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Architecture

**UNDERSTANDING THE EARTHQUAKE
RISK REGIONS IN BAĞCILAR VIA KMEANS
CLUSTERING FOR URBAN PLANNING
STRATEGIES**

Mohammed Sadeq Jaafar JAAFAR

Master's Thesis

Supervisor
Asst. Prof. Dr. Can UZUN

İstanbul, 2024

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The thesis titled UNDERSTANDING THE EARTHQUAKE RISK REGIONS IN BAĞCILAR VIA KMEANS CLUSTERING FOR URBAN PLANNING STRATEGIES prepared by MOHAMMED SADEQ JAAFAR JAAFAR and submitted on 00/00/2024 has been **accepted unanimously** for the degree Master of Science in Architecture

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I hereby declare that all information/data presented in this graduation project has been obtained in full accordance with academic rules and ethical conduct. I also declare all unoriginal materials and conclusions have been cited in the text and all references mentioned in the Reference List have been cited in the text, and vice versa as required by the above mentioned rules and conduct.

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ABSTRACT

UNDERSTANDING THE EARTHQUAKE RISK REGIONS IN BAĞCILAR VIA KMEANS CLUSTERING FOR URBAN PLANNING STRATEGIES

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In earthquake-particular regions, putting out urban planning first makes it possible to prevent the loss of lives, infrastructure, and communities from the effects of earthquakes. With preventive and comprehensive planning, urban planners will be able to face risks and improve resilience while providing for an area's development to be sustainable. Bağcılar is fourth most populous in the Istanbul Municipality of Turkey, is not exempt from this threat. This research focuses on a Bağcılar, within the broader context of Urban Planning for minimizing Earthquake Risk Building Architectures. The high, medium and low risk neighborhoods in the Bağcılar region and the neighborhoods that suffer from common risk factors were identified and urban planning strategies were given to avoid earthquake risks and their impact on residential and architectural buildings in the urban fabric of the Bağcılar region. The findings and methodologies developed in this study can be extended to other regions within Türkiye and serve as a blueprint for seismic risk assessments in similar urban settings worldwide. Here, we start with a critical analysis of the present urban planning systems in Bağcılar focusing on their ability to represent buildings in the context of seismic risks. It involved a thorough review of the existing policies and decision-making processes with details of the areas that need improvement and they will be used in the next step. In addition to this, we planned to assess the contribution of the different machine learning techniques, including highly intelligent clustering algorithms and feature reduction techniques. Furthermore, targeting those specific building components that make Bağcılar's building collapse uniquely hazardous during earthquakes and that influence the effective earthquake risk assessment and urban planning strategies are also included in our research plan. In a wider sense, it was an investigation of certain determinants such as building

materials, architectural styles, and construction techniques to get a clear picture of how these factors contribute to seismic resistance. As a result, the translation of research outcomes into practical applications contributes to the improvement of earthquake risk assessment and the making of that area to be better prepared before disasters. Such response consists of the provision of implementable suggestions and instructions that involve the local context as well as giving out tools and strategies for the stakeholders to use to build more resilient communities and infrastructure.

Keywords: Urban Planning, K-Mean, Machine Learning, Earthquake, Risk Factors , Bağcılar.



ÖZET

BAĞCILAR'DA DEPREM RİSKLİ BÖLGELERİN KÜMELENME İLE ANLAŞILMASI ŞEHİR PLANLAMA STRATEJİLERİ İÇİN KÜMELEME ANLAMINA GELİR

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Depremi yoğun olduğu bölgelerde öncelikle şehir planlamasının yapılması, depremin etkilerinden kaynaklanan can, altyapı ve toplum kayıplarının önlenmesini mümkün kılmaktadır. Önleyici ve kapsamlı planlamayla şehir plancıları risklerle yüzleşebilecek ve bir alanın gelişiminin sürdürülebilir olmasını sağlarken dayanıklılığı artıracaklardır. Türkiye'nin en kalabalık dördüncü İstanbul Belediyesi olan Bağcılar da bu tehditten muaf değil. Bu araştırma, daha geniş Kentsel Planlama kapsamında Deprem Riskini En Aza İndirici Bina Mimarileri kapsamında Bağcılar'a odaklanmaktadır. Bağcılar bölgesindeki yüksek, orta ve düşük riskli mahalleler ile ortak risk faktörlerinden etkilenen mahalleler belirlenerek kentsel planlama stratejileri verilmiştir. Deprem risklerinin ve bu risklerin Bağcılar bölgesinin kentsel dokusundaki konut ve mimari yapılara olan etkilerinin önlenmesi. Bu çalışmada geliştirilen bulgular ve metodolojiler Türkiye'nin diğer bölgelerine genişletilebilir ve dünya çapındaki benzer kentsel ortamlarda sismik risk değerlendirmeleri için bir plan görevi görebilir. Burada Bağcılar'daki mevcut kentsel planlama sistemlerinin sismik riskler bağlamında binaları temsil etme yeteneklerine odaklanan eleştirel bir analiziyle başlıyoruz. Mevcut politikaların ve karar alma süreçlerinin, iyileştirilmesi gereken alanların ayrıntılarıyla birlikte kapsamlı bir şekilde gözden geçirilmesini içeriyordu ve bunlar bir sonraki adımda kullanılacaktır. Buna ek olarak, son derece akıllı kümeleme algoritmaları ve özellikle azaltma teknikleri dahil olmak üzere farklı makine öğrenimi tekniklerinin katkısını değerlendirmeyi planladık. Ayrıca Bağcılar'ın binasını deprem sırasında özellikle tehlikeli hale getiren ve etkin deprem risk değerlendirmesini ve kentsel planlama stratejilerini etkileyen belirli bina bileşenlerinin hedeflenmesi de araştırma planımızda yer almaktadır. Daha geniş anlamda, bina inşaatı gibi belirli belirleyicilerin araştırılmasıydı.

Bu faktörlerin sismik dirence nasıl katkıda bulunduğunun net bir resmini elde etmek için malzemeler, mimari tarzlar ve inşaat teknikleri. Sonuç olarak araştırma sonuçlarının pratik uygulamalara dönüştürülmesi, deprem risk değerlendirmesinin geliştirilmesine ve o bölgenin afetlere daha hazırlıklı hale getirilmesine katkı sağlamaktadır. Bu tür bir müdahale, yerel bağlamı da içeren uygulanabilir öneri ve talimatların sağlanmasının yanı sıra paydaşların daha dirençli topluluklar ve altyapı oluşturmak için kullanmaları için araç ve stratejilerin sağlanmasından oluşur.

Anahtar Kelimeler: Şehir Planlama, K-Ortalama, Makine Öğrenmesi, Deprem, Risk Faktörleri, Bağcılar.



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1. INTRODUCTION

1.1 BACKGROUND

Natural hazard can be defined as the source of an unknown danger that humans cannot control, and the likelihood of the event, or vulnerability, depends on the geography or the location of that place. Both hazard and vulnerability lead to the requirement of efficient risk assessment and mapping (Schneiderbauer et al., 2004). Natural disasters like earthquakes are sudden and arise without warning, causing the greatest loss of life and property. According to the World Health Organization (WHO), on average, 750000 deaths died globally in an earthquake between 1998-2017 (Disel et al., 2024). This is more than half of the deaths caused due to natural disasters worldwide. The total number of people affected due to earthquakes is more than 125 million worldwide (Ozus et al., 2011).

Within this context, Türkiye is an earthquake-prone country. The reason is that Türkiye is located on the fault lines, leading to thousands of earthquakes yearly. For example, the Turkish Disaster & Emergency Management Authority (AFAD) reported more than 74000 earthquake tremors in 2023 (Figure 1.1).

