DOKUZ EYLÜL UNIVERSITY

GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

MODEL PROPOSAL TO CREATE A CLIMATE CHANGE RESILIENT AND SUSTAINABLE CITY: AN AHP-BASED VULNERABILITY ANALYSIS APPROACH IZMIR EXAMPLE

by

Nurseli ŞANLI

October, 2024

İZMİR

MODEL PROPOSAL TO CREATE A CLIMATE CHANGE RESILIENT AND SUSTAINABLE CITY: AN AHP-BASED VULNERABILITY ANALYSIS APPROACH IZMIR EXAMPLE

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Nurseli ŞANLI

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We have read the thesis entitled **"MODEL PROPOSAL TO CREATE A CLIMATE CHANGE RESILIENT AND SUSTAINABLE CITY: AN AHP-BASED VULNERABILITY ANALYSIS APPROACH IZMIR EXAMPLE"** completed by **NURSELİ ŞANLI** under supervision of **PROF. DR. SİBEL ECEMİŞ KILIÇ** and we certify that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science.

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ABSTRACT

Urban areas face increasing vulnerabilities due to natural disasters and socio-economic shocks, and climate change poses a significant threat. The concept of resilience has emerged to address these challenges, emphasising the capacity of systems to cope with changes and shocks. However, achieving truly sustainable cities requires a holistic approach that balances economic, social and environmental concerns. This thesis proposes a framework that integrates the concepts of resilience and sustainability to build cities that are resilient to climate change-related disasters. The approach combines vulnerability analysis with the Analytic Hierarchy Process (AHP) to identify factors contributing to urban vulnerability and develop strategies to enhance resilience and vulnerability. The research aims to develop a model that can be applied at different scales, including a customised vulnerability index based on key dimensions of urban resilience and vulnerability. The findings of the model produced within the scope of the study can be used to inform policy makers, urban planners and stakeholders to produce more. In this context, the research provides a model analysis of floods and extreme heat disasters in the context of climate change. The model is produced at two different scales: Metropolitan Scale, which includes the city center of Izmir city, and Planning Scale, which includes the second spatial planning region of Karşıyaka District. The results of the model analysis rationally and consistently express the vulnerability of the city to the crises that occur due to climate change in the current situation. In this respect, the findings of the model produced within the scope of the thesis can be used to inform policy makers, urban planners and stakeholders to produce more rational spatial plans for climate resilient and sustainable urban development.

Keywords: Vulnerability, Analytic Hierarchy Process, Climate Change, Resilience

İKLİM DEĞİŞİKLİĞİNE DAYANIKLI VE SÜRDÜRÜLEBİLİR BİR ŞEHİR YARATMAK İÇİN MODEL ÖNERİSİ: AHP TABANLI BİR HASSASİYET ANALİZİ YAKLAŞIMI İZMİR ÖRNEĞİ

ÖZ

Kentsel alanlar doğal afetler ve sosyo-ekonomik şoklar nedeniyle artan hassasiyetlerle karşı karşıyadır ve iklim değişikliği önemli bir tehdit oluşturmaktadır. Dirençlilik kavramı, bu zorlukların üstesinden gelmede, sistemlerin değişiklikler ve şoklarla başa çıkma kapasitesini vurgulayacak şekilde ortaya çıkmıştır. Ancak gerçekten sürdürülebilir şehirlere ulaşmak ekonomik, sosyal ve çevresel kaygıları dengeleyen bütünsel bir yaklaşımı gerektirir. Bu tez, iklim değişikliğine bağlı felaketlere karşı dayanıklı şehirler inşa etmek için dayanıklılık ve kırılganlık kavramlarını bütünleştiren bir çerçeve önermektedir. Yaklaşım, kentsel kırılganlığa katkıda bulunan faktörleri belirlemek ve dayanıklılığı artırmaya yönelik stratejiler geliştirmek için kırılganlık analizini Analitik Hiyerarşi Süreci (AHP) ile birleştirir. Araştırma, kentsel dirençlilik ve kırılganlığın temel boyutlarına dayalı özelleştirilmiş bir kırılganlık endeksini içeren, farklı ölçeklerde uygulanabilir bir model geliştirmeyi hedeflemektedir. Bu kapsamda araştırma, iklim değişikliğine karşı sel ve aşırı sıcak hava afetleri üzerinden bir model denemesi sunar. Model, İzmir ili kent merkezini içeren Metropolitan Ölçekte ve Karşıyaka İlçesi ikinci mekansal planlama bölgesini içeren Planlama Ölçeğinde olmak üzere iki farklı ölçekte üretilir. Model denemesi sonuçları, mevcut durumda kentin iklim değişikliğine bağlı gelişen krizlere karşı kırılganlığını rasyonel ve tutarlı şekilde ifade eder. Bu yönüyle tez kapsamında üretilen modelin bulguları, iklim değişikliğine dayanıklı ve sürdürülebilir kentsel gelişime için daha rasyonel mekansal planlar üretmesine yönelik politika yapıcıları, şehir plancıları ve paydaşların bilgilendirilmesi amacıyla kullanılabilecektir.

Anahtar kelimeler: Kırılganlık, Analitik Hiyerarşik Süreç, İklim Değişikliği, Dirençlilik

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CHAPTER ONE
INTRODUCTION

Urban areas face an increasing vulnerability to a wide variety of challenges, including natural disasters, climate change and socio-economic shocks. Climate change is one of these difficulties. Unless action is taken against the risks of these threats, urban communities will live under constant threat and more and more people will become vulnerable to risks (UNISDR, 2009). To reduce the risk and impact of threats from climate change and ensure the safety and well-being of the city and its inhabitants, it is clear and indispensable that cities and communities need to be more resilient and prepared to threats (Folke et al., 2002; Zhang et al., 2018). The concept of resilience, in general, is the ability of a system to cope with the changes, threats, risks and surprises it encounters by preventing or minimizing their impact. In addition to determining the framework of urban resilience, one of the most critical issues in achieving resilience is measuring vulnerabilities and assessing how urban resilience can reduce vulnerabilities.

Consequently, the concept of urban resilience and the approach of vulnerability analyses have received considerable attention in recent years as a way to address urban challenges and risks, particularly climate change-related disasters. This interest in risk resilience and vulnerability measurements has resulted in studies based on qualitative and quantitative approaches to measure vulnerability and thus to conduct an accurate resilience study (Balica, et. al, 2009; Sarkodie and Strezoc, 2019; Owrangi, Lanningan and Simonovic, 2015). These approaches explore ways to ensure resilience against a various of disasters such as floods, extreme heat and sea level rise due to climate change. In this context, this thesis proposes a holistic approach that combines the concepts of resilience and sustainability to create a framework for building resilient and sustainable cities against climate change-related disasters. In the thesis, the resilience against floods and extreme heat, which occur due to climate change and whose increasing effect is observed every year, is addressed with the vulnerability approach. The approach in the thesis, combines vulnerability analysis and the analytical hierarchy process (AHP) to identify factors that contribute to urban

vulnerability and develop strategies to increase resilience and sustainability. This approach aims to make an academic contribution to the existing literature and implement an application in the context of the city of Izmir.

1.1 Purpose and Scope

In the industrialization and urbanization processes that started with the Industrial Revolution, the greenhouse gases released due to the use of fossil fuels to meet the energy needs caused climate change by disrupting the atmosphere balance. Climate change has become a global problem that grows exponentially with each day. In recent years, we have become increasingly aware of climate change's great risks our cities. Climate change is likely to bring higher temperatures, sea level rise, more intense rainstorms, droughts and heatwaves, or exacerbate disasters that occur. As adapted in the IPCC assessment report (IPCC, 2018), the frequency and severity of heatwaves, storms, hurricanes and extreme tides will continue to increase unless GHG emissions are reduced by half. Climate change-related disasters are among the main disasters that urban areas are exposed to in this impact spectrum (IPCC, 2007, 2018, 2022; NPCC, 2009; Wardekker et.al., 2003).

Important disasters which urban areas are exposed to within this spectrum of impacts include floods, inundations, extreme heat waves, storms, hurricanes, which occur and/or increase in severity due to climate change. As a result of these disasters occurring in cities, loss of life and property is experienced; urban life is disrupted; transport and infrastructure systems are damaged. Turkey is seriously exposed to the effects of climate change due to its geographical location, natural features and urbanization structure. Izmir is one of the cities that demonstrate Turkey's vulnerability to climate risk. Izmir, Turkey's largest city on the coasts of the Mediterranean Sea, is frequently affected by extreme weather events. The Mediterranean is one of the most affected semi-continental seas by the combined effects of climate change, urbanisation and pollution, and due to this character, it is changing faster than the world average (Gallego et. Al. 2016; Kuc and Chormański, 2019; Munoz-Carpena et. Al, 2007). In terms of extreme precipitation and flooding and extreme heat, insolation and solar

radiation, the most common meteorological disasters in the Aegean Region occurred in Izmir and a number of areas of Aydın (MGM, 2022; Kadıoğlu, 2012). Besides the natural characteristics of Izmir, the high rate of urbanization and population growth are complicating resilience to climate change-related disasters.

There are minimal studies that address the vulnerability and resilience of Izmir to disasters caused by extreme weather events using integrated methods. In these studies, multiple disasters have been dealt with individually or only through disaster areas such as flooded areas. The reason for this is that there is no strictly accepted complementary approach in the literature. The impact of disasters such as floods and extreme heat, which affect not only the area they cause but also the whole city due to their effects on both spatial and physical and socio-economic structure, should be considered with holistic approaches. This thesis, which argues that the sustainability of resilience can only be ensured this way, aims to fill these gaps in the literature with the approach it adopts. In order to provide a demonstration and justification for the proposed methodology and model, the case study will be conducted in Izmir, a city characterized by its vulnerability to climate change.

1.2 Methodology and Objectives

The methodology in this thesis will consist of a literature review of related concepts, theories and previous work on the analysis of urban resilience and vulnerability. 'As a result of the literature review, vulnerability was defined as “a measure of the sensitivity and weakness level of an area to risks, a function directly proportional to exposure and susceptibility and inversely proportional to coping capacity” based on the definitions of IPCC (2014) and Balica et. al, (2012) and translated into a mathematical formula based on the definition of vulnerability as vulnerability is directly proportional to exposure and susceptibility and inversely proportional to coping capacity (IPCC, 2024). Although there are examples in the literature (White et. al, 2005; Balica et. al, 2009; Balica et. al, 2009; Balica et. al; 2012; De Leon and Carlos, 2006), vulnerability analysis is combined with AHP method with a new approach that is not used intensively and is not evaluated in the formula. In this way, the thesis contributed to

the literature by presenting vulnerability and AHP method in an integrated way. This will be followed by a case study of the chosen city to demonstrate the implementation of the proposed approach. The case study will occur in Izmir, Turkey's third largest city, which stands out with its distinctive features. The case study will be repeated for two different disasters to measure how a city can be affected by different disasters and to identify the integrated vulnerability risk. Disasters will be examined within an area boundary that includes metropolitan districts where the dynamics of the city are strongly reflected. As a result of the vulnerability analysis method that can be measured spatially, it will be possible to determine which areas are vulnerable for which reasons. In addition to the methods used in traditional planning studies, the AHP method will be used to analyze the data and create a custom-developed vulnerability index. As a result of the vulnerability analysis evaluation produced in two different hazards, solution proposals for certain areas will be developed according to spatial planning construction techniques, legislation and regulations. At the last stage of the study, the potential, applicability and traceability of the produced model will be evaluated through the relationship of the approach with spatial plans.

The main purpose of this research is to develop a model for creating more resilient and sustainable cities. This thesis is designed with three main phases namely literature review, data processing and analysis, and research conclusion. Thesis research design can be schematized as follows:

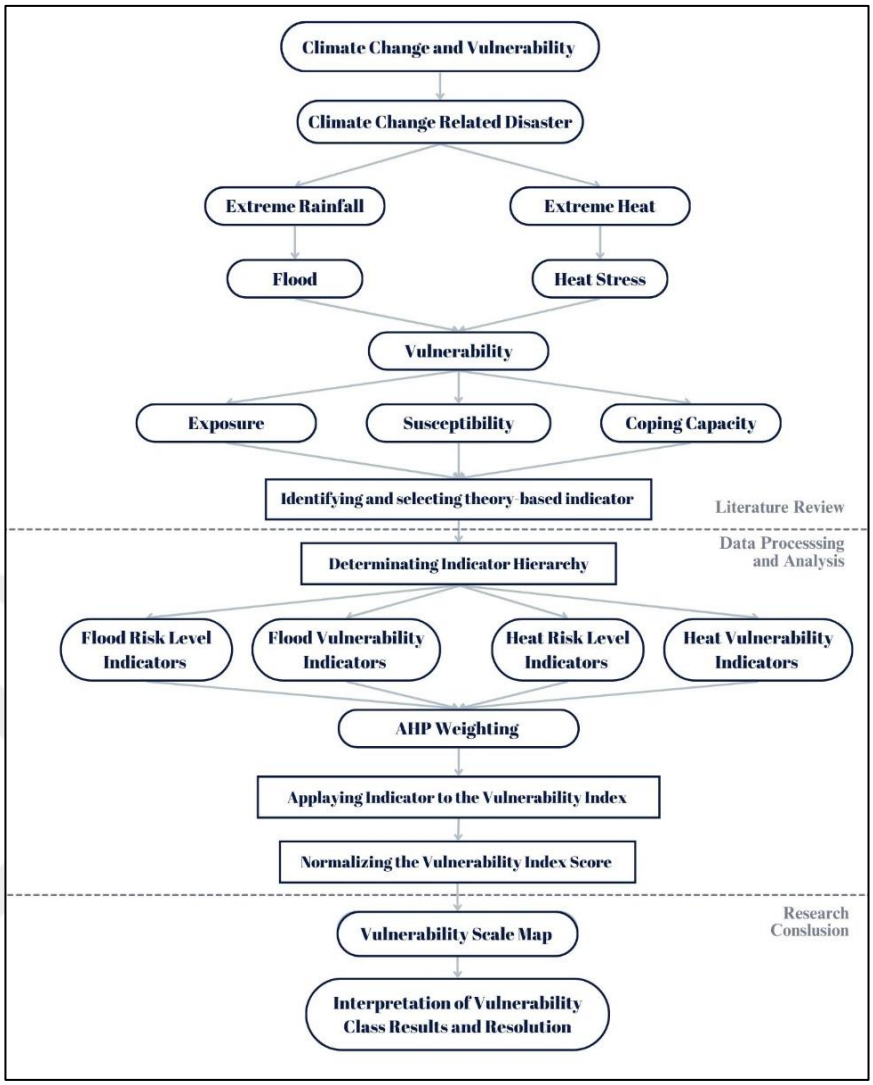

Figure 1.1 Research Design Frameworks

The research design of this thesis is based on the following main questions that constitute the scope of the thesis:

- Which criteria can be used to measure vulnerability to climate change related disaster risks in Izmir?
- What are the weights and importance levels of the indicators to be used in the vulnerability study?
- Is it possible to use similar or the same indicators in projects of different scales?
- Is this method rational, consistent and scalable so that it can be used at different scales in different project area?

In this framework, literature review is conducted with the key theme of climate change and vulnerability, flood and heat stress. Data processing and analysis are conducted with the key theme of AHP-based Indicator approach. In this study, the method that produced at different scales will be applied in the selected study area. In this way, the usability and sustainability of the produced model at different scales will be examined. In the method to be used, a customized vulnerability index will be developed using the AHP that cities can use to assess their resilience and sustainability alongside traditional planning studies. The index will be based on a set of indicators that capture the key dimensions of urban resilience and sustainability, including climate change adaptation, social equity and resource management. After implementing the produced model, solutions will be presented within the framework of spatial plans and relevant regulations in areas that are determined to be vulnerable. Thus, the effect of the developed approach on spatial plans will be observed.

The expected results of this study are twofold:

(1) A framework that takes the unique characteristics and challenges of cities or city segments into account is developed to create more resilient and sustainable cities.

(2) A new generation method is developed to increase the resilience and sustainability of cities is to apply the framework to analysis of different scales and to develop a customized vulnerability index. The developed index will be applied at two different scales and its validity and consistency will be examined. In this way, the scalability and applicability of the developed model will be discussed.

The findings of this research will provide valuable information for policy makers, city planners and other stakeholders involved in urban development. With the model produced as a result of this study, it is thought that the spatial plans produced by the planners in the future can be directed more rationally. Since the areas that need intervention in the city and the reasons for the intervention need are identified rationally with the developed model, it will contribute to the adaptation of a more sustainable approach in terms of resources, labor and cost by ensuring that the decision makers managing the city transfer their limited resources to the right place.

1.3 Outline of the Chapters

This thesis consists of four main chapters, an introduction and a conclusion. As shown in Table 1, the structure of the thesis is designed to respond to the research questions set out in the previous chapter.

Table 1.1 Thesis Chapters and Research Question Relation

Chapter 1	Introduction
Chapter 2	Which criteria can be used to measure vulnerability to climate change related disaster risks in Izmir?
Chapter 3	What are the weights and importance levels of the indicators to be used in the vulnerability study?
	Is it possible to use similar or the same indicators in projects of different scales?
Chapter 4 - 5	How can vulnerability analysis be conducted with existing planning analysis methods and AHP?
Chapter 6	Is this method rational, consistent and scalable so that it can be used at different scales in different project area?

Chapter 1 provides an overview of the research, focusing on the main context, purpose and research questions.

Chapter 2 focuses on the key concepts that shape research on resilience to climate change. The chapter explores the concept of vulnerability as a first step in the study of resilience, adaptation and mitigation. This section consists of a literature review detailing different approaches and conceptualizations, including academic research, to the assessment of climate change vulnerability. The reviews in this section provide important knowledge and insights to identify indicators that affect vulnerability to climate change.

Chapter 3 sets out the details of the methodology, the selection of the dataset and its application. In this chapter, the main definitions to be used in the thesis are defined based on the results of the literature review and the scope of the research. In the conceptual framework based on the definitions, the indicators used to measure vulnerability are selected according to their sensitivity to floods and extreme heat events caused by extreme weather events. The relations of the selected indicators with each other and with disasters are defined and AHP method is used for weighting. This chapter elaborates on the methods used in the study, the selection of data sets, and the characteristics of the study area.

Chapter 4 and 5 are the section where data on indicators of determined risk components are processed and analyzed. The fourth chapter includes the presentation of weighting and traditional spatial analysis, while the fifth chapter presents the main hypothesis of the thesis, the vulnerability analysis and its results. In addition to existing planning approaches, an AHP-based approach for weighting indicators is adopted in the analysis. With the new approach, indicators and weights are input to the vulnerability index and the vulnerability levels of the area are mapped. The method applied in this chapterd are tested at two different scales to determine the levels of risk and vulnerability due to climate change. The outputs of this chapters provide an opportunity to examine the relationship between indicator and scale more precisely.

Chapter 5, the last chapter of the thesis, concludes the thesis by evaluating the research methodology, the limitations of the research and discussions for future research. In this chapter, according to the results obtained in the previous chapters, the contribution and the shortcomings of the method proposed in the thesis in creating resilience in a sustainable way are examined in detail. This stage summarizes the general findings of the research, discusses the implications of the question and purpose of the research, and provides insights into these.

CHAPTER TWO
CLIMATE CHANGE, RESILIENCE AND VULNERABILITY: THEORETICAL FRAMEWORK

Climate change or global warming is a phenomenon caused by human lifestyle and choices. Climate change generates a series of impacts that directly change wildlife and urban life through rising average temperatures and extreme weather events. Climate change in the current climate or in scenarios of climate change are caused by the emission of greenhouse gases that trap heat in the process that started with the industrial revolution.

The number, frequency and magnitude of many disasters have increased due to climate change that affects the city and the entire ecosystem. This situation has initiated climate change mitigation and adaptation researches. As a result, experts have developed solutions in different scopes and themes. Resilience is one of these themes. Although the approach in resilience studies is handled in many different ways, the questions of against what and how to provide resilience are essential. The answers to these questions have led to the concept of vulnerability, which is the main phenomena of this thesis. In this part of the thesis, the concepts of climate change, resilience and vulnerability will be analyzed in detail along with their contents and their relations with each other will be determined.

2.1 Climate Change and Resilience

The concept of resilience is the ability of a system to cope with changes, threats, risks and surprises by preventing or minimising them. In other words, resilience means the capacity of a system to cope with changes (Wieland ve Wallenburg, 2013). The concept is widely used in different issues (Burayidi, 2013). In addition to ecological issues, natural disasters, transport, economic, social and physical issues are also elements that need to be considered in urban resilience. Urban resilience means that a city or a part of a city prepares itself for economic, social, physical or political changes

over time, responds to them and adapts itself against threats with minimum damage. The concept of resilience obtaining ways to cope with the change and the impact of change during the crises and shocks experienced by a system (Davic & Welsh, 2004; Holling, 1973; Folke, 2006; Dolega, 2012; Barnett, 2001; Carpenter et. al, 2001; Zhang et. al., 2018).

The concept of resilience was highlighted in the 1970s by revealing the relationship between the theory of 'resilience of ecological systems' and ensuring the resilience of a system. In ecology, the concept of resilience is the damage caused to an ecosystem by natural disasters (earthquakes, floods, fires, hurricanes, deforestation by humans, population explosion, etc.). The ecosystem may be affected as a result of the damages and the continuity of its function, structure and life may be at risk in the process. Therefore, the ecosystem must recover quickly from the shocks experienced and be restored to the system. In the context of the concept, the word resilience has been expanded in terms of keeping it in equilibrium and securing it. (Holling, 1973). The concept is that, in general, a system can cope with the changes, threats, risks, and surprises it encounters by preventing or minimizing them. In other words, resilience expresses the capacity of a system to cope with changes, over time has been applied in different subjects such as;

-social systems (Adger, 2000, Pelling, 2003);

-urban ecological resilience (Andersson et al., 2006, Barnett, 2001, Ernstson et al., 2010, Folke, 2006, Maru, 2010);

- economic recovery (Rose, 2004; Martin & Sunley, 2007; Pendall, Foster & Cowel, 2010, Pike et al., 2010, Simmie & Martin, 2010),

- disaster recovery (Colten et al., 2008, Cutter et al., 2003, Pais and Elliot, 2008, Vale and Campanella, 2005; Coaffee et al., 2018; UNISDR, 2009)

-Urban security (Coaffee, 2006).

These studies have been developed in an attempt to minimise the effects of risks and shocks affecting the city and its inhabitants. Climate change is the phenomenon that threatens cities and citizens today and is recognized as an imperative problem (IPCC, 2007, IPCC, 2014). Although the Paris Agreement, one of the agreements signed against climate change, tries to limit global warming to a +2 degree increase, it is thought that this change, which developed due to greenhouse gas emissions in the industrial revolution, will progress rapidly (IPCC, 2007; IPCC, 2014; IPCC, 2022). The frequency and magnitude of extreme events caused by climate change, such as heat waves, droughts, floods, sea level rise, etc., are increasing.In this context, mitigation and adaptation approaches have been adopted in order to stand against climate change (IPCC, 2007). Adaptation is a relatively new concept in climate science but has a longer history in, for example, ecology, natural disaster research and risk management (Smith et al., 1999). Climate change adaptation usually refers to adjustments in social-ecological systems that mitigate the negative impacts of inevitable climate change through actions targeting the vulnerable system (Smit et al. 1999), but can also include actions to seize the opportunities presented by climate change (Füssel and Klein 2006). Resilience is a relatively new addition to research on climate change and has developed mainly under adaptation studies (Eakin and Luers 2006; IPCC, 2014).

Resilience studies, including climate change, are basically as follows; it consists of the stages of risk definition, risk and vulnerability detection, evaluation of the identified risks, and production and development of decisions for their reduction. Resilience and vulnerability can be considered to be fundamentally linked, but their conceptual relationship is not clear (Turner et al. 2003; Gallopín 2006; Maru et al. 2014). Resilience is sometimes defined as the direct opposite of vulnerability (Adger 2000; Folke et al. 2004), while it is also argued that resilience is inversely related to vulnerability but less effective than the reverse (Turner et al. 2003; Gallopín 2006).

2.2 Resilience and Vulnerability

Due to the seriousness of the consequences of the climate crisis and the increasing dimensions of the disasters, the issue of resilience maintains its agenda and importance in the planning discipline. In addition to determining the framework of urban resilience, one of the most important points in ensuring resilience is measuring resilience and how urban resilience is evaluated. As a matter of fact, in order to define the resilience of the city, which should be considered as a system as a whole, against possible shocks and crises, these problems should be well understood and defined correctly. To ensure resilience, sensitive elements must be identified; it should be determined from what, to what extent and from which effects they may be harmed. The processes of identification of sensitive elements are vulnerability measurement and assessment processes. In the thesis designed in this context, vulnerability is the main phenomenon.

Vulnerability, which has an important place on the path to resilience, is defined differently depending on the scope, context and examination methods of general research (Table 2.1).

Table 2.1 Vulnerability Definitions by Context

Context	Overall Definition	Referances
Disaster and Risk	Defined vulnerability as violation of rights and inadequacy of capabilities and lack of capacity to adapt	(Sen, 1981; Smith, 1996; Burton et.al, 1978; Anderson and Woodrow, 1998; Blaikie et al., 1994; Cutter, 2003; Cutter, 2006; Downing, 1992)
Climate Change, Disaster, Resilience and Integrated Systems Approach	Defined vulnerability as the level of ecological, economic and social sensitivity of a region, system, society or individual to a risk such as climate change and natural disasters.	(Turner et al., 2003a, b; O'Brien et al., 2004; Balica et. al., 2009, Balica et. al., 2012; De Leon and Carlos, 2016; IPCC, 2007; IPCC, 2014; OECD, 2017; Bulkeley, 2013; Folke et.al, 2002; Krellenberg et. al., 2014; Müller, Reiter and Weiland, 2012; Welle et. al, 2014)

The concept has begun to be evaluated in the search for solutions to famines and natural disasters. In these periods, vulnerability, which is addressed with the risks of natural disasters, is defined by Blaikie et al. (1994) as “the characteristics of a person or group in terms of their capacity to anticipate, cope with, resist and recover from the effects of natural hazards”, while Adger (2006) defines vulnerability as the state of being exposed to stress factors associated with environmental and social change and

being vulnerable to harm due to lack of adaptive capacity. Cutter (1993) defines vulnerability as the possibility of an individual or group being exposed to a hazard and being negatively affected by this hazard. The descriptions and definitions used today were finalised in the 1990s with the rapidly increasing climate change studies.

The conceptual and field analysis studies have attracted the attention of wide audiences and have started to be used and accepted by world organisations such as IPCC, OECD and WHO in a short time. The biggest milestone here is the definition of vulnerability as “The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity”in the 2001 Climate Change report of the IPCC. Another definition made by world organisations is the definition made by WHO. WHO (2022) defines vulnerability as "the conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards". Since these milestones, the concept has been considered by many researchers as a necessary component of climate change studies, although some experts, such as Blaike et. al. (1994), have argued that vulnerability need not be considered as essential to resilience. Nevertheless, it is also clear that vulnerability is a strong instrument for identifying where mistakes have been made to ensure resilience against disasters or abnormal crises.

It is understood that vulnerability has a complex and dynamic structure when its definitions and areas of use are analyzed. In addition to indicating the likelihood of being badly affected by a hazard, it also describes the ability to cope with the impact. This indicates that vulnerability is not only related to hazard or risk. In his research, Downing (1992) distinguishes between the concepts of hazard and vulnerability. He defines hazard as a potential threat to people and their well-being, while he defines vulnerability as exposure and susceptibility to losses for people and their well-being and argues that the combination of these two concepts constitutes risk. Anderson and Woodrow (1998) argue that vulnerability consists of different contents. They attempt to define different dimensions of vulnerability such as physical and material, social

and attitudinal. Another specialist who argues that there are different definition clusters within vulnerability is Cutter. Cutter (1996) states that there are three different clusters in her hazard of place model. These can be summarised as the risk of exposure, the ability to react socially (coping) and a characteristic of places (natural and immutable area characteristics). Indeed, IPCC (2014) also argues that the vulnerability is a cluster of different phenomena. IPCC defines these phenomena as risk, exposure, sensitivity and adaptive capacity and argues that vulnerability is related to these concepts.

The definitions in the reports published by IPCC in different years are as follows;

-Vulnerability;

“The degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity." (2007)

"The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt." (2014)

-Risk;

“the potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values. Risk is often represented as probability of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur. Risk results from the interaction of vulnerability, exposure, and hazard." (2014)

-Exposure;

"the nature and degree to which a system is exposed to significant climatic variations." (2001)

"the presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected." (2014)

-Sensitivity;

“the degree to which the system is affected -either adversely or beneficially- by climate-related stimuli. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal floodingdue to sea level rise)” (2007)

“degree to which a system or species is affected, either adversely or beneficially by climate variability or change. The effect may be direct (e.g., change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea level rise)” (2014)

-Adaptive Capacity;

“the ability of the system to adjust to climate change, to moderate the potential damages from it, to take advantage of its opportunities and to cope with the consequences” (2001)

“the ability of system, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences” (2014).

Despite its dynamic nature, which changes over time, the concept of vulnerability has always been described as a complex system involving different phenomena. For this reason, there is not a standard way of determining vulnerability. The different phenomena it involves lead to the measurement of vulnerability in a combination of multi-step and varied methods. When the literature on resilience and vulnerability measurements is examined, it is seen that it consists of two different approaches: studies based on qualitative and quantitative approaches. In qualitative studies, the meanings, definitions and contents of the concepts were explained in detail and a

framework was created. Sometimes, an approach of creating a database containing past risks was adopted (Adger, 2006; Owrangi, Lannigan, Simonovic, 2015). Quantitative approaches explore the definition of concepts and logical evaluation processes. Quantitative approaches using forecasts, statistics or consisting of indexes produces with mathematical models (Balica et al., 2009; Balica et al., 2012; De Leon, Carlos, 2006; Torresan et al. 2012; Sarkodie, Strezov 2019). The method to be used in the measurement of vulnerability is at the initiative of the researcher. However, since qualitative research are opinion-based approaches, they are used to describe the framework rather than measurement. Quantitative methods are the most preferred methods in the recent period. These methods use the qualitative identification studies at the stage of generating a mathematical formula. The mathematical formula method used in the field of vulnerability is also formed from the different phenomena it contains. Since vulnerability is already defined as a combination of phenomena such as exposure, sensitivity and adaptive capacity, this method is quite suitable for vulnerability research.

The studies that measure vulnerability through mathematical formulas indicate that these formulas are constructed by relating these formulas to other phenomena that define vulnerability (de Leon ve Carlos, 2006; Balica et. al., 2009; IPCC , 2014). In this context, indices have emerged and continued to evolve on the basis of disaster-related risk in the vein of vulnerability research.

-ISDR (2004) associate vulnerability with risk and formulate the risk formula as follows.

$$Risk = Hazard\ x\ Vulnerability \tag{2.1}$$

-Dilley et. al (2005) with a similar approach;

$$Risk = Hazard\ x\ Exposure\ x\ Vulnerability \tag{2.2}$$

In this perspective, vulnerability is an essential part of risk and an index has been developed considering that vulnerability increases risk exponentially.

-Hahn (2003), on the other hand, argues that risk and vulnerability are related, but there is no exponential increase in this relationship and formulates risk as follows;

$$\text{Risk}=\text{Hazard}+\text{Exposure}+\text{Vulnerability-Caping Capacities} \quad (2.3)$$

-Saha et. (2024), in their study on vulnerability to flash float, adopted a risk-based approach and measured the risk as follows.

$$\textit{Flash Flood Risk (FRR)=[Hazard X (Exposure+ Sensitivity)]-Resilience} \quad (2.4)$$

The vulnerability revealed by its relationship with risk can be extracted from these formulae as follows;

$$\text{Vulnerability}=\frac{\text{Risk}}{(\text{Exposure x Sensitivity x Hazard})} \quad (2.5)$$

However, this expression, which is only mathematically correct, has not been used in the literature. Research has developed a formula that focuses on the relationship between vulnerability and coping capacity rather than risk, as follows (White et. al, 2005; Balica et. al, 2009; Balica et. al; 2012; De Leon and Carlos, 2006;);

$$Vulnerability = \frac{Exposure\ x\ Susceptibility}{coping\ Capacity} \quad (2.6)$$

As a result of the adaptation of the vulnerability index approach, research has focussed on how to decide and measure the phenomena within the formula. In vulnerability research, while qualitative approaches that developed a conceptual framework were emphasized in the process until the 2000s, quantitative approaches with an assessment-based indicator approach have become leading in recent years. Comparative vulnerability and risk analyses ensure that resources are appropriately directed by classifying risk issues according to their context and prioritizing them using methods such as AHP (Analytic Hierarchy Process) (Hester and Harrison, 2002).

Quantitative vulnerability and risk analyses are carried out through the use of formulas and indicators that emerge from the definition of risk, including the concepts of exposure, sensitivity, vulnerability, manageability, and coping capacity (Balica et al., 2009; Balica et al., 2012; De Leon, 2006).

The indicator approach, which builds the conceptual framework around specific concepts and variables, is the most widely used approach (Luers et. al., 2003; Tonmoy et. al, 2014; Adger, 2006). This approach, allowing the assessment of indicators representing the vulnerability of a system, enables the conversion of definitions into functions. In this way, it captures the opportunity to understand multiple dimensions of phenomena such as vulnerability, that have a complex structure, by presenting them mathematically in a single composite index (Adger et al. 2004; Tonmoy et al. 2014; Nardo et. al, 2008; Balica et. al., 2012; Saisana et. al 2002). The city consists of 5 components: human capital; socio-economic conditions; built environment; ecosystem services; and governance and institutions. In indicator approaches, these components that constitute the city should be considered in the selection of indicators in order to examine the vulnerability of the city (Beroya-Eitner, 2016; Cutter et al., 2009; Swart et al., 2012; De Leon and Carlos, 2006). In indicator-based vulnerability research, studies focusing only on a disaster or a component of a city are more common. However, this is not the case in reality. The city contains different components in physical, social, economic, natural and structural terms. Urban components directly affect and influence each other. In addition to this, disasters that create risk in the urban area do not always occur alone. Sometimes when two disasters occur one after another, the size of their effects on the city multiplies. An example of this is the 6 February Kahramanmaraş earthquakes. The destructive effect of the two big earthquakes created vulnerability to flood disaster. As a matter of fact, the risk criterion and the impact of the flood disaster and extreme heat risks experienced afterwards have increased (Bassal et. al; 2023; IOM, 2023). Risks and hazards should be well defined in the indicator method. The disasters or crises should be explained and indicators should be selected based on the effects of these hazards on the city.

Despite the dynamic nature of vulnerability and its complex interconnections (Vincent 2007; Luers et al. 2003; Leichenko and O'Brien 2002; Jurgilevich et al. 2017; Eriksen and Kelly 2007), the indicator approach overlaps with the approach of assessing the concept of evaluating the overall picture according to different characteristics, there are also criticisms in this regard (Vincent, 2007; Birkmann, 2006; Eriksen and Kelly, 2007). Indicators describe complex systems in simple terms, but due to their intrinsic non-linearity, they cannot capture all the key features of climate resilient systems, and they cannot provide an overall perspective when the interrelationships of indicators are not known precisely and therefore cannot be applied in equations (Vincent, 2007; Hinkel, 2011).

A single quantitative index of vulnerability can conceal the complexity of a system within a complex overall (Adger, 2006). In vulnerability research, definitions and indicators are shaped by the scope, purpose and perspective of the author. In this context, there is uncertainty about the validity and robustness of the conceptual frameworks of the indicators that should be based on definitions as in the index (Luers et. al, 2013; Eriksen and Kelly, 2008; Vincent, 2007). In the case of vulnerability as a function of exposure, sensitivity and adaptive capacity, it has been argued that the differences between the three phenomena become blurred. Moreover, as a consequence of this blurring, many indicator-based assessments have difficulties categorising indicator variables into the three components of vulnerability (De Leon and Carlos, 2006; Hinkel 2011). Comprehensive critiques such as these emphasise the importance of the choice of methodology, definitions and selection of indicators in vulnerability research. In this context, definitions, methodology and the relationship between selected indicators should be objective orientated and accurately stated in the research.

The process of selecting indicators, weights and aggregation methods when constructing sensitivity indices requires in-depth research and knowledge. Vulnerability indicators can be created using scientific knowledge, statistical models, expert judgments, and multivariate analysis to reduce the number of indicating variables (Adger et al. 2004; Vincent 2007; Binder et al. 2010; Hinkel 2011; Tonmoy et al. 2014; Becker et al. 2015; Balica et. al., 2009; Balica, et. al, 2012; Cutter, 1996).

Although the indicators are intended to be placed in a scientific framework, they are limited by the significance and detail of the data available in real life and field studies. In this context, the main issue to be considered and can be managed by the researcher is the determination of the weights of the indicators that selected from the literature.

