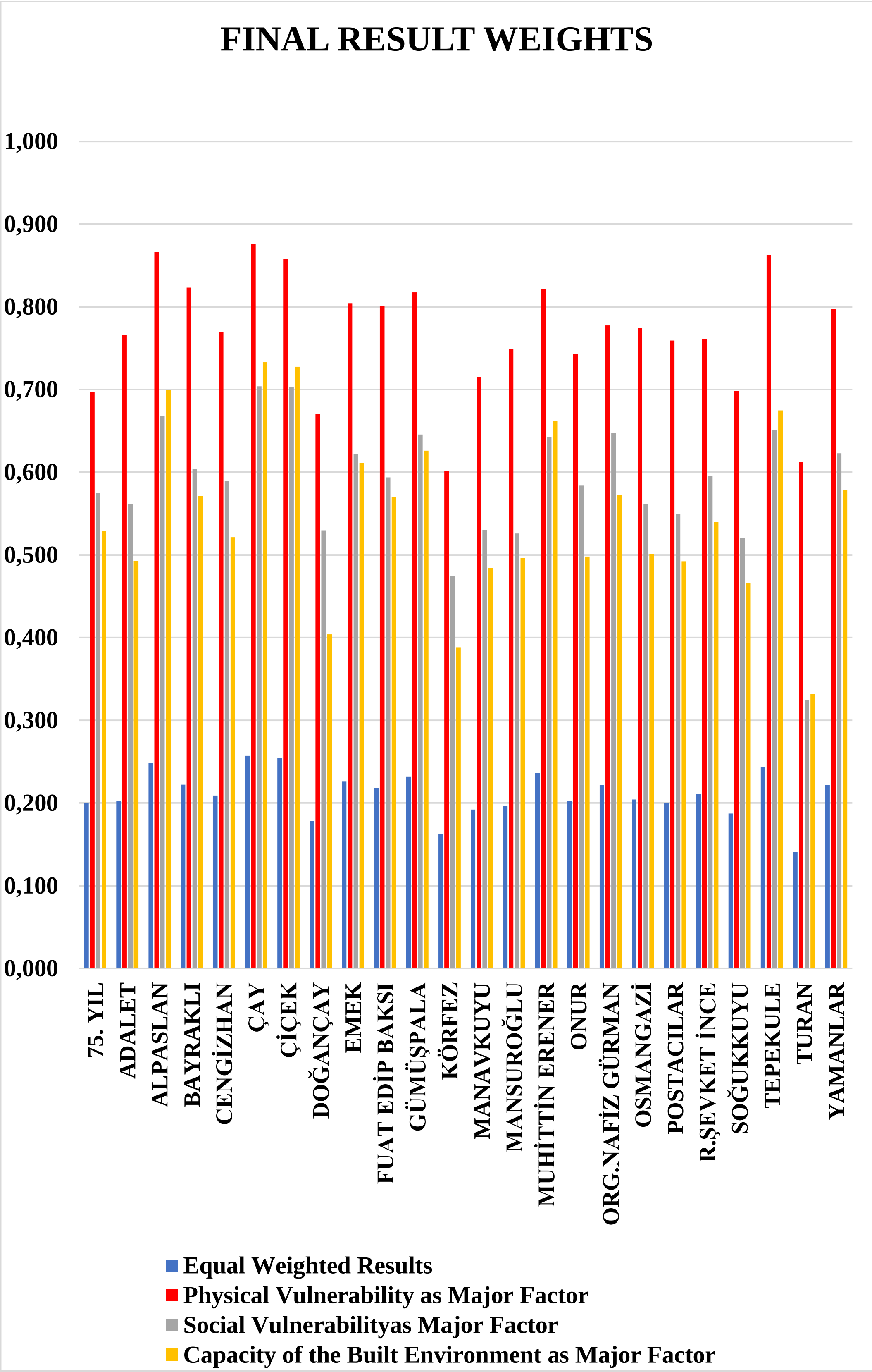

Chart 6: Final Weight Chart on Neighborhood Basis

Table 28: Vulnerable Neighborhoods of Bayraklı

	VULNERABLE NEIGHBORHOODS OF BAYRAKLI			
NEIGHBORHOODS	**Equal Weighted Results**	**Physical Vulnerability as Major Factor**	**Social Vulnerability as Major Factor**	**Capacity of the Built Environment as Major Factor**
ALPASLAN		0.866		
BAYRAKLI		0.823		
ÇAY	0.257	0.876	0.704	0.733
ÇİÇEK	0.254	0.858		0.727
MUHİTTİN ERENER		0.821		
TEPEKULE		0,863		

In the study, a comparison map of the equally weighted results of the three dimensions of vulnerability examined and the separate results where each dimension is considered as a major factor was created (see Figure 62). Then, the maps were tabulated on a neighborhood basis. The results in Table (27) are colored in the same way as the map results, and it is seen that each neighborhood is vulnerable in which dimension and to what degree. Then, Chart (5) was created by adding the weight values of the colors in this table. In the created Chart 5, it is seen which dimension is dominant in terms of vulnerability in which neighborhood. Then, a table with the most vulnerable neighborhoods was created and the results were obtained (see Table 28).

As a result of the analysis carried out with the method applied in the study, it was determined that 6 neighborhoods were the most vulnerable neighborhoods in all three dimensions. For the result, the map in which all dimensions were considered with equal weight, the map in which the physical vulnerability dimension was considered as the major factor, the map in which the social vulnerability dimension was considered as the major factor and the map in which the capacity of the built environment dimension was considered as the major factor were examined and the most vulnerable neighborhoods were determined in all of them. These neighborhoods are Alpaslan, Bayraklı, Çay, Çiçek, Muhittin Erener and Tepekule. As a result of the analysis, it is seen that the physical vulnerability dimension is the most significant dimension in this entire neighborhood. With this result, it can be said that the physical vulnerability dimension is the most decisive dimension in the study.

However, in all dimensions, where the dimensions are considered with equal weight, the physical dimension is considered as the major factor, the social dimension is considered as the major factor and the capacity of the built environment dimension is considered as the major factor, it is seen that the most vulnerable neighborhood is Çay neighborhood. The reasons why Çay neighborhood is the most vulnerable neighborhood can be listed as follows:

- the neighborhood is a “gecekondu” area,
- most of the buildings are corner adjacent or attached,
- the building material is masonry buildings,
- average income is low,
- the literacy rate is low,
- the number of home care patients is high,
- the number of disabled individuals is high,
- the population density is high,
- the building density is high,
- the amount of green space per person is low.

CHAPTER 7

DISCUSSIONS & CONCLUSION

The current research is of significant importance due to the lack of studies conducted on vulnerability to earthquakes in Bayraklı, a densely populated district that is highly vulnerable to hazards such as earthquakes. The framework presented in the study exhibits a good theoretical framework, flexibility and inclusiveness, making it possible to use it to analyze the vulnerability of Bayraklı to other types of disasters. The present study provides a comprehensive framework for assessing vulnerability to earthquake hazards, particularly by utilizing GIS and incorporating multidimensional criteria. The present study used disaster risk, vulnerability and resilience as a conceptual framework to address vulnerability to earthquake hazards in Bayraklı district of Izmir. The study aimed to assess vulnerability to earthquake hazards, particularly focusing on the social, physical and capacity of the built environments' dimensions. The previous chapters of this thesis have explained the importance of vulnerability to earthquake hazards, the extent of vulnerability and the application of MCDM/AHP and GIS-based analysis to assess vulnerability to earthquake hazards.

The research questions of the thesis focused on examining the relationship between vulnerability and its extent, assessing its effects on vulnerability to earthquake hazards, and which neighborhoods of Bayraklı district are more vulnerable based on these three dimensions. Moreover, questions investigate the incorporation of disaster-resilient urban strategies into urban planning and design as a way to increase neighborhood resilience. The study shows that Bayraklı is vulnerable to earthquake hazards according to indicators of social, physical and capacity of the built environment dimensions. The theoretical framework discussed in this study helps to determine vulnerable areas in the district and guides policy makers and stakeholders in developing special adaptation strategies. The study presents important findings on the vulnerability levels that emerge by focusing on the earthquake hazards of Bayraklı in particular. The methodology reveals which dimension affects how much the vulnerability is by revealing the most effective indicators in each dimension based on expert opinions that was performed by the application of AHP and pairwise comparisons. For the result, the map in which all dimensions were considered with equal weight, the map in which the physical vulnerability dimension was considered as the major factor, the map in which the social vulnerability dimension was considered as the major factor, and the map in which the capacity of the built environment dimension was considered as the major factor was examined and the most vulnerable neighborhoods were determined in all of them. These neighborhoods are Alpaslan, Bayraklı, Çay, Çiçek, Muhittin Erener and Tepekule. As a result of the analysis, it is seen that the physical vulnerability dimension is the most significant in this entire neighborhood. With this result, it can be said that the physical vulnerability dimension is the most decisive in the study. It is seen that the high weights of the indicators of the physical vulnerability dimensions compared to the indicators of other dimensions contribute to the most effective dimension (see Chart 4). However, in all dimensions, where the dimensions are considered with equal weight, the physical dimension is considered as the major factor, the social dimension is considered as the major factor and the capacity of the built environment dimension is considered as the major factor, it is seen that the most vulnerable neighborhood is Çay neighborhood. The resulting 6 neighborhoods were found to be the most vulnerable. These neighborhoods are the most vulnerable to earthquake hazards and should be prioritized as high-risk areas. With these results, it is seen that there is a clustering in a certain area (see Figures 50, 54, 56 and 57). With the determination of the most vulnerable neighborhoods, a basis was created for the development of area-specific strategies and policies. These strategies and policies are explained in the following section.

As a result, the disaster risk and vulnerability framework help to examine different dimensions and potential hazards and emphasizes the strategic integration of indicators of these dimensions in revealing vulnerability to earthquake hazards. Using AHP, one of the multi-criteria decision-making methods, the examination of various indicators facilitated the development of different parameters to assess vulnerability and resilience. The indicators listed, organized according to their impact and dimensions, provide decision-makers with a structured approach to determine the importance of actions and investments in the field of disaster-resilient urban planning.

7.1. Future Studies

This study provided valuable insights into the earthquake vulnerability assessment of Bayraklı district of İzmir. It highlights the importance of disaster management and planning as important policy areas that should be prioritized by local governments and the national government due to the sudden and untimely occurrence of disasters, especially earthquakes, and their consequences such as causing great destruction. Addressing multi-dimensional vulnerability to earthquake hazards requires the adoption of integrated approaches compatible with the complex structure of urban systems. For example, traditional solutions such as infrastructure improvements and land use regulations alone, and the difficulty in implementing even these suggestions, have proven to be insufficient in effectively managing the situation during and after earthquake hazards.

Furthermore, policy-making procedures that do not include community participation and lack public information and support often lead to inadequate implementation. Therefore, it is essential to establish a comprehensive and multi-disciplinary policy set rather than relying on a single best practice to promote the development of cities that are more resilient to earthquake hazards. The findings of this study offer several policy implications that can guide disaster management and decision-making against earthquake hazards while embracing the concept of resilient cities.