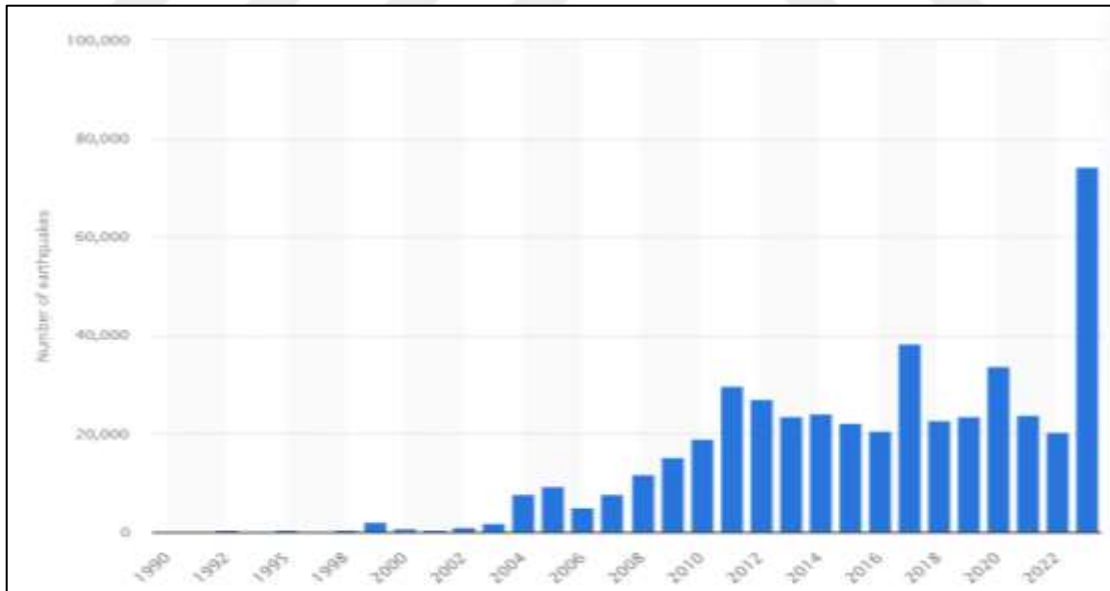


Figure 1.1: Number of Earthquakes in Türkiye from 1990 to 2023 (Turkey: Number of Earthquakes 2023: Available at <https://www.statista.com/statistics/1309531/turkey-number-of-earthquakes>).

Türkiye is one of the world's most earthquake-active regions due to its location on several tectonic plate boundaries, including the North Anatolian Fault Zone (NAFZ). This factor has a direct impact on urban planning by influencing construction laws, infrastructure design, and land use planning. For example, urban sprawl is one of the major challenges in urban planning in which the metropolitan area stretches out across a bigger area, increasing the need for cars and functional transportation (Karakayaci et al., 2016). To reduce this inefficient development, densification has become a planning ideal and sustainable method to generate a shorter distance between urban places (Haaland et al., 2015). Similarly, the demand for housing and infrastructure has become another significant concern in urban planning, yet the development has occurred at the expense of the cities' green spaces (Haaland et al., 2015). These open green spaces, which are located in prime places across the city, are seen as a significant resource that should remain undeveloped. This results in green areas being used for development rather than preservation, which causes challenges for the city's risk management for emerging earthquakes.

Istanbul is one of the megacities in the world and currently the biggest in Türkiye according to the population and built-up area figures, which have a population report of 15, 19, 0336 million people (Istanbul population 2020) and an average daily moving of 672,000 persons to the metropolitan city (Turkey: Population of Istanbul, Online Source: <https://www.statista.com/statistics/899051/turkey-population-of-istanbul/>). Istanbul, which is considered the economic center of Turkey, has a multi-sector business culture that creates space for people who are from smaller cities and the countryside (Yalçıntaş, 2008). The necessity of providing as many houses as population and having functioning infrastructure has deformed the rapid urban growth and grasped the interests and complexity of planning in Turkey.

The complex nature of the urban planning system brings the planning process in Turkish cities to the edge line of being complex, close to being ineffective for sustainable urban development. This means when urban planning is done without thinking of geological phenomena like earthquakes, the problem of the urban population's health and safety gets more chances of getting worse. Istanbul and other districts adjacent to the Marmara Sea lie in the coastal strata of the North Anatolian earthquake region (Drab et al., 2015). Geographically, Istanbul was formed of 39 districts in a geographical sense but as the number of the population went up, old urban areas could no longer provide a healthy, safe

environment and required reorganization to sustain urban necessities (Pakoz et al., 2022). On the east and west sides of these lands, there are situated districts equalling 25 and 14, respectively.

The Bağcılar is one of the working-class suburban municipalities in Istanbul Province, Turkey. It is located on Istanbul's European side, near the city center, approximately north of Bahçelievler, and between the two major ring highways, TEM and D100 (previously E5) (Visiting İstanbul: Available at <https://www.visitingistanbul.com/Bağcılar.html>).

Due to the district's historical development, mixed building ages and typologies, and experiences with seismic events, the site is an ideal case for exploring urban planning and earthquake design. The objective of this study is to determine various clustering patterns and associations between different seismic, geological, and urban factors that influence the risk of an earthquake by employing the K-Means clustering algorithm. The produced clusters will identify areas in Bağcılar most susceptible to different threats, helping urban planners and policymakers adapt relevant strategies precisely towards increasing the community's resistance and minimizing threats. A detailed study of "Bağcılar region" is given in

1.2 RISK ASSESSMENT IN BAĞCILAR DISTRICT.

Rapid urbanization and population growth in seismically active areas have increased the vulnerability of cities to disasters such as earthquakes. This is particularly evident in Bağcılar, a densely populated area of Istanbul, Turkey, which faces a high probability of seismic events due to the nearby North Anatolian Fault. The interaction of geological conditions, urban expansion patterns, and sociolect-economic factors complicates the efforts of urban planners and policymakers to address earthquake risk mitigation. In Bağcılar, the situation is exacerbated by several challenges, including aging residential and architectural structures that pose significant risks during earthquake events. The city's high-rise and mid-rise buildings and dense population in the neighborhoods further amplify these risks. Therefore, it is necessary to develop effective urban planning strategies to identify neighborhoods at risk. The construction history of residential buildings in the Bağcılar district is mostly before 2000, which means that the seismic risk is coming to the urban planning of this area significantly. Planners can better understand the risks shared between neighborhoods and develop customized urban planning strategies to mitigate earthquake risks, which ultimately enhance the safety and resilience of the community. Earthquake risk

factors can vary greatly within relatively small areas. For example, soil type, different building structures, and population densities can vary greatly with respect to several city blocks (Maksom et al., 2022). The dynamic nature of development brings temporal factors into risk assessment as the built environment and population densities are always changing and thus the risk environment changes (Jebreen, Y., 2013). One of the main challenges that need to be addressed to ensure informed and effective urban planning decisions is to develop risk assessment methods that incorporate time factors such as residential and architectural age, number of floors, building materials, and population density of the area. These methods will provide insights into how the risk landscape will evolve in the future and help to develop urban planning strategies for this area to reduce earthquake risks. Furthermore, the approach derived from the analysis conducted in Bağcılar can serve as a valuable resource for similar areas in other urban areas facing similar seismic threats. This contribution will enhance the understanding of urban expansion and its associated risks.

1.2.1 Research Objective and Question

This thesis aims to tackle the urgent need for effective urban planning approaches in areas prone to earthquakes, specifically focusing on Bağcılar, Turkey. Given the significant earthquake risks in the region, it is crucial to create strategies that bolster resilience and reduce vulnerability. The research aims to examine existing urban planning practices in Bağcılar related to earthquake hazards, pinpoint the challenges encountered, and propose customized solutions to minimize these risks.

- i. Develop specific recommendation and guidelines for enhancing earthquake resilience in bağcılar through risky region clustering of bağcılar ?