The weighting analysis is the examination of the effects of the indicators selected according to the scope and framework of the research on vulnerability. Although equal weighting, which is frequently used in the literature, is the most preferred method due to its simplicity, it is controversial because it is not reality-based and cannot be interpreted (Tonmoy et. al., 2014). Obtaining expert opinions is another weighting method. It is criticised for the difficulty of bringing experts to a common denominator and for the controversial nature of examining all facts at the same time from different viewpoints (Brooks et al. 2005; Gbetibouo et al. 2010). Statistical methods can also be used in weighting. One example is factor and principal component analysis (PCA). This analysis, however, can only determine the overall level of vulnerability. Since there is not any information on the impact of indicators on vulnerability, they are irrelevant in resilience studies (Nardo et. al, 2008; Cutter and Finch 2008; Holand et al. 2011). Another weighting approach that combines statistical models and expert opinion is the Analytic Hierarchy Process (AHP) method. Abdrabo et. al (2023) investigated the performance of two statistical methods in the same field within the scope of a study on vulnerability to climate change-related floods. As a result of the study, they stated that these two approaches yielded similar results, but in both physical and social criteria, the AHP approach led with 13 indicators, while in economic terms, it may be insufficient in terms of the number of indicators to obtain results close to the results of PCA with 38 indicators. The AHP method is essentially a multi-criteria decision-making method, but it is used in many different fields such as resilience, climate change and vulnerability (Cabrera-Barona et al., 2018; Hagenlocher et al., 2013; Kienberger et al., 2014; Qiu et al., 2008). In this context, the AHP method is preferred for weighting in this thesis.

In vulnerability research, the concept and the phenomena it contains should be well defined. The relationships between the phenomena should be interpreted. The risks

and hazards that cause vulnerability creation research should be expressed, its framework and limitations should be determined. Indicators affecting vulnerability should be identified and measured in detail according to risks and hazards, and the degree of their relationship with each other should be understood and determined. Finally, vulnerability should be measured by preferring a calculation approach in accordance with the definitions and determinations.

2.3 Urban Flood Vulnerability

Climate change has brought extreme weather events and increased the impact of flooding in the urban areas. According to the Intergovernmental Panel on Climate Change (IPCC) 5th assessment report, the frequency and magnitude of flood hazards are expected to increase in large urban areas of the world with high population density (Jime´nez Cisneros et al. 2014). Flood disaster, one of the most common disasters in the world, constitutes 40% of global losses caused by natural disasters (Zhou et. al., 2019). Globally, floods have caused huge economic and social losses and these losses continue to increase (Kundzewicz et. al, 2014). Urban areas are especially vulnerable to extreme hydrological events such as heavy rainfall and related floods due to the density of population, infrastructure and human activities (Chang and Franczyk 2008). In a similar trend to the rest of the world, Izmir represents a special case as the city has experienced one of the fastest land use change in the last three decades and has a high population growth rate. Between 1990 and 2018, with the urbanisation process that has taken place in the whole province of Izmir, the growth rate of artificial land has reached 99.3% (Li et. al, 2014). At the same time, the population of Izmir increased by 60.3% (Leal Filho, et. al., 2019). This is another important aspect that shows that Izmir is significantly vulnerable to flooding.

Under the influence of climate change and unplanned human activities, the form and mechanism of urban flood disasters have been critically changed. The development of urban flood control and disaster mitigation system is facing new pressures and challenges, and the risk of urban flood disaster is increasing (Wan et. al, 2019). Faced with severe flood disaster situation, flood disaster monitoring and risk

assessment have become an urgent need for enhancing disaster prevention and mitigation capacity (Li et. al, 2014). In this context, the main objective of improving flood risk management is to reduce flood impacts through mitigation and adaptation processes (UNISDR 2009). The basic steps of risk management are planning of flood mitigation measures before the disaster, response measures during the disaster and recovery activities after the disaster (Tingsanchali, 2012). Flood management is an important aspect of urban resilience (Ahmad and Simonovic, 2013). In this context, flood management and vulnerability are strongly related. In order to achieve resilience, it is very appropriate to develop vulnerability assessment methods (Adger, 2006; Cutter, 2006). Relevant to previous studies emphasising flood hazard, the primary methods of vulnerability assessment can be categorised into three groups (Huang et al. 2012) as vulnerability index method, disaster loss estimation and modelling (Balica et. al. 2009; Balica et al., 2012; Nasiri and Shahmohammadi-kalalagh, 2013; Cutter, 2006). As discussed in the context of resilience studies, the index approach is the most common approach to flood resilience. In this approach, the systems that affect the floods and are affected by floods are analysed under the topics of exposure, susceptibility (susceptivity) and adaptive capacity (coping capacity) (Balica et. al., 2009; Balica et. al, 2012; Connor and Hiroki, 2005). As mentioned before, the selection of indicators that enable the measurement and calculation of these three topics is of critical importance in vulnerability studies.

In the studies examining flood vulnerability, indicators are the factors that cause flood disasters, factors that increase the impact of flood disasters and indicators that represent the segments that are more affected by flood disasters. Balica et. Al., (2009) investigated flood vulnerability at different scales and chose indicators under four main headings: Social Component, Economic component, Environmental component and Physical component. Under the title of Social Component, indicators such as population density, population in flood area, population under povetry, rural population and percentage of urbanised area that reveal the social structure of the city were preferred. In the economic component, indicators such as land use, proximity to river, closeness to inundation area and in the environmental component, values such as over used area, unpopulated land area were chosen as indicators. Slope, precipitation amount and soil properties that cause or contribute to the disaster are

considered through physical component. In a similar approach, Dandapat and Panda (2017) analysed flood vulnerability due to climate change in 7 main groups from social and physical aspects. In the physical aspects group, elevation, land use and land cover and gegology were considered, while in the social aspects group, population density, elderly and child population, gender and poverty indicators were preferred. The vulnerability in this study was calculated by the mathematical index method, and the weights of the indicators were determined by AHP analysis. Identifying indicators and establishing a minimum starting point has also been an important issue for researchers. Accordingly, Moreira et. al. (2021) reached the following results in their research on the indicators in the literature on flood vulnerability. In the indicator approach, the main group that is mostly addressed from a social perspective is the social dimension and the physical dimension. In these dimensions, population density, gender rate and education level are frequently preferred from a social perspective, while household sanitation and safe water and material and condition of the building are frequently preferred. In another study Bigi et. al (2021) analysed 60 articles on indicator approaches for vulnerability and identified 33 most commonly used sub-indicators. Arguing that these indicators would be a good starting point, the study identified 8 exposures, 18 sensitivity and 7 adaptive capacity indicators. In the publications analysed, the authors found that the concept of exposure is most commonly used with population density and elderly people; sensitivity is most commonly used with people with disabilities, unemployment and building condition; and adaptive capacity is most commonly used with awareness and drainage. The analysis of these studies reveals that vulnerability has a dynamic and complex structure. Although vulnerability is considered in different ways, it is also understood that there are some common indicators.

When the literature and case studies are analysed, it is seen that the components of the city have been examined in detail in previous studies and main groups have been formed according to urban components. For urban vulnerability, population density, age and education characteristics are mostly taken into consideration among social indicators, while physical indicators, land use distribution and change, urban critical functions are analysed together with natural features that constitute flood risk.

2.4 Urban Extreme Heat Vulnerability

In studies examining flood vulnerability, the most prominent effect of climate change is global warming. World agreements such as the Paris Agreement, which tries to stop global warming at +2 degrees, have increased awareness on this issue. Temperatures in cities have been increased due to global warming. Extreme heat weather has created many negative effects in urban areas. One of these effects is heat wave disaster. Extreme temperatures cause various diseases in people and reduce the quality of life to a great extent (Braga et al., 2002; Curriero et al., 2002; Della-Marta et al., 2007; Fouillet et al., 2006). In this context, it is seen that heat wave disaster has serious effects on the city and urbanites (Marsha et al., 2018; Reid et al., 2009). Urban areas with excessive urbanisation, unplanned construction and poor quality infrastructure are affected by extreme heat in different ways, this situation is called Urban Heat Island (UHI). This effect is an important phenomenon that causes the air temperature to be felt differently and is directly related to spatial policies. Izmir province is located in the mid-latitude climate zone and the city is a Mediterranean coastal city. The average temperature in June was 26.0 °C between 1981 and 2010, and the average temperature as well as the maximum temperature is 31 °C, which still has an increasing trend until today. Izmir is the second hottest city in Turkey (MGM, 2024). Being a city with a typical Mediterranean climate in Turkey, having experienced a significant urbanisation process in the last quarter century and facing the urban heat island problem, Izmir is vulnerable to extreme heat events (Adıgüzel et. al, 2018).

The most effective and widely recognised impact of climate change is extreme heat weather. Extreme heat weather reduces the quality of life in urban areas and has been proven to adversely affect the health of urban residents. As extreme heat weather combined with other suitable conditions increases the risk of fire, it is clear that it can bring about a series of highly dangerous disasters. It is therefore important to take precautions against extreme heat to create a resilient city. Vulnerability to extreme heat has an important place in the literature, as well as rapid disasters such as floods, sea level rise and storms that develop instantaneously or within a short period of time.

Studies on vulnerability to extreme heat have increased in recent years following Cutter's methodology and definitions (Cutter, 2003). The vulnerability index approach of the IPCC (2014) has become the main approach used to measure the vulnerability to extreme heat (Wilhelmi and Hayden, 2010). In this context, the phenomena affecting vulnerability and the indicators that include the components of vulnerability have a critical role in developing cities that are resilient against extreme heat, just as in flood disasters.

In the studies examining the vulnerability caused by extreme heat, indicators consist of elements that create the conditions that cause extreme heat, elements that can be affected by extreme heat and elements that increase the effects of extreme heat. Rathi et. al. (2021) conducted a study on vulnerability to extreme heat in four cities in India and analysed it under the headings of exposure, sensitivity and adaptive capacity. Under the exposure heading, building height, time spent outside and traffic condition are discussed. Under sensitivity, indicators such as age, income and education level are discussed. Under the adaptivity heading, indicators such as green spaces, water elements and cooling home indicators were analysed. In the analysis, the weighting of the indicators is considered equal and an index-based approach is adopted. For the calculation of indicators, sub-indicator approach was used. Sub-indicators related to the main groups determined were analysed for four provinces. In another study conducted under the same headings, Rana et al. (2022) analysed vulnerability to heat waves from both physical and socio-economic perspectives. In the study, indicators are analysed under the headings of exposure, sensitivity and coping capacity. Exposure includes indicators such as household size, family type, building height and working hours. Under sensitivity, there are indicators such as dependency ratio, gender ratio, disabilities and population age. There are indicators such as average household income, access to public transport, access to hospital and education status under coping capacity. In this study, 44 indicators were selected. Index approach was adopted in the analysis of vulnerability. In another study that classifies indicators with another approach, Xiang et. al. (2022) analysed the city from physical and social aspects in their extreme temperature vulnerability study in China. Physical indicators Land Surface Temperature (LST), Floor Area Ratio, Sky View Factor (SVF) and NDVI were preferred. In terms of social indicators, population density, building age and

access to medical services indicators were considered. Index method was used in the study, but equal weight was given for the indicators. Similarly, Alonso and Florent Renard (2020) examined the heat wave vulnerability of Lyon city due to climate change in psychological and socio-economic terms. The indicators analysed are population age breakdown, gender breakdown, educational information, number of health workers, average income and distance to hospital.. In this study, 40 indicators were selected according to the approaches in the literature. AHP was used to understand the effect of indicators on overall vulnerability. For this reason, 40 indicators were grouped into 8 main groups. The vulnerability analysis of the indicators was produced by PCA. In a study conducted at a higher scale, Tapia et. al. (2017) aimed to determine the vulnerability of the European Union to climate change and preferred indicators to divide 5 main groups into 18 subgroups. These groups include population dynamics, education and knowledge dynamics, race and ethnicity under human capital, gender, quality of government, plans and policies, macro and micro economy, technology and access to basic needs under governance and institutions, macro and micro economy, technology and access to basic needs under socio-eocnomic conditions, building characteristics under built environment, infrastructure quality, land use, production and emissions under natural capital and ecosystem services. These indicators were analysed under the headings of sensitivity and adaptive capacity. In the article, vulnerability was determined by mathematical index approach and weighting was carried out by PCA.

When the literature and field studies are analysed, the city is evaluated as a whole with its different components in the studies on vulnerability to extreme heat as in the case of floods. Among the social indicators for urban vulnerability, population density, age and education characteristics are mostly taken into consideration, while physical indicators, natural and artificial features affecting the sensitivity of extreme heat, land use distribution and change, urban critical functions are examined.

2.5 Conclusion

This thesis provides a comprehensive understanding of the concepts of climate change, resilience and vulnerability, the relationships between these concepts and the importance of each in the context of urban planning and disaster management. Climate change is a phenomenon triggered by anthropogenic greenhouse gas emissions, leading to a rise in global temperatures and an increase in the frequency and severity of extreme weather events. This has a profound impact not only on natural life but also on urban life. The thesis focuses on the impacts of this climate change on cities and the resilience and sensitivity strategies developed to cope with it.

While explaining the relationship between climate change and resilience, the thesis states that the concept of resilience is not only limited to ecosystems, but also has a much broader meaning, including social, economic and physical domains. Resilience is the capacity of a system to resist the changes, threats and risks it faces and to overcome them with minimal damage. Although this concept was first used in the field of ecology to explain how ecological systems recover from disasters, it has since been applied to broader areas such as cities, social structures and economic systems. In this context, urban resilience refers to how a city adapts to, responds to and adapts to economic, social, political and physical changes. In the thesis, the concept of resilience is defined as an approach that aims not only to counter threats, but also to develop strategies to understand how systems can be made resilient to crisis, shock or major change.

The impacts of climate change on cities have become more pronounced, especially with the increasing frequency and severity of extreme weather events. Therefore, increasing city resilience, how best to be prepared for such threats and how to minimize their impacts have become an important research topic. Resilience stands out as a strategy to make cities more resilient and sustainable, especially in the face of the dangers and disasters posed by climate change. However, for resilience to be effective, it is necessary to understand which factors cities are vulnerable to and develop a strategy in line with these vulnerabilities. At this point, the concept of vulnerability comes into play. Vulnerability refers to how sensitive a system is to unavoidable threats such as climate change and how vulnerable it is to the impacts of

these threats. The thesis emphasizes that vulnerability and resilience are complementary concepts. It is stated that there is a strong relationship between resilience and vulnerability, but that this relationship is complex and dynamic. How vulnerable the system is to climate change is also directly related to how quickly and effectively the system can adapt to these changes.

Vulnerability is a multidimensional and dynamic concept that can have different meanings for each system or community. When defining the vulnerability of a system to threats such as climate change and disasters, many different elements such as physical infrastructure, social structures, economic resources and environmental conditions should be considered. In the thesis, it is stated that vulnerability is not only related to susceptibility to hazards, but also to how prepared and adaptive a system is against these hazards. Therefore, sensitivity measurements should also take into account how effectively the system or society can cope with these hazards.

In this context, it is emphasized that in the fight against climate change, vulnerability needs to be accurately measured and understood in order to increase resilience. This process requires the use of various methods to identify sensitivities and develop resilience strategies accordingly.

In the thesis, it is stated that vulnerability measurement is a complex and multifaceted process and that it can be done through quantitative and qualitative approaches. Qualitative approaches aim to examine the meaning and content of concepts in more depth, while quantitative approaches aim to analyze risk through statistical data and mathematical models. Therefore, the combination of these two approaches provides a more comprehensive assessment both conceptually and quantitatively.

In conclusion, the thesis emphasizes the need to accurately measure and understand vulnerability in order to build cities that are resilient to climate change and disasters. While resilience is a critical concept for a city, ecosystem or community to be resilient to climate change, vulnerability needs to be properly addressed for this resilience to be well-founded. In this context, it is clear that understanding and measuring both resilience and vulnerability is fundamental to success in tackling climate change.

CHAPTER THREE
METHODOLOGY OF VULNERABILITY

Climate change affects the physical, spatial, economic, and social structures in urban areas in different dimensions. The increasing severity of climate change-related disasters has made it urgent and prioritized identifying vulnerability to climate change (Bulkeley, 2013; Folke et.al, 2002; IPCC, 2014). Consequently, the number of academic studies on this subject have increased at various scales and scopes (Ramyar and Zarghami, 2017). These studies examine the risk levels of disasters that potentially occur due to climate change and the reasons that will demonstrate the vulnerability to these disasters.

Urban areas are complex systems composed of social, economic, natural and built environment. In order to understand the vulnerability or resilience of a city or urban unit to climate change, it is necessary to examine each element that compose the city in its specificity and in relation to each other. Another critical point in ensuring urban resilience against climate change is to measure resilience and design a system to assess urban resilience. In order to define the resilience of the city against possible shocks and crises, these problems need to be properly understood and accurately defined (İSMEP, 2014a; 2014b). In this context, the study adopted the Vulnerability Index approach, which enables the simultaneous evaluation of different characteristics in İzmir. The methodology and case study prepared in this direction consists of 6 stages (Figure 3.1).

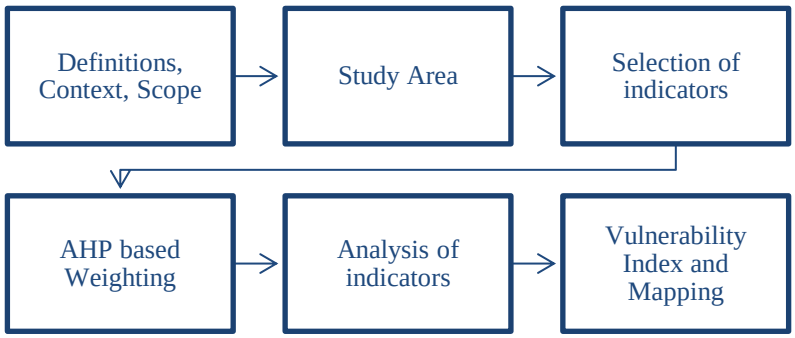

Figure 3.1 Flowchart of Methodology and Case Study

3.1 Definitions, Context, Scope

In the first methodology phase of the thesis, which aims to examine the levels of vulnerability due to climate change, according to the results of the literature review, the main definitions of the thesis were made which are *risk, hazard, exposure, susceptibility, coping capacity and vulnerability*, and the scope of the research was determined.

The concept of "risk", which is an integral part of the concept of resilience and used in different fields, is a measure of the damage/losses that may occur as a result of a potential hazard. Hazard is a chain of events and incidents originating from nature, technology and humans that have the potential to cause loss of life and property, as well as to harm society, the natural environment, and historical and cultural resources (ISMEP, 2014a: ISMEP, 2014b). There is a link between risk and danger, but they are not synonymous. If there are not any assets (population, structure, infrastructure, etc.) to be damaged, only the hazard itself remains and risk can no longer be mentioned (Balamir, 2007). Therefore, risk represents a value that can be damaged or lost and hazard represents an event that can cause risk. In this context, the meaning of *risk* is defined as “the processes and factors that cause vulnerability as a result of loss of assets” and the definition of *hazard* as “the events that cause risk and generate vulnerability”. Among the disasters that occur due to climate change, floods and extreme heat events are the hazards chosen to be examined within the scope of this thesis.

Susceptibility is defined as a combination of physical, social, economic, and environmental factors that express the extent and geographic spread to which a system, community or individual will be affected by crises and risks to a hazard threat (IPCC, 2014; OECD, 2017). Exposure can be defined as the geographical spread of people, ecosystems, infrastructures and economic assets exposed to the negative impacts of climate change. In other words, it is the presence and extent of assets exposed to a risk (IPCC, 2014; OECD, 2017; Balica et al. 2009; Balica et al. 2012; Fekete, 2009; UN, 2003). Coping capacity is defined as the ability of a system, community or individual to cope with existing threats and minimize harm, and the effectiveness of strategies and resources that improve these capabilities (IPCC, 2014; OECD, 2017). In this

direction, the meaning of *exposure* in this thesis is defined as “the assets themselves that are subjected to risk”; *susceptibility* is defined as “the likelihood that the assets can be negatively affected by risks” and *coping capacity* is defined as “the ability of the assets to cope with the negative effects of risk”.

Vulnerability is defined as the combination of social, economic and environmental factors that determine the level of sensitivity of a region, a system, a community or an individual to a risk such as climate change and natural disasters (Balica et al., 2009; Balica et al., 2012; De Leon, Carlos, 2006; IPCC, 2014; OECD, 2017; White et al., 2005). With this definition, vulnerability is a combination of concepts such as risk, exposure, susceptibility, adaptive capacity, coping capacity, sensitivity. In this thesis, the concept of *vulnerability* is defined as "a measure of the sensitivity and weakness level of an area to risks, a function directly proportional to exposure and susceptibility and inversely proportional to coping capacity".

3.2 Case Study Area of Interest

Izmir, located on the Aegean coast of Turkey, is called a ‘port city’ with its geographical location, easily accessible to land, sea and air transport systems, hosting strong social and cultural characteristics and having a climate suitable for tourism (Yanardağ, 2014). The city reflects the characteristics of the Mediterranean climate and has a variable altitude between 2000 meters. For this reason, it contains more biodiversity compared to other Mediterranean cities.

Izmir is the third most populous city in Turkey with a population of 4,425,789 (Population and Housing Census, 2022). Izmir Metropolitan Municipality governs thirty districts. Izmir has 20 rural districts. These are Aliağa, Bayındır, Bergama, Beydağ, Çeşme, Dikili, Foça, Güzelbahçe, Karaburun, Kemalpaşa, Kınık, Kiraz, Menderes, Menemen, Ödemiş, Seferihisar, Selçuk, Tire, Torbalı and Urla. In addition to rural districts, Izmir has 10 central districts. These are; Balçova, Bayraklı, Bornova, Buca, Çiğli, Gaziemir, Karabağlar, Karşıyaka, Konak and Narlıdere districts (Figure 3.2).

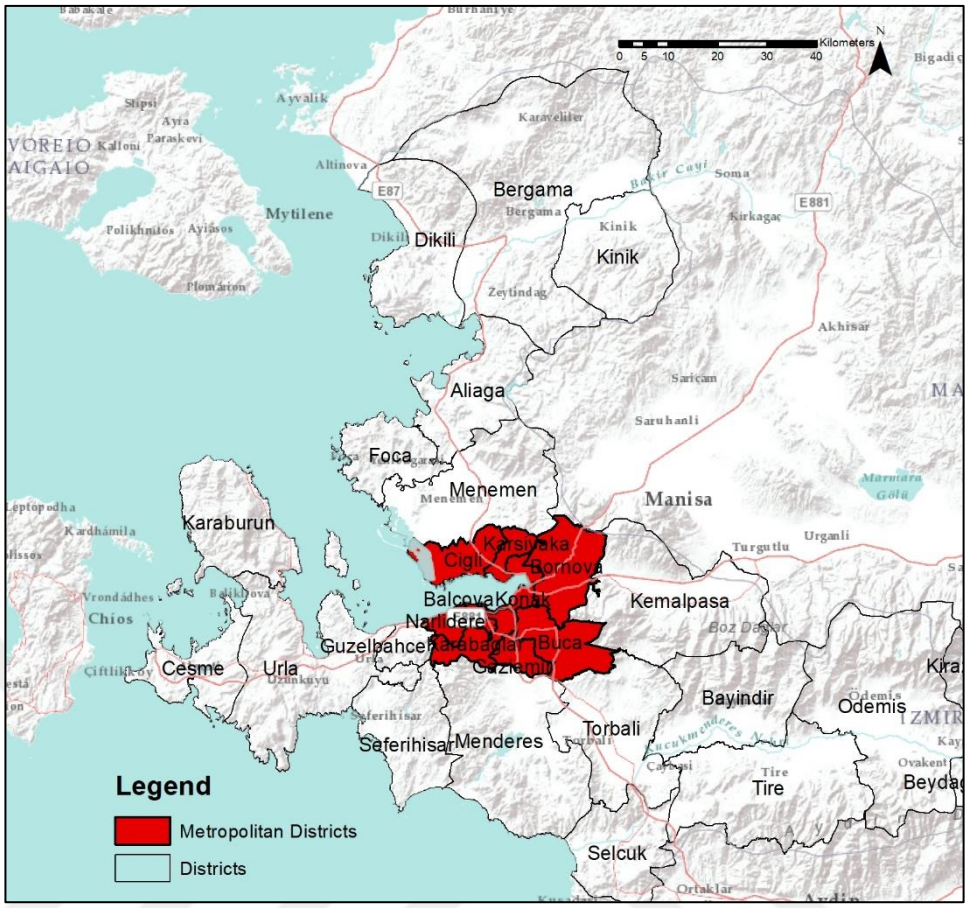

Figure 3.1 Rural and Metropolitan Districts of Izmir

Izmir is in the Mediterranean climate zone where the summer months are hot and dry and the winter months are mild and rainy. A transition climate between Mediterranean and continental climate is observed in the eastern part of the city, where the altitude is higher. The average annual temperature in the province varies between 14-18 ºC in the coastal areas (MGM, 2024).

Izmir and Karşıyaka, a coastal city located in the Mediterranean Basin, are vulnerable to the risks that may occur due to climate change. The possibility of occurrence of severe meteorological events in Izmir is a result of climate change. The riskiest change for the city is heat waves. As temperatures rise, the frequency and intensity of heat waves may increase, causing health risks for residents, especially for the elderly and children, and adversely affecting individuals with health problems. Hotter and drier weather conditions may also increase the risk of forest fires in the surrounding area. As a matter of fact, in forest fire research covering the years 1976-

2010 for the Izmir-Manisa region, Sütgibi (2013) stated that 49360.9 hectares of land were burnt as a result of 6359 fires in 35 years. 56.53% of these fires occurred in the center of Izmir city.

In 2022, although rainfall rates have decreased, Izmir is a vulnerable city to flooding due to extreme rainfall. The city has suffered from flood disasters many times in its history. On 34 November 1995, 61 people lost their lives as a result of the disaster in Karşıyaka and Çiğli districts. In this disaster, more than 100 kg of rainfall per square meter fell in about 4 hours, causing the destroying of 322 houses and causing flood damage to 10.000 buildings in the region (Sezer, 1997). The main districts where the flood and the fire disasters occurred are Karşıyaka and Çiğli districts. In this context, the second scale of the thesis was selected as the 2nd Spatial Planning region of Karşıyaka district (Figure 3.3).

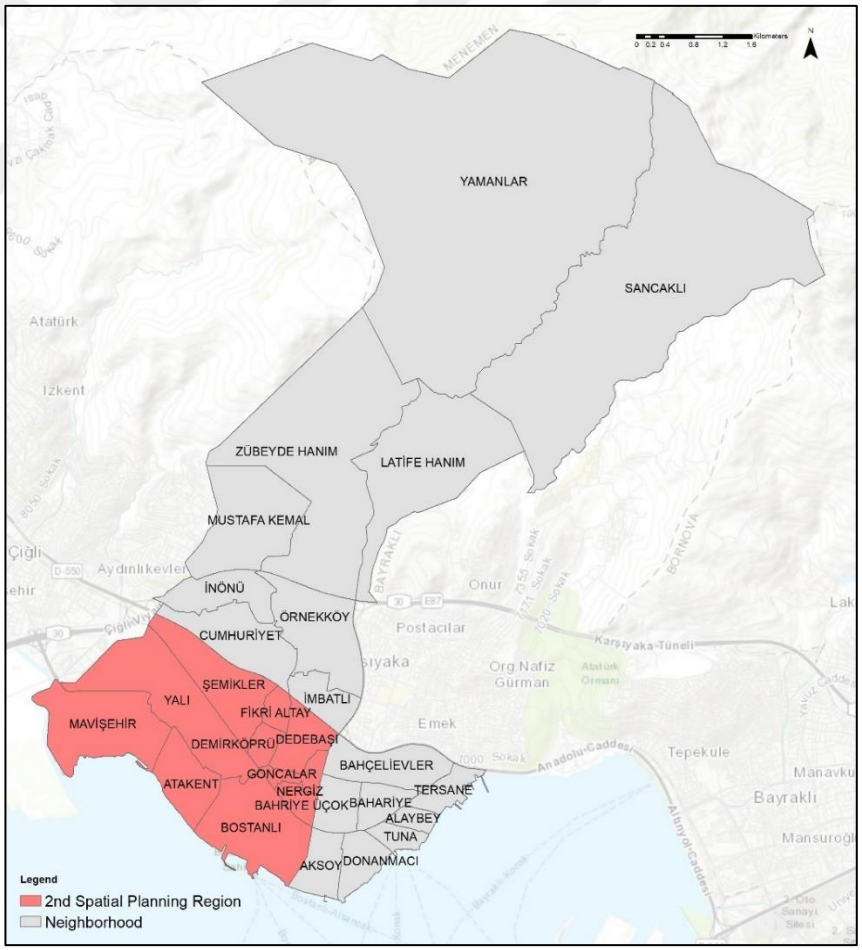

Figure 3.2 Neighborhood of Karsiyaka District

Karşıyaka district is divided into two main spatial planning zones. Karşıyaka district consists of Bahçelievler, Örneköy, Mavişehir, Atakent, Nergiz, Bostanlı, Şemikler, Zübeyde Hanım, Cumhuriyet, Bahriye Üçok, Bahriye, Aksoy, Donanmacı, Tuna, Alaybey, Tersane, İmbatlı, İnönü, Latife Hanım, Mustafa Kemal, Yamanlar, Sancaklı, Yalı, , Fikri Altay, Dedebaşı, Goncalar, Demirköprü neighborhoods. The second planning region selected as the study area in the thesis consists of 10 neighborhoods named Yalı, Bostanlı, Şemikler, Dedebaşı, Mavişehir, Atakent, Nergiz, Goncalar, Demirköprü and Fikri Altay (Figure 3.4).

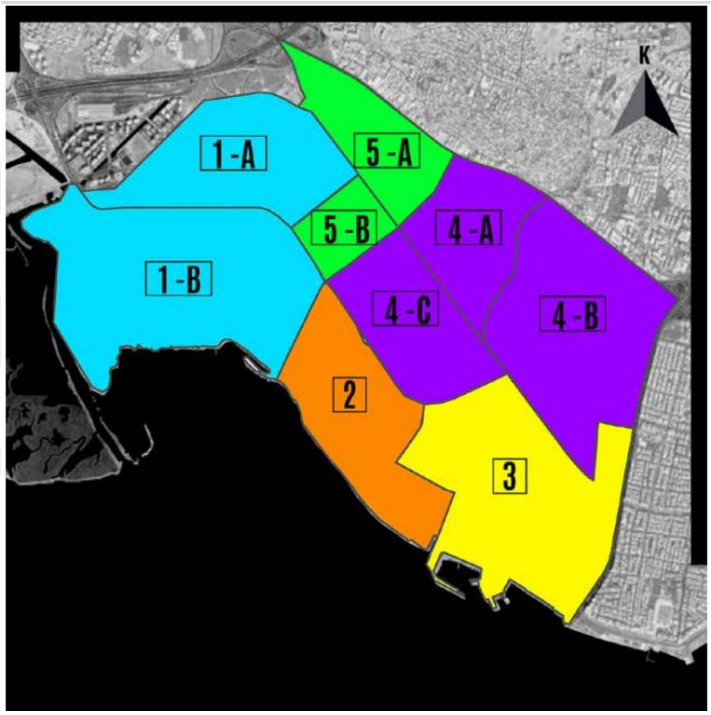

Figure 3.3 Karşıyaka 10 Neighborhood Project, Synthesis Zones (Edited from IZKA, 2023)

According to the report of the 'Project for the Preparation of Urban Researches, Analyses, Synthesis and Strategy Zoning in 10 Neighborhoods in Karşıyaka' carried out in 2023 in partnership with İzmir Development Agency, Karşıyaka Municipality and Dokuz Eylül University, the study area was divided into five zones according to similar characteristics (Figure 3.4). In the study, the characteristics of the regions and the risks and potentials they contain were determined. Accordingly, the ten neighborhoods selected as the study area have risks against climate change due to their ground conditions, the density of the building inventory before the year 1998, the

dense population of elderly and children compared to the city, the presence of construction in embankment areas, the high permeable surface area in most districts, and the proximity to the sea, while they have potential in combating risks against climate change due to the transportation network structure, the presence of green spaces, the presence of different land use types and the quality of the settlement.

3.3 Selection of Indicators

In order to ensure resilience, vulnerable elements should be identified; what they can be damaged by, to what extent and with what effects should be determined (Varol and Buluş Kırıkkaya, 2017; Şanlı vd. 2021). In this context, floods and extreme heat, two disasters related to climate change that increase in magnitude every year in Izmir, are taken into considered.

In this research that adopts the mentioned approach, the disasters to be assessed and the reflection of the systems impacted by the disasters in the city have been selected and their interrelationships have been questioned as follows:

Table 3.1 Research questions used in indicator selection

Which disaster creates the risk?	**Which systems are heavily impacted by these disasters?**	**Which components of the city represent these systems?**
Flood and Extreme Heat	Natural Environment	Natural infrastructure, Sensitive Areas, Topography etc.
	Built Environment	Built infrastructure, transport infrastructure, built conservation areas, etc.
	Social Dynamics	Population Dynamics, Education, Dependency etc.
	Economic Dynamics	Distribution of Income, Economic Conditions and Opportunities, Development Level etc.

In this thesis, the indicators to be used in the vulnerability index analysis have been selected according to the significant answers to the above questions and the characteristics of the city of Izmir. In this context, the selection of indicators affecting vulnerability has been completed in three stages.

3.3.1 Disaster Risk Level Indicators

In order to understand the risks of disasters and classify the risk level in the city, spesific indicators frequently encountered in the literature research are selected and their levels in the study area are examined.

Table 3.2. Flood Disaster Risk Level Indicators

Main Indicator	**Sub-indicator or Content**	**Referances**
Precipitation and Rainfall	Annual Maximum Precipitation and Flood Seasonal Maximum Rainfall	Chen et. al., 2020; Sun et. al., 2017; Li et. al., 2017; Shi et. al., 2019; Balica et. al., 2010; Jeong and Yoon, 2018; Lee and Jun, 2018; Nasiri et. al., 2019; Balica et. al, 2009
Flood Risk	Number of Occurrences of Flood Events, Flooded Area Ratio and Land Use, Slope, Elevation	Marta et. al, 2020;Li et. al., 2017; Koc ve Işık, 2020;Balica et. al, 2009;Chen et. al, 2020;Rana and Routray, 2018;Erena and Worku, 2019;Karunarathne et. al., 2020, Kablan, Dongo and Coulibaly, 2017;Nasiri et. al., 2019;Aroca-Jimenez et. al, 2018; Balica et. al, 2009;Shi et. al., 2019;Jeong and Yoon, 2018; Shi et. al., 2019; Sun et. al., 2017; Rash, 2016;Kablan, Dongo and Coulibaly, 2017;Niyongabire and Rhinane, 2019;Li et. al., 2017;Lee et al., 2017

The indicators selected for the flood (Table 3.2) and extreme heat (Table 3.3) in the review were carried out at the Metropolitan Scale over the city of Izmir, covering both study areas.

Table 3.3 Extreme Heat Disaster Risk Level Indicators

Main Indicator	**Sub-indicator or Content**	**Referances**
Air Temperature and Humidity	Annual Maximum, Mean air Temperature and Humidity	Harlan et al., 2006; Uejio et al., 2011; Kumar et al., 2016; Meerow and Newell, 2017; Voelkel et al., 2018; Oke, 1Karunarathne et. al., 20202; Huang et al., 2011
UHI	UHI, Urban Canyon, Street-Building Relationship , Urbanization and Urban Land Use Changes	Sharifi and Lehmann, 2014; Canan, 2017; Streutker, 2003;Grimmond and Oke, 1999;Ahmadpour et.al., 2021;Kim et. Al., 2022; Balaban, 2012;Streutker, 2003;Erdogan and Çubukçu, 2012
Air Quality	Pollution, Wind	Balaban, 2012; Takebayashi and Moriyama, 2012; Shirzadi, Naghashzadegan and Mirzaei, 2019; Chatzidimitriou and Yannas, 2017; Ngarambe et. Al, 2021

3.3.2 Main Indicators of Vulnerability

The study, which aims to create a sustainable resilience approach to vulnerability, provides a simple and understandable methodology to be applied at different scales and in various thematic areas. Therefore, this study has considered using a fixed and standard set of data and indicators that are frequently used in current planning practices that every municipality and local government already has. In this context, eight main indicators have been selected to answer the questions mentioned above and include all parts of the city.

Table 3.4 Main Indicator of the Vulnerability to Flood and Extreme Heat Events

Urban System	**Main Indicator**
Built Environment	Land Use
Natural Environment	Green Spaces
Built Environment	Building Condition
Built Environment	Street Network Quality
Social Dynamics	Population Density and Changes
Social Dynamics	Disadvantaged Population
Economic Status	Economic Status
Natural Environment	Disaster Related Risk Level

The selected indicators were classified according to the definitions of exposure, susceptibility and coping capacity to be used in vulnerability index analysis. The classification was made based on their impact on disasters or their affectability to disasters (Table 3.5). In order to determine the relationship of individual indicators with disaster vulnerability, the main indicator groups were primarily categorised according to the phenomena coming from the definition of vulnerability (Table 3.6).