The primary and indisputably most important issue among the studies that can be conducted with the obtained results is the creation of plans that consider possible earthquake hazards. While it is not possible to eliminate potential earthquakes, their negative effects can be reduced. Cities are complex systems with interrelated sectors and services. Therefore, decisions and strategies to develop less vulnerable communities will affect multiple sectors. A comprehensive approach and consideration of the interrelationship of sectors is more effective in reducing the vulnerability of the urban system. It is seen that there are 6 neighborhoods that are most vulnerable in terms of physical vulnerability (see Table 28). These neighborhoods have emerged with the weight results of the three indicators examined in the physical dimension. The common characteristics of the most vulnerable neighborhoods determined according to the indicators are that they are irregular settlements, the building material is masonry buildings that are not resistant to earthquakes, the average age of the buildings is high, and the building order is attached and corner adjacent. Area-specific strategies should be produced together with the determination of the vulnerable neighborhoods. Either reinforcement or demolition operations should be carried out according to the damage status after the locations of the damaged buildings are determined. However, the social status of the area should not be ignored. Strategies should be implemented with special support by the local government, considering the social conditions of the people living in the area.

7.2. Recommendations

When looking at the most vulnerable neighborhoods, it was revealed that Çay neighborhood was the most vulnerable neighborhood in terms of social vulnerability. Generally, the cluster of vulnerable neighborhoods is the neighborhoods surrounding Çay neighborhood. The low average income support of this area also affects the inability of people to reinforce the buildings they live in. Therefore, support policies should be developed for these situations. It is also seen that the literacy rate of these vulnerable neighborhoods is quite low (see Figures 30 and 31). Earthquake preparedness, response, and recovery capabilities can be significantly improved through community participation and education. Implementation of awareness campaigns, training courses, and grassroots initiatives can successfully improve awareness and understanding of earthquake risks among individuals and encourage community participation. It is seen that the rates of socially disadvantaged groups are high in these neighborhoods. It is seen that the number of patients receiving home care support, and the number of disabled individuals is most concentrated in the Çay, Çiçek, Alpaslan and Tepekule neighborhoods (see Figures 33 and 34). More detailed studies should be conducted in disadvantaged groups, and this study can be improved with the studies to be conducted.

Another dimension of the study, the capacity of the built environment, should not be ignored. In the analysis results where the capacity of the built environment dimension is considered as the major factor, it is seen that the most vulnerable neighborhoods are Çay and Çiçek (see Figure 57). Considering the population density living in these neighborhoods, they should be considered as high-risk priority areas. These two neighborhoods are in a disadvantaged position due to the very low amount of open and green space per capita and the high density of buildings. If demolition strategies are to be implemented along with the identification of damaged buildings, new buildings should not be built in their place. Instead, the amount of open and green space per person should be increased, and areas that people can access during and after the earthquake should be created. Along with these strategies, structures should be built on a neighborhood basis, using earthquake-resistant construction techniques, close to disaster and emergency assembly areas and open green areas. where people can take shelter during and after an earthquake, and which contain first aid items and materials that people can use in emergencies. At the same time, integrating real-time monitoring systems and communication with the public is also vital for effective earthquake management and improved early warning systems. The use of advanced sensor technologies and communication systems ensures that highly accurate and immediate earthquake warnings are provided. allowing residents and emergency responders to take appropriate action.

Finally, along with all these suggestions and strategies, the scale of the neighborhoods at risk of earthquakes that emerged as a result of this study should be reduced, more sampling studies should be conducted at the building scale in the settlements, and the problems should be revealed more clearly with a detailed analysis study by creating wider indicator sets by eliminating data limitations.

REFERENCES

Adger, W. Neil, and P. Mick Kelly. "Social Vulnerability to Climate Change and the Architecture of Entitlements." *Mitigation and Adaptation Strategies for Global Change* 4, no. 3/4 (January 1, 1999): 253–66. https://doi.org/10.1023/a:1009601904210.

Adger, W. Neil, Ricardo Safra De Campos, Tasneem Siddiqui, and Lucy Szaboova. "Commentary: Inequality, Precarity and Sustainable Ecosystems as Elements of Urban Resilience." *Urban Studies* 57, no. 7 (March 13, 2020): 1588–95. https://doi.org/10.1177/0042098020904594.

Adger, W. Neil, Terry P. Hughes, Carl Folke, Stephen R. Carpenter, and Johan RockströM. "Social-Ecological Resilience to Coastal Disasters." *Science* 309, no. 5737 (August 12, 2005): 1036–39. https://doi.org/10.1126/science.1112122.

Adger, W. Neil. "Social and Ecological Resilience: Are They Related?" *Progress in Human Geography* 24, no. 3 (September 1, 2000): 347–64. https://doi.org/10.1191/030913200701540465.

Adger, W. Neil. "Social Vulnerability to Climate Change and Extremes in Coastal Vietnam." *World Development* 27, no. 2 (February 1, 1999): 249–69. https://doi.org/10.1016/s0305-750x(98)00136-3.

Adger, W. Neil. "Vulnerability." *Global Environmental Change* 16, no. 3 (August 1, 2006): 268–81. https://doi.org/10.1016/j.gloenvcha.2006.02.006.

AFAD 2020a. Türkiye İvme Veri Tabanı ve Analiz Sistemi (TADAS). https://tadas.afad.gov.tr/

AFAD Earthquake Department 2020.30 October 2020 Aegean Sea, Seferihisar (İzmir) Offshore (17.26 km) Preliminary Evaluation Report on Mw 6.6 Earthquake, AFAD.

AFAD, 2021. İzmir İl Afet Risk Azaltma Planı (İRAP). İzmir Valiliği İl Afet ve Acil Durum Müdürlüğü

AFAD. 2024. Afet ve Acil Durum Yönetimi Başkanlığı.

Agliata, Rosa, Antonio Bortone, and Luigi Mollo. "Indicator-based Approach for the Assessment of Intrinsic Physical Vulnerability of the Built Environment to Hydro-meteorological Hazards: Review of Indicators and Example of Parameters Selection for a Sample Area." *International Journal of Disaster Risk Reduction* 58 (May 1, 2021): 102199. https://doi.org/10.1016/j.ijdrr.2021.102199.

Akduman, Öznur. "Depremler ve Afet Yönetimi: 30 Ekim 2020 İzmir Depremi Örneği." *Academic Perspective Procedia* 4, no. 2 (November 6, 2021): 21–32. https://doi.org/10.33793/acperpro.04.02.6.

Akurgal, Ekrem. *Eski İzmir: Yerleşme Katları ve Athena Tapınağı,* 1993.

Alberti, Marina. "Urban Patterns and Environmental Performance: What Do We Know?" *Journal of Planning Education and Research* 19, no. 2 (December 1, 1999): 151–63. https://doi.org/10.1177/0739456x9901900205.

Aliabadi, Saeed Fallah, Alireza Sarsangi, and Ehsan Modiri. "The Social and Physical Vulnerability Assessment of Old Texture Against Earthquake (Case Study: Fahadan District in Yazd City)." *Arabian Journal of Geosciences* 8, no. 12 (May 19, 2015): 10775–87. https://doi.org/10.1007/s12517-015-1939-8.

Alizadeh, Mohsen, Mazlan Hashim, Esmaeil Alizadeh, Himan Shahabi, Mohammad Reza Karami, Âmin Beiranvand Pour, Biswajeet Pradhan, and Hassan Zabihi. "Multi-Criteria Decision Making (MCDM) Model for Seismic Vulnerability Assessment (SVA) of Urban Residential Buildings." *ISPRS International Journal of Geo-Information* 7, no. 11 (November 14, 2018): 444. https://doi.org/10.3390/ijgi7110444.

Amirzadeh, Melika, Saeideh Sobhaninia, and Ayyoob Sharifi. "Urban Resilience: A Vague or an Evolutionary Concept?" *Sustainable Cities and Society* 81 (June 1, 2022): 103853. https://doi.org/10.1016/j.scs.2022.103853.

Anderson, Mary B. "Vulnerability to disaster and sustainable development: A general framework for assessing vulnerability," *Disaster Prevention for Sustainable Development*, (January 1, 1995): 41–59, https://pesquisa.bvsalud.org/portal/resource/pt/des-6539.

Anderson, Mg, T Glade, and Mj Crozier. "The nature of landslide hazard impact" In Landslide Hazard and Risk. John Wiley eBooks, 2005. http://dept.ru.ac.bd/geology/acad/landslide_hazard_1-35.pdf.

Aral Merşa, and Gökhan Tunç. "Türkiye'de Deprem Performansına Dayalı Bina Kimlik Bilgilerinin Oluşturulmasına Yönelik Çalışma ve Öneriler." *Afet ve Risk Dergisi* 4, no. 1 (May 30, 2021): 20–41. https://doi.org/10.35341/afet.825123.

ArcGIS Resource Center, https://desktop.arcgis.com/en/arcmap/latest/extensions/network-analyst/exercise-1-creating-a-network-dataset.html Last access date: August, 2024

Armaş, Iuliana, and Alexandru Gavriş. "Social Vulnerability Assessment Using Spatial Multi-criteria Analysis (SEVI Model) and the Social Vulnerability Index (SoVI Model) – a Case Study for Bucharest, Romania." *Natural Hazards and Earth System Sciences* 13, no. 6 (June 18, 2013): 1481–99. https://doi.org/10.5194/nhess-13-1481-2013.

Armaş, Iuliana. "Multi-criteria Vulnerability Analysis to Earthquake Hazard of Bucharest, Romania." *Natural Hazards* 63, no. 2 (May 30, 2012): 1129–56. https://doi.org/10.1007/s11069-012-0209-2.

Azhar, Adriana Nayli, Mohamed Nurul Radzi Asyikin, Wan Siti Halimatul Munirah Wan Ahmad. "Multi-criteria Decision Making: A Systematic Review" *Recent Advances in Electrical & Electronic Engineering*; Volume 14, Issue 8, 2021, e291021197468.

Badmos, Biola K., Ademola A. Adenle, Sampson K. Agodzo, Grace B. Villamor, Daniel K. Asare-Kyei, Laouali M. Amadou, and Samuel N. Odai. "Micro-level Social Vulnerability Assessment Towards Climate Change Adaptation in Semi-arid Ghana, West Africa." *Environment Development and Sustainability* 20, no. 5 (June 13, 2017): 2261–79. https://doi.org/10.1007/s10668-017-9988-7.

Bahadori, Hadi, Araz Hasheminezhad, and Amjad Karimi. "Development of an Integrated Model for Seismic Vulnerability Assessment of Residential Buildings: Application to Mahabad City, Iran." *Journal of Building Engineering* 12 (July 1, 2017): 118–31. https://doi.org/10.1016/j.jobe.2017.05.014.

Barrows, Harlan H. "GEOGRAPHY AS HUMAN ECOLOGY." *Annals of the Association of American Geographers* 13, no. 1 (March 1, 1923): 1–14. https://doi.org/10.1080/00045602309356882.

Bergstrand, Kelly, Brian Mayer, Babette Brumback, and Yi Zhang. "Assessing the Relationship Between Social Vulnerability and Community Resilience to Hazards." *Social Indicators Research* 122, no. 2 (July 16, 2014): 391–409. https://doi.org/10.1007/s11205-014-0698-3.

Berke, Philip and Thomas J. Campanella. "Planning for Postdisaster Resiliency." *The Annals of the American Academy of Political and Social Science* 604 (2006): 192 – 207

Berkes, Fikret, Johan Colding, and Carl Folke. *Navigating Social-Ecological Systems: Building Resilience for Complexity and Change*, 2008. http://ci.nii.ac.jp/ncid/BA59863930.