1.3 THESIS SCOPE

Considering the above-mentioned challenges, this thesis aims to implement the machine learning method called K-Means clustering to identify and categorize the neighborhoods of the Bağcılar district to mitigate the risk of earthquakes. This approach seems to respond to a number of the aforementioned concerns since it intends to gather diverse datasets into an analysis framework in order to capture spatial heterogeneity of risks in the mentioned region, offer data-driven approach towards risk prioritization to inform the planning and resource allocation, provide a computational framework that can be easily updated as and when new

risk data is obtained and finally, offer insights into the fundamental nature of the district risk which can help in formulating

It is in this context that the present study aims to contribute to the advancement of the earthquake risk mitigation policies for urban planners and architects” that can be applied in Bağcılar by addressing these challenges provided that they are solved by employing a more methodical and scientific approach. The discoveries and procedures generated in this study can strengthen The main objective of this study is to develop an urban planning strategy informed by a comprehensive analysis of the risks present in the neighborhoods of Bağcılar district. This involves classifying and assessing the degree of risk associated with each neighborhood. The strategy specifically aims to mitigate earthquake risks by using K-means clustering techniques on relevant data from Bağcılar district. This approach aims not only to enhance safety but also to create a more resilient urban environment for the residents of Bağcılar.

1.4 MOTIVATION

The pace and intensity of urbanization of Bağcılar over the last three decades in the current situation, and it has made it stand among the prosperous and advanced European cities, powering up the production of goods and services, as well as, opening up to cultural diversity (Bayraktar et al., 2024) . On the other hand, urbanization can make the region step into greater danger, including earthquakes; therefore, the whole system of the urban area architecture design and urban planning strategy should be settled as early as possible (He et al., 2016). With the increase in the human population in city centers, the intensity of destruction from earthquakes gets intensify, thus pinpointing the necessity of inclusive urban planning which holds public safety and resilience as a top priority.

Urban areas with rapid growth are increasingly accompanied by formal settlements and substandard housing which consequently imply a serious threat during earthquake events because such buildings are not aware of the principle of earthquake safety (Anhorn et al., 2015). This vulnerability shines a light on the significance of such integral urban planning, which, first of all, takes into account public safety and endurance. In addition to this, the disruption of infrastructure during shake events causes deficiency in the response efforts of responsible bodies, which directly affects a superior infrastructure resilience examination.

Other ways in which the earthquake tectonic activity escalates the vulnerability of the region include land use change which directly influences the intensity and frequency of earthquakes, while the economic losses resulting from earthquakes put jobs and prosperity at stake (Zorat, (2015)). Another issue is that when social vulnerability increases, groups and individuals who are marginalized are more strongly adversely affected by the earthquake outcomes. Deal with these problems by incorporating urban planning principles based on such factors as inclusiveness, adaptability, and empowerment of the population that lives in Bağcılar.

This thesis will show that there are some issues urban planners need to consider and at the same time, give tips, effective strategies, and inspirations that could help individuals to design earthquake-resilient building architectures in Bağcılar district.

1.5 SIGNIFICANCE OF THE STUDY

This research focuses on a specific geographical area, Bağcılar, within the broader context of Urban Planning for minimizing Earthquake Risk Building Architectures. The findings and methodologies developed in this study can be extended to other regions within Türkiye and serve as a blueprint for earthquake risk assessments in similar urban settings worldwide. Moreover, the significance of the thesis can be summarized as follows:

- i. **Enhancing Disaster Preparedness:** Via architecture and urban planning and design, we are enhancing a community's disaster preparedness by prioritizing this urban area that regularly suffers from earthquakes. The unique features of location as well as specific challenges faced by this region in the event of earthquakes can be used to develop targeted strategies that will focus on strong architecture and infrastructure to reduce the risks that may arise during these natural disasters.
- ii. **Promoting Sustainable Development:** The thesis provides a platform, where the main ideas of sustainable transformation of urban areas are being enlightened. Identification of these existing similar communities (subregions) in the Bağcılar is the beginning of these kinds of projects that will make villages not only resilient to natural disasters which is an earthquake in this case, but also address the coupled problems of the environment and socio-economy.

- iii. **Optimizing Resource Allocation in Bağcılar:** The research will, hence, use a purposeful investigation of similar sub regions, the statement leads to several useful tips in budgeting for urban development schemes. The city may make sure that construction is restricted in high-risk locations and that newly constructed buildings are earthquake-resistant by enforcing tight building rules and zoning laws. Refitting pre-exist structures increases their resilience and lowers the amount of resources required in the case of a earthquake disaster. Developing thorough disaster response plans, increasing public awareness, and making investments in robust infrastructure are crucial tactics to reduce casualties and property loss. Other strategies that improve resilience and maximize resource allocation include including green areas, creating evacuation routes, and encouraging community involvement in urban planning processes. By making these efforts, Bağcılar will be able to efficiently manage the hazards associated with earthquakes and devote resources to safeguarding the city and its citizens.

1.6 THESIS OUTLINE

The proposed thesis follows the given structure: Chapter 2 serves as the theoretical foundation of the proposed research. Here, we explore the existing knowledge on earthquake risk assessment and the role of machine learning techniques in this domain. In Chapter 3, we provide the details of the Bağcılar city datasets released by the National Disaster Management Department of Turkey. Furthermore, in the same chapter, we cover the details of employed machine learning methods and the evaluation metrics used to assess their performance. Chapter 4 presents a descriptive data analysis and a comprehensive assessment of machine learning models' performance, visualizations, and maps to support our research findings. In Chapter 5, we provide a concise summary of the key findings from our research. The final Chapter 6 encapsulates our study's significance and real-world applications, emphasizing its contribution to construction engineering and the safety of the Bağcılar community.

2. LITERATURE REVIEW

Natural disasters have caused a sharp rise in both human casualties and global economic loss over the last few decades. Earthquakes have proven to be the most catastrophic natural disaster. There are several causes for these higher losses, but population growth is the most obvious. The construction industry is experiencing tremendous demand due to the rapidly expanding urban population. In developing nations, insufficient funds, vague laws, unplanned urbanization, and a lack of experience all contribute to issues with city planning and construction quality. Buildings have responded poorly and unexpectedly to earthquakes as a result of this chaotic development, which has caused significant damage and occasionally even building collapse. Several scientific facts and policies have been introduced to understand the causes and effects of earthquakes and advanced techniques for minimizing their effects, disasters continue to have destructive consequences, especially in Anatolian plate regions.

2.1 URBAN PLANNING IN BAĞCILAR

Türkiye is highly susceptible to earthquakes, primarily due to its geological and climatic conditions. Since the establishment of the Republic in the 1920s, the country has developed considerable experience in managing natural disasters, particularly earthquakes. However, rapid urbanization and poorly supervised development have significantly increased the vulnerability of urban areas to various hazards, including earthquakes (Uzun et al., 2019). In February 2023, Türkiye experienced two devastating earthquakes with magnitudes of 7.8 and 7.5. These quakes caused extensive destruction across 11 major cities, affecting approximately 15 million people and leading to a death toll exceeding 47,000. The earthquakes have been described as the deadliest disaster in the region since the Erzincan earthquake of 1939 (Bakir, et al., 2004).

The recent earthquakes have highlighted critical issues in Turkey's disaster management and urban planning. Despite the government's efforts to improve building codes and enforcement, the construction boom over the past two decades has often prioritized speed and cost over safety, resulting in many buildings being inadequately prepared for seismic events(Kelman, et al., 2020).

Bağcılar is one of the districts of Istanbul that is considered at risk in the event of an earthquake due to several factors. These include the presence of old and multi-storey residential buildings, as well as high population density ((Turkey: Population of Istanbul, Online Source: <https://www.statista.com/statistics/899051/turkey-population-of-istanbul/>)). Bağcılar was a village in the open countryside until the 1970s when land brokers began selling shared title deeds for small plots of peripheral agricultural land. In the 1980s it developed rapidly almost exclusively illegally, with two significant exceptions of the cluster of cooperative Blocks of flats, and became a separated Municipality in 1992. An irreversible process of urbanization was taking shape in a short span of two decades and the population was about 746,650 in 2010. In 2002, a study that was carried out by the Japan International Cooperation Agency (JICA) affirmed that 90% of the residential buildings deemed as earthquake-resistant were concrete frame structures (Balamir, et al., (2005)). The area is expanded with modest four- to eight-story housing blocks in the center of residential neighborhoods including some small-scale business and manufacturing outlets on the ground floor (Figure 2.1). According to JICA, Bağcılar was shown as one of the riskiest 11 districts in Istanbul against the possibility of a random earthquake. It estimated that 7000 buildings, 20% of the district total, would suffer heavy or moderate damage, causing over 5000 deaths with more than 7000 severely injured (Balamir et al., 2005).. The research highlighted the dire need in all 22 neighborhoods to delve into or redevelop in that order.