Table 3.5 Main Indicators Vulnerability Phenomena Based on Disaster

Main Indicator	**Vulnerability Index Categories**	
	Flood	**Extreme Heat**
Land Use	**Exposure**	**Susceptibility**
Green Spaces	Coping Capacity	Coping Capacity
Building Condition	Susceptibility	Susceptibility
Street Network Quality	**Coping Capacity**	**Susceptibility**
Population Density and Changes	**Exposure**	**Susceptibility**
Disadvantaged Population	**Susceptibility**	**Exposure**
Economic Status	**Susceptibility**	**Coping Capacity**
Disaster Related Risk Level	**Exposure**	**Exposure**

This classification is made according to the relationship between disaster and vulnerability, which is explained in detail in the previous section and emphasized in the literature. The main indicators are Land Use, Street Network Quality, Population Density and Changes, Disadvantaged Population, and Economic Situation, which are evaluated under different cases according to the type of disaster. The indicators in the assessment consist of the leading indicators that are most frequently used in the literature and considered consistent with the dynamics of Izmir city. The selected main indicators can be summarised as follows;

Land Use: Mainly describes the distribution and relationship of different types of land use (residential, public infrastructure, etc.) in the city.

Green Spaces: mainly refers to natural green spaces as a natural asset in the city or green spaces used for recreational purposes such as parks.

Building Condition: mainly indicates the current condition of the building stock in the city. This condition can be expressed in terms of age, height, building material, density and distribution.

Street Network Quality: mainly represents the character of the city's road networks and connectivity. The character can be described by the levels of closeness and accessibility of the road network, street widths, street slope, street-building relationship, walkability, mobility density, public transport opportunities, presence and distribution of emergency routes.

Population Density and Changes: mainly expresses the population distribution of urban inhabitants and its change over the years or future projections.

Disadvantaged Population: mainly defines the population characteristics of urban inhabitants in terms of disadvantaged groups. These groups consist of the elderly, children, disabled people, and inequalities in the distribution of women and men, and gaps in the level of education.

Economic Status: reflects the economic character of the city and its inhabitants. It can be defined by the location of workplaces, the distribution of unemployment, the affordability of basic living expenses, and the economic gap in the population.

Disaster Related Risk Level: mainly represents the risk levels created by disasters. This study calculates risk levels with a separate evaluation by considering the characteristics of disasters that will increase their effects on the city. This indicator used in vulnerability expresses the results of the risk level calculation.

3.3.3 Sub-Indicators of Vulnerability

Every main indicator contains sub-indicators that may affect the vulnerability of the city in different dimensions. Therefore, in this research, the categorization of indicators of vulnerability phenomena was created with sub-indicators besides main indicators (Table 3.5) so the parts of the city at different scales can be analysed together.

The main and sub-indicators determined within the scope of this thesis are evaluated separately at different analysis stages. AHP analysis will be carried out in order to determine to what extent the determined indicators have an impact on vulnerability and which indicators are prioritized. At this stage, the main indicators are used for weighting in accordance with the optimum number of indicators of the AHP method in the literature. The sub-categories that directly overlap with the main indicators provide input to the vulnerability analysis by considering the weights of the main categories from the AHP analysis. In this context, the sub-criteria and vulnerability phenomena groups related to the selected main criteria are presented below (Table 3.7 and Table 3.8).

Table 3.6 Flood Vulnerability Sub-indicator

Main Indicator	Flood Vulnerability		Explanation	Referances	Data
	Sub-Indicator	**Vulnerability Phenomena**			
Land Use	Commercial	EXPOSURE	Various land use types respond to floods in different ways and are affected differently. For example, while commercial areas experience economic loss, residential areas are sensitive because of the loss of life and human factor.	Krellenberg et.al.,2017; Balica et. al., 2009; Sun et. al., 2017; Djamaluddin et. al., 2020; Lee et. al., 2017	Izmir Metropolitan Municipality and Karşıyaka Municipality
	Industrial	EXPOSURE			
	Open Spaces	EXPOSURE			
	Public Infrastructure	EXPOSURE			
	Recreative	EXPOSURE			
	Land Use Changes	SUSCEPTIBILITY			
	Residential	SUSCEPTIBILITY			
Green Spaces	Green Spaces Ratio	COPING CAPASITY	Green spaces are composed of permeable surfaces, which increases their coping capacity, while green spaces whose natural quality needs to be preserved indicate exposure. Poor quality and absence of green space constitutes sensitivity.	Krellenberg et.al.,2017; Chen et. al., 2020; Jeong and Yoon, 2018; Müller et. al., 2011; Krellenberg et. al., 2014; Nasiri et. al., 2019; Rana and Rputray, 2018	Izmir Metropolitan Municipality and Karşıyaka Municipality
	Natural Green Asset	EXPOSURE			
Building Condition	Building-Number of Floors and Height	EXPOSURE	Although structures are mostly vulnerable to floods, high building density increases the threat and creates exposure	Krellenberg et.al.,2017; Elboshy et. al., 2019; Marta et.al., 2020; Koc and Işık, 2020; Ronco et. al., 2015; Rasch, 2016; Erena and Worku, 2019; Aroca-Jimenez et. al, 2017; Müller et. al., 2011; Krellenberg et. al., 2014; Niyongabire and Rhinane, 2019; Nasiri et. al., 2019; Rana and Rputray, 2018; Sorg et. al., 2018; Zegerek, 1997	Izmir Metropolitan Municipality and Karşıyaka Municipality
	Building Age	SUSCEPTIBILITY			
	Building Density	EXPOSURE			
	*Building Material**	*SUSCEPTIBILITY*			
Street Network Quality	Accessibility to Crtical Infrastructure	COPING CAPASITY	Streets connecting all components of the city can be described as coping capacity when designed effectively. Sloping roads create sensitivity as they restrict movement on the rescue route and increase flood flow velocity. The spatial size of the road network invites exposure, as roads not made of permeable material will have the same effect. Intense mobility will increase exposure during floods. The presence of rescue routes, the availability of public transportation and high accessibility to critical uses define coping capacity.	Sarmah et. al., 2020; Aroca-Jimenez et. al, 2017; Niyongabire and Rhinane, 2019; Chen et. al., 2020; Balica et. al., 2009; Balica and Wright, 2010; Erena and Worku, 2019; Tascón-González et. al., 2020; Lee et. al., 2017; Koc and Işık, 2020; Shi et. al., 2019; Barroca et. al., 2006; Karunarathn and Lee, 2020; Santos et. al., 2018; Erena and Worku, 2019; Rana and Rputray, 2018	Izmir Metropolitan Municipality and Karşıyaka Municipality, OSM Open Data
	Elevation	EXPOSURE			
	*Emergency and Rescue Routes**	*COPING CAPASITY*			
	*Mobility Density**	*EXPOSURE*			
	Street Network Area Ratio	EXPOSURE			
	Public Transportation	SUSCEPTIBILITY			
	Street Width	COPING CAPASITY			
	Street-Building Relationship	SUSCEPTIBILITY			
Population Density and Changes	Education Levels Ratio	COPING CAPASITY	Although population-related dynamics often create vulnerability, higher levels of education define coping and population density defines exposure.	Balica et. al., 2009; Niyongabire and Rhinane, 2019; Elboshy et. al., 2019; Marta et.al., 2020; Koc and Işık, 2020; Lv, Guan and Meng, 2020; Shi et. al., 2019; Yoon et. al., 2014; Balica and Wright, 2010; Rasch, 2016; Gu et. al, 2018; Kirby et. al., 2019; Welle et. al., 2014; Djamaluddin et. al., 2020; Erena and Worku, 2019; Tascón-González et. al., 2020; Aroca-Jimenez et. al, 2017; Krellenberg et. al., 2014; Rahman et. al, 2016; Lee et. al., 2017; Rana and Rputray, 2018; Santos et. al., 2018; Sorg et. al., 2018; Wang et. al, 2020	Izmir Metropolitan Municipality and Karşıyaka Municipality, TURKSAT
	Population Density	EXPOSURE			
Disadvantaged **Population**	Children <5	SUSCEPTIBILITY	Vulnerable populations, including the elderly, women and children, are often associated with vulnerability, while low levels of independence are associated with coping capacity and persons with disabilities are associated with exposure.	Gu et. al, 2018; de Andrade and Szlafsztein, 2018; Djamaluddin et. al., 2020; Erena and Worku, 2019; Mansur et. al, 2016; Aroca-Jimenez et. al, 2017; Krellenberg et. al., 2014; Fernandez et. al, 2016; Lee et. al., 2017; Karunarathn and Lee, 2020; Krellenberg et.al.,2017; Niyongabire and Rhinane, 2019; Elboshy et. al., 2019; Marta et.al., 2020; Rasch, 2016; Gu et. al, 2018; Welle et. al., 2014–Tascón-González et. al., 2020; Aroca-Jimenez et. al, 2017; Lee and Choi, 2018; Barroca et. al., 2006; Krellenberg et. al., 2014; Fernandez et. al, 2016; Rahman et. al, 2016; Sorg et. al., 2018; Remo et. al, 2016; Solin, 2012; Garbutt et. al., 2015	Izmir Metropolitan Municipality and Karşıyaka Municipality, TURKSAT
	Elderly>65	SUSCEPTIBILITY			
	Female Ratio	SUSCEPTIBILITY			
	Dependency Ratio	COPING CAPASITY			
	People with Disabilities Ratio	EXPOSURE			
Economic Status	Socio-Economic Status	COPING CAPASITY	The economy reveals vulnerabilities in the post-disaster recovery process. The ability to replace damaged assets, coping capacity, the difference in economic power in society and the distribution of workplaces create exposure, and low income groups and unemployment generate sensitivity.	Balica et. al., 2009; Rasch, 2016; Djamaluddin et. al., 2020; Sorg et. al., 2018;Alonso and Florent Renard, 2020; Tapia et. al., 2017	Izmir Metropolitan Municipality and Karşıyaka Municipality, TURKSAT
	Low Income Households Ratio	SUSCEPTIBILITY			
	Unemployment Raito	SUSCEPTIBILITY			
*NOTE: Since there is no data set for sub-indicators with * symbol, they could not be evaluated within the scope of the thesis.*					

Table 3.7 Extreme Heat Vulnerability Sub-indicator

Main Indicator	Extreme Heat Vulnerability		Explanation	Referances	Data
	Sub-Indicator	**Vulnerability Phenomena**			
Land Use	Commercial	EXPOSURE	Land use patterns can be distributed in a way that can increase or decrease the heat. For example, commercial areas are mostly pedestrianized and used by everyone, mostly during the daytime, which creates exposure, while public infrastructures have support mechanisms against extreme heat, which can be explained by their coping capacity.	Krellenberg et.al.,2017; Balica et. al., 2009; Sun et. al., 2017; Djamaluddin et. al., 2020; Lee et. al., 2017	Izmir Metropolitan Municipality and Karşıyaka Municipality
	Industrial	EXPOSURE			
	Open Spaces	EXPOSURE			
	Public Infrastructure	EXPOSURE			
	Recreative	EXPOSURE			
	Land Use Changes	SUSCEPTIBILITY			
	Residential	SUSCEPTIBILITY			
Green Spaces	Green Spaces Ratio	COPING CAPASITY	Green spaces are associated with the capacity to cope with many factors such as shading and oxygen content. Yet areas of natural character are susceptible to the risk of fire due to extreme heat.	Krellenberg et.al.,2017; Chen et. al., 2020; Jeong and Yoon, 2018; Müller et. al., 2011; Krellenberg et. al., 2014; Nasiri et. al., 2019; Rana and Rputray, 2018	Izmir Metropolitan Municipality and Karşıyaka Municipality
	Natural Green Asset	EXPOSURE			
Building Condition	Building-Number of Floors and Height	EXPOSURE	Building material will affect the UHI in the city and is explained by the coping capacity. The way areas with high building density generate energy and the thermal dissipation of the energy they produce creates sensitivity. Building length is explained by the coping capacity due to shading. However, the high number of floors creates exposure as it increases the temperature felt by people living on high floors. The age of the building creates sensitivity due to the technology in the construction stages such as insulation.	Krellenberg et.al.,2017; Elboshy et. al., 2019; Marta et.al., 2020; Koc and Işık, 2020; Ronco et. al., 2015; Rasch, 2016; Erena and Worku, 2019; Aroca-Jimenez et. al, 2017; Müller et. al., 2011; Krellenberg et. al., 2014; Niyongabire and Rhinane, 2019; Nasiri et. al., 2019; Rana and Rputray, 2018; Sorg et. al., 2018; Zegerek, 1997	Izmir Metropolitan Municipality and Karşıyaka Municipality
	Building Age	SUSCEPTIBILITY			
	Building Density	EXPOSURE			
	*Building Material**	*SUSCEPTIBILITY*			
Street Network Quality	Accessibility to Crtical Infrastructure	COPING CAPASITY	The roads and streets that make transportation possible constitute coping capacity when they make accessibility varied and convenient. Sloping roads create obstacles that are difficult to walk on and cross in extreme heat, which is explained by exposure. The spatial size of the road network invites exposure as roads not made of permeable material increase the UHI effect. Intense mobility increases exposure as it increases the perceived heat effect. The presence of rescue routes and the availability of various modes of public transportation define the coping capacity. The street-building relationship is again explained by coping capacity, as it can reduce the insolation effect. Width of roads, on the other hand, creates vulnerability as they do not provide shading and increase the UHI effect. High accessibility to critical uses due to heart and lung problems caused by extreme heat describes coping capacity.	Sarmah et. al., 2020; Aroca-Jimenez et. al, 2017; Niyongabire and Rhinane, 2019; Chen et. al., 2020; Balica et. al., 2009; Balica and Wright, 2010; Erena and Worku, 2019; Tascón-González et. al., 2020; Lee et. al., 2017; Koc and Işık, 2020; Shi et. al., 2019; Barroca et. al., 2006; Karunarathn and Lee, 2020; Santos et. al., 2018; Erena and Worku, 2019; Rana and Rputray, 2018 Sarmah et. al., 2020; Aroca-Jimenez et. al, 2017; Niyongabire and Rhinane, 2019; Chen et. al., 2020; Balica et. al., 2009; Balica and Wright, 2010; Erena and Worku, 2019; Tascón-González et. al., 2020; Lee et. al., 2017; Koc and Işık, 2020; Shi et. al., 2019; Barroca et. al., 2006; Karunarathn and Lee, 2020; Santos et. al., 2018; Erena and Worku, 2019; Rana and Rputray, 2018	Izmir Metropolitan Municipality and Karşıyaka Municipality, OSM Open Data
	*Emergency and Rescue Routes**	*COPING CAPASITY*			
	*Mobility Density**	*EXPOSURE*			
	Street Network Area Ratio	EXPOSURE			
	Public Transportation	SUSCEPTIBILITY			
	Street Width	COPING CAPASITY			
	Street-Building Relationship	SUSCEPTIBILITY			
Population Density and Changes	Education Levels Ratio	COPING CAPASITY	Although population-related dynamics often create vulnerability, higher levels of education define coping and population density defines exposure.	Balica et. al., 2009; Niyongabire and Rhinane, 2019; Elboshy et. al., 2019; Marta et.al., 2020; Koc and Işık, 2020; Lv, Guan and Meng, 2020; Shi et. al., 2019; Yoon et. al., 2014; Balica and Wright, 2010; Rasch, 2016; Gu et. al, 2018; Kirby et. al., 2019; Welle et. al., 2014; Djamaluddin et. al., 2020; Erena and Worku, 2019; Tascón-González et. al., 2020; Aroca-Jimenez et. al, 2017; Krellenberg et. al., 2014; Rahman et. al, 2016; Lee et. al., 2017; Rana and Rputray, 2018; Santos et. al., 2018; Sorg et. al., 2018; Wang et. al, 2020	Izmir Metropolitan Municipality and Karşıyaka Municipality, TURKSAT
	Population Density	EXPOSURE			
Disadvantaged Population	Children <5	SUSCEPTIBILITY	Vulnerable populations, including the elderly, women and children, are often associated with vulnerability, while low levels of independence are associated with coping capacity and persons with disabilities are associated with exposure.	Gu et. al, 2018; de Andrade and Szlafsztein, 2018; Djamaluddin et. al., 2020; Erena and Worku, 2019; Mansur et. al, 2016; Aroca-Jimenez et. al, 2017; Krellenberg et. al., 2014; Fernandez et. al, 2016; Lee et. al., 2017; Karunarathn and Lee, 2020; Krellenberg et.al.,2017; Niyongabire and Rhinane, 2019; Elboshy et. al., 2019; Marta et.al., 2020; Rasch, 2016; Gu et. al, 2018; Welle et. al., 2014–Tascón-González et. al., 2020; Aroca-Jimenez et. al, 2017; Lee and Choi, 2018; Barroca et. al., 2006; Krellenberg et. al., 2014; Fernandez et. al, 2016; Rahman et. al, 2016; Sorg et. al., 2018; Remo et. al, 2016; Solin, 2012; Garbutt et. al., 2015 Balica et. al., 2009; Niyongabire and Rhinane, 2019; Elboshy et. al., 2019; Marta et.al., 2020; Koc and Işık, 2020; Lv, Guan and Meng, 2020; Shi et. al., 2019; Yoon et. al., 2014; Balica and Wright, 2010; Rasch, 2016; Gu et. al, 2018; Kirby et. al., 2019; Welle et. al., 2014; Djamaluddin et. al., 2020; Erena and Worku, 2019; Tascón-González et. al., 2020; Aroca-Jimenez et. al, 2017; Krellenberg et. al., 2014; Rahman et. al, 2016; Lee et. al., 2017; Rana and Rputray, 2018; Santos et. al., 2018; Sorg et. al., 2018; Wang et. al, 2020	Izmir Metropolitan Municipality and Karşıyaka Municipality, TURKSAT
	Elderly>65	SUSCEPTIBILITY			
	Female Ratio	SUSCEPTIBILITY			
	Dependency Ratio	COPING CAPASITY			
	People with Disabilities Ratio	EXPOSURE			
Economic Status	Socio-Economic Status	COPING CAPASITY	The economy reveals vulnerabilities in the post-disaster recovery process. The ability to replace damaged assets, coping capacity, the difference in economic power in society and the distribution of workplaces create exposure, and low income groups and unemployment generate sensitivity.	Balica et. al., 2009; Rasch, 2016; Djamaluddin et. al., 2020; Sorg et. al., 2018;Alonso and Florent Renard, 2020; Tapia et. al., 2017	Izmir Metropolitan Municipality and Karşıyaka Municipality, TURKSAT
	Low Income Households Ratio	SUSCEPTIBILITY			
	Unemployment Raito	SUSCEPTIBILITY			
NOTE: Since there is no data set for sub-indicators with * symbol, they could not be evaluated within the scope of the thesis.					

3.4 The Analysis of Indicators

This thesis is designed by using quantitative and qualitative patterns in combination. In this context, primary data source was used to determine the weights of vulnerability indicators. Secondary data sources were utilized to examine the risks and vulnerabilities to flood and extreme heat disasters against climate change.

The analysis of indicators consists of two main stages. These stages are weighting analysis of indicators and spatial analysis of indicators. In the first stage of analysis, the main indicators were analysed to determine weight. The second stage of analysis consists of spatial analysis of indicators.

3.4.1 Weighting Analysis of Indicators

It is clear that to ensure urban resilience, which factors and the extent to which risks affect the vulnerability level are of critical importance (IPCC, 2014; Balica et. al., 2009; De Leon and Carlos, 2006). Although there are different methods used in calculating vulnerability, one of the most common methods is the index approach (Balica et al., 2009; Balica et al., 2012; De Leon, Carlos, 2006; Torresan et al. 2012). In this approach, which starts from the definition of vulnerability and translates it into a mathematical expression, determining the importance levels of the indicators evaluated and how to analyze their relationships is an important question frequently encountered in the literature. In order to answer these questions, the AHP method was used in the thesis to determine the impact levels of indicators that have various positive and negative effects on vulnerability.

AHP (Analytic Hierarchy Process) is a method developed by Thomas L. Saaty to help decision makers in complex decision problems by ranking alternatives according to specified criteria and indicating priorities (Saaty, 1977; Saaty, 1980). The AHP method is used in many different fields such as social, political, engineering, manufacturing, management and sustainability, due to its many advantages as it can

be applied to a large number of criteria, it is a suitable method for group decisions, it can represent the decision-making problem in a hierarchical structure, it is applicable and understandable since it does not require intensive mathematical calculations, it can calculate the consistency of pairwise comparisons, and it can be applied on qualitative and quantitative data (Özbek,2019; Dişkaya ve Emir, 2021; Angelis and Lee, 1996; Azis, 1990; Tummala et. Al., 1997; Vaidyya and Kumar, 2006; Dos Santos et. Al., 2019).

The AHP method introduced by Saaty is based on three basic principles: decomposition, comparative judgment and synthesis of priorities. Following these principles, AHP encompasses three basic steps;

- Improving the hierarchical structure:

This step is to create a hierarchical structure. It is based on the first principle that emphasizes the need to decompose the decision problem into simpler decision problems. It presents the criteria and options leading to the purpose (Figure 3.5).

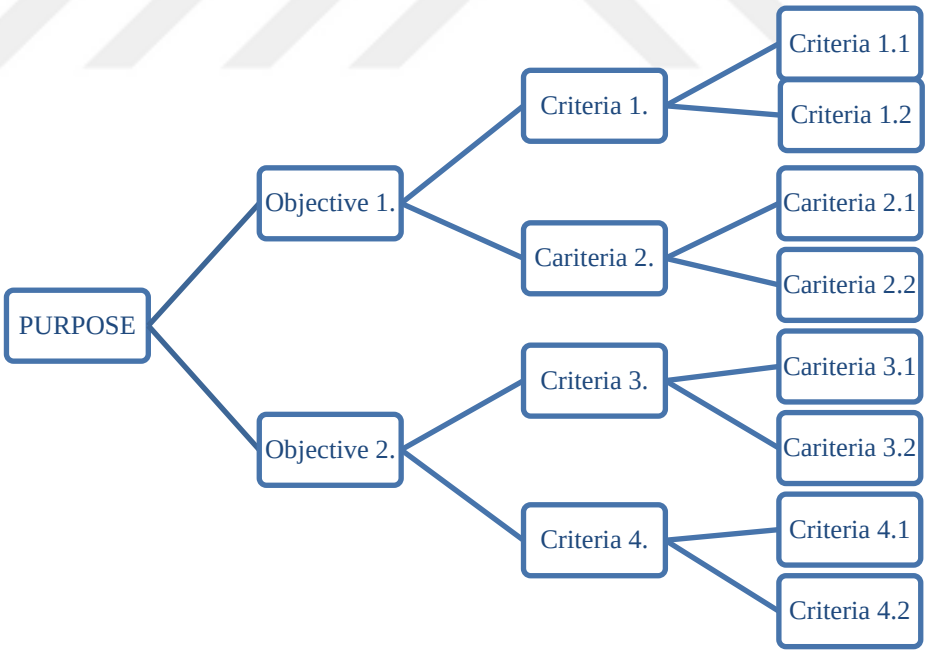

Figure 3.4 Hierarchical Structure of AHP

In this thesis, a hierarchy of main indicator is constructed for the purpose of calculating vulnerability.

- Pair-wise Comprasion and Assesment:

This method is characterized by simplifying complex processes as only two elements are considered at a time (Malczewski, 1999). And it constitutes the main stage of the method. The evaluation of the comparisons takes place in three stages: the creation of comparison matrices, the calculation of weights from all matrices for the final hierarchy levels, and the determination of consistency ratios (Erdem & Coşkun, 2011; Gökkaya, 2014). Although this method stands out with its simplification of very complex processes, Saatsy has stated the optimum number of indicators to be used in this method as 7 (+2, -2) (Saatsy, 2003; Gawlik, 2008). Therefore, the main indicators were used in the comparison phase of the AHP method in this thesis.

The first step of the pair-wise comparison method is the survey step. The pair-wise comparison method creates a ratio matrix and produces relative weights. The comparison uses Saaty's nine relative importance scales (Table 3.8).

Table 3.8 Saaty's nine relative importance scales (Saaty, 1980)

Numerical Rating	Definition
1	Equal (1)
3	Slightly Important (3)
5	Strongly Important (5)
7	Very Strong Important (7)
9	Extremely Important (9)
2,4,6 or 8	Intermediate Values

Following this stage, a survey was conducted within the scope of the thesis to determine the relative important scale, i.e. the weights. The survey was conducted online. Saaty and Özdemir (2014), in their study on how many people should be involved in determining the expert opinion in AHP-based weighting studies, stated that this number is “between six and eight; the nearest whole number is seven” in order to keep the error rate at the lowest levels. Hence, seven expert opinions were selected

from the surveys conducted in the thesis based on their experience and field of profession.

The remaining steps of the study are as follows;

Creating a comparison matrix (Figure 3.6) of the survey results produced using the relative importance scale for each level of the hierarchy.

	Criteria 1	Criteria 2	Criteria 3	Criteria 4	…	Criteria n
Criteria 1	$a_{C1,C1}$	$a_{C1,C2}$	$a_{C1,C3}$	$a_{C1,C4}$	...	$a_{C1,Cn}$
Criteria 2	$a_{C2,C1}$	$a_{C2,C2}$	$a_{C2,C3}$	$a_{C2,C4}$	...	$a_{C2,Cn}$
Criteria 3	$a_{C3,C1}$	$a_{C3,C2}$	$a_{C3,C3}$	$a_{C3,C4}$	...	$a_{C3,Cn}$
Criteria 4	$a_{C4,C1}$	$a_{C4,C2}$	$a_{C4,C3}$	$a_{C4,C4}$	...	$a_{C4,Cn}$
…	…	…	...	…	...	...
Criteria n	$a_{Cn,C1}$	$a_{Cn,C2}$	$a_{Cn,C3}$	$a_{Cn,C4}$	...	$a_{Cn,Cn}$

Figure 3.5 Comparison Matrix

Calculation of weights for each element: First, the matrix is normalized with the formula (3.1)

$$a_{cx,cy} = \frac{a_{cx,cy}}{\sum_{cx=1}^{n} a_{cx,cy}} \tag{3.1}$$

In order to calculate the relative weights of criteria, each value is averaged using equation (3.2) and the weighting process is completed.

$$w_{cx} = \frac{\sum_{cy}^{n} a_{cx,cy}}{n} \tag{3.2}$$

According to Saaty (1980), there is a correlation between the weight vector and the pairwise comparison matrix as shown in equation (3.3)

$$Aw = \lambda_{max} w \tag{3.3}$$

The λmax value is obtained by multiplying the weight vector with the pairwise comparison matrix, and is a value called the largest eigenvalue of the A matrix and used in the Consistency Ratio (CR) calculations.

Estimation of the consistency ratio (CR): The CR validates the accuracy of the study by measuring the acceptable level of consistency in pairwise comparison. CR is expressed as a combination of Consistency Index CI and Random Index (RI) in the form of formula (3.4).

$$CR = \frac{CI}{CR} \tag{3.4}$$

Consistency Index (CI) is calculated with formula (3.5)

$$CI = \frac{\lambda_{max} - n}{n - 1} \tag{3.5}$$

Random Index (RI) are coefficient values generated from pairwise comparison matrices. Table 3.9 shows the RI values of the matrices proposed by Saaty (1980) from the 1st to the 10th criterion

Table 3.9 Random Index Values Obtained for 10 Criteria (Saaty, 1980)

Number of Criteria (n)	1	2	3	4	5	6	7	8	9	10
RI Value	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

In this way, the CR calculation is completed. To have a reasonable consistency, the CR value should be less than 0.10. The pairwise comparison should be revised if the CR is equal to or higher than 0.10.

- Synthesis of Priorities

This last step is achieved by multiplying the relative weight matrices at every level of the hierarchy to produce composite weights. These composite weights represent the ratings of the alternatives concerning the purpose.

Through AHP method, the steps of which are explained above and the scopes considered in the study, weightings for each disaster related to the indicators will be obtained. These weighting results will be integrated with the analyses to be explained in the next chapter and will provide input to the vulnerability analysis. In this way, it is possible to achieve a vulnerability analysis determined by weighting with expert decisions.

3.4.2 Spatial Analysis of Indicators

This stage consists of spatial analysis of disaster risk level and sub-indicators of vulnerability. The present situation analyses were applied as an integration of classical planning analysis approaches and innovative analytical approaches. ArcGIS Pro and ArcGIS 10.3-10.8 programs, Excel, AutoCAD program and SPSS programs were used in the analyses of this study.

3.5 Vulnerability Index Analysis

In this phase of the thesis, the methods and their contents to be used in the case study were determined. As Turkey's third-largest city, Izmir must address the challenges posed by climate change-related disasters due to its geographical location, natural environment, and built infrastructure. In alignment with the research

framework, concept, and keyword definitions, the case study has been conducted within the context of İzmir's central urban districts. The thesis conducted in Izmir aims to create a model approach that can be used to create a sustainable resilient city against climate change. For this purpose, existing urban planning analyses have been combined with the definitions of the vulnerability concept. As stated previously, this thesis defines vulnerability as a function of exposure, susceptibility, and coping capacity factors. From the definition, this relationship is frequently used in the creation of calculation formulas in the indicator-based vulnerability index analysis approach. In a study adopting this approach, the vulnerability index was considered as follows (De Leon and Carlos, 2006):

$$Vulnerability = \frac{Exposure\ x\ Susceptibility}{Adaptive\ Capacity} \quad (3.6)$$

In another study, the formula (3.7) was used with a similar approach (Balica et al., 2009; Balica et al., 2012);

$$Vulnerability = \frac{Exposure\ x\ Sensitivity}{Adaptive\ Capacity} \quad (3.7)$$

In this thesis, the following formula was used in the analysis of indicators that increase and decrease vulnerability (3.8):

$$Vulnerability = \frac{Exposure\ x\ Susceptibility}{Coping\ Capacity} \quad (3.8)$$

In this approach, a set of indicators are selected based on the phenomena used in the definition and mathematical expression of vulnerability, and the vulnerability index analysis is produced based on these indicators (Table 3.7 and Table 3.8).

In this context, in order to spatialise and apply this formula within the study area determined in the thesis, a fishnet analysis was prepared over GIS by dividing the

spatial projection of the main indicators in the study area into cells (squares) of 250 x 250 m for Metropolitan scale and 50 m x 50 m for Planning Region Scale, which is the average of the data area, in order to analyse the values related to the vulnerability indicators. The cellisation method is a frequently used method that enables the simultaneous perception of data at different scales and depths (Abuodha and Woodroffe, 2010). The cellisation method allowed the data in different units to be expressed in a single form and the vulnerability index to be applied to each cell. In this way, an integrated vulnerability analysis was conducted. The large number of differences between the vulnerability levels among the cells makes it difficult to understand them. There is not a clear and definite answer in the literature to determine the size of a cell in the cellization method. When the studies in the literature are examined, there are studies using the quadrat formula method (Çolak et. Al, 2009; Şenol and Atay Kaya, 2024; Orndorff et.al., 2000) and studies using Moran's I method (Guerrero et. Al., 2019; Nagle-McNaughton and Constantine, 2019; Hou et. Al., 2023). The common point of these methods is that the cell size is chosen according to the diversity and scale of the data set. While Moran's I method has been used in studies with more than 30 variables, the Quadrat formula method has generally been used in biodiversity studies or studies with point data sets. In both statistical methods, the cell size is determined by the size of the data and the relationship of the smallest unit representing the data with other units. Within the scope of this thesis, since data of various scales and depths were used and the relationships between the data were not clear, the average area size of the spatial elements that constitute the data set was calculated to determine the cell size. As a result, 250 m x 250 m in Metropolitan Scale and 50 m x 50 m in Planning Scale were chosen as cell sizes. These dimensions both define the smallest data unit and accurately represent the data depth. In order to perceive the vulnerability levels properly and rationally, the normalisation process, which is frequently used in the literature, was applied to the cells. In this thesis, the maximum-minimum normalisation formula (3.9) was used as follows (Singh A., Pathirana S. ve Shi H., 2005);

$$Vulnerability_{norm} = \frac{vulnerability - vulnerability_{min}}{vulnerability_{max} - vulnerability_{min}} \quad (3.9)$$

This method allows the determination of the vulnerability levels by reorganising the vulnerability values in the cell into the range of 0 and 1 values. At the end of the vulnerability analysis process, a final vulnerability level map was obtained from the evaluation of the indicators. As a result of this analysis, it is possible to achieve a resilient city through decision-making and prioritisation regarding the spatial areas that cover the grid cells.

3.6 Conclusion

In this part of the thesis, a sustainable and applicable vulnerability analysis that will contribute to the resilience of a city, which is the main objective of the thesis, is produced for the city of Izmir. The main purpose of the study is to assess the impacts of climate change risks on various systems in the city and to create a sustainable analysis method that can be used to understand how the social, economic and physical structures of the city respond to these impacts. In this framework, the effectiveness of the indicator set developed for accurately identifying climate change-related risks in Izmir, measuring the city's resilience to these risks and increasing its resilience is addressed. In this context, the vulnerability analysis approach will be tested at two different scales over the city of Izmir.

The thesis emphasizes that climate change is a threat to cities and resilience against these threats has become a critical issue for the sustainability of cities. Basic concepts such as risk, hazard, sensitivity, exposure and coping capacity have an important place in understanding disaster risks and determining how vulnerable cities are to these risks. In particular, the distinction between risk and hazard is an important basis for the analysis in this thesis. Risk refers to the likelihood of damage to existing assets (buildings, infrastructure, population, etc.), while hazard refers to natural or man-made disasters themselves. A clear definition of these concepts facilitates the understanding of the areas of vulnerability to various hazards that may affect the city. One of the

most important features of the thesis is the comprehensive selection of indicators to understand Izmir's vulnerability to current climate change risks. One of the most important criteria for selecting the indicators is that they consist of all municipality, local government and open source data in line with the thesis' organization. In this way, the method produced within the scope of this thesis can be reproduced with similar indicators in different provinces and regions. The important point here, as emphasized in the thesis, is that the indicator sets are created from the projection of critical features for the city.

Deciding which climate change-related disasters to analyze, such as indicators, is also a criterion for applying the vulnerability analysis method. While Izmir's climatic structure is characterized by the Mediterranean climate, it also experiences climatic changes such as high temperatures and sudden precipitation at the local level. Such disasters have major impacts on the city's infrastructure, residential areas, social structure and economic levels. Disasters such as floods and extreme heat have been selected as the most affected factors in Izmir and vulnerability to these disasters has been analyzed through specific indicators in different residential areas of the city.

Within the scope of the study, Karşıyaka district, one of the districts in Izmir city center, was preferred to be applied in the second scale. Karşıyaka district stands out with the presence of natural disasters experienced in the past. Karşıyaka district has been selected as one of the most vulnerable areas in Izmir to such disasters, and it has been analyzed in detail how vulnerability is distributed at the local scale and which spatial, social, physical and socio-economic factors increase vulnerability to disasters. For example, the population density in Karşıyaka, especially the high number of vulnerable groups such as elderly population and children, stands out as an important indicator of how vulnerable this region is to disasters. Likewise, physical factors such as land use, old buildings and low built-up areas in Karşıyaka cause disasters such as floods and extreme temperatures to be more destructive. Identifying such local risks is crucial for developing city-specific strategies.

Indicators used to measure the impacts of disasters include land use, green spaces, building condition and street network quality. In addition to assessing a city's resilience to disasters, these indicators also provide important data on how disasters can impact the social, economic and physical structures of a city. In particular, green spaces play a critical role in enhancing the city's ecosystem services and mitigating the impact of extreme heat, while elements such as street network quality and transportation infrastructure stand out as factors that determine the capacity to respond to emergencies. Building condition is another important indicator that increases or decreases resilience to disasters. The fact that older buildings are more likely to be damaged and the population living in these buildings is more likely to suffer more damage is an important factor to consider in terms of the overall resilience of the city and the region.

Social dynamics affecting the city also play an important role against disasters. Indicators such as population density, disadvantaged population and economic status help to understand how large an area and which groups can be affected by disasters. In particular, the disadvantaged population group consists of groups such as the elderly, children, people with disabilities and people with low income, and these groups are more vulnerable to disasters. This reveals the importance of social structures and economic conditions in assessing the impacts of disasters threatening the city.