Berkes, Fikret. "Understanding Uncertainty and Reducing Vulnerability: Lessons From Resilience Thinking." *Natural Hazards* 41, no. 2 (January 16, 2007): 283–95. https://doi.org/10.1007/s11069-006-9036-7.

Birkmann, J. "Risk and Vulnerability Indicators at Different Scales: Applicability, Usefulness and Policy Implications." *Environmental Hazards* 7, no. 1 (January 1, 2007): 20–31. https://doi.org/10.1016/j.envhaz.2007.04.002.

Birkmann, Joern, and Ben Wisner. "Measuring the unmeasurable: the challenge of vulnerability." *UNU Institute for Environment and Human Security*, (January 1, 2006), http://collections.unu.edu/eserv/UNU:1872/pdf3962.pdf.

Biswas, Sneha, and Sunil Nautiyal. "A Review of Socio-economic Vulnerability: The Emergence of Its Theoretical Concepts, Models and Methodologies." *Natural Hazards Research* 3, no. 3 (September 1, 2023): 563–71. https://doi.org/10.1016/j.nhres.2023.05.005.

Blaikie, Piers, Ben Wisner, Terry Cannon and Ian Davis. Routledge: At Risk 2nd Edition (2005), 471 Pp. "Natural Hazards, People's Vulnerability and Disasters." *Natural Hazards* 40, no. 2 (July 15, 2006): 495–97. https://doi.org/10.1007/s11069-006-9000-6.

Bollin, Christina, Camilo Cárdenas, Hahn, Herwig, and Krishna S. Vatsa. "Natural Disaster Network; Disaster Risk Management by Communities and Local Governments," Inter-American Development Bank, Washington DC, (2003), http://www.iadb.org/sds/doc/GTZ%2DStudyFinal.pdf

Bollin, Christina, Camilo Cárdenas, Hahn, Herwig, and Krishna S. Vatsa. "Disaster Risk Management by Communities and Local Governments," (December 1, 2003), https://doi.org/10.18235/0008775.

Bruneau, Michel, Stephanie E. Chang, Ronald T. Eguchi, George C. Lee, Thomas D. O'Rourke, Andrei M. Reinhorn, Masanobu Shinozuka, Kathleen Tierney, William A. Wallace, and Detlof Von Winterfeldt. "A Framework to Quantitatively Assess and Enhance the Seismic Resilience of Communities." *Earthquake Spectra* 19, no. 4 (November 1, 2003): 733–52. https://doi.org/10.1193/1.1623497.

Buckle, Philip, Mars Graham, Syd, Smale. "New Approaches to Assessing Vulnerability and Resilience." Australian Journal of Emergency Management 15, no. 2 (January 1, 2000): 0. https://search.informit.com.au/fullText;dn=369155833780624;res=IELHSS. Burton, I., Kates, R.W., White, G. F., (1993). The Environment as Hazard (2nd ed.). New York: Guildford.

Campanella, Thomas J. "Urban Resilience and the Recovery of New Orleans." *Journal of the American Planning Association* 72, no. 2 (June 30, 2006): 141–46. https://doi.org/10.1080/01944360608976734.

Carmin, Joan, Nikhil Nadkarni, Christopher Rhie. "Progress and challenges in urban climate adaptation planning: Results of a global survey." Massachusetts Cambridge, MA, USA. (2012): http://web.mit.edu/jcarmin/www/urbanadapt/Urban Adaptation Report FINAL.pdf

Carpenter, Stephen R., Frances Westley, and Monica G. Turner. "Surrogates for Resilience of Social–Ecological Systems." *Ecosystems* 8, no. 8 (November 28, 2005): 941–44. https://doi.org/10.1007/s10021-005-0170-y.

Carpenter, Steve, Brian Walker, J. Marty Anderies, and Nick Abel. “From Metaphor to Measurement: Resilience of What to What?” *Ecosystems* 4, no. 8 (December 1, 2001): 765–81. https://doi.org/10.1007/s10021-001-0045-9.

Carreño, Martha-Liliana, Omar D. Cardona, and Alex H. Barbat. “Urban Seismic Risk Evaluation: A Holistic Approach.” *Natural Hazards* 40, no. 1 (September 22, 2006): 137–72. https://doi.org/10.1007/s11069-006-0008-8.

Cecchini, Simone, Guillermo Sunkel, and Alexandra Barrantes. “Social Protection for Children at Times of Disaster.” *SSRN Electronic Journal*, January 1, 2017. https://doi.org/10.2139/ssrn.3089975.

Çelebi, M. “Topographical and Geological Amplification: Case Studies and Engineering Implications.” *Structural Safety* 10, no. 1–3 (May 1, 1991): 199–217. https://doi.org/10.1016/0167-4730(91)90015-2.

Chang, Chia-Ling, and Yu-Chi Chao. “Using the Analytical Hierarchy Process to Assess the Environmental Vulnerabilities of Basins in Taiwan.” *Environmental Monitoring and Assessment* 184, no. 5 (June 29, 2011): 2939–45. https://doi.org/10.1007/s10661-011-2162-z.

Chang, Stephanie E., Jackie Z. K. Yip, Shona L. Van Zijll De Jong, Rebecca Chaster, and Ashley Lowcock. “Using Vulnerability Indicators to Develop Resilience Networks: A Similarity Approach.” *Natural Hazards* 78, no. 3 (May 20, 2015): 1827–41. https://doi.org/10.1007/s11069-015-1803-x.

Collins, Andrew E. *Disaster and Development*. *Routledge eBooks*, 2009. https://doi.org/10.4324/9780203879238.

Crichton, D. “The Risk Triangle.” *Natural Disaster Management*. Jon Ingleton (Ed.), Tudor Rose, 1999 London.

Crowley, Helen, Venetia Despotaki, Daniela Rodrigues, Vitor Silva, Dragos Toma-Danila, Evi Riga, Anna Karatzetzou, et al. “Exposure Model for European Seismic Risk Assessment.” *Earthquake Spectra* 36, no. 1_suppl (June 7, 2020): 252–73. https://doi.org/10.1177/8755293020919429.

Crowley, Julia. "Social Vulnerability Factors and Reported Post-Disaster Needs in the Aftermath of Hurricane Florence." *International Journal of Disaster Risk Science* 12, no. 1 (November 3, 2020): 13–23. https://doi.org/10.1007/s13753-020-00315-5.

Cutter, Susan L, Bryan J. Boruff, and W. Lynn Shirley. "Social Vulnerability to Environmental Hazards." *Social Science Quarterly* 84, no. 2 (May 19, 2003): 242–61. https://doi.org/10.1111/1540-6237.8402002.

Cutter, Susan L, Jerry T Mitchell, and Michael S. Scott. "Revealing the Vulnerability of People and Places: A Case Study of Georgetown County, South Carolina." *Annals of the Association of American Geographers* 90, no. 4 (December 1, 2000): 713–37. https://doi.org/10.1111/0004-5608.00219.

Cutter, Susan L, and Christina Finch, "Temporal and Spatial Changes in Social Vulnerability to Natural Hazards," *Proceedings of the National Academy of Sciences* 105, no. 7 (February 19, 2008): 2301–6, https://doi.org/10.1073/pnas.0710375105.

Cutter, Susan L, Boruff Bryan J., and Shirley W. Lynn. "Social Vulnerability to Environmental Hazards," *Social Science Quarterly* 84, no. 2 (May 19, 2003): 242–61, https://doi.org/10.1111/1540-6237.8402002.

Cutter, Susan L, Christopher T. Emrich, Jennifer J. Webb, and Daniel Morath. "Social vulnerability to climate variability hazards: a review of the literature." *Hazards and Vulnerability Research Institute,* Final Report to Oxfam America 5, (2009): 1–44.

Cutter, Susan L, Lindsey Barnes, Melissa Berry, Christopher Burton, Elijah Evans, Eric Tate, and Jennifer Webb. "A Place-based Model for Understanding Community Resilience to Natural Disasters." *Global Environmental Change* 18, no. 4 (October 1, 2008): 598–606. https://doi.org/10.1016/j.gloenvcha.2008.07.013.

Cutter, Susan L. *"American Hazardscapes: The Regionalization of Hazards and Disasters."* Washington, DC: Joseph Henry Press., 2001. https://doi.org/10.17226/10132.

Cutter, Susan L. "Social Science Perspectives on Hazards and Vulnerability Science," in *Springer eBooks*, 2009, 17–30, https://doi.org/10.1007/978-90-481-3236-2_2.

Cutter, Susan L. *Living with Risk: The Geography of Technological Hazards*. Hodder Education, 1993.

Daddoust, Leila, HamidReza Khankeh, Abbas Ebadi, Robab Sahaf, Maryam Nakhaei, and Ali Asgary. "The Social Vulnerability of Older People to Natural Disasters: An Integrative Review." *Health in Emergencies & Disasters Quarterly*, (October 30, 2018): 5–14. https://doi.org/10.32598/hdq.4.1.5.

Davidson, Rachel Ann, H.C. Shah. (1997). An urban earthquake risk index. *The John A Blume Earthquake Engineering Center,* Department of Civil Engineering, Stanford University, Standford https://doi.org/10.25740/zy159jm6182

Davoudi, Simin, Elizabeth Brooks, and Abid Mehmood. "Evolutionary Resilience and Strategies for Climate Adaptation." *Planning Practice and Research* 28, no. 3 (June 1, 2013): 307–22. https://doi.org/10.1080/02697459.2013.787695.

Davoudi, Simin. "Resilience: A Bridging Concept or a Dead End?" In: Applying the Resilience Perspective to Planning: Critical Thoughts from Theory and Practice. *Planning Theory & Practice*, Vol. 13, No. 2, (June 1, 2012): 299–333 https://doi.org/10.1080/14649357.2012.677124

Dayton-Johnson, Jeff. "Natural Disasters and Adaptive Capacity." *OECD Development Centre Working Papers*, August 1, 2004. https://doi.org/10.1787/827805005406.

DBYBHY. Deprem Bölgelerinde Yapılacak Binalar Hakkında Yönetmelik. Ankara: Bayındırlık ve İskan Bakanlığı, 2007

De Moel, H, B Jongman, H Kreibich, B Merz, E Penning-Rowsell, and P J Ward. "Flood Risk Assessments at Different Spatial Scales." *Mitigation and Adaptation Strategies for Global Change* 20, no. 6 (May 22, 2015): 865–90. https://doi.org/10.1007/s11027-015-9654-z.

DeVerteuil, Geoff, Oleg Golubchikov, and Zoe Sheridan. “Disaster and the Lived Politics of the Resilient City.” *Geoforum* 125 (October 1, 2021): 78–86. https://doi.org/10.1016/j.geoforum.2021.07.004.

Dilshad, Tanzina, Dwijen Mallick, Pranita B. Udas, Chanda G. Goodrich, Anjal Prakash, Ganesh Gorti, Suruchi Bhadwal, et al. “Growing Social Vulnerability in the River Basins: Evidence From the Hindu Kush Himalaya (HKH) Region.” *Environmental Development* 31 (September 1, 2019): 19–33. https://doi.org/10.1016/j.envdev.2018.12.004.

Dokuz Eylül University Earthquake Research and Application Center, 30 October 2020 Samos (Samos) Earthquake (Mw: 6.9) Evaluation Report

Douglas, John. “Physical Vulnerability Modelling in Natural Hazard Risk Assessment.” *Natural Hazards and Earth System Sciences* 7, no. 2 (April 5, 2007): 283–88. https://doi.org/10.5194/nhess-7-283-2007.