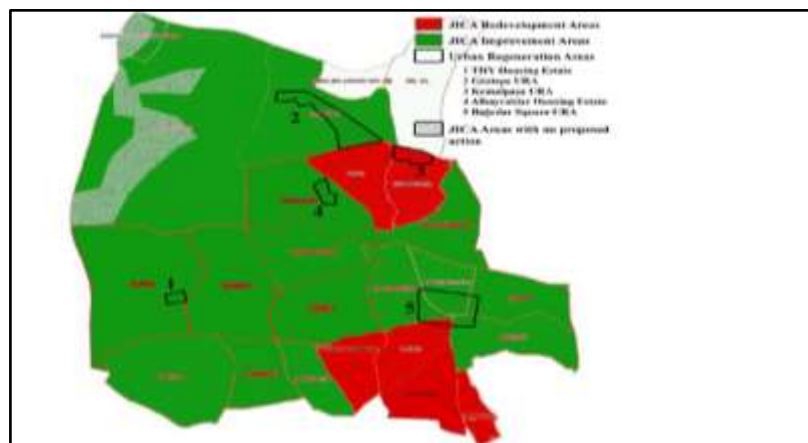


Figure 2.1: Urban Growth And High-Risk Neighborhoods In Bağcılar (Balamir, (2005)).

In 2008, the municipality developed the Bağcılar Spatial Development Strategy, emphasizing earthquake resilience. The strategy included a District-wide Emergency Action Plan and targeted neighborhood redevelopment areas, building on the experience of the 2005-06 Zeytinburnu Project(Polat, et al., (2005)).The aftermath of the earthquakes has revealed significant gaps in the country's disaster response capabilities, necessitating urgent reforms in governance and disaster management strategies. The recent earthquakes in Türkiye underscore the urgent need for enhanced earthquake resilience and improved urban planning to mitigate the risks associated with natural disasters. As the country continues to recover, it faces the challenge of rebuilding in a way that prioritizes safety and sustainability to protect its population from future disasters.In the following chapter I will elaborate Bağcılar District.The following (figure2:2) presents a map of Bağcılar, a district comprising 22 neighborhoods. Each neighborhood is designated by a number; for instance, 1 represents Mahmutbey, while2 denotes the Evren neighborhood.To provide a comprehensive view of the residential and architectural styles within each neighborhood, images showcasing the various areas of Bağcılar will be displayed. These visuals are particularly important as they highlight the potential risks associated with earthquakes, emphasizing the need for awareness and preparedness in the event of such natural disasters.

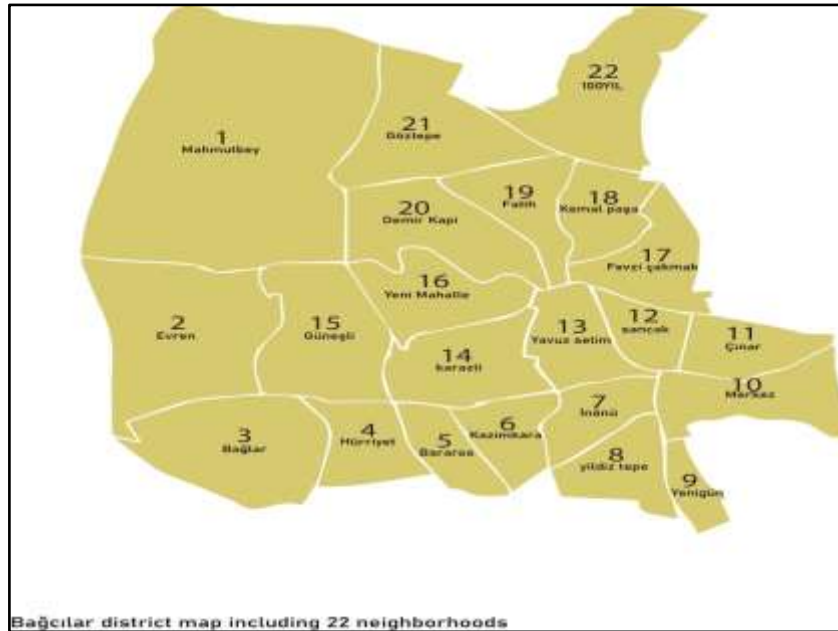


Figure 2.2: Bağcılar District Map Including 22 Neighborhoods

In the following forms, pictures from inside the neighborhoods of the Bağcılar district will be displayed according to the numbering of each district on the map. The following figure(2.3) shows pictures from inside the Mahmutbey and Evren neighborhoods. The following figure(2.3) represents pictures of the Mahmutbey and Evren neighborhoods and shows the residential and architectural buildings of the district .



Figure 2.3: Shows Pictures From Inside The Mahmutbey And Evren Neighborhoods.

The following figure(2.4) represents pictures of the Bağlar and Hürriyet neighborhoods and shows the residential and architectural buildings of the district .



Figure 2.4: Shows Pictures From Inside The Bağlar And Hürriyet Neighborhoods.

The following figure(2.5) represents pictures of the Bararos and Kazim karabekir neighborhoods and shows the residential and architectural buildings of the district



1



2

Figure 2.5: Shows Pictures From Inside The Bararos And Kazim Karabekir Neighborhoods.

The following figure(2.6) represents pictures of the İnönü , Yıldıztepe and Yenigün neighborhoods and shows the residential and architectural buildings of the district.



1



2



3

Figure 2.6: Shows Pictures From Inside The İnönü , Yıldıztepe,And Yenigün Neighborhoods.

The following figure(2.7) represents pictures of the Merkez, Yıldıztepe and Yenigün neighborhoods and shows the residential and architectural buildings of the district.



1



2



3

Figure 2.7: Shows Pictures From Inside The Merkez , Çınar And Sancaktepe Neighborhoods.

The following figure(2.8) represents pictures of the Yavuz Selim , Karazli and Güneşli neighborhoods and shows the residential and architectural buildings of the district.



Figure 2.8: Shows Pictures From Inside The Yavuz Selim , Karazli And Güneşli Neighborhoods.

The following figure(2.8) represents pictures of the Yeni Mahalle , Fevzi çakmak and Kemal Paşa neighborhoods and shows the residential and architectural buildings of the district.



Figure 2.9: Shows Pictures From Inside The Yeni Mahalle , Fevzi Çakmak And Kemal Paşa Neighborhoods.

The following figure(2.10) represents pictures of the Fatih , and Demirkapı neighborhoods and shows the residential and architectural buildings of the district.



Figure 2.10: Shows Pictures From Inside The Fatih , And Demirkapı Neighborhoods.

The Following Figure(2.11) Represents Pictures Of The Göztepe And 100yıl Neighborhoods And Shows The Residential And Architectural Buildings Of The District.



Figure 2.11: Shows Pictures From Inside The Göztepe And 100Yıl Neighborhoods.

In the previous figures, a map of the Bağcılar region was presented, accompanied by images of the associated neighborhoods sourced from Google Maps. This was done to illustrate the residential and architectural characteristics of each neighborhood within the region. In the next chapter of the thesis, I will provide a detailed explanation of the Bağcılar region.

2.2 EXAMPLES OF EARTHQUAKE AND URBAN PLANNING

The design of cities in seismic areas is a vital point that entails the need for an all-encompassing grasp as regards the history of earthquakes and the effect of such occurrences on the settlements. This section aims at a critical analysis and case studies of earthquakes

and urban planning with the thought of exports for learning to be able to respond to such situations and what efficient urban infrastructure can be built.