Indicators such as the level of disaster risk and the risks associated with climate change play an important role in understanding how serious the events that threaten the city are and the impacts these events will have on different systems in the city. In this thesis, the fact that disasters can affect not only the natural but also the socio-economic structure is addressed, which is of great importance for the development of city- and region-specific response strategies. Furthermore, these analyses not only provide an understanding of the current state of the city, but also provide data that can guide the city to become more resilient to possible future climate change scenarios. This chapter provides a comprehensive framework for understanding climate change

disaster risks in Izmir and the city's vulnerability to these risks. The selected indicators allow for analyzing the impacts of disasters at a local scale and also help to develop strategies to increase the resilience of the city. In this framework, the methodology presented in the thesis provides an effective strategy that is applicable not only for Izmir but also for similar cities. The analysis methods and indicator set used in the thesis will be an important guide to increase the resilience of cities in the face of future climate change scenarios.

This thesis presents a comprehensive vulnerability analysis for increasing resilience to the impacts of climate change on cities. In particular, determining the vulnerability and risk levels of cities in the face of events such as floods and extreme temperatures constitutes the key elements of building resilient cities against such disasters. In this context, a comprehensive assessment of disaster risks and vulnerability indicators has been made through quantitative and qualitative analysis methods used in this thesis. In the research process, the weights of vulnerability indicators were determined with the data collected at local and national level and these indicators were analyzed at spatial level.

Indicator weighting analysis, which constitutes the first stage of the thesis, is one of the most critical methods used to determine the vulnerability of cities to disasters. Vulnerability indicators are important parameters that show how vulnerable a particular region is to disasters. Determining the importance levels of these indicators is vital to understand which areas of cities need priority intervention. At this stage, a specific weight was assigned to each indicator using the Analytic Hierarchy Process (AHP). AHP is an extremely common method used to rank alternatives in complex decision-making processes. The basic principles of this method are based on finding solutions by breaking the problem into smaller, manageable sub-problems, determining priorities by making comparative judgments, and synthesizing these priorities to form final decisions. The weighting results are used to provide a more accurate analysis of the vulnerability of cities to disasters. This methodology has been a fundamental tool in determining the weights of all indicators in the thesis.

The second phase of the thesis is based on spatial analysis. Here, geographic information systems (GIS) tools such as ArcGIS and ArcGIS Pro were used to analyze the spatial distribution of vulnerability indicators. Spatial analysis is particularly critical for identifying where disasters have more concentrated impacts and which indicators are more at risk in these areas. In large cities such as Izmir, a detailed map of how disaster risks are spreading with climate change was created, thus identifying vulnerability levels for each region in the city.

One of the methods used in these spatial analyses is cellization. This methodology divides the data in a given area into small cells, allowing for the analysis of risk and vulnerability levels in each cell separately. In the case of Izmir, the study area was divided into 250 m x 250 m and 50 m x 50 m cells at the Planning scale, and the vulnerability of each cell was calculated. This allowed for a more detailed and focused vulnerability analysis.

The Vulnerability Index is based on a mathematical formula that is often used to determine vulnerability to disasters. The formula used in the thesis is expressed as follows:

$$Vulnerability = \frac{Exposure\ x\ Susceptibility}{Coping\ Capacity} \tag{3.8}$$

This formula takes into account the type of disasters to which a particular region is exposed and the effects of the social structure, infrastructure and environmental factors in that region. The indicators used to calculate the Vulnerability Index are derived from key factors such as exposure, susceptibility and coping capacity. These indicators reveal the degree of vulnerability to disasters for various regions of Izmir.

As a result of the spatial analyses, the vulnerability levels in each region have been reorganized through a normalization process. Normalization makes the data comparable and makes it possible to evaluate different data sets on a single scale. In

this process, the frailty value of each cell was normalized between 0 and 1, resulting in a clearer visual representation.

In conclusion, the methods and analyses used in this thesis provide important data in terms of identifying areas susceptible to disasters and determining the intervention requirements in these areas. Conducting such detailed and comprehensive analyses to increase the resilience levels of cities will help to create societies that are more prepared and resilient against future disasters. The indicator weighting and spatial analysis processes in the thesis provide a model that can be applied to other cities and make an important contribution to combating climate change.

CHAPTER FOUR
CLIMATE CHANGE VULNERABLITY ANALYSIS

In this section, spatial analyses of the selected indicators are produced in order to create a resilient city by implementing the vulnerability index approach within the scope of the method described in the previous chapter. The results of these analyses will not affect the vulnerability index equally, so two AHP-based weighting analysis was completed before the spatial analyses. As a result of this analysis, the importance and impact degrees of the indicators were determined. In the second part of the chapter, vulnerability risk levels and vulnerability indicators analyses were produced as an integration of traditional planning approaches and new generation analysis processes. The results obtained from the analysis of the indicators are produced using the vulnerability index formula and vulnerability analysis approach selected in the third part of this chapter. In this part, vulnerability indexes were first produced separately for floods and extreme temperatures. In this thesis, which attempts to create a methodological model for building Izmir's urban resilience to climate change, the impacts of climate change are considered as integrated since they do not occur at different times and places in the city. Therefore, an integrated vulnerability index was also produced in addition to the vulnerability index produced for two disasters. In addition to determining the level of vulnerability of the same urban area to different disasters, this thesis also presents an integrated approach to observe the impact of different disasters on the city when they occur simultaneously. Since there is no definite method in the literature for measuring the integrated disaster risk, the approach that different disasters increase the vulnerability exponentially is adopted in the vulnerability measurement. As a result of this part of the thesis, the vulnerability levels of the central districts of Izmir city against floods and extreme heat have been spatially determined and mapped.

4.1 AHP based Weighting Analysis

The first stage is to define the weights of the indicators. The AHP method, which is described in detail in the method section, was used to weighting the indicators. In weighting with the AHP method, a pair-wise questionnaire was administered to the experts first. This survey was conducted through an online survey application named 1KA. The questionnaire did not ask for any personal information and the participation of experts was voluntary. The selection of experts to complete the questionnaire was based on the requirement of having worked on flooding or extreme heat and climate change or resilience. The professions of these experts are academicians (3 people), municipality employees (2 people), private sector employees (2 people). The names and status information of the experts were kept anonymous, thus eliminating the possibility of being influenced by other people or persons. In the study, a total of 4 pair-wise questionnaires, 2 for disaster risks and 2 for vulnerability, were created (see Appendix A). As a result of this questionnaire study, experts in different fields analyzed each indicator.

The data obtained from the questionnaires is processed as described in the methodology chapter the weight of each value was calculated. At this stage, due to the limited number of indicator values, Excel is used instead of Super Decision program, which is designed to be used in very complex processes.

As mentioned in the previous chapters, AHP analyses have been conducted with seven experts. These experts have expertise in one or more of the keywords: climate change, flooding, extreme heat or vulnerability (Table 4.1).

Table 4.1 Expert Information of AHP survey.

Expert No	Education	Area of Profession	Years of Experience
E1	PhD	Academics-Planner	10+
E2	PhD	Academics-Planner	5-10
E3	PhD	Engineer	5-10
E4	Master	Academics-Architect	5-10
E5	Master	Engineer	0-4
E6	Bachelor’s	Urban Planner	5-10
E7	Bachelor’s	Urban Planner	0-4

In this method used to determine the weights of 8 main indicators, Pair-wise Comparison Matrices for floods (Table 4.2) and extreme heat (Table 4.3) were first created.

Table 4.2 Flood-Pair-wise Comparison Matrix

Factors	LU	GS	BC	SNQ	PD	VB	ES	DRL
Land Use	1	1 3/4	2 5/6	3 3/8	3 5/7	3 2/5	2 1/7	2
Green Spaces	4/7	1	3	3 2/9	2 5/6	4 2/3	2 2/5	1
Building Condition	1/3	1/3	1	1 1/6	3	2 7/9	1 1/2	1 1/5
Street Network Quality	2/7	1/3	6/7	1	4 1/2	3 1/6	3 2/3	2
Population Density and Changes	1/4	1/3	1/3	2/9	1	2 1/2	1 1/3	1
Disadvantaged Population	2/7	2/9	1/3	1/3	2/5	1	3/4	2
Economic Status	1/2	3/7	2/3	2/7	3/4	1 1/3	1	1/2
Disaster Related Risk Level	1/2	1	5/6	1/2	1	1/2	2	1

Table 4.3 Extreme-Pair-wise Comparison Matrix

Factors	LU	GS	BC	SNQ	PD	VB	ES	DRL
Land Use	1	1 1/2	1 2/9	2	1 2/3	1 1/5	2 1/5	4 4/5
Green Spaces	2/3	1	2 3/8	3 4/9	2 1/6	3 2/3	2 2/5	1
Building Condition	5/6	3/7	1	1 1/6	1 1/7	2 7/9	1 3/4	1 4/5
Street Network Quality	1/2	2/7	6/7	1	2 1/2	2 1/6	1 1/6	2 4/5
Population Density and Changes	3/5	1/2	7/8	2/5	1	2 1/2	1 1/3	3 4/9
Disadvantaged Population	5/6	2/7	1/3	1/2	2/5	1	5/7	2 2/3
Economic Status	1/2	3/7	4/7	6/7	3/4	1 2/5	1	1/2
Disaster Related Risk Level	1/5	1	5/9	1/3	2/7	3/8	2	1

These tables indicate the priority of each indicator in the total target. For the ranking, the values have been normalised and re-presented in the range 0-1 (Table 4.4, Table 4.5). For the survey to be valid, the consistency of the normalised ranking of importance produced had to be less than 0.10. In this study, the consistency index value was 0.890 for the flood survey and 0.892 for extreme heat. This means that the survey is valid. Therefore, the AHP analysis can be proceeded.

Table 4.4 Flood-Normalized Pair-wise Comparison Matrix

Factors	LU	GS	BC	SNQ	PD	VB	ES	DRL
Land Use	0.266	0.323	0.287	0.336	0.217	0.176	0.145	0.186
Green Spaces	0.153	0.186	0.297	0.319	0.166	0.241	0.162	0.093
Building Condition	0.094	0.064	0.102	0.115	0.170	0.144	0.099	0.112
Street Network Quality	0.079	0.058	0.088	0.099	0.261	0.164	0.248	0.186
Population Density and Changes	0.072	0.066	0.035	0.022	0.059	0.132	0.090	0.091
Disadvantaged Population	0.078	0.040	0.037	0.031	0.023	0.052	0.052	0.193
Economic Status	0.124	0.078	0.069	0.027	0.044	0.068	0.068	0.046
Disaster Related Risk Level	0.133	0.186	0.085	0.050	0.059	0.025	0.135	0.093

Table 4.5 Extreme Heat-Normalized Pair-wise Comparison Matrix

Factors	LU	GS	BC	SNQ	PD	VB	ES	DRL
Land Use	0.196	0.275	0.155	0.207	0.168	0.080	0.174	0.267
Green Spaces	0.134	0.188	0.304	0.357	0.219	0.242	0.191	0.055
Building Condition	0.161	0.079	0.128	0.119	0.116	0.184	0.138	0.101
Street Network Quality	0.098	0.054	0.111	0.103	0.250	0.143	0.094	0.156
Population Density and Changes	0.118	0.087	0.112	0.042	0.101	0.168	0.106	0.191
Disadvantaged Population	0.162	0.051	0.046	0.048	0.040	0.066	0.057	0.147
Economic Status	0.090	0.078	0.074	0.087	0.076	0.092	0.080	0.028
Disaster Related Risk Level	0.041	0.188	0.070	0.037	0.029	0.025	0.159	0.055

The weighting of the normalised values is completed with equation (2) (Table 4.6). When the weighting results are analysed, it is seen that similar results are obtained at most points with the literature. It is noticeable that the most important indicator for flooding (table xx) is Land Use (24%) and the least important indicator is Disadvantaged Population (6%). In the weighting for extreme heat weather, the most important indicator is Green Spaces (21%) and the least important indicators are Economic Status (8%), Vulnerable People (8%) and Disaster Raleted Risk Level (8%).

Table 4.6 Indicator Weights by Hazard

Indictors	**FLOOD**	**EXTREME HEAT**
	Criteria Weights	**Criteria Weights**
Land Use	0.2421	0.1903
Green Spaces	0.2023	0.2112
Street Network Quality	0.1479	0.1283
Building Condition	0.1125	0.1262
Disaster Related Risk Level	0.0958	0.1158
Population Density and Changes	0.0708	0.0771
Economic Status	0.0655	0.0756
Disadvantaged Population	0.0632	0.0756

Since the consistency index value of the survey is less than 0.10(0.890 for flood and 0.892 for extreme heat), this AHP analysis is valid. Therefore, these weights of the main indicator groups determined by the AHP method were used in the vulnerability index.

4.2 Spatial Analysis of Disaster Risk Level

First, areas with a high risk of flooding and extreme heat weather were identified in this context. The vulnerability analysis under the exposure heading includes these areas and the results of this analysis (values).

4.2.1 Flood Disaster Risk Analysis

Flood disaster risk, which can be summarised as the probability of flood disasters, has been addressed by rainfall analysis and flood analysis in the study area.

4.2.1.1. Extreme Rainfall Analysis

This analysis uses; annual average precipitation data, slope and elevation data for the central districts of Izmir. Open data published by MGM and WorldClim are used in the analysis. At the end of the analysis, the risk was graded and mapped in 5 degrees.

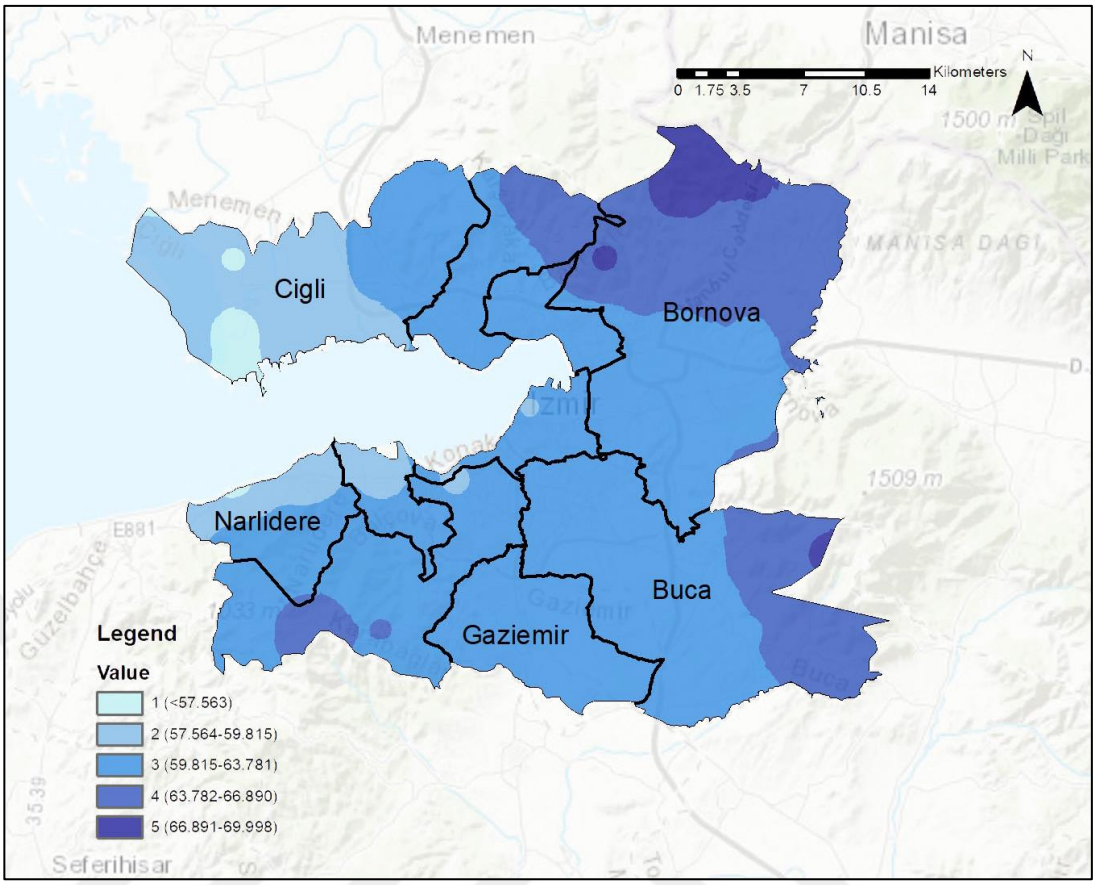

Figure 4.1 Izmir Metropolitan Districts Extreme Precipitation Risk Level

The risk of flood events occurring in Izmir every year is higher in the higher elevations and rural areas of the city. On the other hand, it was seen that the risk levels of the important centers of the city were also relatively high (Figure 4.1).

4.2.1.2. Flood Risk Analysis

This analysis considers active or dried streams, watercourses, and lakes in the central Izmir districts as the primary elements. A risk analysis has been made according to the alluvial soils around these areas, flood areas and the areas defined as risky by the municipality. Data published by Izmir Metropolitan Municipality and WorldClim are used in the analysis. At the end of the analysis, the risk was graded and mapped in 5 degrees (Figure 4.2).

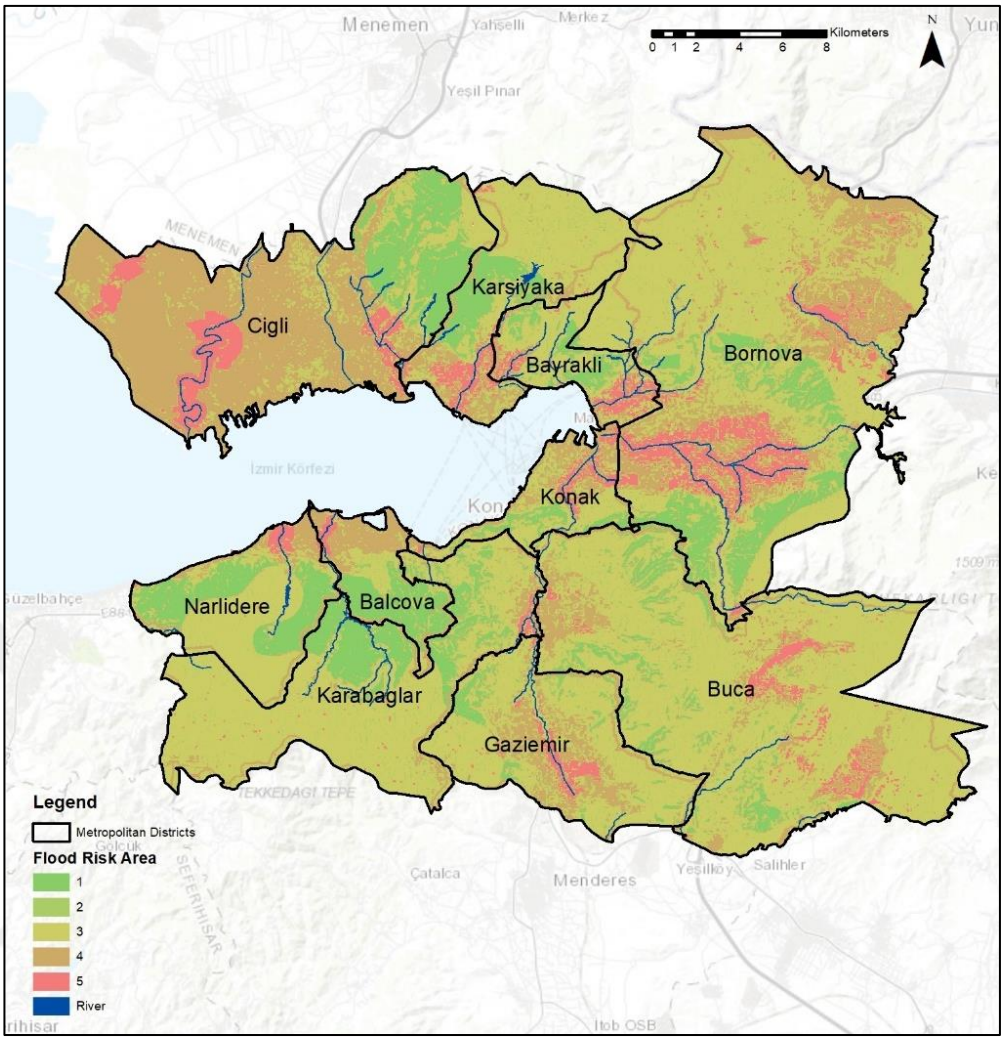

Figure 4.1 Flood Risk Level of Izmir Metropolitan Districts

The streams in Izmir city centre are an important part of a sustainable ecosystem, contributing to biodiversity. On the other hand, untreated streams within the urban centres of Izmir increase the likelihood and severity of flood disasters. In this context, the most risky districts are Çiğli, which hosts the Organised Industrial Zone, and Karşıyaka, which is on the agenda with reclamation projects in the built-up texture.

4.2.2 Extreme Heat Disaster Risk Analysis

UHI and average air temperatures is analysed in this section where the risks that cause or increase the impact of extreme temperatures are compiled.

4.2.2.1. Average Temperature Analysis

In this analysis, annual temperature data for the central districts of Izmir are used. Open data published by MGM and WorldClim are used in the analysis. As a result of the analysis, the risk was graded and mapped in 5 degrees (Figure 4.3).

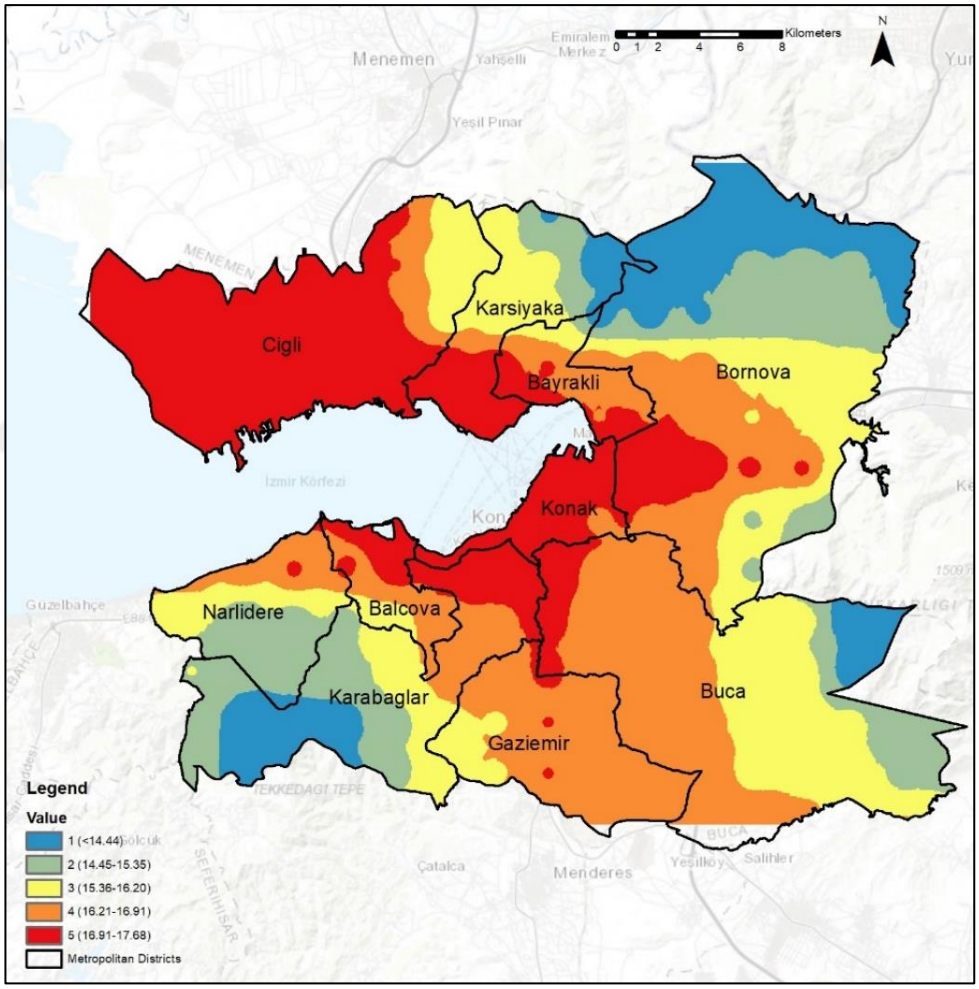

Figure 4.2 Izmir Metropolitan Districts Average Temperature Risk Level

The average annual temperature of Izmir varies between 14 and 17 degrees. The districts with the highest average temperature are Çiğli, Karşıyaka and Konak districts.

4.2.2.2. Urban Heat Island Analysis

In this analysis, the UHI effect in Izmir Metropolitan districts has been analysed. The most pronounced impact of climate change on urban life is the urban heat island effect due to temperature increases. Urban heat island; it is defined as the tendency of the city to create its own microclimate with a higher temperature than its surroundings due to its radiation and geometric properties (Oke, 1976; Oke, 1982). It is mainly related to the urban heat island effect, the form of construction and the materials used on surfaces. The reflection of heat in the structured areas by holding more than natural surfaces changes the temperatures felt day and night. While the stress of urban heat island harms human health and the comfort of life in the city, it can increase energy demand (Perini and Rosasco, 2013). In this context, UHI, which has a direct connection with extreme heat, is analysed by LST calculation method. In this study, Landsat 8 satellite images with a cloudiness value below 15% between 2014 and 2024, published by USGS as open source, is used.

In this thesis, the TIR bands 10 and 11 were used to estimate the brightness temperature and OLI spectral bands 4 and 5 were used to generate NDVI of the Izmir Metropolitan distircts. LST is calculated by applying a structured mathematical algorithm, the Split Window (SW) algorithm. The computational processes and equations of LST from satellite images are well introduced in the literature (Weng et al., 2004; Li, Z et al., 2013).

In this process, the first step of the algorithm is to enter Band 10. After entering Band 10, in the background, the tool uses formulas from the USGS website to get above the atmospheric (TOA) spectrum. Brightness (Lλ):

$$L\lambda = M_L * Q_{cal} + A_L - O_i \tag{3.10}$$

Lλ means TOA spectral radiation, ML represents the band-specific multiplicative rescaling factor, Qcal is the Band 10 image, AL is the band-specific additive rescaling factor, and Oi is the correction for Band 10. The next step is the Conversion of Brightness to At-Sensor Temperature. Brightness to At-Sensor Temperature (BT):

$$BT = \frac{K_2}{ln\left[\left(\frac{K_1}{L\lambda}\right) + 1\right]} - 273.15 \tag{3.11}$$

BT is the temperature of satellite brightness in Kelvin, Lε, TOA means spectral radiation, and K1 and K2 are constants for band-specific thermal transformations. 273.15 is removed to convert the process to Celsius. In the continuation of the process, NDVI is calculated for emicition correction. Normal Difference Vegetation (NDVI) index can be used to extract the general vegetation state. By calculating this index, the power of release can be calculated. (NDVI):

$$NDVI = \frac{NIR(Band\ 5) - R(Band\ 4)}{NIR(Band\ 5) + R(Band\ 4)} \tag{3.12}$$

where NIR represents the near-infrared band (Band 5) and R represents the red band (Band 4).

For emisivite correction, Proportion of Vegetation is calculated in a way associated with NDVI. Proportion of Vegetation (P_v):

$$P_v = \left(\frac{NDVI - NDVI}{NDVI_{min} + NDVI_{max}}\right)^2 \tag{3.13}$$

The land surface emissivity (LSE (ε)) must be known in order to estimate LST. The land surface emissivity LSE (ε):

$$\varepsilon_\lambda = \varepsilon_{v\lambda} P_V + \varepsilon_{s\lambda}(1 - P_V) + C_\lambda \tag{3.14}$$

where ε_v and ε_s are the vegetation and soil emissivities, respectively. And

$$\varepsilon_\lambda = \begin{cases} \varepsilon_{s\lambda}, & \leq NDVI_v, \\ & NDVI < NDVI_s, \\ \varepsilon_{v\lambda} P_V + \varepsilon_{s\lambda}(1 - P_V) + C_\lambda & NDVI_s \leq NDVI \\ \varepsilon_{s\lambda} + C_\lambda & NDVI > NDVI_v \end{cases} \tag{3.15}$$

The land surface emissivity LSE (ε) is calculated differently according to the results of NDVI. This is because the results of NDVI describe different surfaces.

The last stage of agorıthm ıs calculate lst or emissivity correction land surface temperature LST_s:

$$LST_s = \frac{BT}{\left\{1 + \left[\left(\frac{\lambda BT}{\rho}\right) * ln\varepsilon_\lambda\right]\right\}} \tag{3.16}$$

where Ts is the LST in Celsius (∘ C, (2)), BT is at-sensor BT (∘ C), λ is the wavelength of emitted radiance (for which the peak response and the average of the limiting wavelength (λ = 10.895) will be used), $\varepsilon\lambda$ is the emissivity calculated in (6), and

$$\rho = h\frac{c}{\sigma} = 1.4388 * 10^{-2}\ m\ K, \tag{3.17}$$

where σ is the Boltzmann constant (1.38 × 10−23 J/K), h is Planck's constant (6.626 × 10−34 J s), and c is the velocity of light (2.998 × 108 m/s)

The ultimate LST we obtain here is the land surface temperature. This process is repeated eleven times (2014, 2015, 2016, 2017, 2018, 2019, 2020, 2021, 2022, 2023, 2024 images) and LST data is finalized by calculating the average of the seven images of the study area. The LST values are rated in 5 degrees to create the UHI Risk map (Figure 4.4).

When the UHI effect of Izmir is analysed, it is seen that the districts with the highest effect are Çiğli and Karşıyaka Districts. It is seen that the UHI effect increases in densely built-up areas and areas with low vegetation covarage value and the effect decreases due to the reflective effects of the sea in the coastal areas.

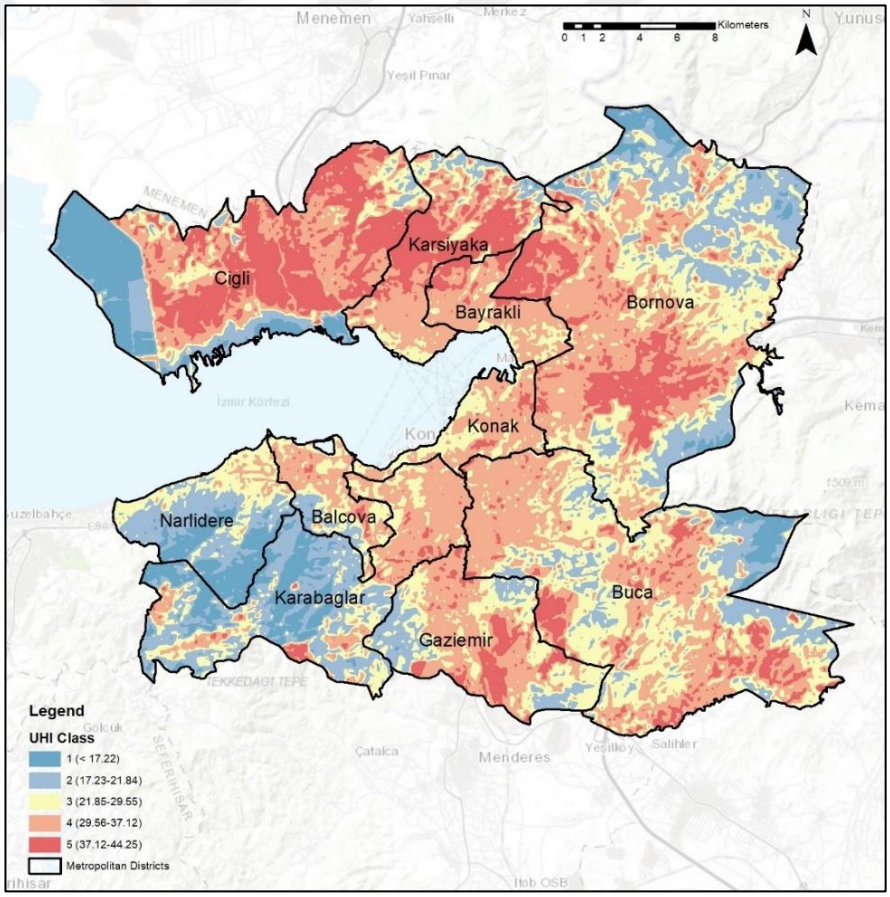

Figure 4.3 Izmir Metropolitan Districts UHI Risk Level

The urban heat island effect is seen to increase in the built-up areas of the city as well as in the non-forested dry peripheral areas. The low UHI effect of the coastal area in Izmir is due to the reflection of the sea on satellite images. Among the districts, Karşıayaka district is the most intense district where the UHI effect is observed with its natural features and structure of settlement. Nevertheless, the high urban heat effect in Izmir city centre integrated with the coast and the average surface temperature between 30-37 degrees increase the risk of extreme heat-related disasters.

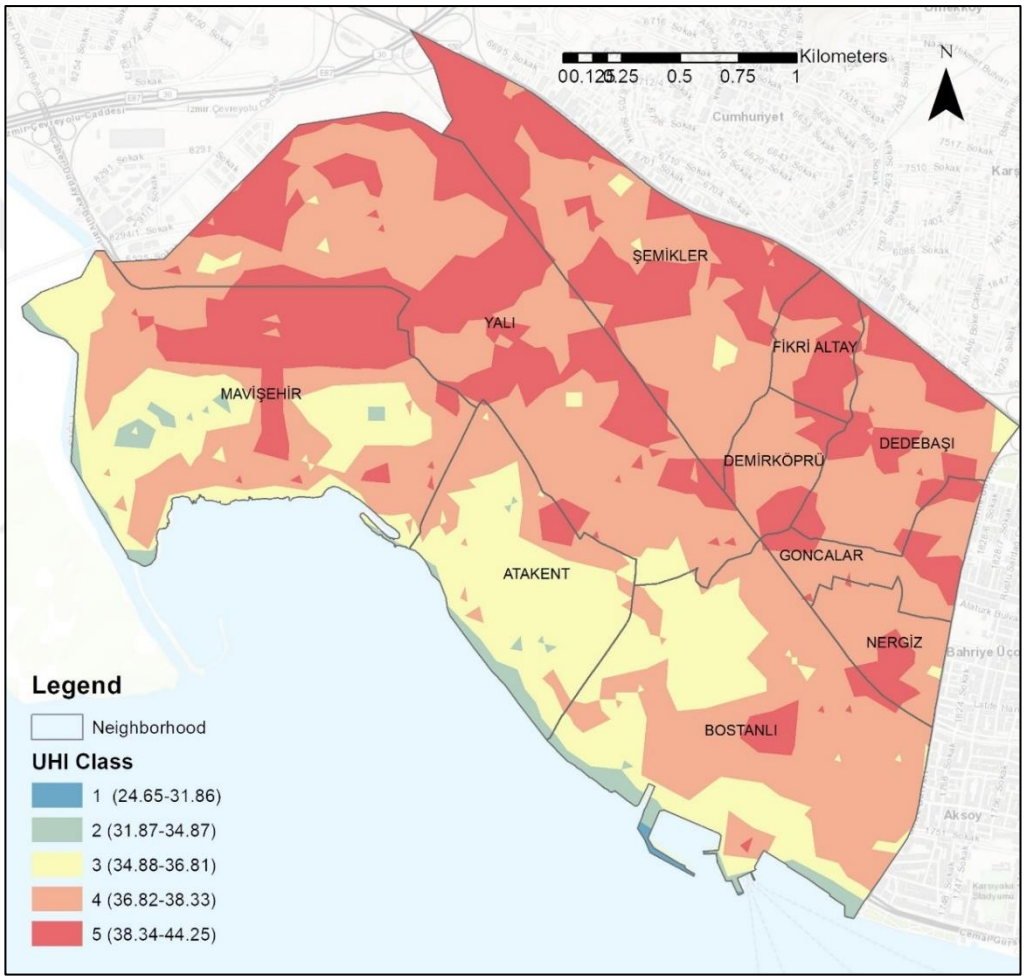

Figure 4.4 Karşıayaka Districts 2. Spatial Planning Region UHI Risk Level

UHI is one of the most important indicators of climate change. Hence, the urban heat island analysis is repeated in the second scale of the study, the district of

Karşıyaka (Figure 4.5). In this analysis, which has similar results to the Izmir scale, it is seen that the surface temperature is at dangerous limits in the Mavişehir neighborhood with its high-rise buildings with large floor areas, and in the northern neighborhoods, which are noteworthy for their building density and lack of green spaces.

4.2.2.3. Air Quality Analysis

In this analysis, wind and air quality and important gas data for the central districts of Izmir are used. Open data published by IZMM and WorldClim are used in the analysis. As a result of the analysis, the risk was graded and mapped in 5 degrees (Figure 4.6).