Dow, Kirstin. “Exploring Differences in Our Common Future(S): The Meaning of Vulnerability to Global Environmental Change.” *Geoforum* 23, no. 3 (January 1, 1992): 417–36. https://doi.org/10.1016/0016-7185(92)90052-6.

Downing, Thomas E., Lasse Ringius, Mike Hulme, and Dominic Waughray. “Adapting to Climate Change in Africa.” *Mitigation and Adaptation Strategies for Global Change* 2, no. 1 (January 1, 1996): 19–44. https://doi.org/10.1023/b:miti.0000004663.31074.64.

Duzgun, H. S. B., M. S. Yucemen, H. S. Kalaycioglu, K. Celik, S. Kemec, K. Ertugay, and A. Deniz. “An Integrated Earthquake Vulnerability Assessment Framework for Urban Areas.” *Natural Hazards* 59, no. 2 (April 27, 2011): 917–47. https://doi.org/10.1007/s11069-011-9808-6.

Dwyer, Anita, Christopher Zoppou, Ole M. Nielsen, Susan Day, Stephen G. Roberts. (2004). “Quantifying social vulnerability: a methodology for identifying those at risk to natural hazards.” *Geoscience Austuralia Record*, (January 2004) ISSN 1448-2177

Eğilmez, D. Burcu. "İzmir’de kentsel dönüşüm ve dönüştürülemeyen zorunlu yoksulluk halleri." *Değişen İzmir’i Anlamak* (2010): 601-638.

Emre, Ömer, Selim Özalp, Ahmet Doğan, Volkan Özaksoy, Cengiz Yıldırım ve Fikret Göktaş. *İzmir Yakın Çevresinin Diri Fayları ve Deprem Potansiyelleri*. MTA Rapor No: 10754, (2005): 80s.

Engle, Nathan L. “Adaptive Capacity and Its Assessment.” *Global Environmental Change* 21, no. 2 (May 1, 2011): 647–56. https://doi.org/10.1016/j.gloenvcha.2011.01.019.

Eraydin, Ayda. “‘Resilience Thinking’ for Planning.” In *The Geojournal Library*, 17–37, 2012. https://doi.org/10.1007/978-94-007-5476-8_2.

Ettinger, Susanne, Loïc Mounaud, Christina Magill, Anne-Françoise Yao-Lafourcade, Jean-Claude Thouret, Vern Manville, Caterina Negulescu, et al. “Building Vulnerability to Hydro-geomorphic Hazards: Estimating Damage Probability From Qualitative Vulnerability Assessment Using Logistic Regression.” *Journal of Hydrology* 541 (October 1, 2016): 563–81. https://doi.org/10.1016/j.jhydrol.2015.04.017.

ESRI. “ArcGIS Data Classification Methods.” Accessed September 5, 2024. https://pro.arcgis.com/en/pro-app/latest/help/mapping/layer-properties/data-classification-methods.htm.

Fatemi, Farin, Ali Ardalan, Benigno Aguirre, Nabiollah Mansouri, Iraj Mohammadfam. “Social vulnerability indicators in disasters: Findings from a systematic review,” *International Journal of Disaster Risk Reduction,* Volume 22, (June 2017): Pages 219-227, https://doi.org/10.1016/j.ijdrr.2016.09.006.

Fekete, A. “Validation of a Social Vulnerability Index in Context to River-floods in Germany.” *Natural Hazards and Earth System Sciences* 9, no. 2 (March 19, 2009): 393–403. https://doi.org/10.5194/nhess-9-393-2009.

Fekete, Alexander, Marion Damm, and Joern Birkmann. “Scales as a Challenge for Vulnerability Assessment.” *Natural Hazards* 55, no. 3 (September 2, 2009): 729–47. https://doi.org/10.1007/s11069-009-9445-5.

FEMA, (2013a). *Multi-Hazard Loss Estimation Methodology: Earthquake Model Technical Manual*. Department of Homeland Security, FEMA, Washington, DC

FEMA, (2013V). *Multi-Hazard Loss Estimation Methodology: Flood Model Technical Manual.* Department of Homeland Security, FEMA, Washington, DC

FEMA. "Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook." Disaster Prevention and Management an International Journal 12, no. 4 (October 1, 2003).

Fischer, T., M. Alvarez, J.C. De La Llera, and R. Riddell. "An Integrated Model for Earthquake Risk Assessment of Buildings." *Engineering Structures* 24, no. 7 (July 1, 2002): 979–98. https://doi.org/10.1016/s0141-0296(02)00018-4.

Flanagan, Barry E., Edward W. Gregory, Elaine J Hallisey, Janet L. Heitgerd, and Brian Lewis. "A Social Vulnerability Index for Disaster Management." *Journal of Homeland Security and Emergency Management* 8, no. 1 (January 5, 2011). https://doi.org/10.2202/1547-7355.1792.

Folke, Carl, Stephen R. Carpenter, Brian Walker, Marten Scheffer, Terry Chapin, and Johan Rockström. "Resilience Thinking: Integrating Resilience, Adaptability and Transformability." *Ecology and Society* 15, no. 4 (January 1, 2010). https://doi.org/10.5751/es-03610-150420.

Folke, Carl. "Resilience: The Emergence of a Perspective for Social–ecological Systems Analyses." *Global Environmental Change* 16, no. 3 (August 1, 2006): 253–67. https://doi.org/10.1016/j.gloenvcha.2006.04.002.

Forman, Ernest H., and Saul I. Gass. "The Analytic Hierarchy Process—An Exposition." *Operations Research* 49, no. 4 (August 1, 2001): 469–86. https://doi.org/10.1287/opre.49.4.469.11231.

Fuchs, S. "Susceptibility Versus Resilience to Mountain Hazards in Austria - Paradigms of Vulnerability Revisited." *Natural Hazards and Earth System Sciences* 9, no. 2 (March 13, 2009): 337–52. https://doi.org/10.5194/nhess-9-337-2009.

Fuchs, S., M. Keiler, R. Ortlepp, R. Schinke, and M. Papathoma-Köhle. "Recent Advances in Vulnerability Assessment for the Built Environment Exposed to Torrential Hazards: Challenges and the Way Forward." *Journal of Hydrology* 575 (August 1, 2019): 587–95. https://doi.org/10.1016/j.jhydrol.2019.05.067.

Füssel, Hans-Martin. "Vulnerability: A Generally Applicable Conceptual Framework for Climate Change Research." *Global Environmental Change* 17, no. 2 (May 1, 2007): 155–67. https://doi.org/10.1016/j.gloenvcha.2006.05.002.

Gallopín, Gilberto C. "Linkages Between Vulnerability, Resilience, and Adaptive Capacity." *Global Environmental Change* 16, no. 3 (August 1, 2006): 293–303. https://doi.org/10.1016/j.gloenvcha.2006.02.004.

Gares, Christine E., and Burrell E. Montz. "Disaster Vulnerability of Migrant and Seasonal Farmworkers: A Comparison of Texas and North Carolina." *Southeastern Geographer* 54, no. 1 (January 1, 2014): 36–54. https://doi.org/10.1353/sgo.2014.0000.

Gaume, Eric, Valerie Bain, Pietro Bernardara, Olivier Newinger, Mihai Barbuc, Allen Bateman, Lotta Blaškovičová, et al. "A Compilation of Data on European Flash Floods." *Journal of Hydrology* 367, no. 1–2 (March 1, 2009): 70–78. https://doi.org/10.1016/j.jhydrol.2008.12.028.

Gerçek, Deniz, ve İsmail Talih Güven. "Kentsel Dirençliliğin Coğrafi Bilgi Sistemleri Ile Analizi: Deprem Ve İzmit Kenti". Harita Teknolojileri Elektronik Dergisi 8, sy. 1 (Nisan 2016): 51-64. https://doi.org/10.15659/hartek.16.04.298.

Gerçek, Deniz, and İsmail Talih Güven. "Urban Earthquake Vulnerability Assessment and Mapping at the Microscale Based on the Catastrophe Progression Method." *International Journal of Disaster Risk Science* 14, no. 5 (October 1, 2023): 768–81. https://doi.org/10.1007/s13753-023-00512-y.

Geurs, Karst T., and Bert Van Wee. "Accessibility Evaluation of Land-use and Transport Strategies: Review and Research Directions." *Journal of Transport Geography* 12, no. 2 (June 1, 2004): 127–40. https://doi.org/10.1016/j.jtrangeo.2003.10.005.

Giovinazzi, Sonia, and Sergio Lagomarsino. "A macroseismic method for the vulnerability assessment of buildings." *13th world conference on earthquake engineering*. Vol. 896. 2004.

Godschalk, David R. "Urban Hazard Mitigation: Creating Resilient Cities." Natural Hazards Review 4, no. 3 (August 1, 2003): 136–43. https://doi.org/10.1061/(asce)1527-6988(2003)4:3(136.

Gökçe, Oktay, Şenay Özden, Ahmet Demir. "Türkiye'de Afetlerin Mekansal Ve İstatistiksel Dağılımı Afet Bilgileri Envanteri." *T.C Bayındırlık Ve İskan Bakanlığı Afet İşleri Genel Müdürlüğü Afet Etüt Ve Hasar Tespit Daire Başkanlığı,* 2008.

Guadagno, Lorenzo. "Reducing Migrants' Vulnerability to Natural Disasters through Disaster Risk Reduction Measures Including Migrants in Disaster Prevention, Preparedness, Response, and Recovery Efforts" *Migrants in Countries in Crisis Initiative*, 2016.

Guillard-Gonçalves, C, J.L. Zêzere, S Pereira, and R.A.C. Garcia, "Assessment of physical vulnerability of buildings and analysis of landslide risk at the municipal scale: application to the Loures municipality, Portugal" *Nat. Hazards Earth Syst. Sci.,* 16, (2016): 311–331, https://doi.org/10.5194/nhess-16-311-2016

Gunderson, Lance H, C.S. Holling, L. Pritchard, G. Peterson. "Resilience in Ecosystems, Institutions and Societies, Propositions for a Research Agenda." 1996. Stockholm: *Beijer Institution Discussion Paper*

Gunderson, Lance H, Ronald D. Brunner, C. S. Holling, and Stephen S. Light. "Barriers and Bridges to the Renewal of Ecosystems and Institutions." *Journal of Wildlife Management 61, no.* 4 (October 1, 1995): 1437. https://doi.org/10.2307/3802148.

Gunderson, Lance H. "Ecological Resilience—In Theory and Application." *Annual Review of Ecology and Systematics* 31, no. 1 (November 1, 2000): 425–39. https://doi.org/10.1146/annurev.ecolsys.31.1.425.

Gunderson, Lance H., and C. S. Holling. Panarchy: Understanding Transformations in Human and Natural Systems, 2002. https://ci.nii.ac.jp/ncid/BA55772345.

Gunderson, Lance H., Craig R. Allen, and C. S. Holling. Foundations of Ecological Resilience. Island Press eBooks, 2010. http://ci.nii.ac.jp/ncid/BB0072417X.

Gurbuz, Tuba, Abdullah Cengiz, Sener Kolemenoglu, Cem Demir, and Alper Ilki. “Damages and Failures of Structures in İzmir (Turkey) During the October 30, 2020 Aegean Sea Earthquake.” *Journal of Earthquake Engineering* 27, no. 6 (July 13, 2022): 1565–1606. https://doi.org/10.1080/13632469.2022.2086186.