The review will have two different kinds of case studies which will give the readers glimpses of different situations involving earthquakes and urban planning methods. The first category aims at the case studies in Turkey, a country with a complicated interaction of these dynamic factors that determine urban quality. Looming over Istanbul from the South are the mountains, home to the most active fault lines in Türkiye and around the world. This provides a powerful context for viewing the intersection of earthquakes and urban development. In the first category, we will narrate the case studies from Türkiye and the remaining category will be based on the case studies from regions of the world other than Türkiye establishing a comparative approach to evaluate different approaches for executing urbanization plans. Examples of successful policies and practices from these regions will be used to demonstrate regional implementation and share these lessons through forums and workshops with global actors to build up resilience against earthquakes and also to improve urban sustainability.

We do this with the dual categorization of earthquakes and planning policy for urban areas, which includes international practice and local case studies. The details of these case studies are given below:

2.2.1 Türkiye Example

The below-mentioned case studies are discussed based on surveys, performed in four different regions of Türkiye and two distinct territories from Asia. The details of these surveys are given below.

- i. Erzincan City: The scope of the investigation was the entire city's area, except the two neighborhoods that suffered no damage. Reinforced concrete buildings were built after the introduction of the National Seismic Code in Türkiye in 1975. The survey brought out an interesting perspective regarding the damage incurred by buildings in the aftermath of the earthquake. It was revealed that the quake completely demolished 5% of the buildings, moderate damage was observed in 7% of the buildings and 23% of buildings recorded light damage (Bonstrom, (2013)). Only those that remained had been damaged or fallen in catastrophic ways.

- ii. Adapazari City Center: In the densely populated Adapazari downtown, the surveyors inspected 1,805 structures with 6,340 residential units and 4,000 business units (Bonstrom, (2013)). Because the city center was more densely built than the periphery, these made up approximately 18% of all residential and commercial units in the city, while the survey area made up only 10% of the entire settlement area.
- iii. Maltepe District of Adapazari: Maltepe is situated on a rock. Although it is roughly four to five kilometers closer to the North Anatolian Fault Line than the center of Adapazari, it was less severely damaged by the 1999 earthquake. The survey looked at 934 structures, comprising 2,900 residential and 500 commercial units (Bonstrom, (2013)). The structures under survey accounted for around 6% of Adapazari's total residential and commercial space.
- iv. Gümüşpala Neighborhood of Avcılar: The districts most affected in Istanbul were Avcılar and Büyüçekmece, two nearby sites in the western portion of the city, despite being 100 kilometers from the epicenter of the Kocaeli-Gölcük earthquake. The corresponding average damage rates were 8.2% and 13%. The average damage in Istanbul's other districts ranged from 0% to 1.4% . The damage in Avcılar was not uniformly spread; rather, it was concentrated in the Gümüşpala neighborhood and several commercial districts. Gümüşpala was chosen as one of the survey areas as a result. Nearly ten percent of the overall Avcılar settlement, or 969 buildings, comprising 5,750 residential and 730 commercial units, were inspected . The reinforced concrete frame is the most common type of structure.

2.2.2 China Example

- i. Weizhou Town, Wenchuan County (China), in the Chinese province of Sichuan, Ngawa Tibetan and Qiang Autonomous Prefecture contains the county of Wenchuan. As of 2010, the county's population was 100,771 and its area was 4,084 square kilometers or 1,577 square miles. Weizhou Town is a political, economic, and cultural hub of Wenchuan County. The town has a rich history and vivid culture which plays an important role in village life. Weizhou town was one of the most devastated places by the 2008 quake with a loss of 131 lives and nearly 7139 injuries. A 2008 interview with officials of Weizhou town, where the earthquake reportedly destroyed 85% of the

residential buildings (188.17 hectares of gross building area) and 93% of the industrial buildings (13.5 hectares of gross building area) (Giuliani et al. 2022). Around 14% of the cultivated land (occupying 153.67 hectares) was destroyed and 17 km of municipality roads were even ruined. The surveys used in the three main town neighborhoods divided into the county towns in the same year showed the result that 87% of residents had economic problems. Public facilities with a gross building area of 270,000 m² like schools, hospitals, and commerce also suffered huge damage. The spatial distribution of Weizhou Town before the earthquake is shown in Figure 2.12



Figure 2.12: Weizhou Town Before The Earthquake (Giuliani Et Al. 2022).

ii. Weizhou Town: Planning Experience

The urban design for the restoration of the Weizhou town shattered disaster by the application of an integrated approach. Also, the city mentioned above was experiencing lots of damage to its public buildings and their facilities after the earthquake. The questionnaires on the topic of public demand for after-earthquake construction by 2008 showed that public facilities such as the infrastructure, water supply, education, and cultural facilities acquisition by the residents were on the priority list not the houses. The provision of public clubs and structures became one of the focal points in the urban planning system and the recovery plan as they had been the main concerns once the plan was created. The setting up of public facilities and infrastructure together with the construction of public buildings eventually led to a habit of keeping open spaces around. An integrated course of action could improve the day-to-day use of open space and lead to mixed land use patterns. Therefore, the city was facing several challenges in getting new houses built and long-term economic development of the city that were very important things in the city's life.

The original core of the central axis attracted RMB 20 million in investment from the Guangzhou Municipal Government, and in total its area covers 14,100 m² of premises

(Guangzhou Municipal Government, 2010) (Giuliani et al. 2022). Forty-nine old rundown buildings with false facades or affected by decay were razed and substituted with open playgrounds and public facilities. Comprehension of this integrated reconstitution had two groups of sub projects: water supply, road construction, greening, and lighting. The main venue for recreation and disaster prevention was built in front of the river facing the new culture center. This project, undoubtedly, is a boon for the city center, with the new, open vacuums and the installation of public amenities. This project has several sub projects such as greening projects, square and road projects, municipal pipe network and lighting projects, and embankment reinforcement projects. The project was based upon the idea of the previously very densely populated waterfront transformed into a mix of land use that includes parkland, public facilities, and commercial buildings. The spatial distribution of the urban infrastructure of Weizhou Town after urban planning is shown in Figure 2.12.

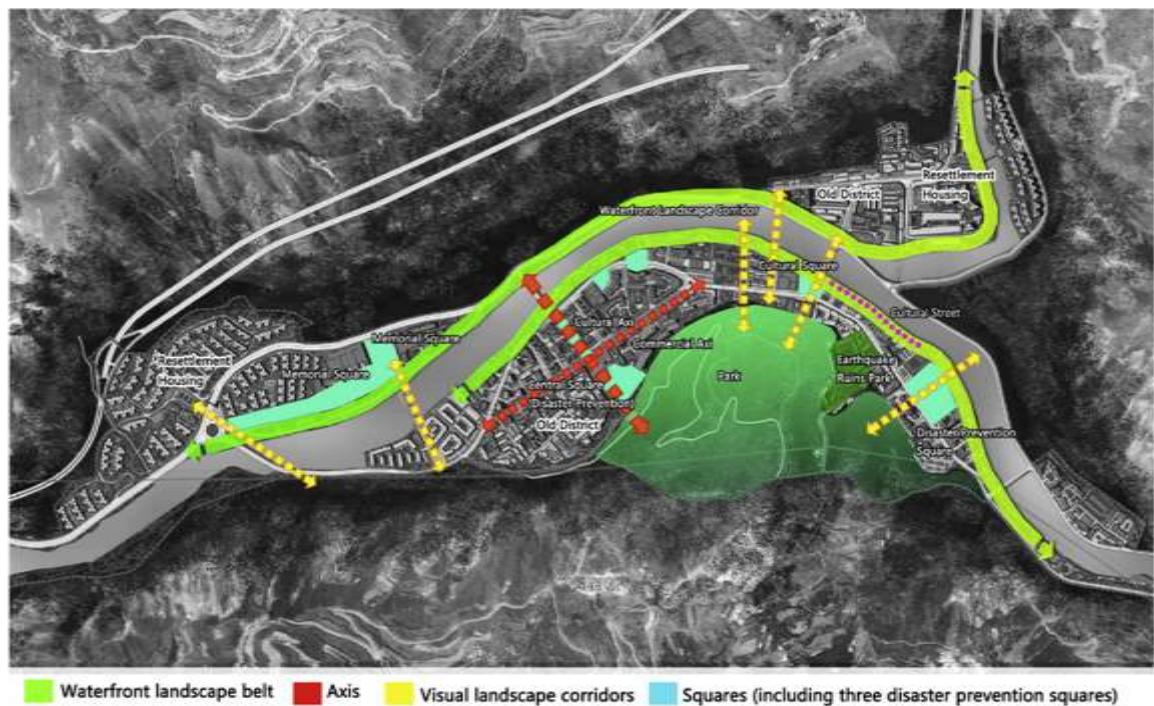


Figure 2.13: New Spatial Structures In Weizhou Town After Urban Planning(Giuliani et al. 2022).