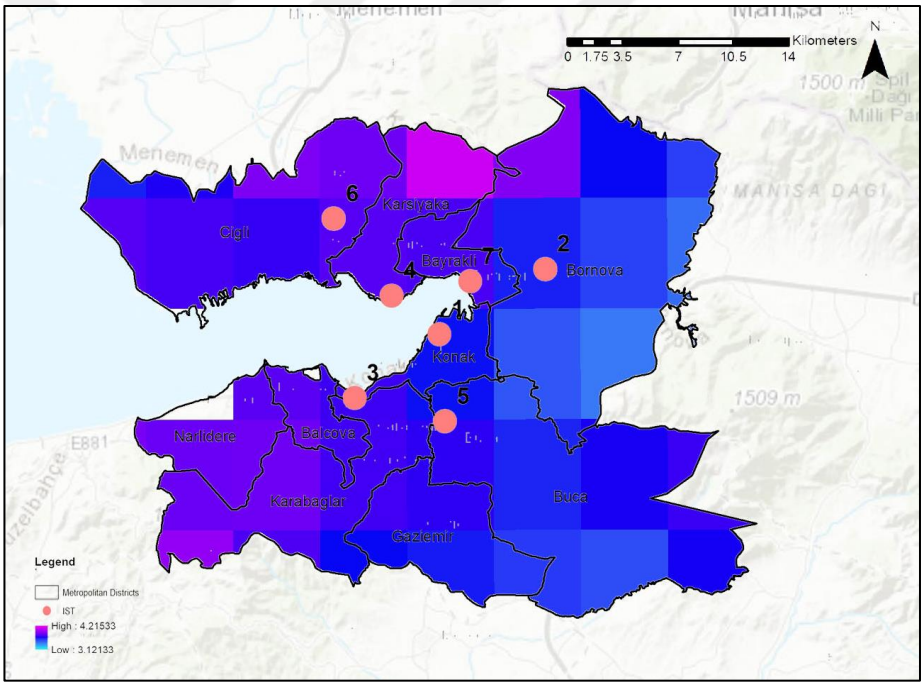

Figure 4.5 Metropolitan Scale Air Quality Risk Level

The highest risk areas in the classification according to the average wind speed are Bornova district and a part of Buca districts where the wind speed decreases. The fact

that the wind speed in Karşıyaka district is higher than the average of the area indicates that the risk level is low and there is a potential to cope with extreme heat. In addition, there are 9 stations in the whole Izmir city. While there are 7 stations in the study area, the others are located in Güzelbahçe and Bergama districts (Figure 4.6). According to the measurement values taken from this station in 2016, the riskiest station is Bayraklı district, which is station number 7 for PM10 gas and Çiğli district number 6 for SO2 gas. In this context, Karşıyaka district is also at risk in terms of air quality due to its location in the two most risky districts and wind speed Considering the total situation, it is understood that the area numbered 2 is the highest risk. (Table 4.7).

Table 4.7 Metropolitan Region Average Gas measurement results

Station Id	District	PM10	SO2	Total
1	KONAK	40.611	8.791	25
2	BORNOVA	43.103	11.282	**27**
3	KONAK-KARABAĞLAR	33.798	10.558	22
4	KARŞIYAKA	29.207	11.418	20
5	BUCA	34.068	11.308	23
6	ÇİĞLİ	35.828	**13.004**	24
7	**BAYRAKLI**	**44.107**	9.462	27

4.2.3 Sub-Indicator Vulnerability Analysis- Land Use

The Land Use indicator analyses the current land use in terms of vulnerability to floods and extreme heat. Land use types and land use change are included in the vulnerability analysis as considered in the literature. Within the scope of the thesis, the sub-indicators in this section were handled in different ways for both disasters (Table 4.8) and the analysis evaluations were made according to these approaches. Among these indicators preferred within the scope of the thesis, land use distribution data were obtained at both scales and analysed. However, since past data could not be used at the district scale in the land use change analysis, the analysis was carried out only at the Izmir scale.

Table 4.8 Sub-Indicator of Land Use and Vulnerability Phenomena

Main Indicator	Sub-Indicator	Flood Vulnerability	Extreme Vulnerability
		Vulnerability Phenomena	Vulnerability Phenomena
Land Use	Commercial	EXPOSURE	EXPOSURE
	Industrial	**EXPOSURE**	**SUSCEPTIBILITY**
	Land Use Changes	SUSCEPTIBILITY	SUSCEPTIBILITY
	Open Spaces	EXPOSURE	EXPOSURE
	Public Infrastructure	**EXPOSURE**	**COPING CAPASITY**
	Recreative	**EXPOSURE**	**COPING CAPASITY**
	Residential	SUSCEPTIBILITY	SUSCEPTIBILITY

4.2.3.1. Land Use

Land use types are the main elements that create and shape the dynamics of the city. The basic components of land use can be handled in different ways against flood and extreme heat disasters. The commercial areas evaluated in this thesis are considered as exposure for both disasters since they are the areas that increase pedestrian and vehicle mobility and Çiğli where the main business activities are located. Industrial areas attract attention with their economic development, large surface area and construction with different materials and they are evaluated differently in terms of flood and extreme heat vulnerability. Industrial areas are considered as exposure because they will cause economic losses in flood disasters and the recovery process will be long. They are considered as susceptibility in the context of extreme heat due to their structuring characteristics, being the main workplace located far from the urban settlement, energy consumption and production. When the Public Infrastructure areas are evaluated as gathering, rescue and emergency response areas, they are considered as coping capacity under the heading of extreme heat, and as exposure in flood disasters due to the damage they may cause to social knowledge. Similarly, open spaces and green spaces for recreational purposes are considered as exposure in flood disasters, while they are considered as coping capacity against extreme heat. Residential areas are described as susceptibility for both disasters since they harbour population and are a critical use during and after disasters. The land use analyses considered in this context are evaluated separately at Metropolitan and Planning

Region scales. In Land Use analysis, land use data for the metropolitan districts of Izmir are used. The land use map obtained from Izmir Metropolitan Municipality and Karşıyaka Municipality has been used in this analysis.

In the land use distribution analysis of Metropolitan Scale, it is seen that commercial and residential use is intensive in the city centre of Izmir. Industrial areas are concentrated in the north and north-east of the city. In the south and south-west of the city, there are more public infrastructure and green spaces (Figure 4.7). In this context, the most vulnerable districts against flood disasters are Karşıyaka, Konak and Çiğli districts. In these districts, industrial areas, residential areas and commercial areas are denser than the other districts of the city. Similarly, Karşıyaka and Konak districts are the most vulnerable to extreme heat disasters. In these districts, the presence of green spaces and the low surface area of public infrastructre areas stand out. The assessment is based on the interaction of each spatial land use type with vulnerability. For example, industrial areas are considered within the exposure phenomenon for flooding, susceptibility for residential area and exposure for commercial and public infrastructure. In this context, the presence of these elements is directly proportional to vulnerability. While calculating the elements affecting vulnerability in the selected vulnerability formula, the presence of more than one of the directly proportional factors affecting vulnerability increases the level of vulnerability. In this thesis, while assessing vulnerability to flood disaster, areas with different land uses are considered as more vulnerable areas. For example, industrial areas are considered as exposure and are concentrated in the districts of Çiğli, Bornova and Gaziemir within the city. However, since the districts that do not have a high density of commercial, residential and public infrastructure in these areas are Balçova and Gaziemir districts, the most vulnerable districts are Çiğli, Bayraklı, Konak and Karşıyaka districts. In the same way, when evaluated against extreme heat weather, it is accepted that the vulnerability of Balçova district has decreased as the recreational areas in Bornova district, which stands out with its industrial areas, increase the coping capacity.

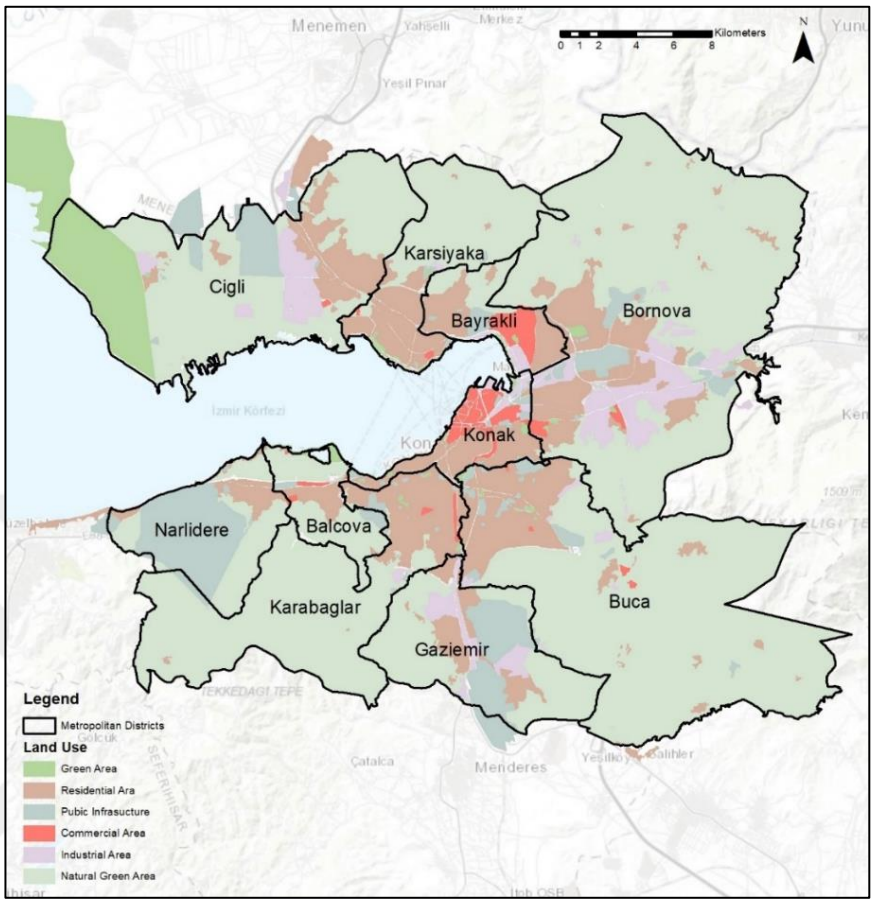

Figure 4.6 Izmir Metropolitan Districts Land Use Distribution

Land use distribution analysis in Karşıyaka district is based on the building unit and the use of ground floor is taken into consideration. In this region, it is seen that the ground floor use is mostly commercial areas and generally located on the roadside of the building island, while the residential area is concentrated in the middle of the neighborhood (Figure 4.8). It is seen that the active and usable green space is considerably low and there is no industrial area in the region. The most vulnerable areas of the region to floods are Bostanlı, Nergiz and Yalı neighborhoods. Due to the presence of public infrastructure and recreational areas, the most vulnerable areas to extreme heat are not Bostanlı and Yalı neighborhoods, but Nergiz Şemikler, Dedebaşı and Goncalar neighborhoods. As in the disaster of floods, the most vulnerable areas to extreme heat are neighborhoods with dense commercial and residential areas but low

amount of open spaces and public areas. In this context, the most vulnerable neighborhoods to extreme heat are Nergiz, Dedebaşı and Goncalar neighborhoods. As a result, the most vulnerable neighborhoods for both disasters are Nergiz, Dedebaşı and Goncalar neighborhoods.

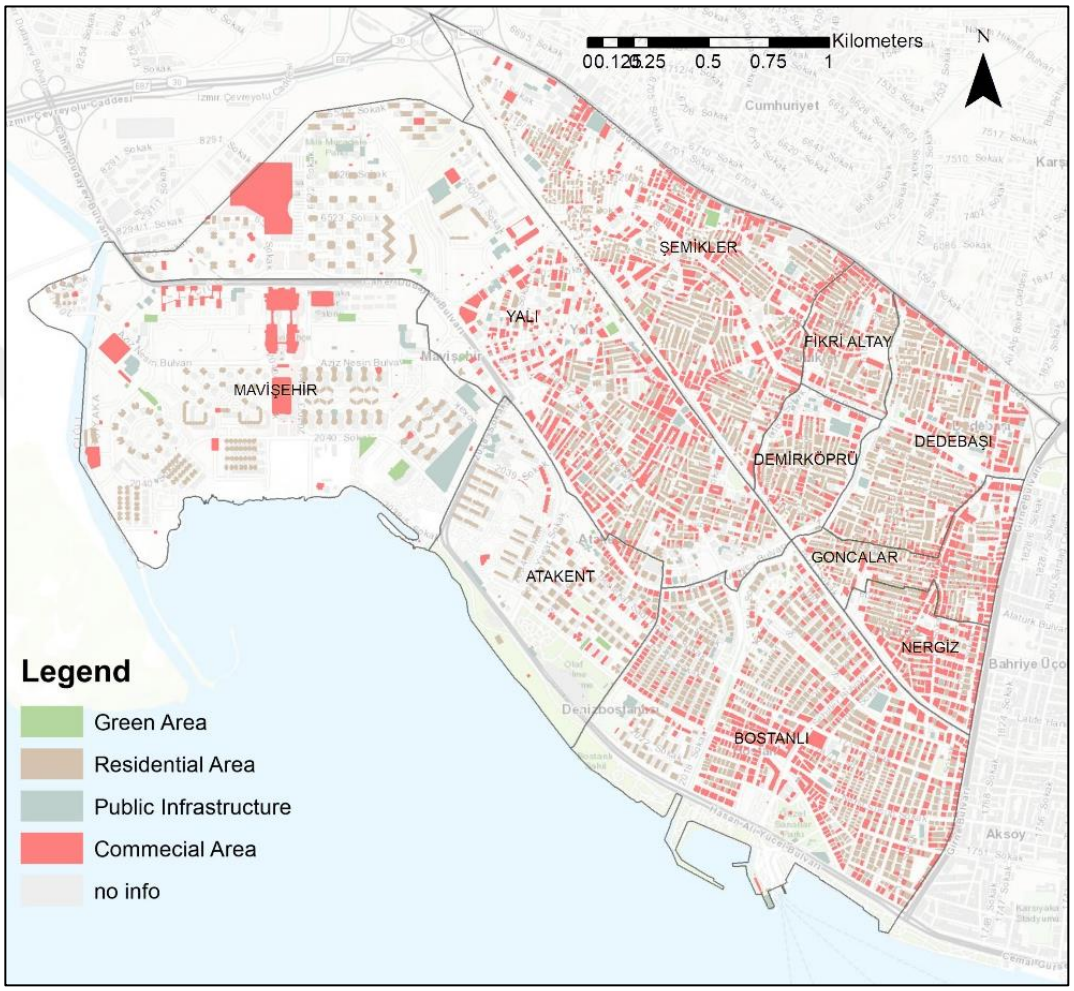

Figure 4.7 Karşıyaka 2nd Spatial Planning Region Structures by Land Use Types

4.2.3.2. Land Use Change Over Time

Land use change defines the urbanisation character of a city and its connection with the environment. The city, which develops and sprawls in natural areas, becomes vulnerable to risks, and is therefore considered as susceptibility in the context of

vulnerability. This analysis was conducted only at the Metropolitan scale due to data accuracy and availability of publishable data. The land use change analysis of Izmir, which has been preferred as a settlement area from ancient times to the present day, has been produced from the 1990, 2000, 2006, 2012 and 20018 land use status data published by CORINE (Figure 4.9).

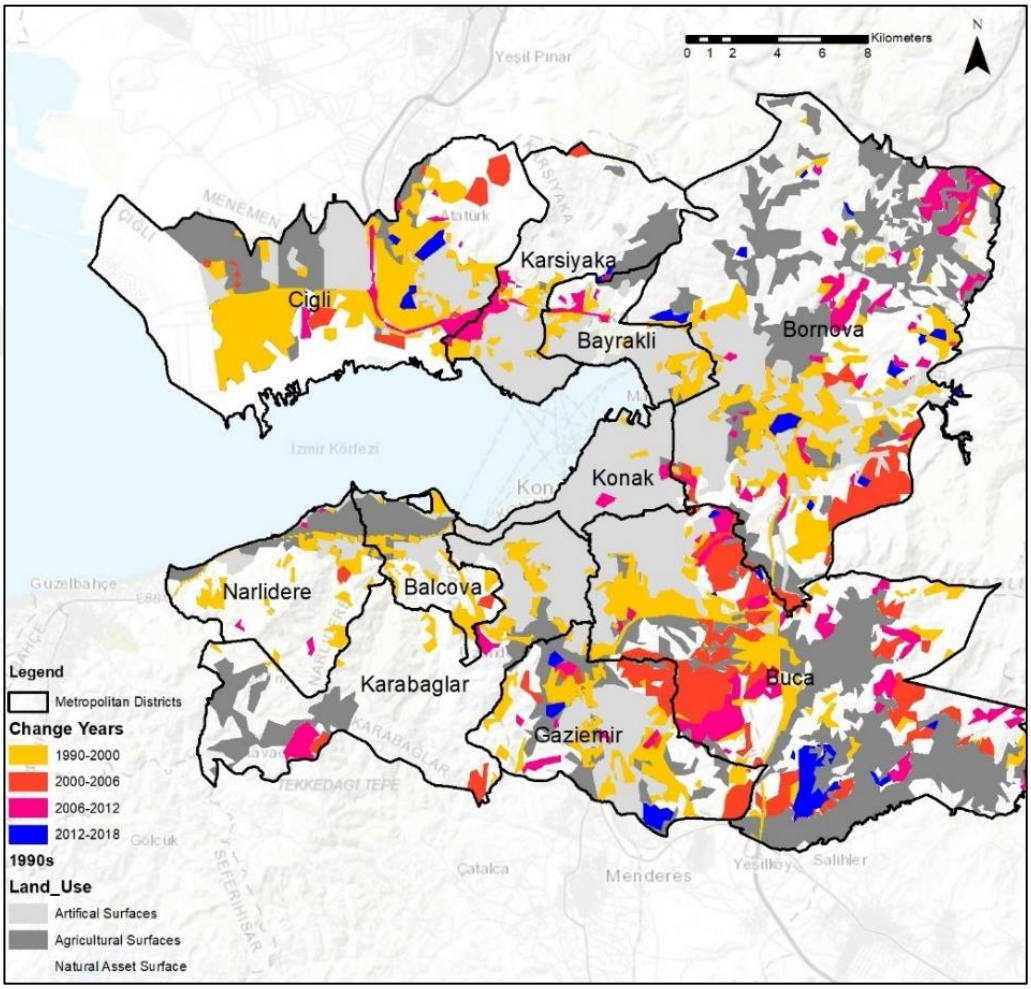

Figure 4.8 Land Use Change (1990-2000-2006-2012-2018)

In 1990, the majority of the districts of today's city centre were already urbanised. Izmir's urbanisation accelerated between 2000 and 2006, during which time Agriultural Surfaces began to be occupied. Another important six years of urban sprawl is between 2006 and 2012. After this period, there is not a great difference in land change. Since the change in land use status and urban sprawl brought about the

concretisation of existing natural areas, it is considered as susceptibility to flooding. The most vulnerable districts of the city in this regard are Buca and Çiğli districts.

4.2.4 Sub-Indicator Analysis of Green Spaces

In the analysis of green spaces, the ratio of the green space and the green spaces that should be preserved or have a natural character are analysed (Table 4.9). Natural green spaces are natural resources that build a city's relationship with the environment and environmental balance, and are non-renewable or take centuries to regenerate. In this context, these areas have a critical vulnerability level against floods and extreme temperatures. Natural areas are considered to be exposed to floods due to the side events such as landslides brought about by flood disasters, while they are considered to be susceptible to disasters such as fire, which can increase the effect of extreme heat weather or create suitable conditions for its occurrence. Urban green spaces are evaluated in a similar way. However, urban green space is considered as coping capacity due to its contribution to an urbanised environment. It is more meaningful to evaluate the ratio of green space to the urbanised area rather than the size of the green space in the city in order to determine the effect of these areas on vulnerability.

Table 4.9 Sub-Indicator of Green Spaces and Vulnerability Phenomena

Main Indicator	**Sub-Indicator**	**Flood Vulnerability**	**Extreme Vulnerability**
		Vulnerability Phenomena	**Vulnerability Phenomena**
Green Spaces	Green Spaces Ratio	COPING CAPASITY	COPING CAPASITY
	Natural Green Asset	**EXPOSURE**	**SUSCEPTIBILITY**

In this main indicator section, natural assest analysis could only be analysed at the Izmir scale since it is not available at the Karşıyaka scale. In this analysis, the land use map obtained from Izmir Metropolitan Municipality and OSM open database data have been used.

4.2.4.1. Natural Green Assest

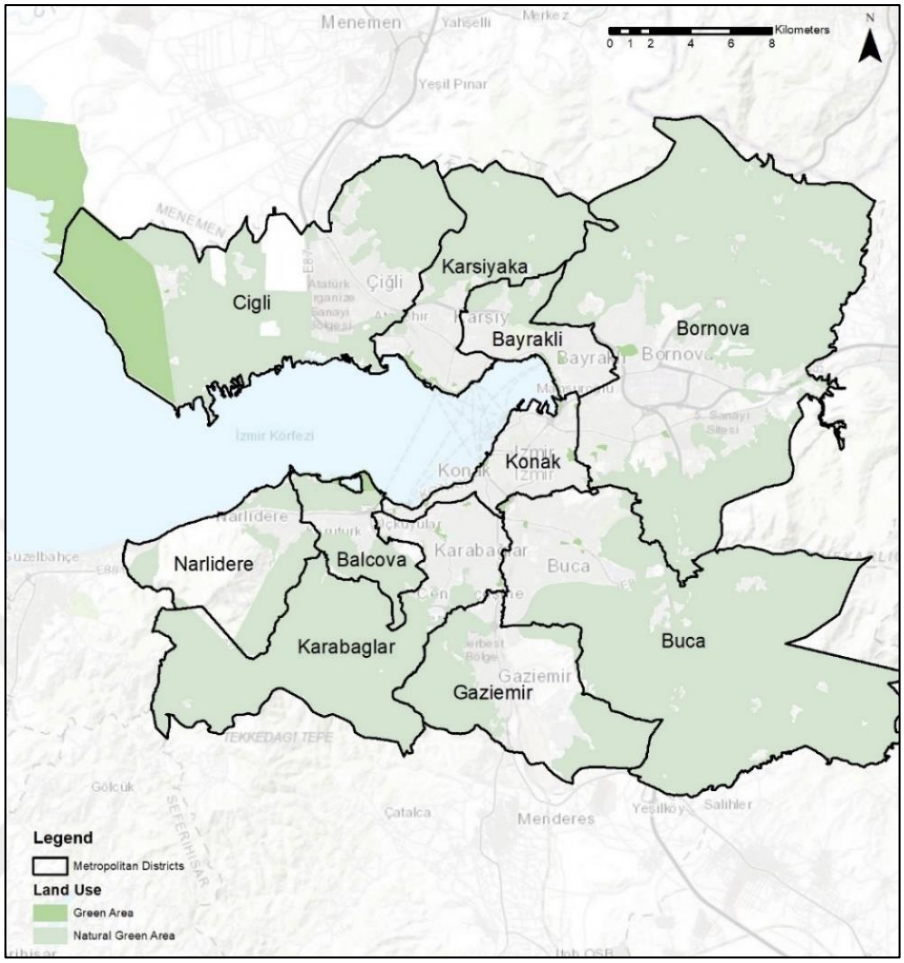

Figure 4.9 Green Spaces and Natural Green Assets of Izmir Metropolitan Districts

Although Izmir is known for its rapid urbanisation, it also has natural areas. There are 54604 ha of natural green spaces on the periphery of the city (Figure 4.10). In the north-west of the city there are areas and wetlands to be preserved. In this regard, the most vulnerable districts of the city are Buca, Bornova, Çiğli, Karşiyaka and Karabağar districts.

4.2.4.2. Green Spaces Ratio

The highest percentage of green spaces is in Buca and Karabağlar districts and most of them are forests (Figure 4.11). The districts with the lowest urban green space ratio are Bayraklı and Narlıdere districts.

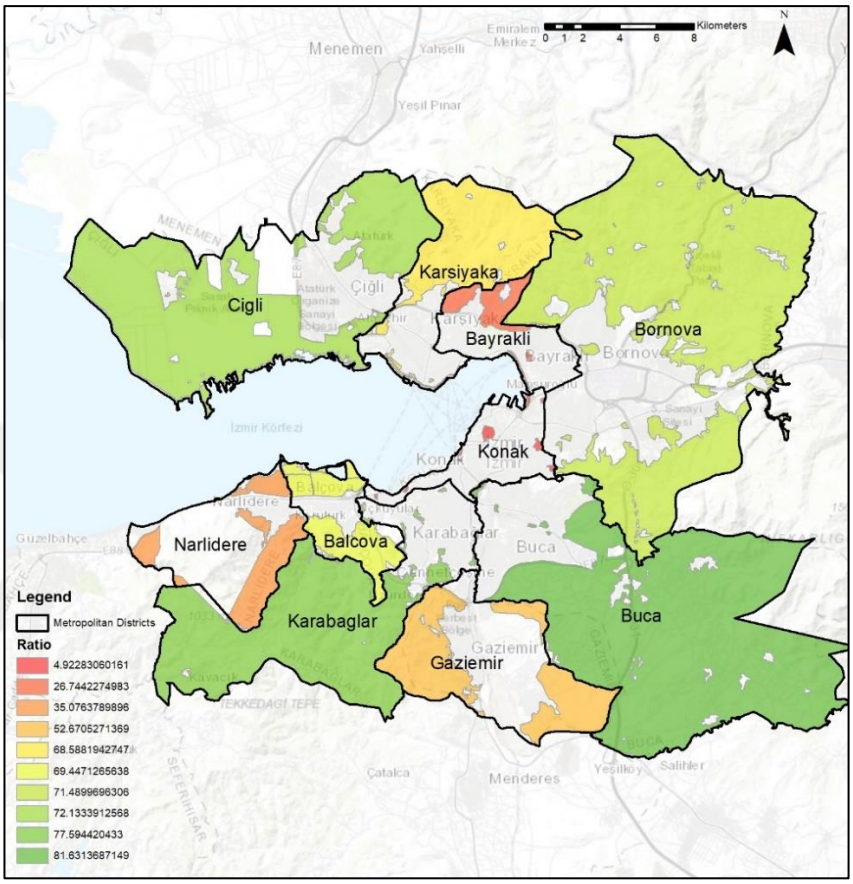

Figure 4.10 Green space Ratio of Metropolitan Scale

As seen in the metropolitan scale, the green space ratio is low in the planning region. The neighborhoods with the highest ratio of active green spaces are Ataşehir and Bostalı, while the neighborhoods with the lowest ratio are Şemikler, Nergiz and Goncalar. In this context, the most vulnerable neighborhoods are Şemikler, Nergiz and Goncalar neighborhoods (Figure 4.12).

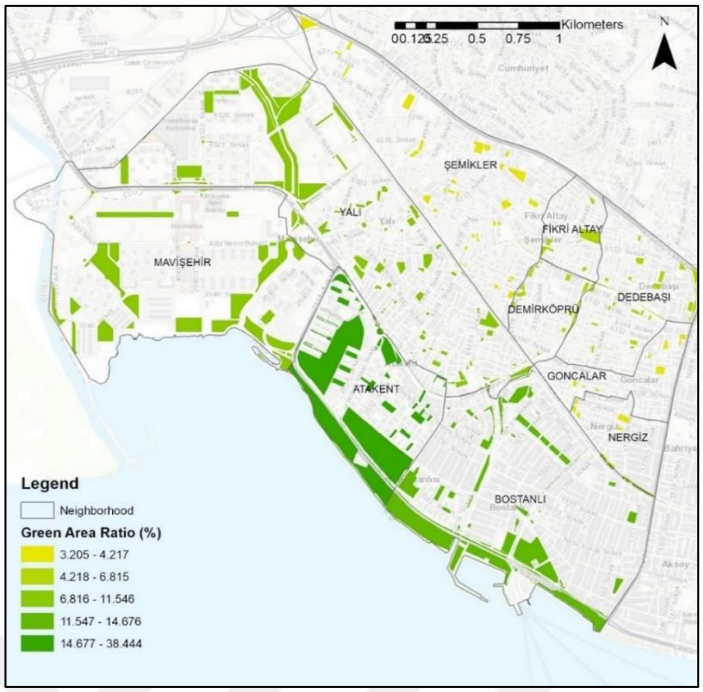

Figure 4.11 Green are Ratio of Planning Region Scale

4.2.5 Sub-Indicator Analysis of Building Condition

Building Condition analysis included the number of floors, building height, density and age of the buildings in the urban inventory (Table 4.10). As mentioned in the previous sections, building characteristics and condition are frequently analysed in the literature. In the researches, data such as number of building storeys, number of independent units, building material, building density, roof type and roof characteristics are used. Building material, which is one of the selected criteria within the scope of the thesis, has not been analysed due to the unavailability of the data. On the other hand, since there is no registration data on the age of the buildings for the entire city of Izmir, this analysis is conducted only at the scale of Planning Region. In this analysis, building data obtained from Izmir Metropolitan Municipality and registered building data obtained from Karşıayaka Municipality is used.

Table 4.10 Sub-Indicators of Builfing Condition and Vulnerability Phenomena

Main Indicator	Sub-Indicator	Flood Vulnerability	Extreme Vulnerability
		Vulnerability Phenomena	**Vulnerability Phenomena**
Building Condition	Building Age	SUSCEPTIBILITY	SUSCEPTIBILITY
	Building Density	**EXPOSURE**	**SUSCEPTIBILITY**
	Building Material	SUSCEPTIBILITY	COPING CAPASITY
	Number of Floors and Height	**SUSCEPTIBILITY**	**EXPOSURE**

4.2.5.1. Building Age

The age of the building is basically important in terms of reflecting the technology of the year the building was built, not needing to be maintained and repaired, and having equipments such as insulation. In this context, within the scope of the thesis, the building age is considered as susceptibility and evaluated on the Planning region scale due to the availability of data (Figure 4.13).

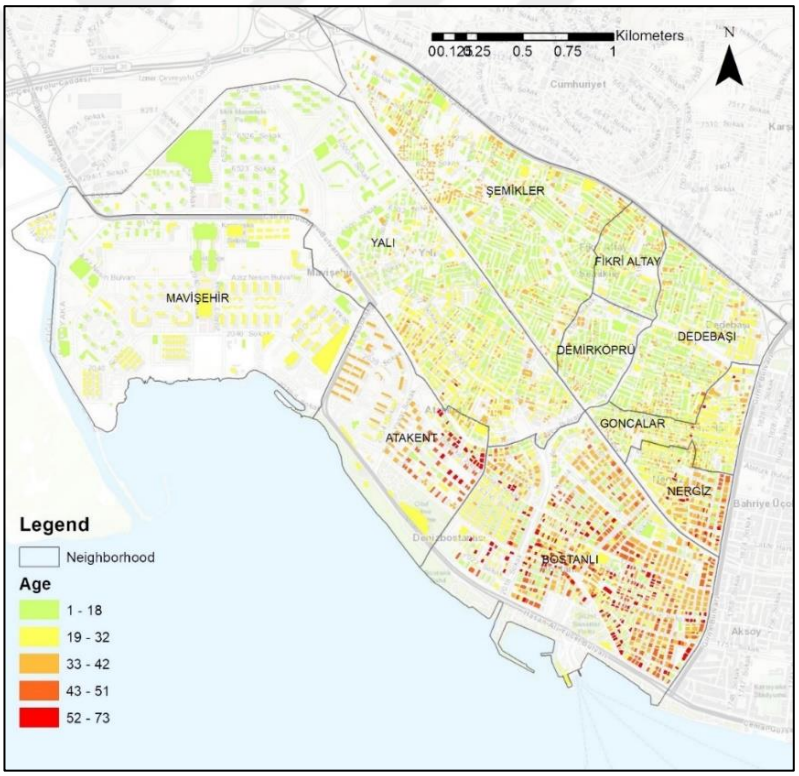

Figure 4.12 Building Age in Planning Region Scale

Although the average age of the buildings in the planning area is 22 years, there are also buildings with historical characteristics in Bostanlı neighborhood. Increasing the age of the building is important because it reduces the durability of the building and has the potential to put the assets it harbours at risk. In this context, Ataşehir, Bostanlı and Nergiz neighborhoods, which are located in the south of the area and have an average building age of 45 years, are the most vulnerable neighborhoods.

4.2.5.2. Building Density

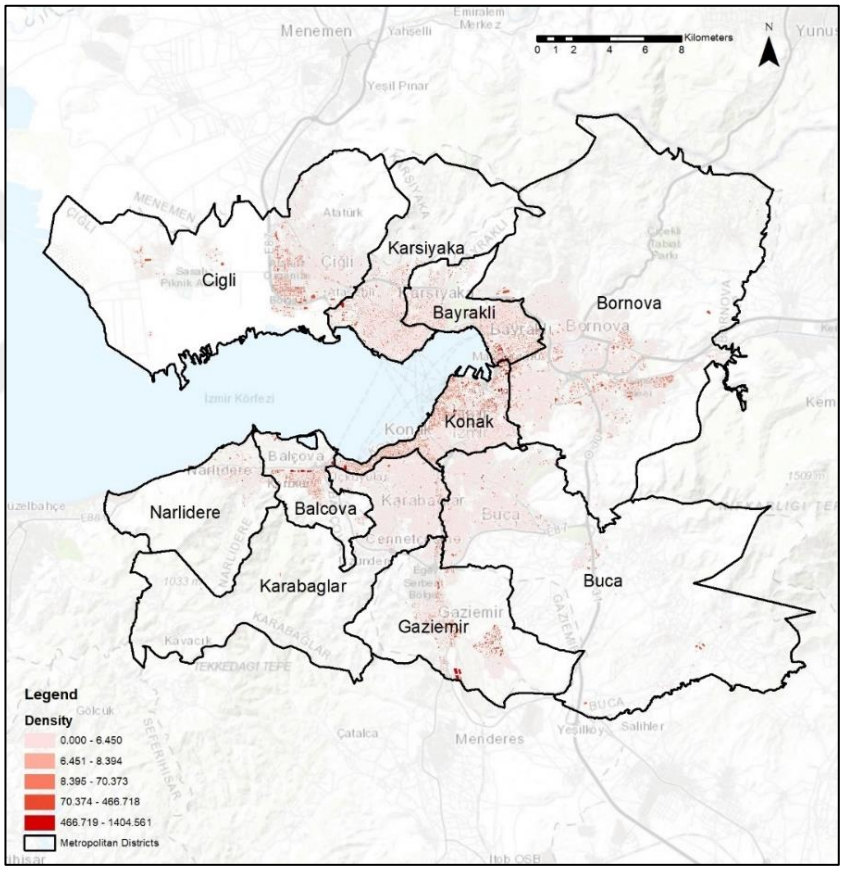

Figure 4.13 Building Density in Metropolitan Scale

Building density has an important place in the vulnerability literature due to the reasons such as concretisation, population density and mobility density. In flood

disasters, building density is considered as exposure because it increases the density of exposed people and values. While the proximity, relationship and density of buildings reduce energy consumption, they increase the amount of heat released and lead to changes in the perceived temperature. In this context, building density is considered as susceptibility against extreme temperatures. With this regard, analysis conducted firstly for the metropolitan scale (Figure 4.14). The districts with the highest building density in the metropolitan districts of Izmir are Konak, Karsiyaka and Karabağlar districts. It is also noteworthy that the building density is developed in parallel with the coast. In this context, the most vulnerable districts are Konak and Karsiyaka districts.

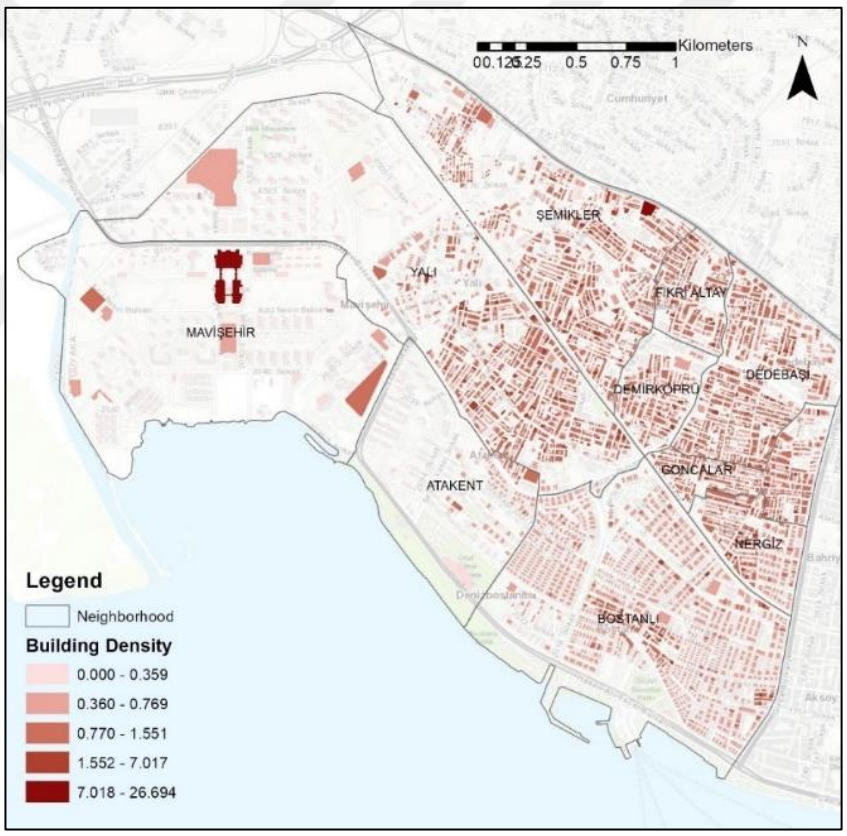

Figure 4.14 Building Density in Planning Region Scale

Unlike the metropolitan scale, building density in Karşıayaka planning region increases in the north of the district rather than the coastline (Figure 4.15). While the

Mavişehir neighborhood stands out due to its broad-based construction, dense construction is mostly seen in Nergiz, Goncalar and Dedebaşı neighborhoods. In this context, these are the most vulnerable neighborhoods.