Han, Ju, Arip Nur, Mutiara Syifa, Minsu Ha, Chang-Wook Lee, and Ki-Young Lee. “Improvement of Earthquake Risk Awareness and Seismic Literacy of Korean Citizens Through Earthquake Vulnerability Map From the 2017 Pohang Earthquake, South Korea.” *Remote Sensing* 13, no. 7 (April 2, 2021): 1365. https://doi.org/10.3390/rs13071365.

Hassanzadeh, Reza, Zorica Nedović- Budić, Akbar Alavi Razavi, Mohsen Norouzzadeh, and Hassan Hodhodkian. “Interactive Approach for GIS-based Earthquake Scenario Development and Resource Estimation (Karmania Hazard Model).” *Computers & Geosciences* 51 (February 1, 2013): 324–38. https://doi.org/10.1016/j.cageo.2012.08.016.

Hejazi, Seyed Jafar, Ayyoob Sharifi, and Mahmoud Arvin. “Assessment of Social Vulnerability in Areas Exposed to Multiple Hazards: A Case Study of the Khuzestan Province, Iran.” *International Journal of Disaster Risk Reduction* 78 (August 1, 2022): 103127. https://doi.org/10.1016/j.ijdrr.2022.103127.

Hirayama, Makoto, Hiroki Shinozaki, Naoya Kasai, and Tsutomu Otaki. “Comparative Risk Study of Hydrogen and Gasoline Dispensers for Vehicles.” *International Journal of Hydrogen Energy* 43, no. 27 (July 1, 2018): 12584–94. https://doi.org/10.1016/j.ijhydene.2018.05.003.

Högberg Yilmaz, Melissa. “The Urban Planning of Istanbul and the Provision of Green Resilient Zones in an Earthquake-Hit Metropolitan Area-A Case Study of Istanbul & Avcılar.” Bachelor, Örebro University, 2020.

Holling, C.S. (1996). “Engineering resilience versus ecological resilience.” National Academies of Sciences, Engineering, and Medicine. 1996. *Engineering Within Ecological Constraints.* Washington, DC: The National Academies Press. https://doi.org/10.17226/4919.

Holling, C.S. “Resilience and Stability of Ecological Systems.” *Annual Review of Ecology and Systematics* 4, no. 1 (November 1, 1973): 1–23. https://doi.org/10.1146/annurev.es.04.110173.000245.

Hosseini, Kambod Amini, Maziar Hosseini, Mohammad Kazem Jafari, and S. Hosseinioon. “Recognition of Vulnerable Urban Fabrics in Earthquake Zones: A Case Study of the Tehran Metropolitan Area.” *Journal of Seismology and Earthquake Engineering* 10, no. 4 (January 1, 2009): 175–87. http://www.jsee.ir/article_240580_aaa2ded41818499fa0c9ebd9b211f4ba.pdf.

Hudson, R. “Resilient Regions in an Uncertain World: Wishful Thinking or a Practical Reality?” *Cambridge Journal of Regions Economy and Society* 3, no. 1 (October 27, 2009): 11–25. https://doi.org/10.1093/cjres/rsp026.

Ishizaka, Alessio, and Ashraf Labib. “Review of the Main Developments in the Analytic Hierarchy Process.” *Expert Systems With Applications*, May 1, 2011. https://doi.org/10.1016/j.eswa.2011.04.143.

İzmir Büyükşehir Belediyesi. İzmir Deprem Senaryosu ve Deprem Master Planı. 2018. https://www.izmir.bel.tr/izmirdeprem/

Jabareen, Yosef. “Planning the Resilient City: Concepts and Strategies for Coping With Climate Change and Environmental Risk.” *Cities* 31 (April 1, 2013): 220–29. https://doi.org/10.1016/j.cities.2012.05.004.

Joshi, Girish Chandra, Shailesh Ghildiyal, and Piyoosh Rautela. “Seismic Vulnerability of Lifeline Buildings in Himalayan Province of Uttarakhand in India.” *International Journal of Disaster Risk Reduction* 37 (July 1, 2019): 101168. https://doi.org/10.1016/j.ijdrr.2019.101168.

Kamranzad, Farnaz, Hossein Memarian, and Mehdi Zare. “Earthquake Risk Assessment for Tehran, Iran.” *ISPRS International Journal of Geo-Information* 9, no. 7 (July 9, 2020): 430. https://doi.org/10.3390/ijgi9070430.

Kappes, M. Papathoma-Köhle, and M. Keiler. “Assessing Physical Vulnerability for Multi-hazards Using an Indicator-based Methodology.” *Applied Geography* 32, no. 2 (March 1, 2012): 577–90. https://doi.org/10.1016/j.apgeog.2011.07.002.

Karadağ, Arife, and Güldane Mirioğlu. “Bayraklı Kentsel Dönüşüm Projesi Üzerine Coğrafi Değerlendirmeler.” *Türk Coğrafya Dergisi* , no. 57 (December 30, 2011): 21–32. https://doi.org/10.17211/tcd.53573.

Karadaş, Aylin, and Ertuğ Öner. 2021. “Effects of the Alluvial Geomorphology on the Damage of the Sisam Earthquake in the Bornova Plain.” *Journal of Geography* 0, no. 42: 139-153. https://doi.org/10.26650/JGEOG2021-872890

Karimzadeh, Sadra, Masakatsu Miyajima, Reza Hassanzadeh, Reza Amiraslanzadeh, and Batoul Kamel. “A GIS-based Seismic Hazard, Building Vulnerability and Human Loss Assessment for the Earthquake Scenario in Tabriz.” *Soil Dynamics and Earthquake Engineering* 66 (November 1, 2014): 263–80. https://doi.org/10.1016/j.soildyn.2014.06.026.

Kasperson, Re, Jeanne X. Kasperson, T. D., K. Dow and William B. Meyer. “Critical environmental regions: concepts distinctions and issues.” (1995). In: Kasperson, R.E., Kasperson, J.X., Turner II, B.L. (Eds.), Regions at Risk: Comparisons of Threatened Environments. *United Nations University, Tokyo*. http://unu.edu

Kates, Robert W. “The Interaction of Climate and Society.” Climate Impact Assessment, (January 1, 1985): 3. http://ui.adsabs.harvard.edu/abs/1985cias.conf....3K/abstract.

Khan, Sibghat Ullah, Muhammad Irshad Qureshi, Irfan Ahmad Rana, and Ahsen Maqsoom. “An Empirical Relationship Between Seismic Risk Perception and Physical Vulnerability: A Case Study of Malakand, Pakistan.” *International Journal of Disaster Risk Reduction* 41 (December 1, 2019): 101317. https://doi.org/10.1016/j.ijdrr.2019.101317.

Khan, Sibghat Ullah, Muhammad Irshad Qureshi, Irfan Ahmad Rana, and Ahsen Maqsoom. “Seismic Vulnerability Assessment of Building Stock of Malakand (Pakistan) Using FEMA P-154 Method.” *SN Applied Sciences* 1, no. 12 (November 16, 2019). https://doi.org/10.1007/s42452-019-1681-z.

Kıncal, Cem. “Engineering Geological Evaluation of the Geological Units Exposed in Inner Bay Area (Izmir)’s Vicinity Using Geographical Information Systems and Remote Sensing.” PhD, Dokuz Eylul University, 2005.

Kircher, Charles A., Robert V. Whitman, and William T. Holmes. "HAZUS Earthquake Loss Estimation Methods." Natural Hazards Review 7, no. 2 (May 1, 2006): 45–59. https://doi.org/10.1061/(asce)1527-6988(2006)7:2(45.

Kreibich, Heidi, Isabel Seifert, Bruno Merz, and Annegret H. Thieken. "Development of FLEMOcs – a New Model for the Estimation of Flood Losses in the Commercial Sector." *Hydrological Sciences Journal* 55, no. 8 (November 29, 2010): 1302–14. https://doi.org/10.1080/02626667.2010.529815.

Kusenbach, Margarethe, Jason L. Simms, and Graham A. Tobin. "Disaster Vulnerability and Evacuation Readiness: Coastal Mobile Home Residents in Florida." *Natural Hazards* 52, no. 1 (February 25, 2009): 79–95. https://doi.org/10.1007/s11069-009-9358-3.

Lee, Yung-Jaan. "Social Vulnerability Indicators as a Sustainable Planning Tool." Environmental Impact Assessment Review 44 (January 1, 2014): 31–42. https://doi.org/10.1016/j.eiar.2013.08.002.

Lei, Yongdeng, Jing'ai Wang, Yaojie Yue, Hongjian Zhou, and Weixia Yin. "Rethinking the Relationships of Vulnerability, Resilience, and Adaptation From a Disaster Risk Perspective." *Natural Hazards* 70, no. 1 (September 3, 2013): 609–27. https://doi.org/10.1007/s11069-013-0831-7.

Leichenko, Robin. "Climate Change and Urban Resilience." *Current Opinion in Environmental Sustainability* 3, no. 3 (May 1, 2011): 164–68. https://doi.org/10.1016/j.cosust.2010.12.014.

Liu, Jifu, Yida Fan, and Peijun Shi. "Response to a High-altitude Earthquake: The Yushu Earthquake Example." *International Journal of Disaster Risk Science* 2, no. 1 (March 1, 2011): 43–53. https://doi.org/10.1007/s13753-011-0005-8.

Liu, Kenan. "Post-earthquake Medical Evacuation System Design Based on Hierarchical Multi-objective Optimization Model: An Earthquake Case Study." *International Journal of Disaster Risk Reduction* 51 (December 1, 2020): 101785. https://doi.org/10.1016/j.ijdrr.2020.101785.

Llorente-Marrón, Mar, Montserrat Díaz-Fernández, Paz Méndez-Rodríguez, and Rosario González Arias. "Social Vulnerability, Gender and Disasters. The Case of Haiti in 2010." *Sustainability* 12, no. 9 (April 28, 2020): 3574. https://doi.org/10.3390/su12093574.

Lloyd, Sophie, Jasmine Gray, Sarah Healey, and Aaron Opdyke. "Social Vulnerability to Natural Hazards in the Philippines." *International Journal of Disaster Risk Reduction* 79 (September 1, 2022): 103103. https://doi.org/10.1016/j.ijdrr.2022.103103.

Lu, Peiwen, and Dominic Stead. "Understanding the Notion of Resilience in Spatial Planning: A Case Study of Rotterdam, the Netherlands." *Cities* 35 (December 1, 2013): 200–212. https://doi.org/10.1016/j.cities.2013.06.001.

Ludwig, Don, Brian Walker, and C. S. Holling. "Sustainability, Stability, and Resilience." *Conservation Ecology* 1, no. 1 (January 1, 1997). https://doi.org/10.5751/es-00012-010107.

Lummen, Natainia S., and Fumihiko Yamada. "Implementation of an Integrated Vulnerability and Risk Assessment Model." *Natural Hazards* 73, no. 2 (March 18, 2014): 1085–1117. https://doi.org/10.1007/s11069-014-1123-6.

Malgwi, Mark Bawa, Sven Fuchs, and Margreth Keiler. "A Generic Physical Vulnerability Model for Floods: Review and Concept for Data-scarce Regions." *Natural Hazards and Earth System Sciences* 20, no. 7 (July 31, 2020): 2067–90. https://doi.org/10.5194/nhess-20-2067-2020.

Maltais, Danielle. "Elderly People With Disabilities and Natural Disasters: Vulnerability of Seniors and Post Trauma." *Gerontology & Geriatric Medicine* 5, no. 4 (December 23, 2019): 1–7. https://doi.org/10.24966/ggm-8662/100041.