2.2.3 Italy Example

- i. Tuscany Region, Italy is positioned in the most earthquake-affected region of Europe and its entire area is taken as seismically active today. From hazard maps, the highest seismicity is located in the south-central part of Italy, specifically along the Apennines,

from Tuscany to Calabria, and also in Sicily and some northern areas, such as Friuli, Veneto and a western part of Liguria. Throughout its history, the nation has been the victim of several strong earthquakes that led to catastrophic mortality rates and incalculable property damage. Among the most recent events, the L'Aquila (2009), Emilia Romagna (2012), and Central Italy (2016) earthquakes have damaged or even destroyed many historic centers, affecting their cultural, economic, and social values (Contreras et al., 2017) (Figure 2.13). these earthquakes caused a lot of damage, even destroying some historic centers and damaging their cultural, economic, and social values.

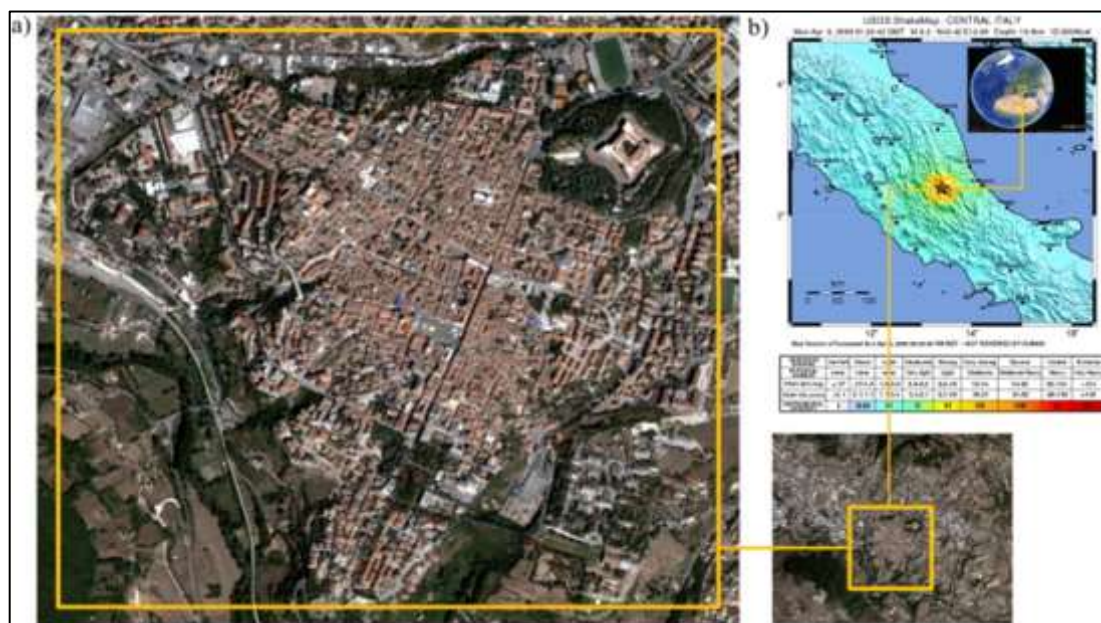


Figure 2.14: Case Study Area: L'Aquila (Italy). (A) Location. Source: Google Earth, Distributed By European Space Imaging On 11 September 2011. (B) Map Of The Ground Motion Intensity During The Earthquake In L'Aquila. Source: USGS (Contreras Et Al., 2017)

ii. Tuscany Region: Planning Experience

The urban planning processes were executed as a detailed resettlement scheme including fieldwork, to search various urban facilities in the earthquake-affected regions in Italy. The area of the case was the classic center of L'Aquila and the housing and accommodations that were created for the displaced population. In 2010, one year after the earthquake, five new settlements visited were: Cese di Preturo, Coppito 2, Coppito 3, and Sassa y Pagliare di Sassa (Harirchian et al., 2020). The nine resettlements visited in 2012 were: Sant'Antonio,

Sant'Elia, Sant'Elia2, Gignano, Bazzano, Paganica sud, Tempera, Camarda, and Assergi2. The final five resettlements were visited in fieldwork conducted in 2014, five years after the earthquake: Paganica 2, Roio Poggio, Roio2, Collebrincioni, and Arischia, located to the north, south and east of L'Aquila.

Tuscany municipality development authority implemented a combination of different techniques to the house. The solar cells will be placed either on the top floor or on balcony rails, the house has seismic isolation at the bottom of it and we will always use the ground floor for a parking space (see Figure 2.13 a and b). Access to the necessary urban facilities in all these newly resettled places is made easily available for all as illustrated in Figure 2.13 c and d. Even though the four new settlements lie in the farthest corners of the Sant'Antonio area which was already established before the earthquake, none of the existing facilities like markets, hospitals, schools, and public buildings there could be used for the reconstruction activities. The only community center that is found in Sassa and Camarda in Figure 2.14(e); and basketball courts to be found in Sant'Antonio, Gignano, and Bazzano are depicted in Figure 2.14 (f).



Figure 2.15: New Settlements Were Built Around L'Aquila (Italy) To Accommodate The Homeless Survivors Of The Earthquake In 2009. A) Collebrincioni (2014). B) Sant' Elia 2 (2012). C) Roio 2 (2014). D) Arischia (2014). E) Camarda (2012), And F) Gignano (2012). Photos: Diana Contreras. (Harirchian Et Al., 2020).

2.3 ROLE OF MACHINE LEARNING AND EARTHQUAKE

Urban planning, as a discipline faced several challenges in the 21st century that have never existed before due to the growth of urbanization, rapid population growth, and in general, rising complexity of cities. To this end, merging machine learning (ML) solutions is full of potential to significantly restructure the standard urban planning procedures. King methods that assure better efficiency, sustainability, and equity in urban development.

One of the main functions of machine learning in urban planning is predictive analysis. Through the assessment of the previous urban data by ML algorithms which pertain to risk-assessment-based urban planning, land use dynamics, and demographic trends, the planners can prognosticate the future trends and hence, anticipate and manage any possible challenges. For example, (Harirchian et al. (2020)). employed Machine Learning (ML), especially a Support Vector Machine (SVM) model, to forecast damage in buildings following an earthquake. They used Rapid Visual Screening (RVS) as its primary screening platform and tested the effectiveness of the ML model with data from earthquakes in Ecuador, Haiti, Nepal, and South Korea. Tunahan (2023) used various ML algorithms in seismic risk assessment for low-rise reinforced concrete buildings using a dataset of 4699 buildings. (Karlbrg et al. (2023)). addressed the limits of ground-based disaster response by presenting an artificial intelligence-driven approach for distant damage assessment using satellite imagery. This study used a dual-task U-Net deep learning model trained on the xBD dataset to automate building damage assessment for the earthquakes in Türkiye on February 6, 2023, potentially streamlining and accelerating disaster response.