4.2.5.3. Number of Floors and Height

The number of floors and height of the building is an important component used to measure vulnerability to flood and extreme heat disasters. Since low-rise buildings or ground floors or basements of buildings are directly affected by flood disasters, they are considered as exposure. In the case of extreme heat, the number of floors works in the opposite way. In high-rise buildings, heat accumulation is higher, so they produce and consume more energy, as well as the difficulty of evacuation of high-rise buildings is also a striking factor. In this context, building height is considered as susceptibility in the context of extreme heat.

The average number of floors of every type of building in Metropolitan region is 4 floors and 14 m. The highest buildings in the city are in Karşıyaka, Konak and Bayraklı districts, which are the northern districts of the city. Therefore, these districts are the most vulnerable districts (Figure 4.16).

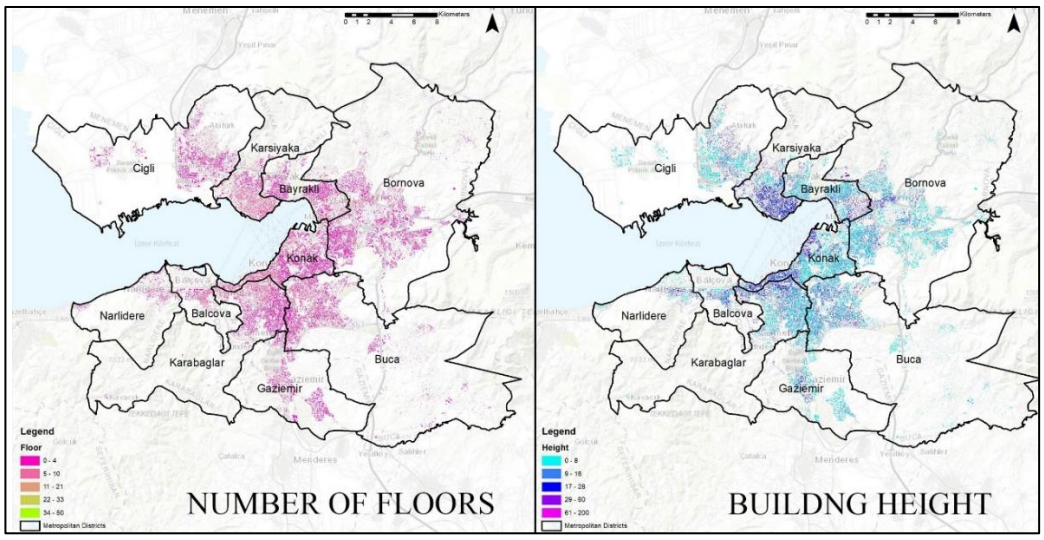

Figure 4.15 Building Number of Floors andHeight in Izmir Metropolitan Districts

The average number of floors of every type of building in Metropolitan region is 4 floors and 14 m (Figure 4.17). The highest buildings in the city are in Karşıyaka, Konak and Bayraklı districts, which are the northern districts of the city. Therefore, these districts are the most vulnerable districts.

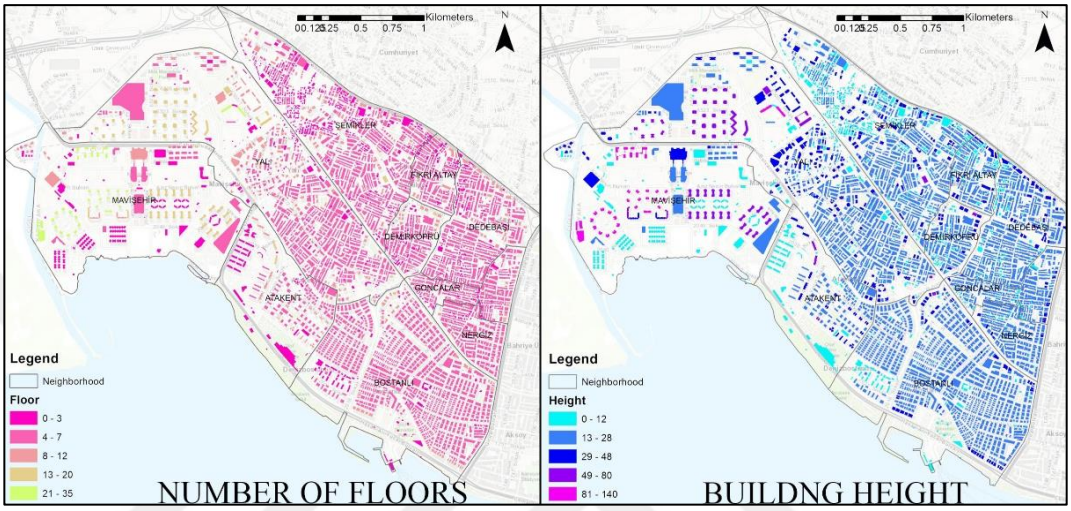

Figure 4.16 Building Number of Floors and Height in Planning Region Scale

While similar floor numbers are observed in the north and east of the region, there are sharp increases in the floor numbers in the neighborhoods located in the west of the area. In this context, Mavişehir neighborhood is the most vulnerable neighborhood in terms of both disasters.

4.2.6 Sub-Indicator Analysis of Street Network Quality

Street Network Quality analysis includes important transport intersections such as street width, street structure relationship, access to important areas, public transport, which demonstrate the quality of the street network in the urban inventory (Table 4.11).

Table 4.11 Sub-Indicators of Street Network Quality and Vulnerability Phenomena

Main Indicator	**Sub-Indicator**	**Flood Vulnerability**	**Extreme Vulnerability**
		Vulnerability Phenomena	**Vulnerability Phenomena**
Street Network Quality	Accessibility to Crtical Infrastructure	COPING CAPASITY	COPING CAPASITY
	Elevation	***EXPOSURE***	***SUSCEPTIBILITY***
	Emergency and Rescue Routes	COPING CAPASITY	COPING CAPASITY
	Mobility Density	***EXPOSURE***	***EXPOSURE***
	Public Transportation	**SUSCEPTIBILITY**	**COPING CAPASITY**
	Slope	***EXPOSURE***	***SUSCEPTIBILITY***
	Street Network Area Ratio	SUSCEPTIBILITY	SUSCEPTIBILITY
	Street Width	**COPING CAPASITY**	**SUSCEPTIBILITY**
	Street-Building Relationship	**SUSCEPTIBILITY**	**COPING CAPASITY**
	Walkability	**COPING CAPASITY**	**EXPOSURE**

Among the sub-indicators selected within the scope of the thesis, elevation and slope analyses were excluded from the research as they were not meaningful in the second scale of the case study in the thesis. Mobility Density and Emergency and Rescue Routes data was not analysed due to its unavailability. In this analysis, street and road data from Izmir Metropolitan Municipality, Karşıyaka Municipality and open-source street and road data published through OSM were used.

4.2.6.1. Accessibility to Crtical Infrastructure

The critical infrastructures located in the urban area are considered as health related area such as hospitals, public buildings and gathering areas. Accessibility to these areas is evaluated as coping capacity within vulnerability for both disasters. In this analysis, it is assumed that the areas within 500 meters of urban critical uses provide fast and

effective access and network analysis is made according to pedestrian characteristics through ArcGIS software.

It is seen that critical uses in the city centre are intensified in Konak, Buca and Karabağlar districts. In this context, it is observed that the level of vulnerability is low in these areas. In Narlıdere, Karşıyaka and Çiğli districts, on the other hand, the access rate and critical uses are limited. In this context, these districts are the most vulnerable districts (Figure 4.18).

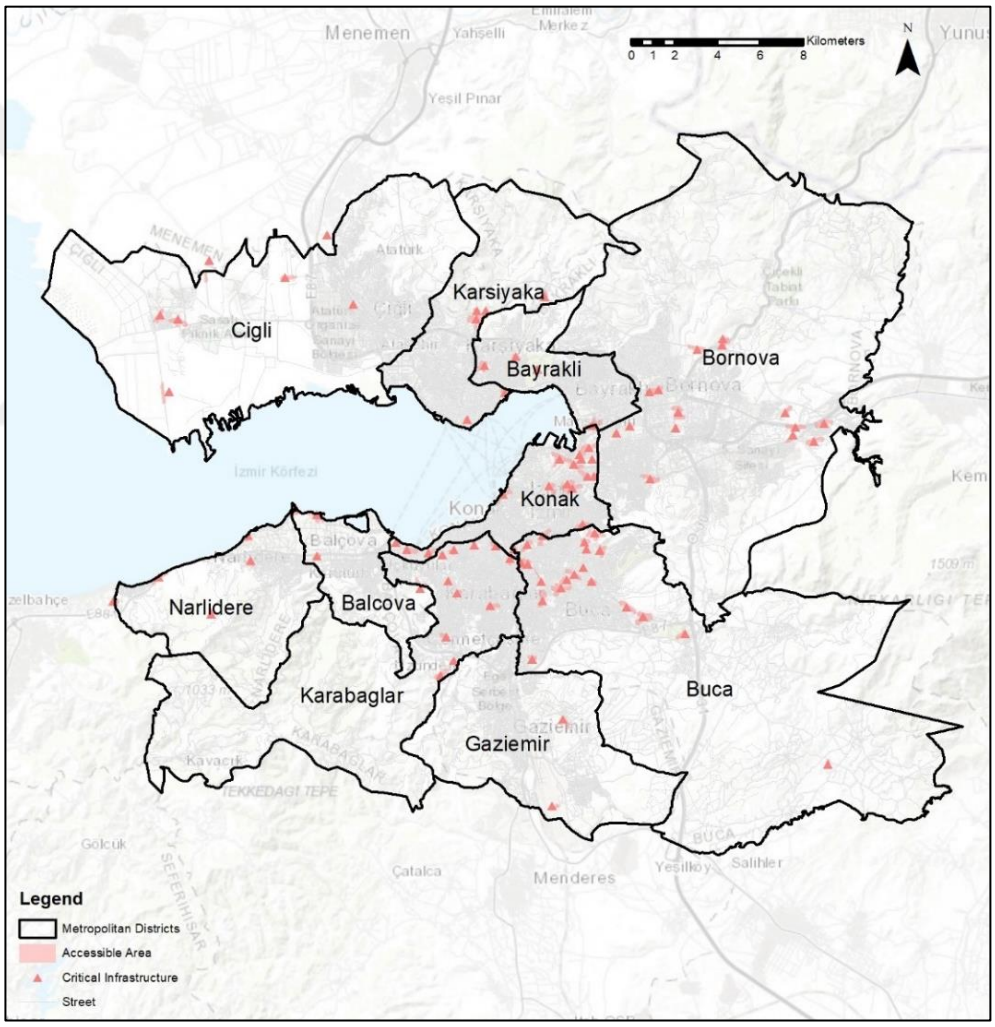

Figure 4.17 Accessibility to Critical Infrastructure in Metropolitan Scale

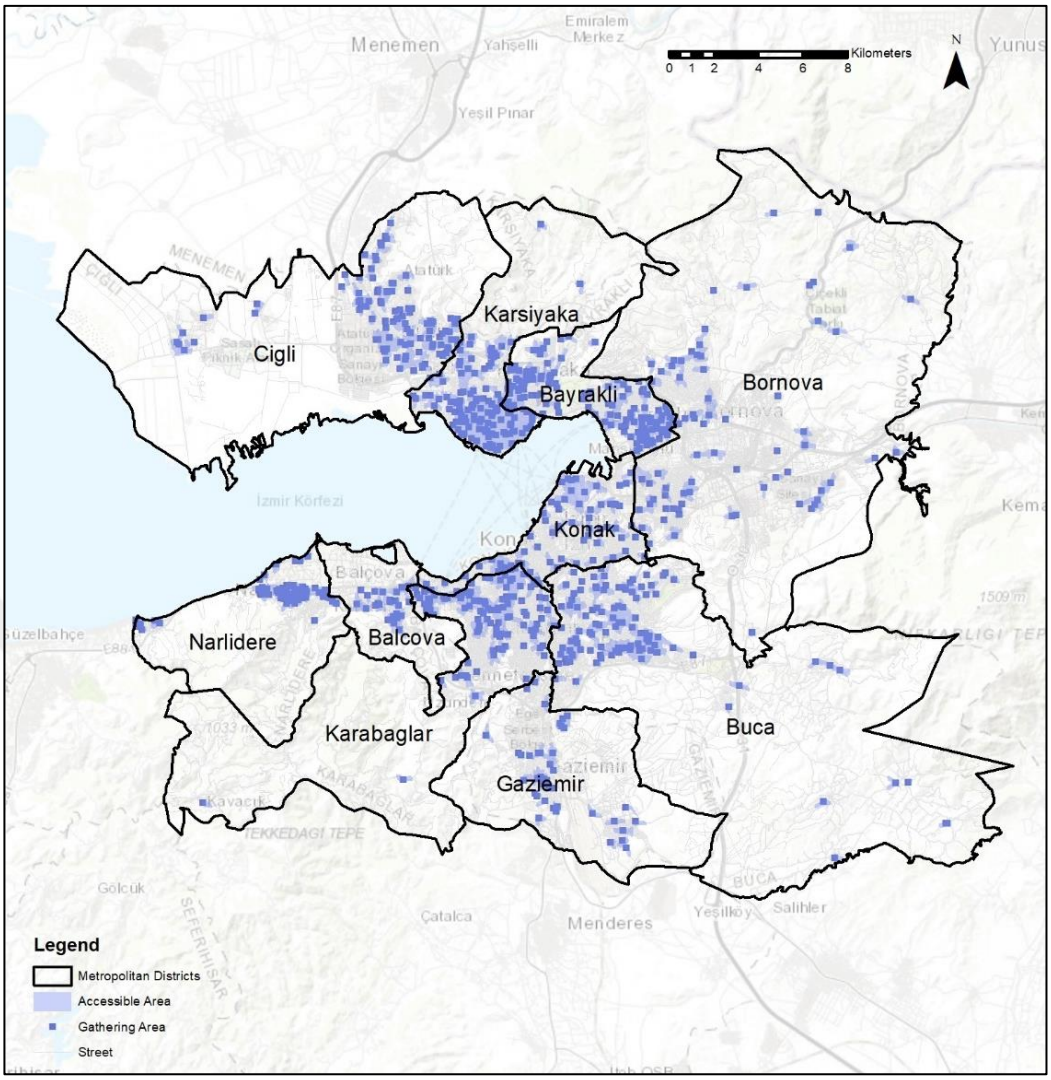

Figure 4.18 Accessibility to Gathering Area in Metropolitan Scale

On the other hand, gathering areas are equally distributed in nearly every part of the city (Figure 4.19). In 2020, the city experienced an earthquake disaster and efforts were made to plan and increase the quality of the gathering areas. As a matter of fact, it is seen that the city is quite resilient in terms of access to gathering areas. Narlıdere district is the most vulnerable district in terms of access to gathering areas due to its single-centered approach.

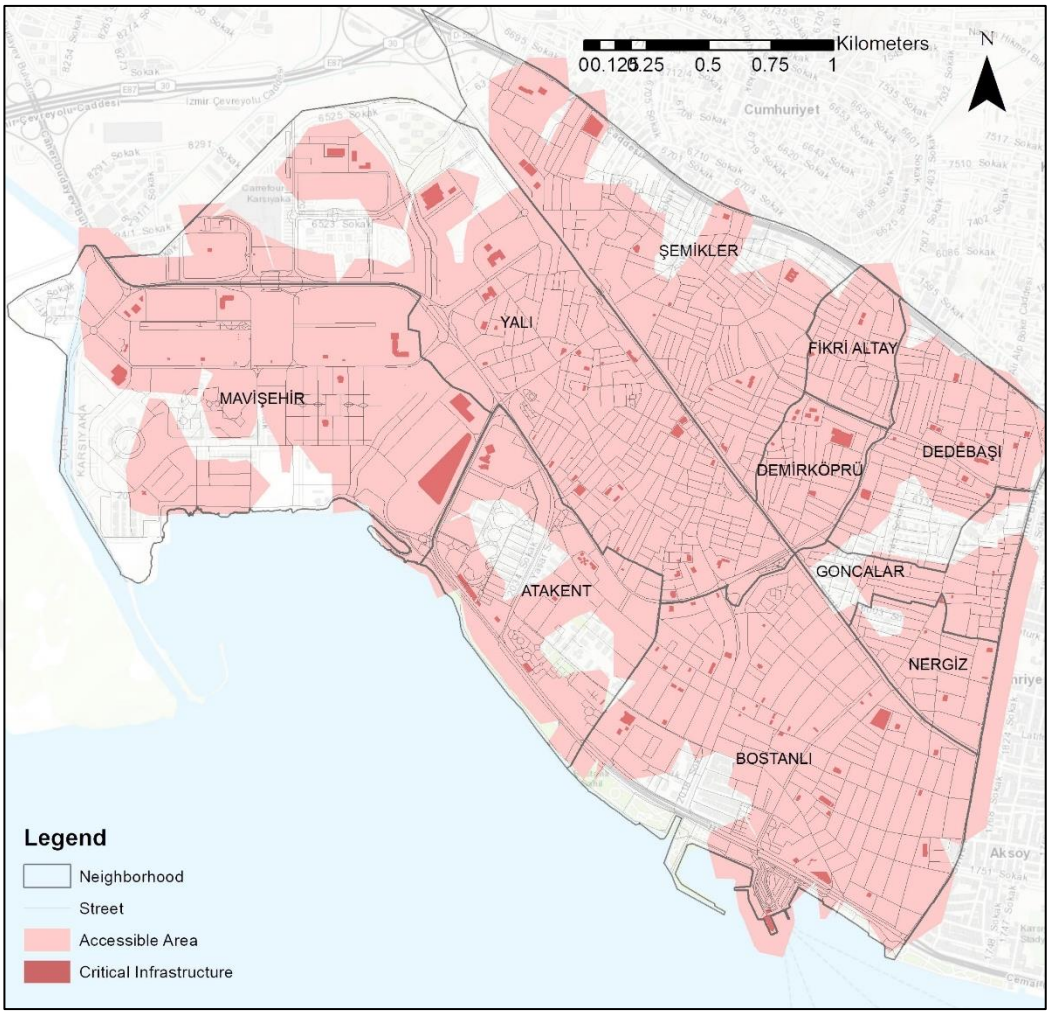

Figure 4.19 Accessibility to Crictical Infrastructure Area in Planning Region Scale

In the planning region, which is rich in critical infrastructure, critical infrastructure access is possible by practically the entire region. The most vulnerable neighborhoods in the region, where land features such as slope and elevation increase the accessibility, are Dedebaşı and Yalı neighborhoods.

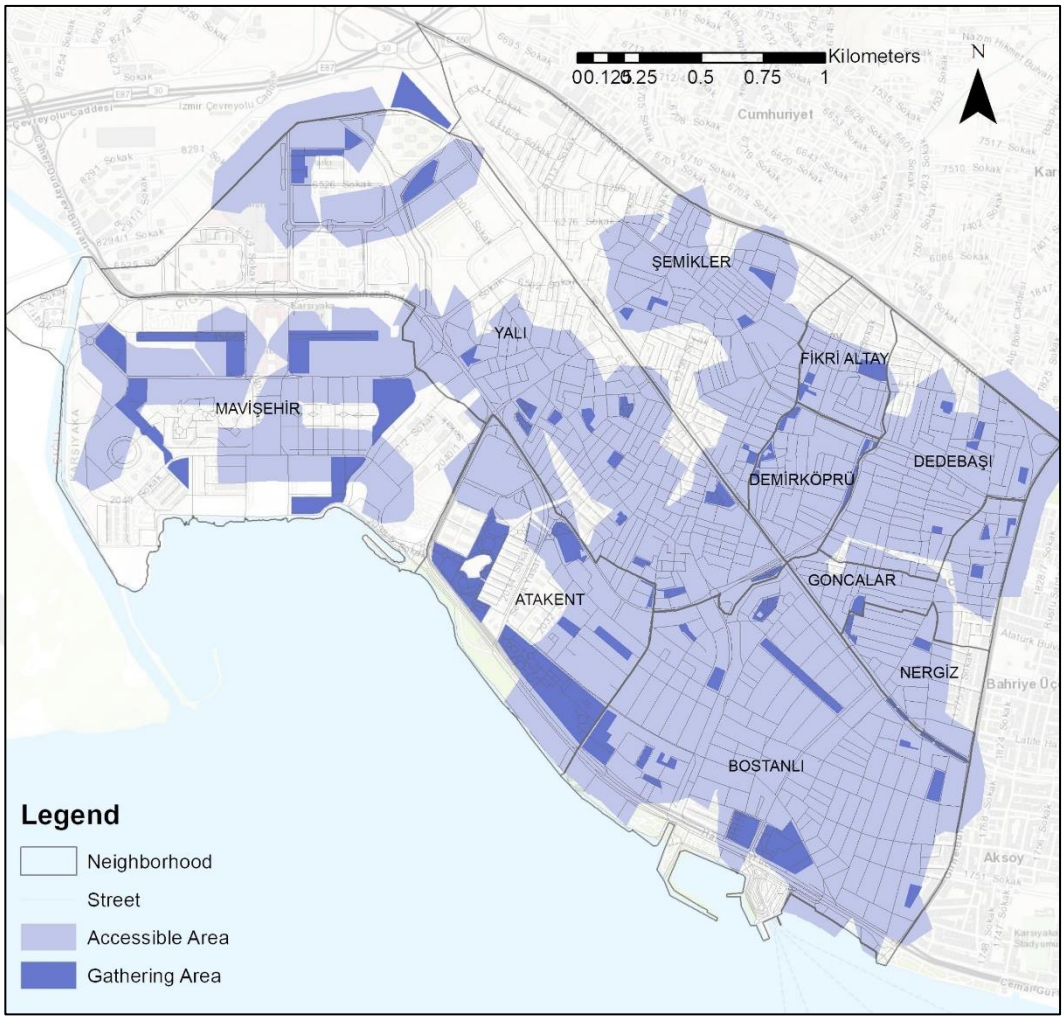

Figure 4.20 Accessibility to Gathering Area in Planning Region Scale

Similar to critical infrastructures, access to gathering areas is better than most parts of Izmir city. However, access to gathering areas is considered problematic especially in Şemikler and some parts of Yalı neighborhoods and Mavişehir neighborhood. The high building density and number of floors in these areas have a negative impact on the vulnerability levels of the neighborhoods. In this context, the most vulnerable neighborhoods of the region are Mavişehşr, Şemikler and Yalı neighborhoods (Figure 4.21).

4.2.6.2. Public Transportation

Public transport systems are the most important component that manages and guides the mobility in the city. The status of this system, which is accessible to every segment of the society, can be interpreted with concepts such as the number of stops, mode diversity, average journey time and number of passengers. The relationship between disasters and public transport starts during the disaster. Public transport can provide the masses, who need to be away from the disaster, to safety areas and gathering areas during the disaster. Besides, some types of public transport are vulnerable to disasters. One of these systems is rail systems. Rail systems are vulnerable because they are costly and their maintenance and repair times are long. In intense disasters, it is possible for rail systems to stop their operations or close their stations. On the other hand, public transport with Tyre Wheels is more flexible. It responds faster to crises and its costs are lower. In the analysis considered in this context, the vulnerability of public transport in terms of flood disaster is considered as susceptibility. While extreme heat makes the travelling process difficult, public transport is evaluated with coping capacity because it provides access to ventilation and air conditioning and reduces pedestrian mobility. In this context, Public transport is analysed only on a metropolitan scale due to its connectivity and scale. Another reason for this is that Karşıyaka district has a rail system, tyre wheel system and sea lines system and the journeys are distributed to all areas of the city. The data used in the analysis was obtained from Izmir Metropolitan Municipality open data platform.

At a metropolitan scale, Izmir has a strong rail system and a successful public transport system with good transfer habits. Providing access to all parts of the city, public transport offers diversity, especially in the coastal districts. The most vulnerable districts in this context are Buca and Karabağlar (Figure 4.22).

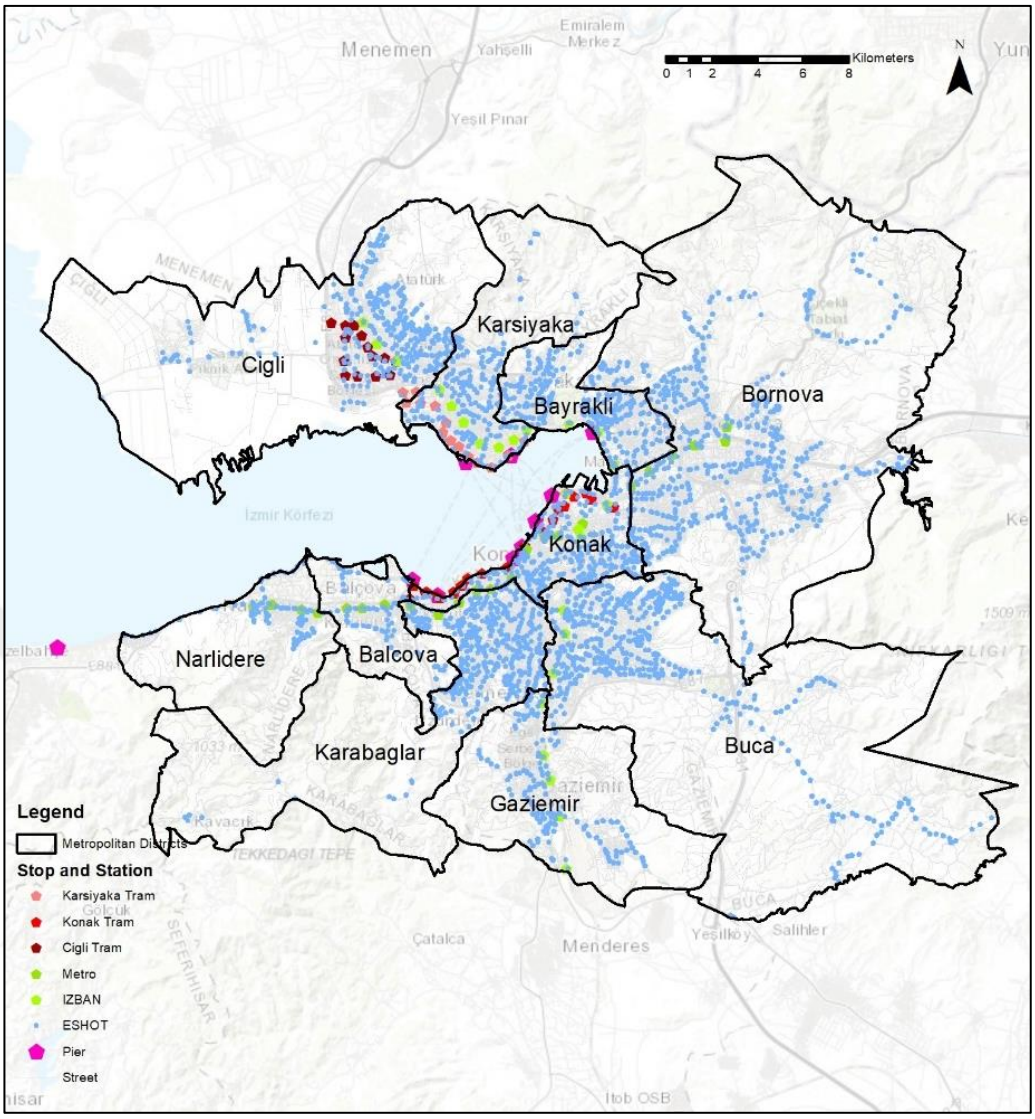

Figure 4.21 Public Transportation System in Metropolitan Scale

4.2.6.3. Street Width

Street width is an important indicator that can characterize the network structure that is used in many disaster related studies. Street width is an important phenomenon in order not to be closed in emergency intervention moments and not to decrease the speed of traffic flow. In flood disasters, high street width reduces the vulnerability for this reason. The same indicator has the opposite effect in extreme heat. Because of the

material used in the streets and the traffic mobility it creates, it causes UHI and heat generation. In this context, street width, which is defined as the capacity to cope with flooding, is considered as susceptibility in terms of extreme heat. In this analysis, data obtained from Izmir Metropolitan Municipality, OSM open data and Google Earth Pro application were used.

The average width of streets and roads in the metropolitan area is between 7 and 12 meters. Access in Izmir is quite easy due to the ring road connecting the districts, but the streets in the neighborhoods are narrow, sloping and have ground problems. The most vulnerable districts in this context are Konak and Karabağlar districts (Figure 4.23).

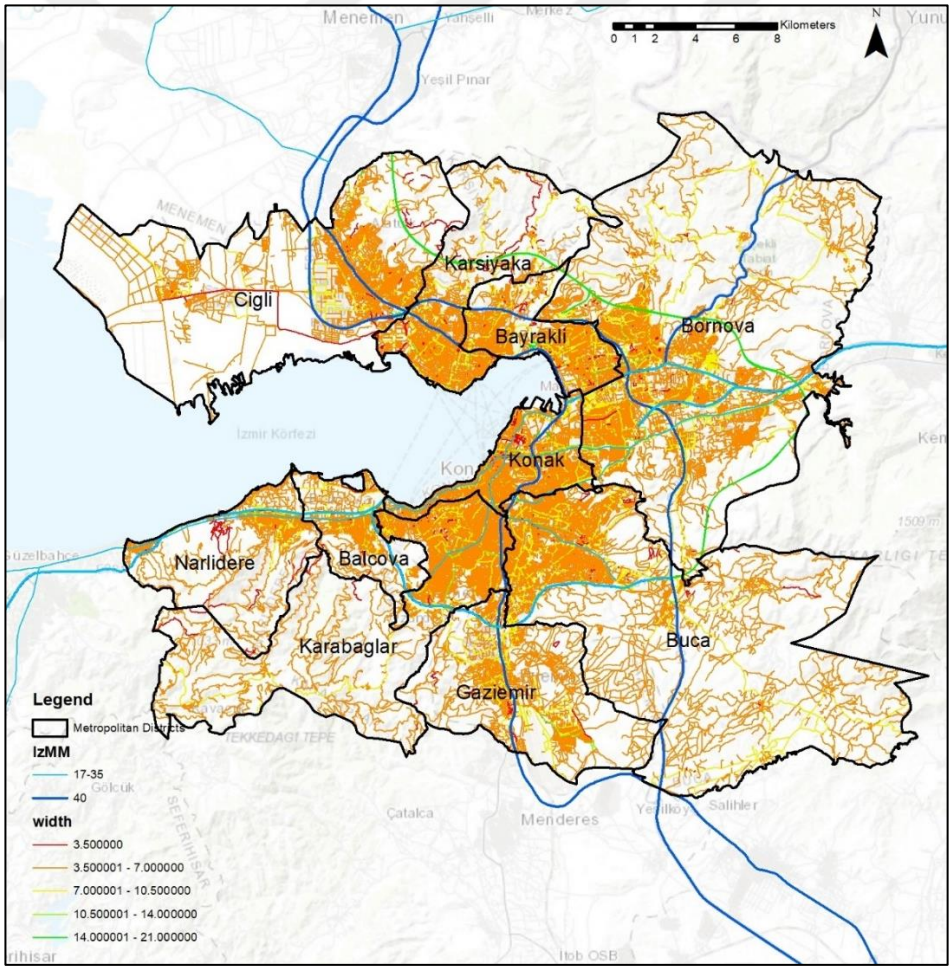

Figure 4.22 Street Width of Metropolitan Scale

Street widths in the planning area vary mostly between 3.5 meters and 7 meters. There are major roads in the north, south and east of the area. In this context, the most vulnerable neighborhoods of the study area are Nergiz, Goncalar and Demirköprü neighborhoods (Figure 4.24).

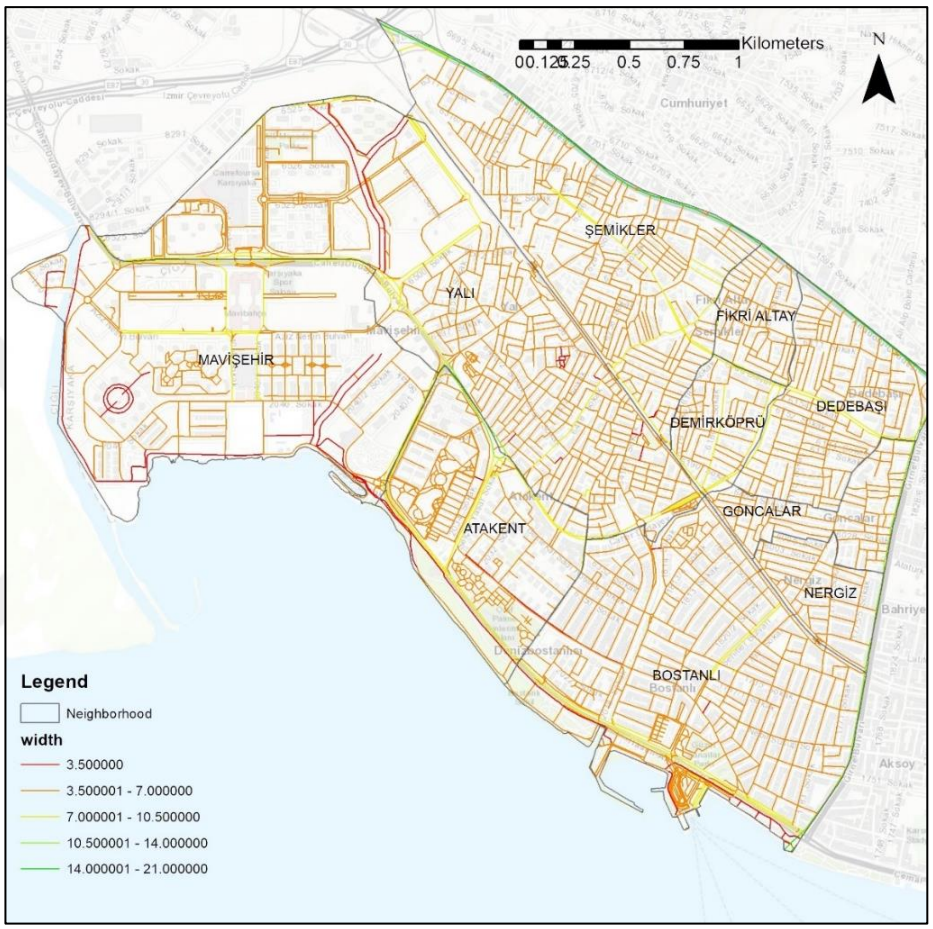

Figure 4.23 Street Width of Planning Region Scale

4.2.6.4. Street-Building Relationship

Street-structure relationship is an indicator that should be taken into consideration in many disasters. In terms of flooding, the street-building relationship affects the urban area by defining the built concrete surface. It can affect the flow rate of water

and plays an important role in search and rescue operations. This reason is considered as susceptibility. Against extreme heat, it is considered as coping capacity as it can be used for various purposes such as the formation of shade areas, preventing open surfaces from creating UHI effect. In this context, the street-road relationship at different scales has been analyzed with building conditions. Structures designed with discrete building conditions have the lowest vulnerability, while buildings designed attached building have the highest vulnerability. In this context, the analysis was created with the data provided by Izmir Metropolitan Municipality.

In most of the central districts, discrete and attached settlements are observed. The most vulnerable districts are Buca and Karabağlar districts, where attached building is predominant (Figure 4.25).