Manyena, Siambabala Bernard. "The concept of resilience revisited." *Disasters* vol. 30,4 (2006): 433-50. doi:10.1111/j.0361-3666.2006.00331.x

Marchi, L., M. Borga, E. Preciso, and E. Gaume. “Characterisation of Selected Extreme Flash Floods in Europe and Implications for Flood Risk Management.” *Journal of Hydrology* 394, no. 1–2 (November 1, 2010): 118–33. https://doi.org/10.1016/j.jhydrol.2010.07.017.

Mardani, Abbas, Ahmad Jusoh, Khalil MD Nor, Zainab Khalifah, Norhayati Zakwan, and Alireza Valipour. 2015. “Multiple Criteria Decision-Making Techniques and Their Applications – a Review of the Literature from 2000 to 2014.” *Economic Research-Ekonomska Istraživanja* 28 (1): 516–71. doi:10.1080/1331677X.2015.1075139.

Martins, V. Nuno, Delta Sousa E Silva, and Pedro Cabral. “Social Vulnerability Assessment to Seismic Risk Using Multicriteria Analysis: The Case Study of Vila Franca Do Campo (São Miguel Island, Azores, Portugal).” *Natural Hazards* 62, no. 2 (January 12, 2012): 385–404. https://doi.org/10.1007/s11069-012-0084-x.

Masnavi, Mohammad Reza, Fariba Gharai and Mona Hajibandeh. “Exploring urban resilience thinking for its application in urban planning: a review of literature.” *International Journal of Environmental Science and Technology* 16 (2018): 567-582.

Mavhura, Emmanuel, and Tawanda Manyangadze. “A Comprehensive Spatial Analysis of Social Vulnerability to Natural Hazards in Zimbabwe: Driving Factors and Policy Implications.” *International Journal of Disaster Risk Reduction* 56 (April 1, 2021): 102139. https://doi.org/10.1016/j.ijdrr.2021.102139.

Mavhura, Emmanuel, Bernard Manyena, and Andrew E. Collins. “An Approach for Measuring Social Vulnerability in Context: The Case of Flood Hazards in Muzarabani District, Zimbabwe.” *Geoforum* 86 (November 1, 2017): 103–17. https://doi.org/10.1016/j.geoforum.2017.09.008.

Mavhura, Emmanuel. “Analysing Drivers of Vulnerability to Flooding: A Systems Approach.” *South African Geographical Journal* 101, no. 1 (October 31, 2018): 72–90. https://doi.org/10.1080/03736245.2018.1541020.

Mavhura, Emmanuel. “Systems Analysis of Vulnerability to Hydrometeorological Threats: An Exploratory Study of Vulnerability Drivers in Northern Zimbabwe.” *International Journal of Disaster Risk Science* 10, no. 2 (April 30, 2019): 204–19. https://doi.org/10.1007/s13753-019-0217-x.

McEntire, David. “Understanding and Reducing Vulnerability: From the Approach of Liabilities and Capabilities.” *Disaster Prevention and Management an International Journal* 21, no. 2 (April 20, 2012): 206–25. https://doi.org/10.1108/09653561211220007.

Meerow, Sara, and Joshua P. Newell. "Resilience and complexity: A bibliometric review and prospects for industrial ecology." *Journal of Industrial Ecology* 19.2 (2015): 236-251.

Meerow, Sara, Joshua P. Newell, and Melissa Stults. "Defining urban resilience: A review." *Landscape and urban planning* 147 (2016): 38-49.

Meerow, Sara, Mary Fastiggi, and Thaddeus R Miller. “Governing Urban Resilience: Organisational Structures and Coordination Strategies in 20 North American City Governments.” *Urban Studies* 58, no. 6 (March 13, 2020): 1262–85. https://doi.org/10.1177/0042098020907277.

Mileti, Dennis S. *Disasters by Design: A Reassessment of Natural Hazards in the United States*, 1999. http://ci.nii.ac.jp/ncid/BA41819393.

Miller, Fiona, Henny Osbahr, Emily Boyd, Frank Thomalla, Sukaina Bharwani, Gina Ziervogel, Brian Walker, et al. “Resilience and Vulnerability: Complementary or Conflicting Concepts?” *Ecology and Society* 15, no. 3 (2010). http://www.jstor.org/stable/26268184.

Miller, James Rumrill. “The Assessment of Worth: A Systematic Procedure and Its Experimental Validation.,” 1966. https://dspace.mit.edu/handle/1721.1/13513.

MTA 30 October 2020 Aegean Sea Earthquake (Mw=6.9) Field Observations and Evaluation Report

MTA. “İZMİR YAKIN ÇEVRESİNİN DİRİ FAYLARI VE DEPREM POTANSİYELLERİ,” 2005. Accessed June 3, 2024. https://www.mta.gov.tr/v3.0/sayfalar/bilgi-merkezi/deprem/pdf/izmir_rapor.pdf.

Müller, A., J. Reiter, and U. Weiland. "Assessment of Urban Vulnerability Towards Floods Using an Indicator-based Approach – a Case Study for Santiago De Chile." *Natural Hazards and Earth System Sciences* 11, no. 8 (August 4, 2011): 2107–23. https://doi.org/10.5194/nhess-11-2107-2011

Muttarak, Raya, and Wolfgang Lutz. "Is Education a Key to Reducing Vulnerability to Natural Disasters and Hence Unavoidable Climate Change?" *Ecology and Society* 19, no. 1 (January 1, 2014). https://doi.org/10.5751/es-06476-190142.

National Research Council. 2006. Facing Hazards and Disasters: Understanding Human Dimensions. Washington, DC: The National Academies Press. https://doi.org/10.17226/11671.

Nguyen, Cuong Viet, Ralph Horne, John Fien, and France Cheong. "Assessment of Social Vulnerability to Climate Change at the Local Scale: Development and Application of a Social Vulnerability Index." *Climatic Change* 143, no. 3–4 (July 7, 2017): 355–70. https://doi.org/10.1007/s10584-017-2012-2.

No, Wonjun, Junyong Choi, Sangjoon Park, and David Lee. "Balancing Hazard Exposure and Walking Distance in Evacuation Route Planning During Earthquake Disasters." *ISPRS International Journal of Geo-Information* 9, no. 7 (July 10, 2020): 432. https://doi.org/10.3390/ijgi9070432.

Norris, F.H., S.P. Stevens, and B Pfefferbaum. "Community Resilience as a Metaphor, Theory, Set of Capacities, and Strategy for Disaster Readiness." *Am J Community Psychol*, (2008):127–150 https://doi.org/10.1007/s10464-007-9156-6

Notaro, Vincenza, Mauro De Marchis, Chiara Fontanazza, Goffredo la Loggia, Valeria Puleo, Gabriele Freni. "The Effect of Damage Functions on Urban Flood Damage Appraisal." *Procedia Engineering.* 70. (2014): 1251-1260. 10.1016/j.proeng.2014.02.138.

Nuhoğlu, Ayhan, Mehmet Fahrettin Erener, Çağlayan Hızal, Cem Kıncal, Devrim Şüfa Erdoğan, Özkan Cevdet Özdağ, Mustafa Akgün, et al. "A Reconnaissance Study in Izmir (Bornova Plain) Affected by October 30, 2020 Samos Earthquake." *International Journal of Disaster Risk Reduction* 63 (September 1, 2021): 102465. https://doi.org/10.1016/j.ijdrr.2021.102465.

O'Keefe, Phil, Ken Westgate, and Ben Wisner. "Taking the Naturalness Out of Natural Disasters." *Nature* 260, no. 5552 (April 1, 1976): 566–67. https://doi.org/10.1038/260566a0.

Onat, Ö., (2022). Deprem Etkisindeki Betonarme Yapılarda Meydana Gelen Hasarlara Dolgu Duvar Etkisinin İncelenmesi 30 Ekim 2020 İzmir Depremi Örneği. [Isparta Uygulamalı Bilimler Üniversitesi Lisansüstü Eğitim Enstitüsü].

Önder, Zeynep, Vedia Dökmeci, and Berna Keskin. "The Impact of Public Perception of Earthquake Risk on Istanbul's Housing Market." Journal of Real Estate Literature 12, no. 2 (2004): 181–94. http://www.jstor.org/stable/44103487.

Özcan, Evren Can, Sultan Ünlüsoy, and Tamer Eren. "A Combined Goal Programming – AHP Approach Supported With TOPSIS for Maintenance Strategy Selection in Hydroelectric Power Plants." *Renewable and Sustainable Energy Reviews* 78 (October 1, 2017): 1410–23. https://doi.org/10.1016/j.rser.2017.04.039.

Papathoma-Köhle, M., B. Neuhäuser, K. Ratzinger, H. Wenzel, and D. Dominey-Howes. "Elements at Risk as a Framework for Assessing the Vulnerability of Communities to Landslides." *Natural Hazards and Earth System Sciences* 7, no. 6 (December 5, 2007): 765–79. https://doi.org/10.5194/nhess-7-765-2007.

Papathoma-Köhle, Maria, Bernhard Gems, Michael Sturm, and Sven Fuchs. "Matrices, curves and indicators: A review of approaches to assess physical vulnerability to debris flows." *Earth-Science Reviews.* 2017. 171. 10.1016/j.earscirev.2017.06.007.

Papathoma-Köhle, Maria, Matthias Schlögl, and Sven Fuchs. "Vulnerability Indicators for Natural Hazards: An Innovative Selection and Weighting Approach." *Scientific Reports* 9, no. 1 (October 21, 2019). https://doi.org/10.1038/s41598-019-50257-2.

Papathoma-Köhle, Maria. "Vulnerability Curves Vs. Vulnerability Indicators: Application of an Indicator-based Methodology for Debris-flow Hazards." *Natural Hazards and Earth System Sciences* 16, no. 8 (August 3, 2016): 1771–90. https://doi.org/10.5194/nhess-16-1771-2016.

Papathoma-Köhle, Maria. "Vulnerability Curves Vs. Vulnerability Indicators: Application of an Indicator-based Methodology for Debris-flow Hazards." *Natural Hazards and Earth System Sciences* 16, no. 8 (August 3, 2016): 1771–90. https://doi.org/10.5194/nhess-16-1771-2016.

Parker, Dennis, and James K. Mitchell. "Editorial: Disaster Vulnerability of Megacities: An Expanding Problem That Requires Rethinking and Innovative Responses." *GeoJournal* 37, no. 3 (1995): 295–301. http://www.jstor.org/stable/41146629.

Parry, Martin L., Timothy R. Carter, and Nicolaas T. Konijn. *The Impact of Climatic Variations on Agriculture*. *Springer eBooks*, 1988. https://doi.org/10.1007/978-94-009-2943-2.

Paton, Douglas, and David Johnston. "Disasters and communities: vulnerability, resilience and preparedness." *Disaster Prevention and Management: An International Journal* 10.4 (2001): 270-277.

Paton, Douglas, and David Moore Johnston. *Disaster Resilience: An Integrated Approach*, 2006. http://ecite.utas.edu.au/40977.

Pereira, S., P.P. Santos, J.L. Zêzere, A.O. Tavares, R.A.C. Garcia, and S.C. Oliveira. "A Landslide Risk Index for Municipal Land Use Planning in Portugal." *The Science of the Total Environment* 735 (September 1, 2020): 139463. https://doi.org/10.1016/j.scitotenv.2020.139463.