In addition, machine learning brings about data-based decision-making in urban planning and designing. AI-powered algorithms work with diverse data sets that include urban morphology, socioeconomic indicators, environmental factors, and preferences of local people, offering useful information on issues such as optimal land use patterns, urban form, and infrastructure placement. Through this data-driven way of working, it becomes possible to make evidence-based plans that prioritize sustainability, resilience, and inclusivity. In general, ML methods can be categorized into two groups: (1) Linear, and (2) Non-linear techniques. Some of the popular methods in both groups are given in Table 2.1. Here are some main ideas that illustrate the significance and frequent superiority of machine learning techniques in urban risk management compared to conventional approaches.

Table 2.1: Illustrate The Significance And Frequent Superiority Of Machine Learning Techniques In Urban Risk Management Compared To Conventional Approache

Machine Learning Algorithm	Catego ry	Scope for Urban Planning in High Earthquake-Prone Regions	Application Description
Decision Trees (Samardžić et al., 2015)	Non-linear	Identify vulnerable infrastructure using geological and structural criteria. Decision trees can categorize buildings and infrastructure based on risk,	This classification helps urban planners prioritize resources for retrofitting and strengthening initiatives, focusing on the most susceptible regions.
Linear Regression (Anderson et al., 2006)	Linear	Linear regression can evaluate the impact of numerous factors on building deterioration and aid in retrofitting efforts.	Linear regression represents the linear relationship between seismic hazard parameters (e.g., ground acceleration, building age) and building vulnerability (e.g., damage severity).
Random Forest (Sideris et al., 2019)	Non-linear	Random forests can investigate a variety of characteristics, including building materials, construction procedures, and proximity to fault lines, to accurately assess earthquake risk.	Random forests combine decision trees provide a holistic picture of earthquake risk by taking various aspects into account at the same time, allowing urban planners to prioritize mitigation activities more efficiently.
Support Vector Machines (SVM) (Bashiri et al., 2017)	Non-linear	SVMs may recognize complicated patterns in seismic risk indicators and help urban planners choose mitigation options.	SVMs recognize patterns in seismic risk indicators, urban planners can better allocate resources and adopt targeted mitigation measures to lessen seismic susceptibility.

Tablo 2.1: Illustrate The Significance And Frequent Superiority Of Machine Learning Techniques In Urban Risk Management Compared To Conventional Approache “Table Continued”.

Machine Learning Algorithm	Linear	PCA helps improve data analysis and decision-making in urban planning.	PCA identifies the key components of seismic hazard data, reducing its dimensionality and emphasizing the most important elements influencing building susceptibility.
Principal Component Analysis (PCA) (Li, (2002))	Non-linear	ANNs can use past earthquake data and building attributes to estimate damage severity and suggest retrofitting solutions for various building types.	ANNs can anticipate damage severity and offer retrofitting actions customized to individual building types using previous earthquake data and building attributes, hence improving overall seismic resistance.
Artificial Neural Networks (ANN) (Mohammady et al., 2014)	Non-linear	CNNs can detect building density, land use patterns, and structural issues, assisting with zoning and disaster preparedness planning.	CNNs can identify seismically risky locations, allowing urban planners to make more informed decisions about zoning, land use, and disaster preparedness.
Convolutional Neural Networks (CNN) (Taoufiq et al., 2020)	Non-linear	RNNs can identify temporal connections in earthquake sequences and help with long-term urban resilience planning.	RNNs provide insights into long-term urban resilience planning, assisting in the development of earthquake mitigation and recovery methods.
Recurrent Neural Networks (RNN) (Kong et al., 2019)	Non-linear	Genetic algorithms can produce near-optimal solutions for reducing evacuation times and increasing community resilience during earthquakes.	Genetic algorithms offer near-optimal solutions for reducing evacuation durations and increasing community resilience during earthquakes, thus improving total disaster preparedness and response capabilities.
Machine Learning Algorithm	Non-linear	KNN can detect clusters of buildings with similar risk profiles, allowing for targeted interventions and community-based resilience programs.	KNN identifies clusters of structures with similar risk profiles, it allows urban planners to apply personalized mitigation measures and increase community earthquake resilience.

Tablo 2.1: Illustrate The Significance And Frequent Superiority Of Machine Learning Techniques In Urban Risk Management Compared To Conventional Approache “Table Continued”.

Genetic Algorithms (Tong, (2016))	Non-linear	Gaussian processes can yield probabilistic seismic effect estimates at fine spatial resolution, which can help with land use planning and building code enforcement.	Gaussian processes enhance land use planning and building code enforcement activities by giving probabilistic estimates of seismic damage at fine spatial resolution, allowing urban planners to make educated decisions about development and infrastructure investments in earthquake-prone areas.
K-Nearest Neighbors (KNN) (Liu et al., 2021)	Non-linear	Reinforcement learning algorithms can simulate structural performance under earthquake loads and suggest design changes to increase safety and durability.	Reinforcement learning enhances building design and construction procedures to increase seismic resistance. It identifies design modifications that improve safety and durability by simulating structural performance under seismic loading conditions, allowing architects and engineers to develop innovative solutions for building earthquake-resistant buildings and infrastructure in seismically active areas.
Gaussian Processes (Ladosz et al., 2019)	Linear	Logistic regression can predict construction failures and help guide risk management techniques.	By measuring the chance of building failure, it aids risk management choices and guides the development of resilience strategies in earthquake-prone areas.

Addressing seismic risks in a Bağcılar where there is a high density of population and high seismic hazards, requires a unique approach that combines urban planning with the latest technology.

The application of machine learning in this field is generally a beneficial practice, as this is a tool that can process a huge amount of data and help to find hidden patterns making them invaluable for building smart city architecture that is risk-tolerant (Cao, L. (2022)) . Clustering and gridding, based on unique features of buildings, is another application of ML in this area. Using clustering in the ML studies, regions with similar building components can be easily identified (Djenouri, et al. (2023)). For instance, these might

include the architectural design, construction material, and vulnerability factors. Through studying past seismic information in conjunction with building traits, ML models can pinpoint groups of locations that show similar seismic susceptibility patterns. The purpose of this clumping technique is to allow planners to prioritize resources by the particular needs of a cluster, while at the same time, enabling them to avoid relying on the one-fits-all size approach on how to mitigate seismic hazards.

Besides the sophisticated methods of grouping, ML applications can include an even bigger number of variables for building attributes as well as for environmental ones than simple clustering methods could. Some models go beyond the baseline structural features of constructions by incorporating other factors like soil type, distance to fault lines, population density, and the integral road and green spaces. Employing this kind of approach, scientists can distinguish the multivariate nature of contribution from different factors that make overall seismic vulnerability stronger. The use of the ML-clustering approach will enable urban planners to target interventions and policies that are geared to the peculiar causes of lowering or changing spatial patterns of living in different region grouping (Sengezer, et al. (2023)). To illustrate, regions with aged, non-reinforced masonry buildings might benefit from retrofitting programs that are specific to designated areas, while cities with high-rise buildings that conform to modern seismic design standards may rely on more efficient response protocols. Urban Features

Urban features encompass the various elements that define an urban environment, including physical structures like buildings, roads, parks, and public spaces. They also include social and economic components such as population density, community services, and cultural institutions. Understanding these features is crucial for assessing how cities function and identifying areas for improvement in urban planning

i. Urban Indexes and Indicators

Urban indexes and indicators are metrics used to evaluate and compare different aspects of urban environments. These can include sustainability measures, livability scores, economic performance, and social equity indicators. Common examples include air quality indices, access to public transportation, and housing affordability metrics. Such indicators are vital

for guiding policymakers and urban planners in making informed decisions about urban development and resource allocation

ii. Application Cycle

The application cycle in urban planning refers to the iterative process through which urban plans and policies are developed, implemented, and evaluated. This cycle typically includes several stages:

Assessment of current conditions and community needs.

Planning, where goals and strategies are formulated.

Implementation of the plans through various projects and initiatives.