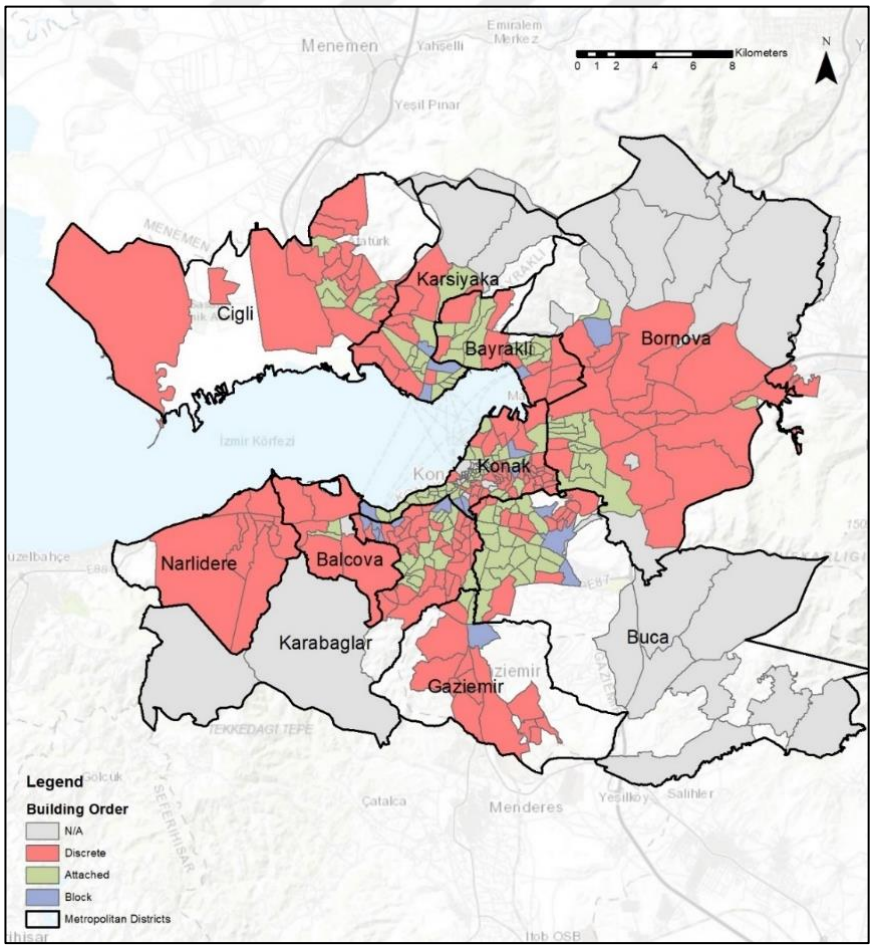

Figure 4.24 Building Order of Metropolitan Scale

There is no block layout in the planning area and most of the buildings are built in discrete order. In this context, IZBAN constitutes a margin. The neighborhoods on the upper part of IZBAN have a higher level of vulnerability (Figure 4.26).

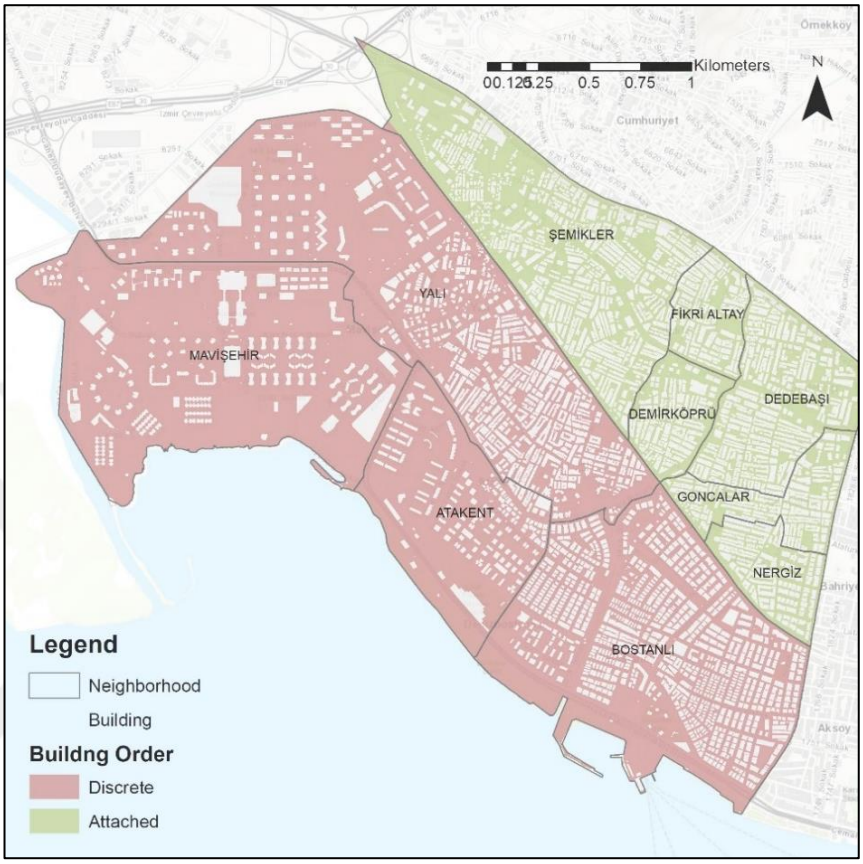

Figure 4.25 Building Order of Planning Region Scale

4.2.7 Sub-Indicator Analysis of Population Density and Change, Disadvantaged Population and Economic Status

This section analyses the social and economic status of the study areas and the two scales. In this context, Population Density and Changes, Disadvantaged Population and Economic Status main indicators are analysed. The data used in the study were obtained from TURKSAT, İŞKUR, Izmir Metropolitan Municipality and Karşıyaka Municipalities. Since there is no data on the number of independent units for houses

in both scales, the analyses were carried out on the basis of neighborhood boundaries and built-up areas (Table 4.12).

Table 4.12 Sub-Indicator of Social and Economic Status

Main Indicator	Sub-Indicator	Flood Vulnerability	Extreme Vulnerability
		Vulnerability Phenomena	Vulnerability Phenomena
Population Density and Changes	Education Levels Ratio	COPING CAPASITY	COPING CAPASITY
	Population Density	EXPOSURE	EXPOSURE
Disadvantaged Population	Children <15 Ratio	SUSCEPTIBILITY	SUSCEPTIBILITY
	Dependency Ratio	COPING CAPASITY	COPING CAPASITY
	Elderly>65 Ratio	SUSCEPTIBILITY	SUSCEPTIBILITY
	Female Ratio	SUSCEPTIBILITY	SUSCEPTIBILITY
	People with Disabilities Ratio	EXPOSURE	EXPOSURE
Economic Status	Socio-Economic Status	COPING CAPASITY	COPING CAPASITY
	Low Income Households Ratio	SUSCEPTIBILITY	SUSCEPTIBILITY
	Unemployment Raito	SUSCEPTIBILITY	SUSCEPTIBILITY

4.2.7.1. Education Levels Ratio

Education level is an important indicator for perceiving the level of awareness of individuals. Disaster awareness enables coping with flood and extreme heat related hazards. Accordingly, the ratio of individuals with higher education, i.e. university and postgraduate education, decreases vulnerability and increases resilience. In this context, the most vulnerable districts of the metropolitan region are Buca and Karabağlar districts (Table 4.13).

Table 4.13 Education Information of Metropolitan Scale

District	High Education Pop.	No School Education	No School Education Pop.
BALÇOVA	22996	29.54606776	3895
BAYRAKLI	62526	20.77627771	22303
BORNOVA	93169	20.81742274	29639
BUCA	**99659**	**19.03753102**	**37246**
ÇIĞLI	50078	23.27347424	13299
GAZIEMIR	34288	24.88821787	9704
KARABAĞLAR	**89099**	**18.69863589**	**36197**
KARŞIYAKA	128127	37.47970643	18023
KONAK	66855	20.42621448	24646
NARLIDERE	21906	35.2481174	3995

The minimum rate of higher education in the planning region is 27%. In this respect, its vulnerability among metropolitan districts is low. When evaluated in the same way as in the metropolitan districts, the most vulnerable districts of the Planning region are Şemikler and Fikri Altay neighborhoods with an average of 27% and 28% high education rate.

4.2.7.2. Population and Population Density

Population density indicates the assets exposed to disasters. Areas with high population density are more vulnerable. In this context, population density is considered as exposure for both disasters.

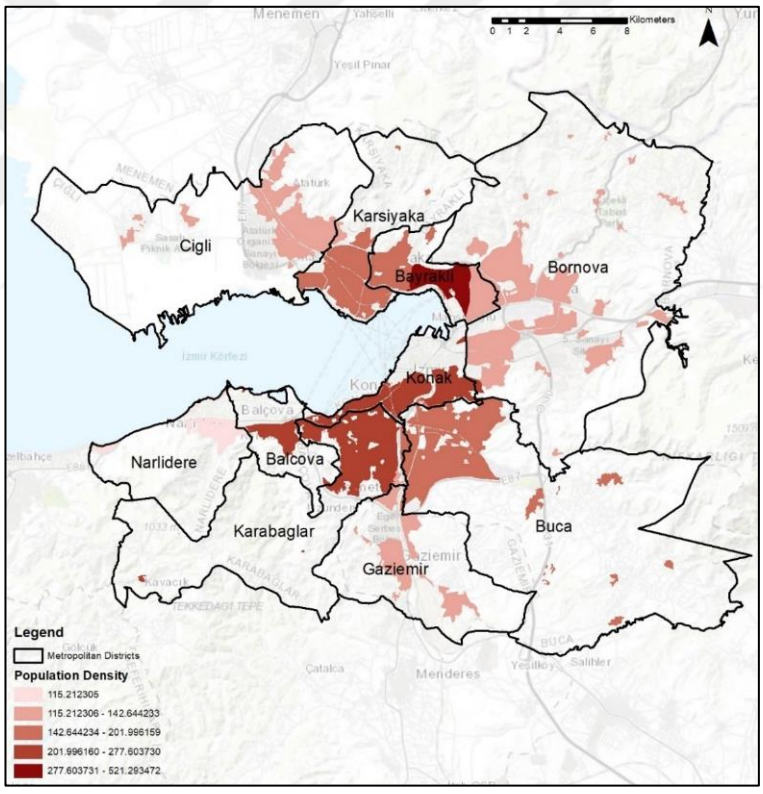

Figure 4.26 Population Density of the Metropolitan Scale

The population of Izmir metropolitan districts was announced by TURKSAT as 2,583,265 people in 2023. The district with the highest population is Buca with

523,487.00 people and the district with the lowest population is Narlıdere with 62,148 people. (Figure 4.27) According to the population density, which is calculated as the ratio of the population of the districts to the residential area, the densest district is Bayraklı with 300,949 people and the least dense district is Balçova with 77,831 people. In this context, the most vulnerable districts are Bayraklı, Konak and Karabağlar districts (Table 4.14).

Table 4.14 Population Information of Metropolitan Scale

District	Population	Population Density
BALÇOVA	77831	242
BAYRAKLI	300949	521
BORNOVA	447553	134
BUCA	523487	202
ÇIĞLI	215172	134
GAZIEMIR	137768	143
KARABAĞLAR	476500	274
KARŞIYAKA	341857	175
KONAK	327300	278
NARLIDERE	62148	115

The highest population density in the planning region is in the Fikri Altay, Nergiz, and Goncalar neighborhoods, and these neighborhoods have high levels of vulnerability (Table 4.15 and Figure 4.28).

Table 4.15 Population Information of Planning Region Scale

Neighborhood	Population	Population Density
ATAKENT	6714	103
BOSTANLI	30773	214
DEDEBAŞI	20312	381
DEMİRKÖPRÜ	6865	312
FİKRİ ALTAY	8138	425
GONCALAR	9252	388
MAVİŞEHİR	13909	90
NERGİZ	8099	404
ŞEMİKLER	29444	244
YALI	37461	204

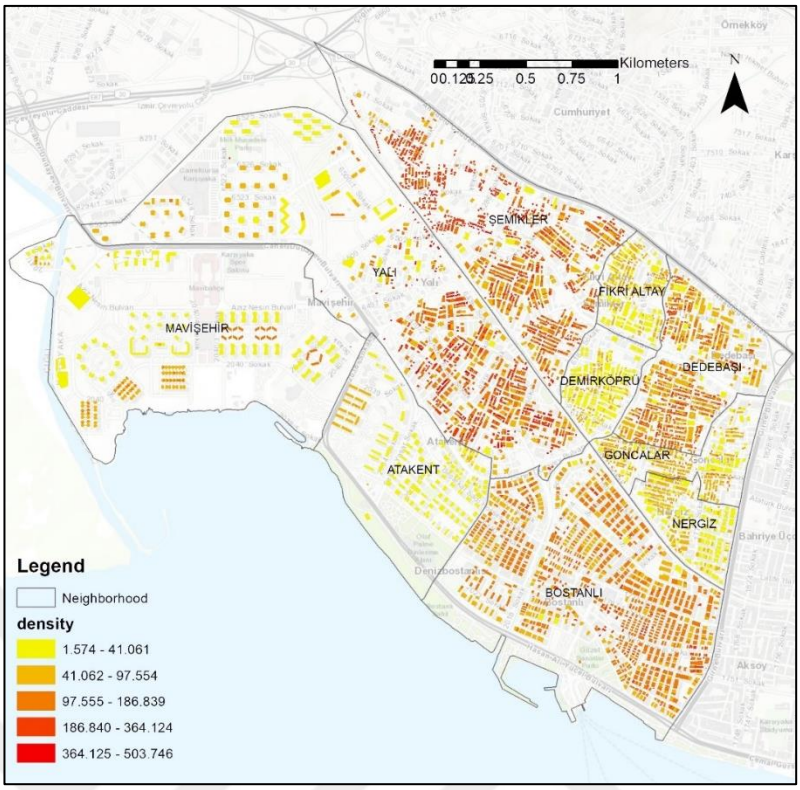

Figure 4.27 Population Density of Planning Region Scale

4.2.7.3. Disadvantaged Population

Disadvantaged population is analyzed by children, dependency ratio, elderly population ratio, female population ratio, number of persons with disabilities and dependency ratio (Table 4.16, Table 4.17). These social groups are vulnerable because they are disadvantaged in various ways.

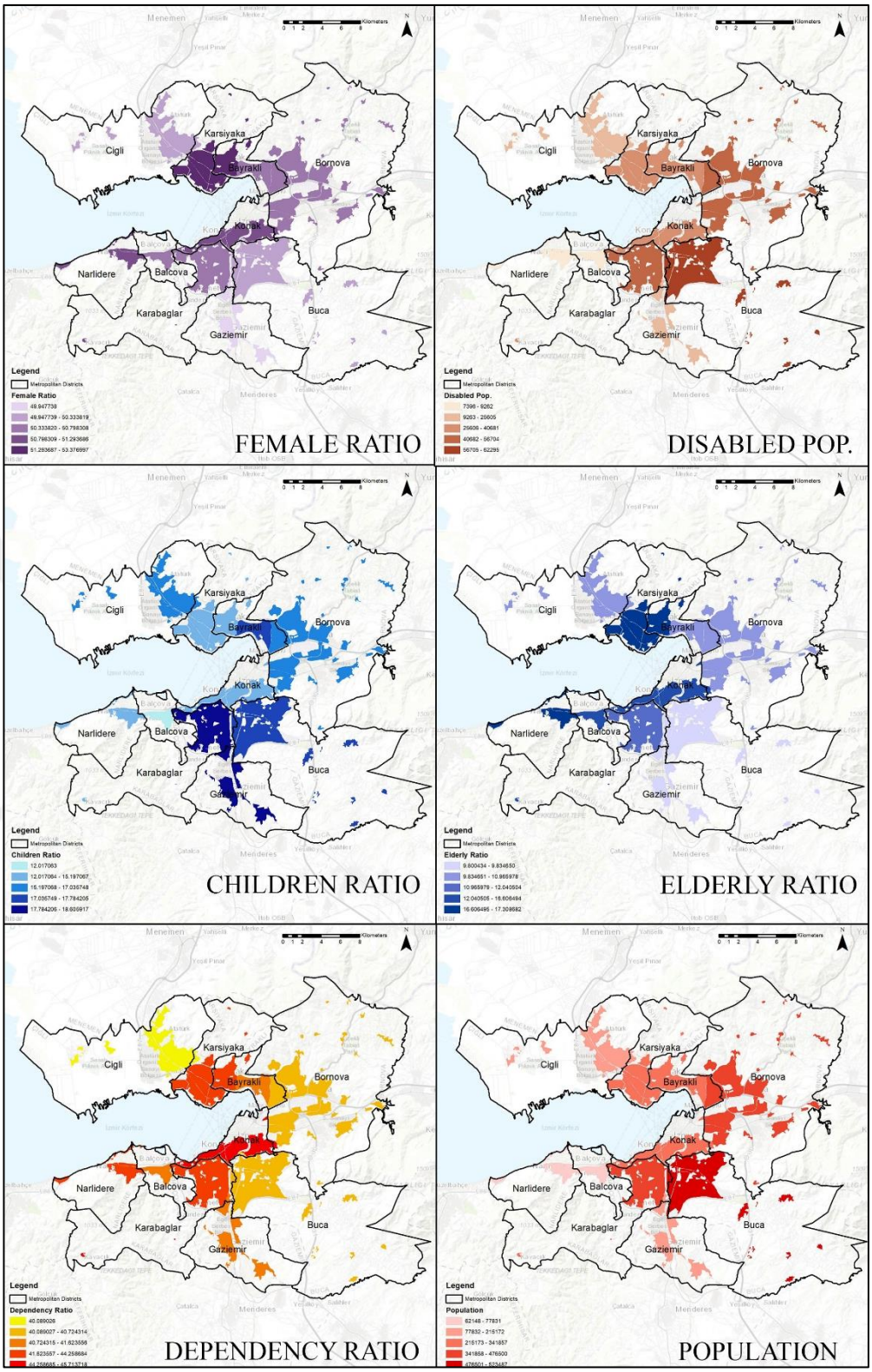

Figure 4.28 Disadvantaged Population of Metropolitan Scale

Table 4.16 Disadvantages Population Information of Metropolitan Scale

District	Female Ratio	Child Ratio	Elderly Ratio	Disable Population	Dependency Ratio
BALÇOVA	50.729	12.017	16.606	9262	41.623
BAYRAKLI	50.798	17.637	10.966	35813	41.603
BORNOVA	50.713	17.0357	10.688	53259	40.724
BUCA	50.333	17.7842	9.800	**62295**	40.584
ÇIĞLI	50.286	16.681	10.407	25605	40.089
GAZIEMIR	49.947	18.605	9.834	16394	41.440
KARABAĞLAR	50.693	**18.154**	12.041	56704	43.194
KARŞIYAKA	**53.377**	14.226	**17.032**	40681	44.258
KONAK	51.234	15.197	16.600	38949	45.713
NARLIDERE	51.294	13.866	**17.308**	7396	44.175

When the vulnerable groups of the city at the metropolitan scale are analyzed (Figure 4.28), it is seen that Balçova district has the lowest child rate. Karabağlar district, which has the highest child rate, is the most vulnerable district. Narlıdere and Karşıyaka districts are the most vulnerable districts in terms of elderly population. Since Buca and Karabağlar districts have the highest number of disabled people in metropolitan districts, their vulnerability levels are higher than other districts. Due to their gender roles as caregivers and nurturers, women are one of the vulnerable groups in terms of climate change related disasters. The most vulnerable district in this regard is Karşıyaka District (Figure 4.30).

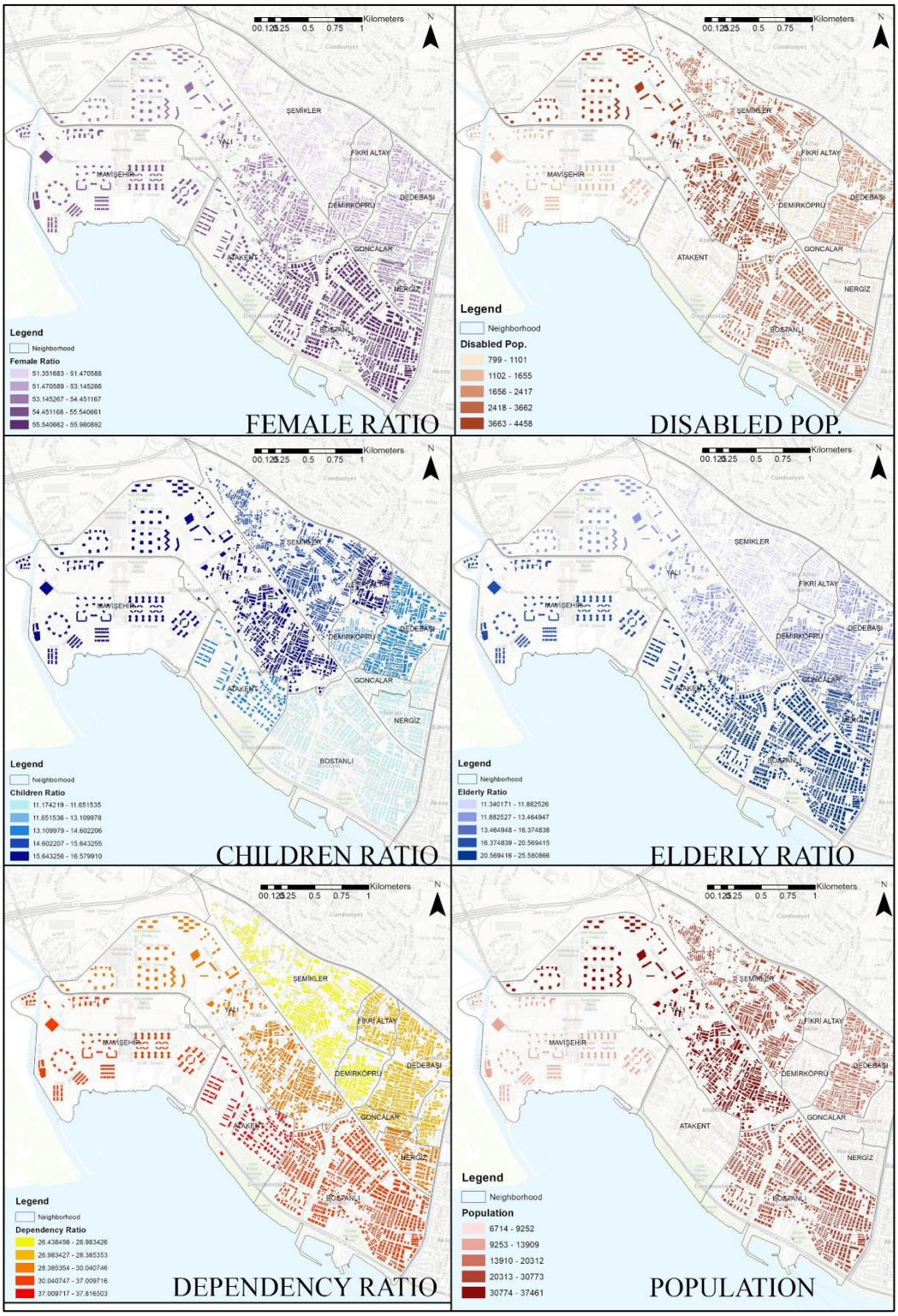

Figure 4.29 Disadvantaged Population of Planning Region Scale

Table 4.17 Disadvantages Population Information of Planning Region Scale

Neighborhood	Female Ratio	Child Ratio	Elderly Ratio	Disable Population	Dependency Ratio	Population
ATAKENT	55.541	14.015	**23.801**	799	**37.816**	6714
BOSTANLI	**55.981**	11.428	**25.581**	**3662**	37.010	30773
DEDEBAŞI	52.806	14.602	13.465	2417	28.067	20312
DEMİRKÖPRÜ	52.920	13.112	13.328	817	26.438	6865
FİKRİ ALTAY	51.351	16.502	11.882	968	28.385	8138
GONCALAR	53.145	11.652	16.375	1100	28.026	9252
MAVİŞEHİR	55.230	16.184	20.569	1655	36.753	13909
NERGİZ	54.45	11.174	18.866	964	30.040	8099
ŞEMİKLER	51.470	15.643	11.340	**3504**	26.983	29444
YALI	54.114	**16.580**	13.235	4458	29.815	37461

When the vulnerable groups of the city at the planning region scale are analysed (Figure 4.29), it is seen that Nergiz neghborhood has the lowest child rate. Since Bostanlı and Şemikler neighborhoods have the highest number of disabled people in metropolitan neighborhoods, their vulnerability levels are higher than other neighborhoods. Yalı neighborhood, which has the highest child rate, is the most vulnerable neighborhood. Atakent and Bostanlı neighborhoods are the most vulnerable neighborhoods in terms of elderly population. Due to their gender roles as caregivers and nurturers, women are one of the vulnerable groups in terms of climate change related disasters. The most vulnerable neighborhood in this regard is Bostanlı Neighborhood. Atakent neighborhood has the highest rate for the dependent population and is the most vulnerable neighborhood (Table 4.17).

4.2.7.4. Economic Status

Economic Status is analyzed by economic class which is describe the rank of income, SES class which is describe the status of socio-economic status and unemployment ratio (Table 4.18, Table 4.19). These social groups are vulnerable because they are disadvantaged in various ways.

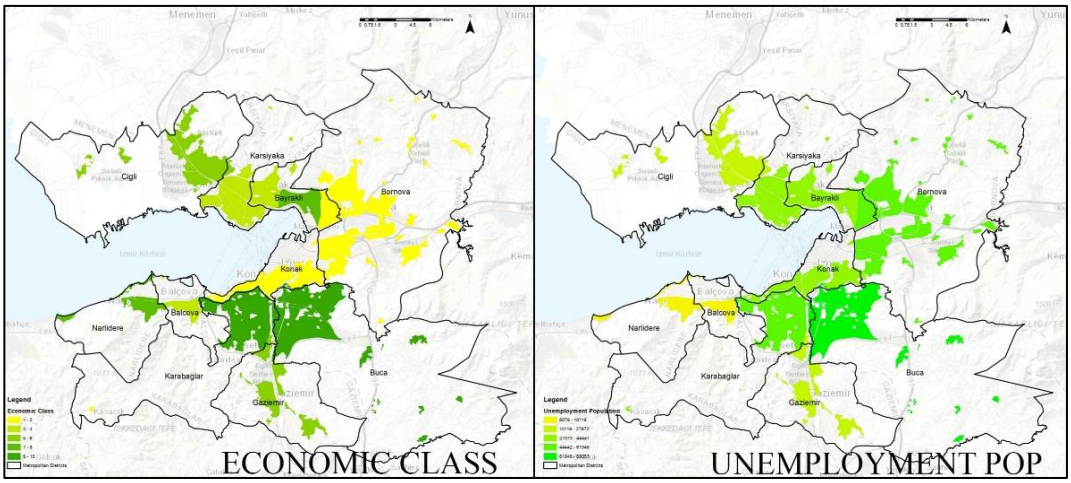

Figure 4.30 Economic Status of Metropolitan Scale

When the economic status of the city at the metropolitan region scale are analysed (Figure 4.31), the highest unemployed population is in Buca district and the lowest economic class is in Karabağlar district, indicating fragile districts. There are only two levels of SES in Izmir metropolitan districts. This situation increases the capacity of the province to cope with risks (Table 4.18).

Table 4.18 Economic Status Information of Metropolitan Scale

District	**Unemployment Population**	**Economic Class**	**SES Class**
BALÇOVA	10118	3	A+
BAYRAKLI	39123	8	A
BORNOVA	58182	2	A+
BUCA	**68053**	9	A
ÇIĞLI	27972	5	A+
GAZIEMIR	17910	6	A+
KARABAĞLAR	61945	**10**	A
KARŞIYAKA	44441	4	A+
KONAK	42549	1	A+
NARLIDERE	8079	7	A+

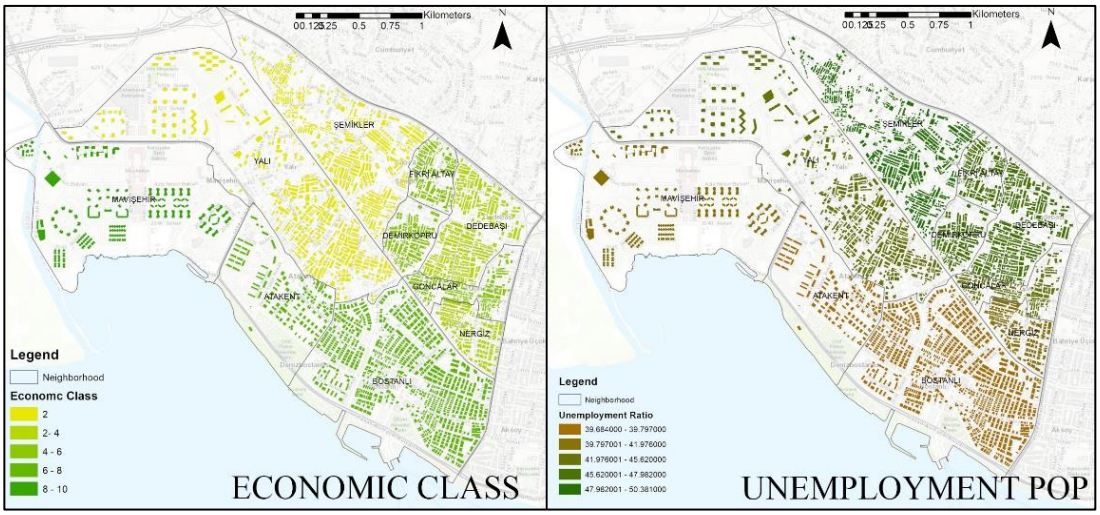

Figure 4.31 Economic Status of Planning Region Scale

When the economic status of the city at the metropolitan region scale are analysed (Figure 4.32), the highest unemployed population is in Bostanlı which is also the highest population of the elderly and children, and the lowest economic class is in Şemikler neighborhood, indicating vulnerable districts. There are only one levels of SES in this region which is A+. This situation increases the capacity of the province to cope with risks (Table 4.19).

Table 4.19 Economic Status Information of Planning Region Scale

Neighborhood	**Unemployment Population**	**Economic Class**	**SES Class**
ATAKENT	2539	3	A+
BOSTANLI	**11389**	4	A+
DEDEBAŞI	5701	8	A+
DEMİRKÖPRÜ	1815	6	A+
FİKRİ ALTAY	2310	5	A+
GONCALAR	2593	7	A+
MAVİŞEHİR	5112	1	A+
NERGİZ	2433	9	A+
ŞEMİKLER	7945	**10**	A+
YALI	11169	2	A+

4.3 Conclusion

This study includes a comprehensive review of Izmir's vulnerability to climate change and disasters, using both expert assessments and spatial analysis. In order to better understand Izmir's vulnerability to various types of disasters, this research provides valuable data to identify the risks in the city, to reveal the geographical distribution of these risks and to determine the measures that can be taken against these risks.

In the first phase of the research, expert opinions were gathered on the factors that may affect climate change and vulnerability to disasters in Izmir. Experts made assessments about the natural disasters that threaten the city and how they cause different impacts in different regions of the city. The most important analysis method used in this process was the Analytic Hierarchy Process (AHP). The AHP method is a decision-making tool that allows ranking the types of disasters, the factors that determine the susceptibility to disasters and the effects of these factors in the city. According to the AHP analysis based on expert opinions, flooding and extreme heat are the most threatening disaster types for Izmir. Experts emphasized that these disasters significantly affect the social, environmental and economic structure of the city. Flood risk is generally concentrated in areas close to the city's water basins, while extreme temperatures are more of a problem in the city center and in areas lacking green spaces. In addition, infrastructure deficiencies in Izmir were identified as an important factor in increasing risks. For example, outdated water drainage systems increase the risk of flooding, and the lack of green spaces increases temperatures in the city center.

In the second phase of the research, various spatial analyses were conducted to see the spatial distribution of disaster risks and vulnerability in the city. These analyses were conducted using GIS (Geographic Information Systems) technologies to visualize the disaster vulnerability in different regions of Izmir and to reveal the vulnerabilities in specific regions in detail. The findings of the spatial analyses were

used to create maps showing how vulnerability is spread geographically and which regions have higher risks.

In this context, Izmir's vulnerability to disasters has been analyzed in detail through factors such as land use, green areas, building structure and street network quality. The vulnerability of land use types to disasters increases especially in areas where residential, industrial and commercial areas are concentrated. In particular, Karşıyaka, Konak and Çiğli districts stand out as regions with high vulnerability to disasters such as floods and extreme temperatures. The rapid urbanization process after the 1990s and the opening of agricultural areas to settlement have made Izmir more vulnerable to natural disasters. The lack of green areas makes the city more vulnerable to disasters such as extreme temperatures and floods. Districts such as Buca and Karabağlar have low levels of green areas and are considered more vulnerable to disasters. Building structure also plays an important role in vulnerability. Older buildings are at higher risk due to building materials and infrastructure deficiencies. Older buildings in areas such as Bostanlı, Ataşehir and Nergiz are particularly vulnerable to floods and heat waves. In addition, high building density is also an important factor against disasters. Densely built-up areas such as Karşıyaka and Konak are more vulnerable to disasters such as floods and extreme temperatures. The quality of the street network is also a determining factor in disaster preparedness. While wide streets facilitate rescue and evacuation operations, narrow and dense streets can make it difficult to respond to disasters. In the thesis, socio-demographic factors such as population density, disadvantaged population groups, education level and economic status are also emphasized as important factors affecting disaster vulnerability. Districts with high population density, such as Bayraklı and Karabağlar, are more at risk in disasters. There is a greater vulnerability to disasters in regions with more disadvantaged groups. Education level and economic status are factors that directly affect disaster preparedness and response capacity. Regions with low education level and low income tend to experience more difficulties after disasters.

As a result, it is clear that various measures need to be taken to increase Izmir's resilience to disasters. In addition to land use intensity, green space deficiencies, old building structures and street network quality, socio-demographic factors are also important factors affecting Izmir's vulnerability to disasters. According to the analysis, the most vulnerable districts of Izmir are Karşıyaka, Konak, Çiğli, Buca, Karabağlar and Bornova.

- Karşıyaka and Konak districts are highly susceptible to disasters such as extreme temperatures and floods due to their dense residential and commercial areas and insufficient green areas. The high building density, speed of construction and lack of green areas in these districts make them more vulnerable.

- Buca and Çiğli districts, on the other hand, stand out as regions where urban sprawl is increasing rapidly and agricultural lands are opened to settlement. These districts are highly susceptible to natural disasters and are among the most vulnerable areas in terms of flood risk.

- Karabağlar and Bornova are districts with high proportions of low-income and disadvantaged populations and are more vulnerable to disasters. The low level of education, infrastructure deficiencies and lack of green areas in these districts make them more vulnerable.

To summarize, for Izmir to become more resilient to disasters, the most vulnerable districts such as Karşıyaka, Konak, Çiğli, Buca, Karabağlar and Bornova need to increase green areas, strengthen old buildings, improve the quality of the street network, and make special disaster planning for disadvantaged groups. In addition, increasing disaster awareness, raising education levels and strengthening social solidarity networks will also be important steps to improve Izmir's overall disaster resilience. Such analyses will enable accurate identification of disaster risks and more effective disaster preparedness plans.

CHAPTER FIVE
AHP BASED VULNERABILITY ANALYSIS

The last analysis and final product of the study is the vulnerability index analysis that combines AHP analysis with spatial analysis. At this stage, 8 main indicators that can be used to measure vulnerability is analyzed for two different disasters and two different scales. The analysis is produced by applying the vulnerability formula detailed in the previous sections. The vulnerability formula used is as follows

In this section, the AHP-based Vulnerability analysis discussed in detail in the previous sections is produced for both disasters and both scales. The analysis is produced with a formula derived from the definition of vulnerability (equation 5.1) and a new formula created by combining it with the results of the AHP analysis (equation 5.2). For the spatial application of the formula selected for use in the analysis, the cellularization method was preferred. The results of the analysis produced by processing each cell of the formula were placed in the range of 0 to 1 with maximum-minimum normalization and the vulnerability results were ranked. In this context, vulnerability scores for two different disasters and two different scales were determined rationally. When the relationship between the results of the analysis and the current situation is determined, it has been determined that the results of the analysis point to the right points. In this context, it was possible to comment on the validity, consistency and scalability of the analysis.

5.1 AHP Based Vulnerability Index Methodology

The last analysis and final product of the study is the vulnerability index analysis that combines AHP analysis with spatial analysis. At this stage, 8 main indicators that can be used to measure vulnerability is analyzed for two different disasters and two different scales. The analysis is produced by applying the vulnerability formula detailed in the previous sections. The vulnerability formula used is as follows (5.1);

$$Vulnerability = \frac{Exposure\ x\ Susceptibility}{Coping\ Capacity} \quad (5.1)$$

The vulnerability formula is combined with the weights obtained from the AHP analysis results as follows;

$$Vulnerability_{flood} = \frac{(Exposure_{si} x\ w_i) x\ (Susceptibility_{sj}\ x\ w_j)}{(Coping\ Capacity_{sk} x\ w_k)} \quad (5.2)$$

Where *i* is main indicator, *si* is sub-indicator and *w* is the weight of main indicator (4.2).

Since the indicators selected within the scope of the thesis represent different characteristics of the city, the units and formats of the data differ. In this context, the cell method has been preferred in order to combine different data sets in the vulnerability analysis. The celling method consists of 250 m x 250 m squares for the scale called metropolitan scale in this thesis, which covers the central districts of Izmir where the case study is conducted (Figure 5.1).