Porter, K.A., K.S. Jaiswal, D.J. Wald, M. Greene, and Craig Comartin. "Whe-Pager Project: A New Initiative in Estimating Global Building Inventory And its Seismic Vulnerability." *Proceedings of the 14th World Conference on Earthquake Engineering*, January 1, 2008.

Porter, Libby, and Simin Davoudi. "The politics of resilience for planning: A cautionary note." In INTERFACE: Applying the Resilience Perspective to Planning: Critical Thoughts from Theory and Practice. *Planning Theory & Practice,* 13(2): (2012): 299–333. http://dx.doi.org/10.1080/14649357.2012.677124

Potter, Robert B., David Barker, Thomas Klak, and Denis Conway. *The Contemporary Caribbean*. *Routledge eBooks*, 2015. https://doi.org/10.4324/9781315838144.

Rabby, Yasin Wahid, Md Belal Hossain, and Mahbub Ul Hasan. “Social Vulnerability in the Coastal Region of Bangladesh: An Investigation of Social Vulnerability Index and Scalar Change Effects.” *International Journal of Disaster Risk Reduction* 41 (December 1, 2019): 101329. https://doi.org/10.1016/j.ijdrr.2019.101329.

Rajarathnam, S., and A. R. Santhakumar. “Assessment of Seismic Building Vulnerability Based on Rapid Visual Screening Technique Aided by Aerial Photographs on a GIS Platform.” *Natural Hazards* 78, no. 2 (July 4, 2015): 779–802. https://doi.org/10.1007/s11069-014-1382-2.

Roberts, N. J., F. Nadim, and B. Kalsnes. "Quantification of vulnerability to natural hazards." *Georisk* 3.3 (2009): 164-173.Saaty, Thomas L. *The Analytic Hierarchy Process.* McGraw-Hill, 1980.

Saaty, R.W. “The Analytic Hierarchy Process—what It Is and How It Is Used.” *Mathematical Modelling* 9, no. 3–5 (January 1, 1987): 161–76. https://doi.org/10.1016/0270-0255(87)90473-8.

Saaty, Thomas L. “An Exposition of the AHP in Reply to the Paper ‘Remarks on the Analytic Hierarchy Process.’” *Management Science* 36, no. 3 (March 1, 1990): 259–68. https://doi.org/10.1287/mnsc.36.3.259.

Saaty, Thomas L. “Decision Making With the Analytic Hierarchy Process.” *International Journal of Services Sciences* 1, no. 1 (January 1, 2008): 83. https://doi.org/10.1504/ijssci.2008.017590.

Saaty, Thomas L. “Fundamentals of the Analytic Hierarchy Process.” In *Managing Forest Ecosystems*, 15–35, 2001. https://doi.org/10.1007/978-94-015-9799-9_2.

Saaty, Thomas L., and Luis G. Vargas. *Models, Methods, Concepts &Amp; Applications of the Analytic Hierarchy Process*. *International Series in Management Science/Operations Research/International Series in Operations Research & Management Science*, 2012. https://doi.org/10.1007/978-1-4614-3597-6.

Sabaei, Davood, John Erkoyuncu, and Rajkumar Roy. “A review of multi-criteria decision making methods for enhanced maintenance delivery.” *Procedia CIRP* 37 (2015): 30-35.

Şahin, İsmail, and Tuğba Kılınç. "Türkiye’de 1980-2014 yılları arasında görülen depremlerin ekonomik etkileri." *İktisadi Yenilik Dergisi* 4.1 (2016): 33-42.

Sarris, A., C. Loupasakis, P. Soupios, V. Trigkas, and F. Vallianatos. “Earthquake Vulnerability and Seismic Risk Assessment of Urban Areas in High Seismic Regions: Application to Chania City, Crete Island, Greece.” *Natural Hazards* 54, no. 2 (October 29, 2009): 395–412. https://doi.org/10.1007/s11069-009-9475-z.

Schmidtlein, Mathew C., John M. Shafer, Melissa Berry, and Susan L. Cutter. “Modeled Earthquake Losses and Social Vulnerability in Charleston, South Carolina.” *Applied Geography* 31, no. 1 (January 1, 2011): 269–81. https://doi.org/10.1016/j.apgeog.2010.06.001.

Schulze, Peter, ed. *Engineering within ecological constraints*. National Academies Press, 1996.

Servi, M. “Assessment of Vulnerability to Earthquake Hazards Using Spatial Multi Criteria Analysis: Odunpazari, Eskisehir Case Study.” M.Sc., Middle East Technical University, 2004.

Shafapourtehrany, Mahyat, Peyman Yariyan, Haluk Özener, Biswajeet Pradhan, and Farzin Shabani. “Evaluating the Application of K-mean Clustering in Earthquake Vulnerability Mapping of Istanbul, Turkey.” *International Journal of Disaster Risk Reduction* 79 (September 1, 2022): 103154. https://doi.org/10.1016/j.ijdrr.2022.103154.

Shapira, Stav, Limor Aharonson-Daniel, and Yaron Bar-Dayan. “Anticipated Behavioral Response Patterns to an Earthquake: The Role of Personal and Household Characteristics, Risk Perception, Previous Experience and Preparedness.” *International Journal of Disaster Risk Reduction* 31 (October 1, 2018): 1–8. https://doi.org/10.1016/j.ijdrr.2018.04.001.

Sharifi, Ayyoob, and Yoshiki Yamagata. "Principles and criteria for assessing urban energy resilience: A literature review." *Renewable and Sustainable Energy Reviews* 60 (2016): 1654-1677.

Sharifi, Ayyoob, and Yoshiki Yamagata. "Resilience-Oriented Urban Planning." In *Lecture Notes in Energy*, 3–27, 2018. https://doi.org/10.1007/978-3-319-75798-8_1.

Sharifi, Ayyoob, and Yoshiki Yamagata. "Resilient Urban Form: A Conceptual Framework." In *Lecture Notes in Energy*, 167–79, 2018. https://doi.org/10.1007/978-3-319-75798-8_9.

Sherman, Mya, James Ford, Alejandro Llanos-Cuentas, María José Valdivia, and Alejandra Bussalleu. "Vulnerability and Adaptive Capacity of Community Food Systems in the Peruvian Amazon: A Case Study From Panaillo." *Natural Hazards* 77, no. 3 (March 12, 2015): 2049–79. https://doi.org/10.1007/s11069-015-1690-1.

Shi, Peijun, Tao Ye, Ying Wang, Tao Zhou, Wei Xu, Juan Du, Jing'ai Wang, et al. "Disaster Risk Science: A Geographical Perspective and a Research Framework." *International Journal of Disaster Risk Science* 11, no. 4 (August 1, 2020): 426–40. https://doi.org/10.1007/s13753-020-00296-5.

Siagian, Tiodora Hadumaon, Purhadi Purhadi, Suhartono Suhartono, and Hamonangan Ritonga. "Social Vulnerability to Natural Hazards in Indonesia: Driving Factors and Policy Implications." *Natural Hazards* 70, no. 2 (October 16, 2013): 1603–17. https://doi.org/10.1007/s11069-013-0888-3.

Silva, M., and S. Pereira. "Assessment of Physical Vulnerability and Potential Losses of Buildings Due to Shallow Slides." *Natural Hazards* 72, no. 2 (January 20, 2014): 1029–50. https://doi.org/10.1007/s11069-014-1052-4.

Singh, Aditi, D. P. Kanungo, and Shilpa Pal. "Physical Vulnerability Assessment of Buildings Exposed to Landslides in India." *Natural Hazards* 96, no. 2 (January 14, 2019): 753–90. https://doi.org/10.1007/s11069-018-03568-y.

Smit, Barry, and Johanna Wandel. “Adaptation, Adaptive Capacity and Vulnerability.” *Global Environmental Change* 16, no. 3 (August 1, 2006): 282–92. https://doi.org/10.1016/j.gloenvcha.2006.03.008.

Smit, Barry, Ian Burton, Richard J. T. Klein, and J. Wandel. “An Anatomy of Adaptation to Climate Change and Variability.” In *Springer eBooks*, 223–51, 2000. https://doi.org/10.1007/978-94-017-3010-5_12.

Smith, Keith, (2007). *Environmental hazards: Assessing Risk and Reducing Disaster. Routledge*, 2007 New York

Smith, Keith. *Environmental Hazards : Assessing Risk and Reducing Disaster*. *Routledge eBooks*, 1996. https://lib.ugent.be/en/catalog/rug01:000420996.

Solangaarachchi, Daminda, Amy L. Griffin, and Michael D. Doherty. "Social vulnerability in the context of bushfire risk at the urban-bush interface in Sydney: a case study of the Blue Mountains and Ku-ring-gai local council areas." *Natural hazards* 64 (2012): 1873-1898.

Spring, Úrsula Oswald. “Dual Vulnerability Among Female Household Heads.” Acta Colombiana De Psicología 16, no. 2 (July 1, 2013): 19–30. https://doi.org/10.14718/acp.2013.16.2.2.

Stephenson, V., and D. D’Ayala. “A New Approach to Flood Vulnerability Assessment for Historic Buildings in England.” *Natural Hazards and Earth System Sciences* 14, no. 5 (May 5, 2014): 1035–48. https://doi.org/10.5194/nhess-14-1035-2014.

Sucuoglu, Haluk, and Ufuk Yazgan. “Simple Survey Procedures for Seismic Risk Assessment in Urban Building Stocks.” In *Springer eBooks*, 97–118, 2003. https://doi.org/10.1007/978-94-010-0021-5_7.

Taherdoost, Hamed, and Mitra Madanchian. “Multi-Criteria Decision Making (MCDM) Methods and Concepts.” *Encyclopedia* 3, no. 1 (January 9, 2023): 77–87. https://doi.org/10.3390/encyclopedia3010006.

Tamiz, Mehrdad, Dylan Jones, and Carlos Romero. "Goal Programming for Decision Making: An Overview of the Current State-of-the-art." *European Journal of Operational Research* 111, no. 3 (December 1, 1998): 569–81. https://doi.org/10.1016/s0377-2217(97)00317-2.

Tantala, Michael W., Guy J.P. Nordenson, George Deodatis, and Klaus Jacob. "Earthquake Loss Estimation for the New York City Metropolitan Region." *Soil Dynamics and Earthquake Engineering* 28, no. 10–11 (October 1, 2008): 812–35. https://doi.org/10.1016/j.soildyn.2007.10.012.

Taşan-Kok, Tuna, Dominic Stead, and Peiwen Lu. "Conceptual Overview of Resilience: History and Context." In *The Geojournal Library,* 39–51, 2012. https://doi.org/10.1007/978-94-007-5476-8_3.

Tate, Eric. "Social Vulnerability Indices: A Comparative Assessment Using Uncertainty and Sensitivity Analysis." *Natural Hazards* 63, no. 2 (April 4, 2012): 325–47. https://doi.org/10.1007/s11069-012-0152-2.

Tierney, Kathleen, and Michel Bruneau. "Conceptualizing and Measuring Resilience: A Key to Disaster Loss Reduction." *TR News,* no. 250 (May 1, 2007). https://trid.trb.org/view/813539.

TMMOB Chamber of Civil Engineers. *Geotechnical Evaluations of Izmir Province and Field Observations for Structural Damage on the Earthquake Occurred in the Aegean Sea off Samos Island on October 30*. 2020

Tran, Hanh, Quoc Nguyen, and Matthieu Kervyn. "Household Social Vulnerability to Natural Hazards in the Coastal Tran Van Thoi District, Ca Mau Province, Mekong Delta, Vietnam." *Journal of Coastal Conservation* 21, no. 4 (May 23, 2017): 489–503. https://doi.org/10.1007/s11852-017-0522-8.

Türkiye Bina Deprem Yönetmeliği (TBDY). *Afet ve Acil Durum Yönetimi Başkanlığı,* Ankara, Türkiye 2019.

Turner, B.L., Roger E. Kasperson, Pamela Matson, James J. McCarthy, Robert W. Corell, Lindsey Christensen, Noelle Eckley, et al. "Framework for Vulnerability Analysis in Sustainability Science, A." *Proceedings of the National Academy of Sciences* 100 (July 8, 2003). https://fse.fsi.stanford.edu/publications/framework_for_vulnerability_analysis_in_sustainability_science_a.

Tyler, Stephen, and Marcus Moench. "A Framework for Urban Climate Resilience." *Climate and Development* 4, no. 4 (October 1, 2012): 311–26. https://doi.org/10.1080/17565529.2012.745389.

UNDRR. (United Nations Disaster Risk Reduction). Terminology—UNDRR. Geneva: *UN Office for Disaster Risk Reduction*. 2017.

UNDRR. "The Human Cost of Disasters - an Overview of the Last 20 Years 2000-2019." Geneva: UN Office for Disaster Risk Reduction, 2017.

UNISDR. "Living With Risk: A Global Review of Disaster Reduction Initiatives." United Nations International Strategy for Disaster Reduction Secretariat (UNISDR), New York, 2004.

Usta, P. "İzmir Kent Merkezi Tarihi Yapılarının Deprem Davranışı Ve Sismik Risk Değerlendirmesi İçin Yaklaşık Bir Yöntem Önerisi." PhD, Süleyman Demirel Üniversitesi Fen Bilimleri Enstitüsü, 2016.

Usta, Pınar, and Özgür Bozdağ. "Tarihi Başdurak Camisinin Deprem Analizi." *Pamukkale Üniversitesi Mühendislik Bilimleri Dergisi* 27, no. 3 (June 9, 2021): 244–50. https://dergipark.org.tr/en/pub/pajes/issue/62735/946956.

Uzelli, Taygun, Esra BiLgiÇ, Bahadır Öztürk, Alper Baba, Hasan SözbiLiR, and Orhan Tatar. "Effects of Seismic Activity on Groundwater Level and Geothermal Systems in İzmir, Western Anatolia, Turkey: The Case Study From October 30, 2020 Samos Earthquake." *TURKISH JOURNAL OF EARTH SCIENCES* 30, no. SI-1 (October 30, 2021): 758–78. https://doi.org/10.3906/yer-2101-9.

Uzielli, M., F. Catani, V. Tofani, and N. Casagli. "Risk Analysis for the Ancona landslide—II: Estimation of Risk to Buildings." *Landslides* 12, no. 1 (February 26, 2014): 83–100. https://doi.org/10.1007/s10346-014-0477-x.

Vogel, Coleen, and Karen O'Brien. "Vulnerability and global environmental change: rhetoric and reality." *Aviso: an information bulletin on global environmental change and human security, issue no. 13, March 2004* (2004).

Vogel, Coleen, Susanne C. Moser, Roger E. Kasperson, and Geoffrey D. Dabelko. “Linking Vulnerability, Adaptation, and Resilience Science to Practice: Pathways, Players, and Partnerships.” *Global Environmental Change* 17, no. 3–4 (August 1, 2007): 349–64. https://doi.org/10.1016/j.gloenvcha.2007.05.002.

Walker, Blake Byron, Cameron Taylor-Noonan, Alan Tabbernor, T’Brenn McKinnon, Harsimran Bal, Dan Bradley, Nadine Schuurman, and John J. Clague. “A Multi-criteria Evaluation Model of Earthquake Vulnerability in Victoria, British Columbia.” *Natural Hazards* 74, no. 2 (May 27, 2014): 1209–22. https://doi.org/10.1007/s11069-014-1240-2.

Walker, Brian, and David Salt. *Resilience Thinking: Sustaining Ecosystems and People in a Changing World*, 2006. http://ci.nii.ac.jp/ncid/BA8104110X.

Watts, Michael J., and Hans G. Bohle. “The Space of Vulnerability: The Causal Structure of Hunger and Famine.” *Progress in Human Geography* 17, no. 1 (March 1, 1993): 43–67. https://doi.org/10.1177/030913259301700103.

White, Iain, and Paul O’Hare. “From Rhetoric to Reality: Which Resilience, Why Resilience, and Whose Resilience in Spatial Planning?” *Environment and Planning C Government and Policy* 32, no. 5 (January 1, 2014): 934–50. https://doi.org/10.1068/c12117.

Wilson, Geoff A. “Community Resilience, Globalization, and Transitional Pathways of Decision-making.” *Geoforum* 43, no. 6 (November 1, 2012): 1218–31. https://doi.org/10.1016/j.geoforum.2012.03.008.

Wisner, Ben, Piers Blaikie, Terry Cannon and Ian Davis. “Routledge: At Risk 2nd Edition (2005), 471 Pp. Natural Hazards, People’s Vulnerability and Disasters.” *Natural Hazards* 40, no. 2 (July 15, 2006): 495–97. https://doi.org/10.1007/s11069-006-9000-6.

Wood, Nathan J., Christopher G. Burton, and Susan L. Cutter. "Community Variations in Social Vulnerability to Cascadia-related Tsunamis in the U.S. Pacific Northwest." *Natural Hazards* 52, no. 2 (March 26, 2009): 369–89. https://doi.org/10.1007/s11069-009-9376-1.

Yakut, Ahmet, Halûk Sucuoğlu, Baris Binici, Erdem Canbay, Cemalettin Donmez, Alper İlki, Alp Caner, Ozan Cem Celik, and Bekir Özer Ay. "Performance of Structures in İzmir After the Samos Island Earthquake." *Bulletin of Earthquake Engineering* 20, no. 14 (September 13, 2021): 7793–7818. https://doi.org/10.1007/s10518-021-01226-6.

Yariyan, P., M. R. Karami, and R. Ali Abbaspour. "Exploitation Of Mcda to Learn The Radial Base Neural Network (Rbfnn) Aim Physical and Social Vulnerability Analysis Versus The Earthquake (Case Study: Sanandaj City, Iran)." *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences/International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* XLII-4/W18 (October 19, 2019): 1071–78. https://doi.org/10.5194/isprs-archives-xlii-4-w18-1071-2019.

Yariyan, Peyman, Hasan Zabihi, Isabelle D. Wolf, Mohammadreza Karami, and Sohrab Amiriyan. "Earthquake Risk Assessment Using an Integrated Fuzzy Analytic Hierarchy Process With Artificial Neural Networks Based on GIS: A Case Study of Sanandaj in Iran." *International Journal of Disaster Risk Reduction* 50 (November 1, 2020): 101705. https://doi.org/10.1016/j.ijdrr.2020.101705.

Yariyan, Peyman, Mohammadtaghi Avand, Fariba Soltani, Omid Ghorbanzadeh, and Thomas Blaschke. "Earthquake Vulnerability Mapping Using Different Hybrid Models." *Symmetry* 12, no. 3 (March 4, 2020): 405. https://doi.org/10.3390/sym12030405.

Yin, Yueping, Fawu Wang, and Ping Sun. "Landslide Hazards Triggered by the 2008 Wenchuan Earthquake, Sichuan, China." *Landslides* 6, no. 2 (March 17, 2009): 139–52. https://doi.org/10.1007/s10346-009-0148-5.

Yoon, D. K. "Assessment of Social Vulnerability to Natural Disasters: A Comparative Study." *Natural Hazards* 63, no. 2 (April 18, 2012): 823–43. https://doi.org/10.1007/s11069-012-0189-2.

Young, Oran R., et al. "The globalization of socio-ecological systems: An agenda for scientific research." *Global environmental change* 16.3 (2006): 304-316.Yücemen, G. Özcebe, and A.C. Pay. “Prediction of Potential Damage Due to Severe Earthquakes.” *Structural Safety* 26, no. 3 (July 1, 2004): 349–66. https://doi.org/10.1016/j.strusafe.2003.09.002.

Zhou, Hongjian, Jing’ai Wang, Jinhong Wan, and Huicong Jia. “Resilience to Natural Hazards: A Geographic Perspective.” *Natural Hazards* 53, no. 1 (June 11, 2009): 21–41. https://doi.org/10.1007/s11069-009-9407-y.

Zhou, Yang, Ning Li, Wenxiang Wu, Jidong Wu, and Peijun Shi. “Local Spatial and Temporal Factors Influencing Population and Societal Vulnerability to Natural Disasters.” *Risk Analysis* 34, no. 4 (March 27, 2014): 614–39. https://doi.org/10.1111/risa.12193.

Zlaugotne, Beate, Lauma Zihare, Lauma Balode, Antra Kalnbalkite, Aset Khabdullin, and Dagnija Blumberga. “Multi-Criteria Decision Analysis Methods Comparison.” *Environmental and Climate Technologies* 24, no. 1 (January 1, 2020): 454–71. https://doi.org/10.2478/rtuect-2020-0028

APPENDICIES

APPENDIX A

QUESTION 1: With respect to AHP priorities, which criterion is more important, and how much more on a scale **1 to 5**?

Notes: Please tick the yellow box to the left of which criterion (between criterion 1 and criterion 2) is more important than the other.
Then, mark one of the values between **1 and 5** in the box, according to which criterion is more important than the other (between criterion 1 and criterion 2).

						PAIRWISE COMPARISONS				
						Equal Importance	Moderate Importance	Strong Importance	Very Strong Importance	Extreme Importance
			CRITERION 1		**CRITERION 2**	1	2	3	4	5
INDICATORS	1	☐	Reinforced Concrete Buildings	☐	Masonry Buildings	☐	☐	☐	☐	☐
	2	☐	Reinforced Concrete Buildings	☐	Attached Buildings	☐	☐	☐	☐	☐
	3	☐	Reinforced Concrete Buildings	☐	Detached Buildings	☐	☐	☐	☐	☐
	3	☐	Reinforced Concrete Buildings	☐	Corner Adjacent Buildings	☐	☐	☐	☐	☐
	3	☐	Reinforced Concrete Buildings	☐	Building Age	☐	☐	☐	☐	☐
	3	☐	Masonry Buildings	☐	Attached Buildings	☐	☐	☐	☐	☐
	3	☐	Masonry Buildings	☐	Detached Buildings	☐	☐	☐	☐	☐
	3	☐	Masonry Buildings	☐	Corner Adjacent Buildings	☐	☐	☐	☐	☐
	3	☐	Masonry Buildings	☐	Building Age	☐	☐	☐	☐	☐
	3	☐	Attached Buildings	☐	Detached Buildings	☐	☐	☐	☐	☐
	3	☐	Attached Buildings	☐	Corner Adjacent Buildings	☐	☐	☐	☐	☐
	3	☐	Attached Buildings	☐	Building Age	☐	☐	☐	☐	☐
	3	☐	Detached Buildings	☐	Corner Adjacent Buildings	☐	☐	☐	☐	☐
	3	☐	Detached Buildings	☐	Building Age	☐	☐	☐	☐	☐
	3	☐	Corner Adjacent Buildings	☐	Building Age	☐	☐	☐	☐	☐

Figure 63: Appendix