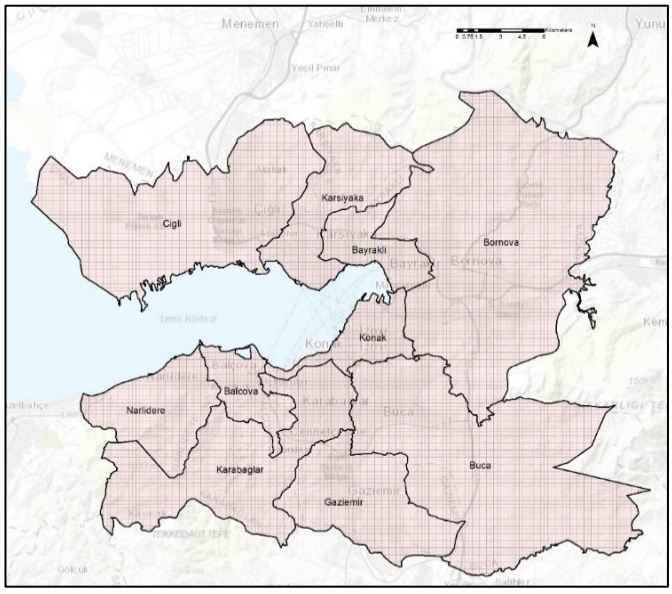

Figure 5.1 Fishnet for Metropolitan Scale (250 m x 250 m)

In order to measure the effect of the analysis method at different scales and to monitor its contribution to spatial plans, the second case study is constructed from 50 x 50 meter squares for the second spatial planning region of Karşıyaka district, which is called planning region scale in this thesis (Figure 5.2).

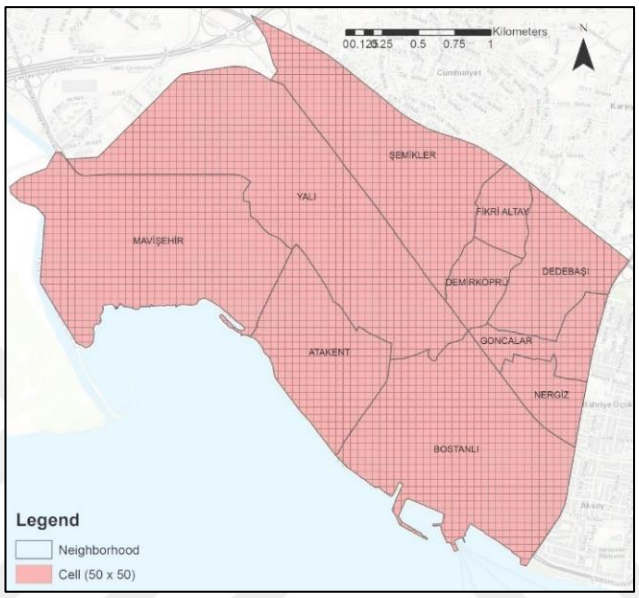

Figure 5.2 Fishnet for Planning Region Scale (50 m x 50 m)

The celling method already incorporates the available data and analyses into a system, so no separate rating process was carried out for the main analyses. Vulnerability assessment was input to the formula as it is considered in spatial analyses and weighted according to the results of AHP analysis. The analysis is conducted by applying the vulnerability formula to each cell in the cell system. The final vulnerability ratings are obtained by fitting the results of the vulnerability analysis to the 0-1 range using the maximum-minimum nomalization technique. At the end of this phase, the thesis tested the proposed methodology on two different disasters at two different scales within the scope of 8 main indicators. In this context, initially the vulnerability to floods and then the vulnerability to extreme heats were analyzed with the vulnerability index approach. The vulnerability of the city of Izmir to flood and extreme heat disaster has been analyzed at two different scales within the scope of the

indicators selected in Table 3.6 and Table 3.7 and for which data is available, based on the considerations specified in the methodology section. The analysis is initially applied to a metropolitan scale consisting of the 10 districts that make up the city center of Izmir on a cellular basis as shown in Figure 4.32. It is then applied to the cell base shown in Figure 4.33 in the Planning Area consisting of 10 neighborhoods described as the 2nd Spatial Planning Area in Karşıyaka district. In this cell base way, the spatial characteristics of the area could be evaluated in place regardless of boundaries.

5.2 Flood Vulnerability Index

In this section of the vulnerability analysis for flood disasters, two different scales are repeated at the metropolitan scale covering the central city districts of Izmir and at the planning region scale, which is the second spatial planning region of Karşıyaka district. In this way, the identical data were evaluated at two different scales and vulnerability was ranked spatially.

5.2.1 Metropolitan Scale Flood Vulnerability Index

The vulnerability analysis indicates that the Metropolitan Scale, where there is a high density of construction, river basins, industrial, commercial and residential areas, have a very high level of vulnerability. In addition to this, regions that are characterized by their green spaces have occasional high levels of vulnerability due to construction pressure and the presence of sensitive areas. When the vulnerability of Izmir metropolitan districts to flooding is analyzed, Bayraklı, Konak (especially Alsancak area) and Karşıyaka districts have very high vulnerability. As a matter of fact, these districts are heavily affected by extreme rainfall every year. In this context, this study, which is produced as an AHP-based vulnerability analysis, reflects the current vulnerability accurately (Figure 5.3).

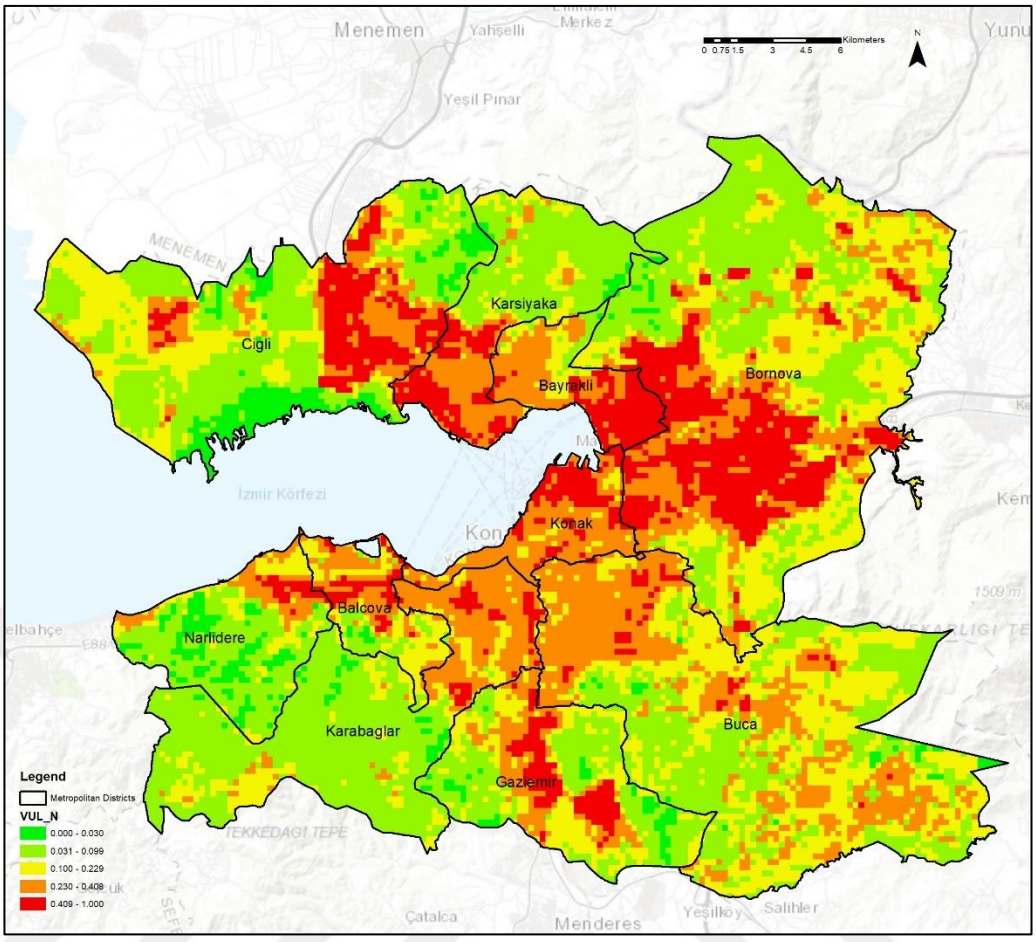

Figure 5.3 Flood Vulnerability Analysis of Metropolitan Area

5.2.2 Planning Region Scale Flood Vulnerability Index

The analysis is applied on a planning region scale consisting of the 10 neighborhood in Karşıyaka District that constitute the city center of Izmir on a cellular basis as shown in figure xx. In this way, the spatial characteristics of the area could be evaluated in place regardless of boundaries.

The analysis of the Planning Region reflects that the northern neighborhoods, where building sizes are small and construction density is high, have a high level of vulnerability to flooding. As a matter of fact, this area is also a risky area in terms of rainfall. Likewise, the eastern region, where different land uses are concentrated, is

also a flood risk area and is expressed with high vulnerability in the analysis. Another critical point is the results of the Mavişehir neighborhood. This area was flooded in 2023. As a matter of fact, the results of this analysis directly describe the areas that have experienced flooding. In this context, it can be said that this analysis accurately reflects the current situation of the planning region (Figure 5.4).

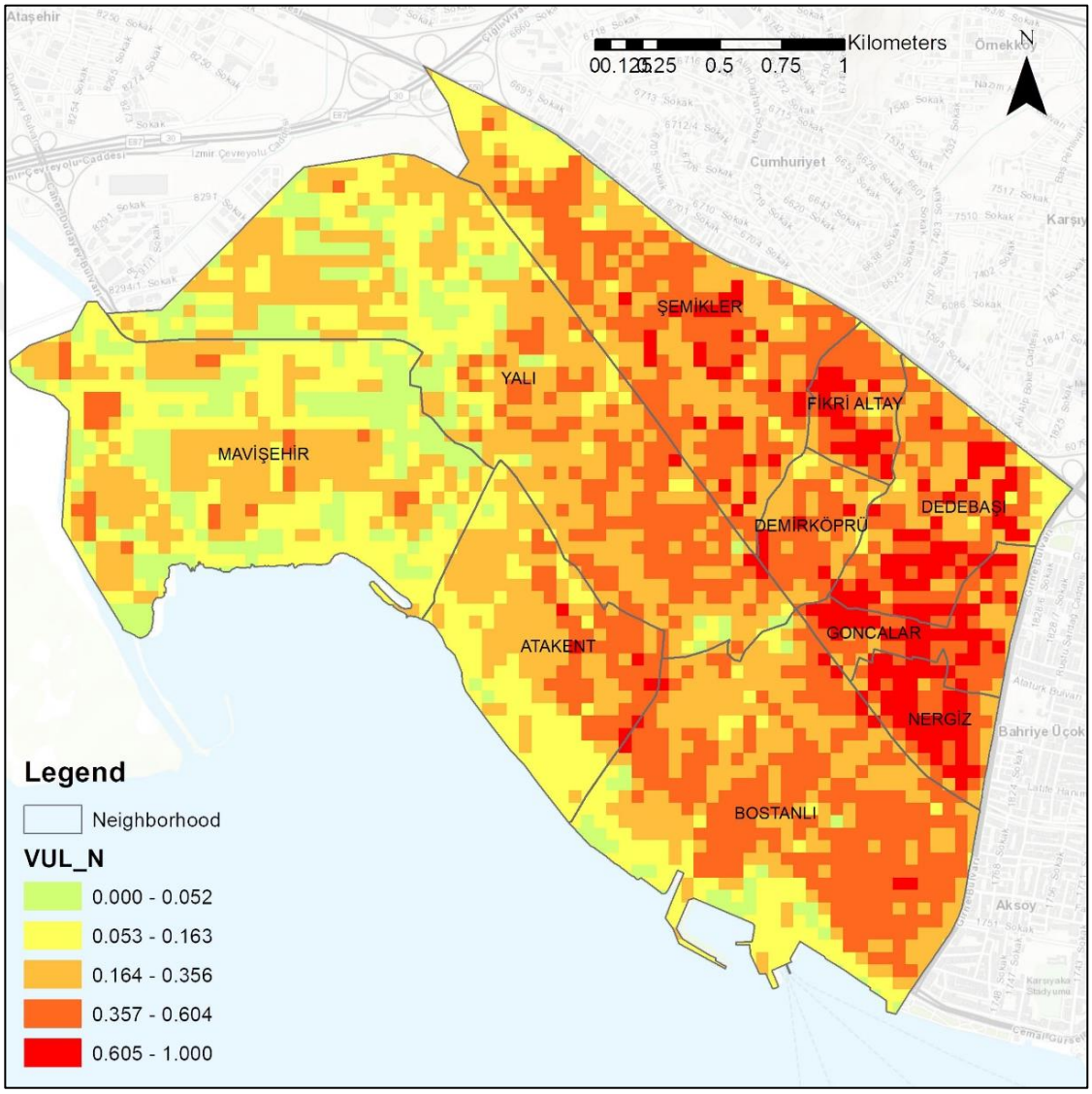

Figure 5.4 Flood Vulnerability Anlaysis of Planning Region Scale

5.3 Extreme Heat Vulnerability Index

In this section of the vulnerability analysis for extreme heat weather, two different scales are repeated at the metropolitan scale covering the metropolitan districts of Izmir and at the scale of the planning region, which is the second spatial planning region of Karşıyaka district. In this way, the same data were evaluated at two different scales and vulnerability was graded spatially.

5.3.1 Metropolitan Scale Extreme Heat Vulnerability Index

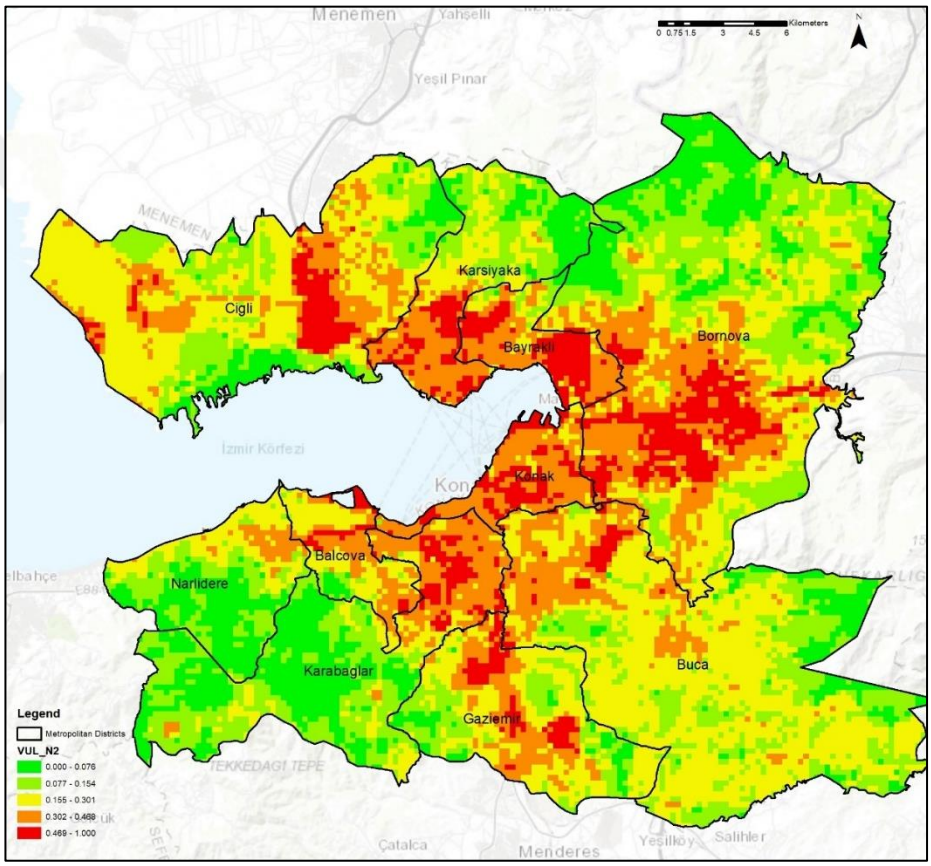

Figure 5.5 Extreme Heat Vulnerability Analysis of Metropolitan Scale

In the vulnerability analysis conducted within the scope of the metropolitan region, the vulnerability level of the districts of Karşıyaka and Konak, which lack green spaces in the urban fabric, and the districts of Çiğli and Bornova, which are characterized by

industrial and commercial areas, is high (Figure 5.5). Inciraltı urban forest area, which is an area to be protected for its natural assets, appears to be high risk due to its vulnerability. In Konak district, the intersection points of main squares and roads are also a region with high UHI impact within the district, which is accurately reflected in the vulnerability analysis. Similarly, the area in the western part of Karşıyaka district, where high-rise high-rise areas are located, is also characterized by high vulnerability values within the district. With these examples, it is seen that the analysis method used reflects the current situation well for both disasters.

5.3.2 Planning Region Scale Extreme Heat Vulnerability Index

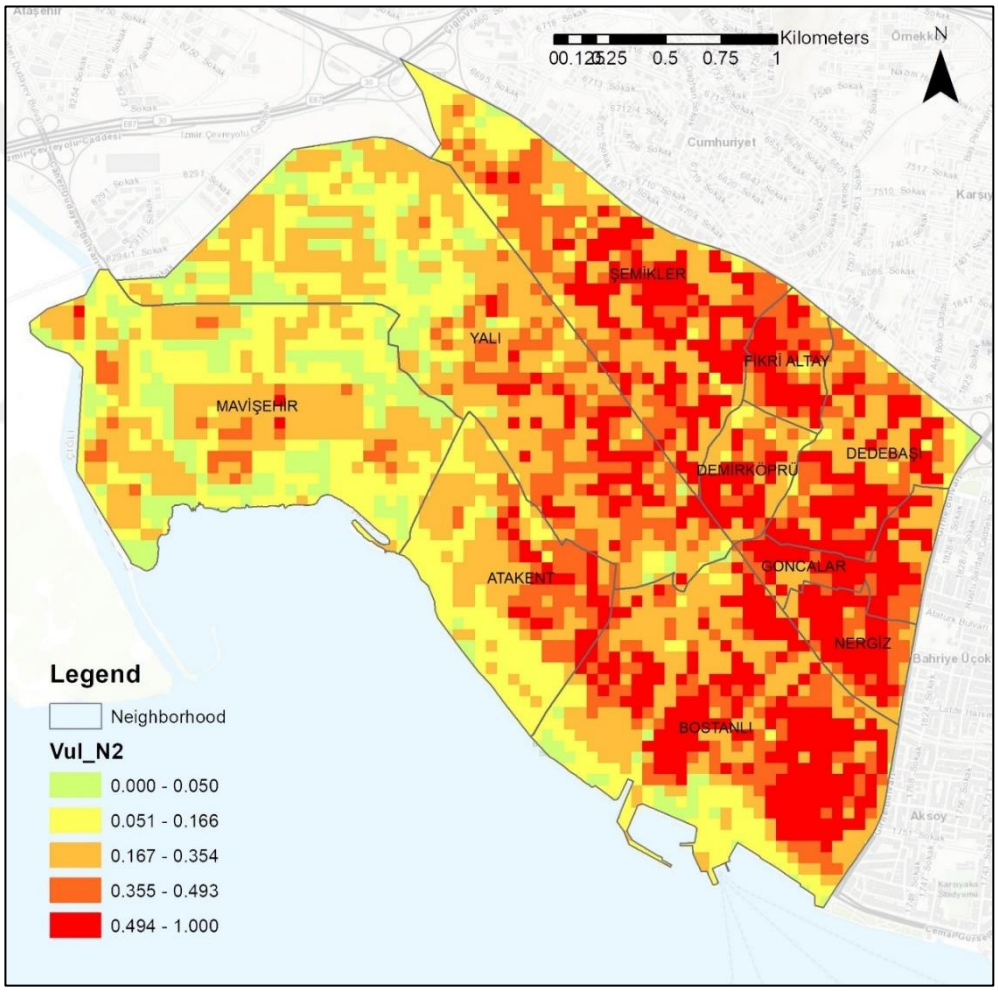

Figure 5.6 Extreme Heat Vulnerability Analysis of Planning Region Scale

In the analysis of the level of vulnerability to climate change, it is seen that the region is divided into two parts as north and south in case of flood disaster, while in the extreme heat analysis, it is seen that the area is divided into two parts as east and west. It is noteworthy that the vulnerability levels are lower in areas where there is a lack of green space. The commercial units located in the east of the region and the rediential areas located in the neighborhood centers have caused high levels of vulnerability in terms of urban heat island. On the other hand, in the Mavişehir neighborhood, which has a large and wide floor area, but has a discrete layout and therefore a high level of ventilation, the vulnerability is low compared to the area. The high-rise split-layout buildings in Atakent neighborhood and the urban fabric of Bostanlı neighborhood are the areas where the vulnerability texture in the coastal band has changed. Since these areas are public transportation centers and main commercial centers, they have intense mobility, and the perceived temperature value is high. In this context, it is seen that this analysis accurately reflects the current situation, just like the other scales and scopes (Figure 5.6).

5.4 Conclusion

This study presents a comprehensive methodology that combines spatial analysis and Analytic Hierarchy Process (AHP) methods to assess the vulnerability of Izmir province to flood and extreme heat disasters. Disaster vulnerability in the city of Izmir is assessed through eight main indicators at two different scales (metropolitan scale and planning region scale). The main formula used in this analysis calculates disaster vulnerability based on three main components: exposure, susceptibility and coping capacity. The analysis process and findings, described in detail below, provide important disaster management and urban planning insights for the city.

The basic formula used to measure disaster susceptibility is expressed as follows:

$$Vulnerability_{flood} = \frac{(Exposure_{si} x\ w_i) x\ (Susceptibility_{sj}\ x\ w_j)}{(Coping\ Capacity_{sk} x\ w_k)} \qquad (5.2)$$

In addition, the weights of each main indicator were determined using the AHP method and these weights were integrated into the sensitivity calculations. The analysis was conducted by aggregating spatial data at different scales (250 m x 250 m cells and 50 m x 50 m cells) and sensitivity calculations were performed on a cell-by-cell basis. In this cell-based analysis, the effect of exposure, vulnerability and coping capacity in each cell was determined and the final susceptibility index was normalized in the range of 0-1. In this way, for each scale and disaster, individual vulnerability levels were created, and their spatial distribution was mapped.

The metropolitan scale consists of 10 districts covering Izmir city center. This scale aims to assess the city's vulnerability to disasters by analyzing the regions with high building density, commercial and industrial areas.

When the studies conducted at the metropolitan scale against flood disasters are analyzed, the districts of Izmir with the highest degree of vulnerability are Bayraklı, Konak and Karşıyaka districts. Areas such as Alsancak in Bayraklı and Konak districts are at high risk of flooding due to dense construction and the encroachment of river basins (Ercan, 2016). These areas are affected by heavy rains every year and experience flooding due to inadequate infrastructure. These structural weaknesses in Konak and Bayraklı, combined with the lack of green space, increase vulnerability to disasters (Şahin, 2018).

In the sensitivity analysis against extreme heat, especially Karşıyaka and Konak districts show high risk due to their lack of green space. The urban heat island (UHI) effect in these districts is due to the structural density and lack of green space in these areas (Taha, 2019). The extreme heat effect is also evident in districts with dense industrial and commercial areas such as Çiğli and Bornova. Commercial and industrial buildings in these regions are generally made of materials that retain heat, increasing air temperatures.

The planning region scale provides an analysis of 10 neighborhoods in Karşıyaka district. This smaller scale analysis allows more detailed results to be obtained on a neighborhood basis. The assessment at this scale allows for a micro-level analysis of vulnerability to disasters.

When vulnerability to flooding is examined at the scale of the planning region, the northern neighborhoods (especially Demirköprü, Atakent) stand out as areas of high vulnerability. These neighborhoods are characterized by high construction density, narrow streets and decreasing green areas. In areas with high building density, water drainage is poor, increasing the risk of flooding (Altın, 2020). Mavişehir Neighborhood also presents an important finding. In 2023, the major flood disaster was among the areas that affected Mavişehir. This region was identified as having a high probability of flood risk, which was confirmed by the analysis results.

In the analysis conducted in terms of extreme temperatures, Atakent and Bostanlı neighborhoods stand out as regions with high temperature values due to the effect of intense commercial areas and transportation centers. In these neighborhoods, the heat island effect created by heavy traffic and trade increases local temperatures (Matzarakis and Mayer, 1997). On the other hand, in neighborhoods with large areas such as Mavişehir, lower temperature values were observed. The large area structure of Mavişehir allows for good air circulation, which reduces the temperature values in the region.

As a result, at the metropolitan scale, the areas in Izmir city center with high density of residential and commercial/industrial areas are at high risk for both types of disasters. Bayraklı, Konak and Karşıyaka districts have been identified as the regions with the highest risk for both flood and extreme heat.

At the Planning Region Scale, among the neighborhoods in Karşıyaka district, the northern neighborhoods are more susceptible to flood risk, while the southern neighborhoods are less susceptible. In terms of extreme heat risk, Atakent and Bostanlı neighborhoods are among the high-risk areas.

CHAPTER SIX
CONCLUSION AND DISCUSSION

Mitigation, reduction and adaptation efforts against climate change, the effects and frequency of which are increasing day by day, have become the focus of planning research in the last decade. The extensive research has led many disciplines, including the planning discipline, to collaborate together. Thus, the common denominators of disciplines with different perspectives could be addressed from a wider perspective. With the adoption of the academic studies by the world organizations, studies on resilience against climate change have been produced on a more robust and solid basis. In this context, the common opinion of the majority, which is rare in the literature, has developed with the adoption of a risk-based approach to resilience. The fact that the effects of academic studies have been reflected in world organizations and even country administrations has constituted an important turning point in ensuring resilience against climate change.

Regardless of their perspectives and disciplines, researchers and organizations have agreed that climate change cannot be prevented, but its impacts can be mitigated. To achieve this, one approach is the risk-based resilience approach. The approach incorporates multiple phenomena and this is where its inclusiveness comes from. In this approach, risks need to be accurately described and the elements affected by risk need to be accurately described. An important phenomenon that emerges in this context is Vulnerability. In the most general terms, vulnerability refers to the level of affectability to a risk. Understanding vulnerability has a critical role in identifying resilient and sustainable cities. Indeed, this view has been widely accepted and research has gained momentum especially after 2000. Although there are many different ways to measure vulnerability emerging from the risk approach, one of the most important approaches that can be calculated rationally and without personal judgment is the vulnerability index approach. The vulnerability index analyses a series of elements from the definition of vulnerability rationally and scientifically. It does

this with functions based on its definition. The most basic formula in this context is that vulnerability is directly proportional to exposure and sensitivity or susceptibility and inversely proportional to coping capacity. This is the focus of this thesis, which is still being clarified in the literature.

This thesis attempts to find an integrated and inclusive method of analysis that can be used to create a resilient city against floods and extreme heat disasters that occur due to climate change and rapidly increasing in the urban environment. In this context, based on a function from the definition of vulnerability, this thesis discusses how vulnerability can be measured more practically and effectively in urban areas. The elements that will form the input to the formula coming from the definition of vulnerability were carried out by selecting 8 main indicators that can be considered the city as a complete structure. The selected indicators are those that are frequently discussed in the theme of vulnerability and resilience and are also meaningful for the city of Izmir, where the case study of the research is conducted. Although each element of the city with its complex structure affects vulnerability to climate change in the city, the relationship between these elements of the city and vulnerability is not clear or equal. Within this approach, the thesis conducted an AHP-based research to understand the relationship between indicators and vulnerability before proceeding to vulnerability index analysis. In order to get the optimum result from the AHP method, a series of pairwaise surveys is conducted for 7 experts with expertise in at least one of the areas of climate change, vulnerability, floods or extreme heat. The results obtained from the AHP analysis are similar to the literature. However, the Economic status indicator, which is frequently used in the literature and expressed in high degrees in weighting studies, has a low priority value in this study, in contrast to what is expected. This may be due to the limited and cursory selection of sub-indicators in this thesis due to the limited availability of open data on economic indicators in Turkey. Another noteworthy point in the AHP process is that occupational and disciplinary differences have become significant especially in the comparison of physical indicators and social indicators. In the survey, engineers and architects emphasized that physical indicators are superior to social phenomena under most circumstances,

while urban planners argued that social and economic indicators are equal or more important than physical indicators. Since vulnerability involves multidimensional and complex processes, it is critical to get expert opinions from different disciplines in order to understand vulnerability accurately and rationally. The study conducted in this thesis also substantiates that.

A key issue in creating resilient cities is the efficient use of limited resources, which has gained prominence in recent years with the sustainability approach. Measuring the current situation and understanding risks, vulnerabilities and exposures requires a great amount of effort, time and material resources. Some researchers who accept this approach argue that vulnerability index is therefore not a sustainable method of vulnerability analysis. This issue, which is an important question mark in the literature, is another important aspect emphasized in this thesis. This is as important as the instruments by which urban vulnerability can be measured and how its weights can be determined, and this topic is in need of sustainable approaches. In this context, the thesis has designed a research based on open data sources or minimum level data. In order to answer this question in the literature, another aim of the thesis is to test whether this vulnerability approach can work for different disasters at different scales with limited data and limited resources. In this context, only the basic data produced by each local government at the minimum level adopted in traditional planning approaches were selected as sub-indicators. With this data, vulnerability analysis at two different scales is created separately for flood and extreme heat disasters. In this way, it will be possible to discuss how the same indicators can be weighted in different disasters, as well as whether a rational and realistic vulnerability analysis can be produced at two different scales with the same indicators and weights. In this context, within the scope of the thesis, the first scale has been determined as Metropolitan scale covering 10 metropolitan districts located in Izmir city center. The second scale is the Planning Region Scale, which describes the 2nd Spatial Planning Region covering 10 neighborhoods of Karşıyaka district. Two separate AHP weighting analyses were conducted for both scales for flood and extreme heat disasters and the relationships between disasters and indicators were calculated for both scales at once. On the way

to the vulnerability analysis, spatial analyses were produced for both disasters and scales at one time and evaluated in the ways frequently adopted in the literature and made to constitute an input for vulnerability. One of the biggest challenges of creating a single data set to be used for two different scales is the different depth and scale of the data set. In order to describe the city in a complex structure, population-related data had to be analyzed together with physical elements. In order to avoid these differences, the celling method, which is frequently used in the literature, is adopted. Based on the average of the dimensions of the spatial uses of the metropolitan scale, the cells were determined as 250 m x 250 m for the metropolitan scale and 50 m x 50 m for the Planning Region with the same approach. This cell system used as a base forms the basis of the vulnerability analysis. The formula based on the definition of vulnerability and the weights from AHP are combined in each cell. In this way, four vulnerability analyses were created for two different disasters and two different scales. Each vulnerability analysis is evaluated according to its current situation, and whether or not the method accurately depicts the place is discussed. It has been determined that a single indicator group, i.e. a single data set, can be considered at different scales, and if the weighting is applied properly, it accurately reflects the current situation.

The vulnerability, as the output product of this thesis, which is a rational and sustainable tool to ensure resilience against climate change, can enable experts from different disciplines such as policy makers and urban planners to make decisions and use their limited resources efficiently. The fact that the outputs of the method are described spatially on a cell basis contributes to the specific identification of areas requiring intervention. New strategies and measures that can be developed against resilience can be implemented in a more sustainable way with this and similar spatial vulnerability and prioritization studies. In addition, since it will be understood which elements affect vulnerability and how they affect it, it may be possible to intervene with limited resources and provide greater benefits with smaller scale projects. In addition to the potentials of the method, there are also possible threats. There is a risk that the factors that will affect vulnerability in the method affect the expert opinions, since the experts cannot be impartial. Another important problem is that there are urban

elements that cannot be measured rationally due to the complex and dynamic structure of the city. Population-oriented data, urban sociology and psychology can be given as an example. These and similar issues are related to the limitations and assumptions of the study. Within the scope of this study, a series of indicators that would reveal the character of Izmir city could not be evaluated due to the inability to obtain data and constituted the limitations of the study. Although controversial, vulnerability analyses are an important tool on the path to resilience. New analysis and evaluation methods that will emerge in the future can be combined with vulnerability and the level of rationality can be increased. In this way, it will be possible to develop more sustainable resilient city development processes where different disciplines against climate change converge on a common denominator.

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APPENDICES

A- AHP SURVEY EXAMPLE

Personal Information					
Gender	Female	Male	Rather Not to Say		
Education Level	Bachelor's	Master		PhD	
Area of Profession	Academics	Urban Planner	Architect	Engineer	Other
Years of Experience	0-4	5-10		10+	

Numerical Rating	**Definition**	**Explanation**
1	Equal (1)	Both options contribute **equally** to the cause. **Example:** When Land Use and Green Spaces evaluated in terms of Flood Vulnerability, if these two factors are equally important, it takes the value "1".
3	Slightly Important (3)	Experience and opinions **slightly outweigh** one option. **Example:** When Land Use and Green Spaces are evaluated in terms of Flood Vulnerability, if Land Use slightly outweighs Green Spaces, it is given a value of "3.".
5	Strongly Important (5)	Experience and evaluations find one option **strongly more important** than the other. **Example:** When Land Use and Green Spaces are evaluated in terms of Flood, if the Land Use factor is significantly superior to the Green Spaces factor, it receives the value "5".
7	Very Strong Important (7)	Experience and evaluations consider one option to be **very important over** the other. **Example:** When Land Use and Green Spaces are evaluated in terms of Flood, if Land Use is very strongly superior to Green Spaces, it is given the value of "7".
9	Extremely Important (9)	Experience and evaluations prefer one option to the **highest possible degree over** the other. **Example:** When Land Use and Green Spaces are evaluated in terms of Flood, if Land Use is absolutely superior to Green Spaces, it is given the value of "9".
2,4,6 or 8	Intermediate Values	Used for evaluations **between ranges.** **Example:** When Land Use is evaluated in terms of Flood, if it is between slightly important and strongly important options from the Green Spaces factor, it takes the value of "4".

Main Indicator	Sub-Indicator
Land Use	Residential, Industrial, Social, Commercial, Open Spaces, Public Spaces and Land Use Changes
Green Spaces	Green Spaces Ratio and Quality
Building Condition	Material, Age, Building Height, Number of Floors, Number of Unit
Street Network Quality	Street Width, Slope, Walkability, Emergency and Rescue Routes, Street-Building Relationship, Accessibility to Hospital, Gathering area, Emergency Facilities and Rescue Routes
Population	Population Density, Mobility Density, Population Over Time (Past), Population Projection (Growth)
Vulnerable Population	Children <5, Elderly>65, Female Ratio, Dependency Ratio, People with Disabilities Ratio
Economic Status	Low Income Households Ratio and Economic Gap in the Population
Disaster Risk Level	Disaster Risk Level of the Area

Flood Vulnerability

	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Land Use																		Green Spaces
Land Use																		Building Condition
Land Use																		Street Network Quality
Land Use																		Population
Land Use																		Disadvantaged Population
Land Use																		Economic Status
Land Use																		Hazard Risk Level
Green Spaces																		Building Condition
Green Spaces																		Street Network Quality
Green Spaces																		Population
Green Spaces																		Disadvantaged Population
Green Spaces																		Economic Status
Green Spaces																		Disaster Risk Level
Building Condition																		Street Network Quality
Building Condition																		Population
Building Condition																		Disadvantaged Population
Building Condition																		Economic Status
Building Condition																		Disaster Risk Level
Street Network Quality																		Population
Street Network Quality																		Disadvantaged Population
Street Network Quality																		Economic Status
Street Network Quality																		Disaster Risk Level
Population																		Disadvantaged Population
Population																		Economic Status
Population																		Disaster Risk Level
Disadvantaged Population																		Economic Status
Disadvantaged Population																		Disaster Risk Level
Economic Status																		Disaster Risk Level

Main Indicator	Sub-Indicator
Land Use	Residential, Industrial, Social, Commercial, Open Spaces, Public Spaces and Land Use Changes
Green Spaces	Green Spaces Ratio and Quality
Building Condition	Material, Age, Building Height, Number of Floors, Number of Unit
Street Network Quality	Street Width, Slope, Walkability, Emergency and Rescue Routes, Street-Building Relationship, Accessibility to Hospital, Gathering area, Emergency Facilities and Rescue Routes
Population	Population Density, Mobility Density, Population Over Time (Past), Population Projection (Growth)
Vulnerable Population	Children <5, Elderly>65, Female Ratio, Dependency Ratio, People with Disabilities Ratio
Economic Status	Low Income Households Ratio and Economic Gap in the Population
Disaster Risk Level	Disaster Risk Level of the Area

Extreme Heat Vulnerability

	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Land Use																		Green Spaces
Land Use																		Building Condition
Land Use																		Street Network Quality
Land Use																		Population
Land Use																		Disadvantaged Population
Land Use																		Economic Status
Land Use																		Hazard Risk Level
Green Spaces																		Building Condition
Green Spaces																		Street Network Quality
Green Spaces																		Population
Green Spaces																		Disadvantaged Population
Green Spaces																		Economic Status
Green Spaces																		Disaster Risk Level
Building Condition																		Street Network Quality
Building Condition																		Population
Building Condition																		Disadvantaged Population
Building Condition																		Economic Status
Building Condition																		Disaster Risk Level
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