Monitoring and evaluation to assess the effectiveness of the strategies and make necessary adjustments. This cyclical approach ensures that urban planning remains responsive to changing conditions and community needs

iii. Urban Planning Decision Support Systems (DSS)

Urban planning decision support systems (DSS) are interactive tools that assist planners and policymakers in making informed decisions regarding urban development. These systems integrate data, models, and analytical tools to evaluate various scenarios and outcomes. They help identify potential issues, assess the impacts of different planning options, and facilitate stakeholder engagement. DSSs are increasingly important in urban planning as they enable more effective and data-driven decision-making processes, particularly in complex environments where multiple factors must be considered all the above stpes related to the ML in urban area shown in figure 2.13.



Figure 2.16: ML Application Cycle For Urban Form Decision Support System.

3. BAĞCILAR DISTRICT URBAN PLANNING AND EARTHQUAKE

This chapter provides an in-depth examination of the Bağcılar district, focusing on four key aspects: (1) Geographical features and Demographic distribution, (2) Building environment, and (3) Urbanization challenges in Bağcılar. It is important to comprehend these basic characteristics as a means to properly frame the next section which focuses on the earthquake risk analysis as well as to formulate appropriate strategic measures for urban development.

The chapter is divided into two sub-sections that are the following -. First, the general location along with all proximate dispositions on the geographical location of Bağcılar, Istanbul, and the physical features surrounding the area. Another section is devoted to the analysis of the demographic aspects of the district, which includes information on the population density and other parameters. The following demographic features will be crucial in the discussion, as they would impact both the earthquake risk and methods of applying urban planning solutions. Taking into consideration these foregoing geographical and demographic factors, a general foundation is created for a thorough study of the Bağcılar district before delving into the necessary focus on the identification of earthquake risk zones and the subsequent determination of specific strategies for the improvement of urban planning and design. Although it is useful to consider this information, it should be noted that geographical and demographic components are not in our data and will not be included in our following K-means clustering analysis. Only the dataset of Bağcılar in chapter 4 is used for earthquake risk assessment.

3.1 GEOGRAPHICAL AND DEMOGRAPHIC CHARACTERISTICS OF BAĞCILAR

Bağcılar is an intense district in Istanbul, Türkiye that can be described as being the epitome of issues that come with urban development within an environment that is prone to disasters such as earthquakes. Bağcılar is one of the districts on the European side of Istanbul with an area of about 22 km² which is inhabited by a population of more than 750 thousand individuals (Bilgen et al., 2016). This makes it one of the most populous districts in Istanbul, its population density is over 34 thousand persons per square kilometer. Its northern border is Esenler, to the east is Güngören, Bahçelievler is to the south and Küçükçekmece to the west, putting the district right in the middle of the expanding Istanbul City (Burdett, (2019)).

Topographically, it is a district on a high plain at an altitude of around 100 meters above sea level . More specifically, the district is flat to gently rolling, although there are some gently undulating parts of the district. This steepness or flatness is far from significant; however, it determines the kind of local soil, the way water drains off, and even how the ground shakes in the event of an earthquake (Sabit, (2012)). Furthermore, the topography of the Bağcılar district is not used as data in this thesis, but it is explained for information and not as data. The data set used in the Bağcılar district will be explained in the next chapter

The urban development plan has also been affected greatly by this aspect as the district is an important transportation center for the country with highways like the TEM and E-5 highway passing through, . The following figure 3,1, shows a map of Istanbul, the Bağcılar district and the surrounding areas in general.



Figure 3.1: Map of Istanbul Showing Bağcılar District.

In Figure 3.2, we have shown the geographical distribution of Bağcılar City in the context of 22 neighborhoods (Source: <https://www.chasingthedonkey.com/39-districts-in-istanbul-eturkiye/>)



Figure 3.2: Geographical Distribution Of 22 Neighbors Of Bağcılar District.

In the study of Bağcılar for the risks posed by earthquake activities characteristic to its soil, the primary approach involved in the process of urban planning is the consideration of extensive seismological risk analyses. This includes outlining areas that are most vulnerable and hence should be protected in case of an earthquake. Education is also necessary to enhance knowledge of the public on the local soil conditions and encourage them to observe the measures that need to be taken. In addition, the presence of those geological factors requires a regulation that can address the issue of raising the vulnerability of the district to an earthquake.. (Kalkan et al., (2023))

Bağcılar representing one of the 39 districts of Istanbul represents its demography, growth, and people with a high growth rate and an ethnic mix. It\ is now one of the largest districts in Istanbul in terms of population. According to available data in 2021, the inhabitants' number in the district will reach approximately 734 000 persons (Akyıldız et al., 2024)).

3.2 BUILT ENVIRONMENT IN BAĞCILAR

Building inventory has been expanded to cover the whole of Bağcılar, to include all structures that are permanent, owned, and used, as well as buildings that are being built or in the early stage of urbanization. The key responsibility for product inventory compilation was carried out with the help of the Istanbul Metropolitan Municipality (IMM) corporate spatial information infrastructure existing on GIS (Nyimbili et al., 2018). In this thesis, I attempted to resolve this challenge by collecting a quantitative building dataset from the Istanbul province possible earthquake loss estimates updating project repository (Department of Earthquake Risk Management and Urban Improvement, Source: <https://8luvomezzzsk.merlincdn.ne>). This dataset was collected from 22 neighbourhoods of the Bağcılar district and it consists of a detailed list of decade-wise constructed buildings from the 1980s. The distribution of all the buildings according to construction year, number of floors, building material, expected number of risk and population density, I will talk about it specifically in chapter 4

In Figure 3.3, we have shown the distribution of buildings in the Bağcılar region in terms of construction year. It can be observed that most of the buildings have been constructed during 1980-2000 (67%), followed by construction years after 2000 (18%). There are limited buildings (15%) constructed before the 1980s. This figure shows that most of the infrastructures and buildings were designed during the 1980s which was the main urbanization stage in the Bağcılar.

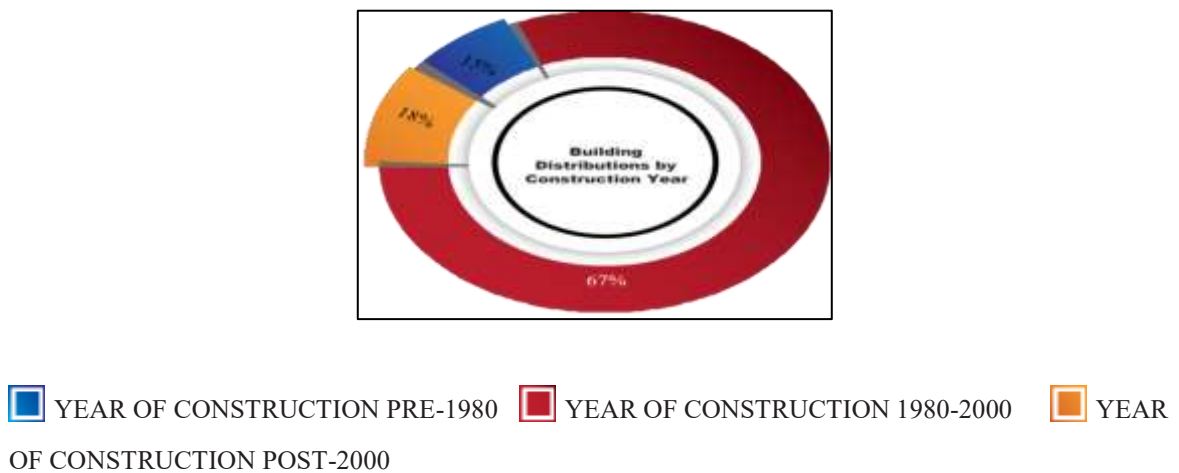


Figure 3.3: Building Distributions by Construction Year

(<https://8luvomezzzsk.merlincdn.ne>)

Figure 3.4 visualizes the distribution of buildings in terms of no. of floors. Here, most of the buildings (56%) have floors in the range of 5-8 levels. Buildings with 1-4 floors have a weight age of 43% and very few buildings (1%) consist of 9-19 floors. It concludes that most of the buildings can buildings (57%) have more than 4 floors which may be a crucial factor in the vulnerability assessment.

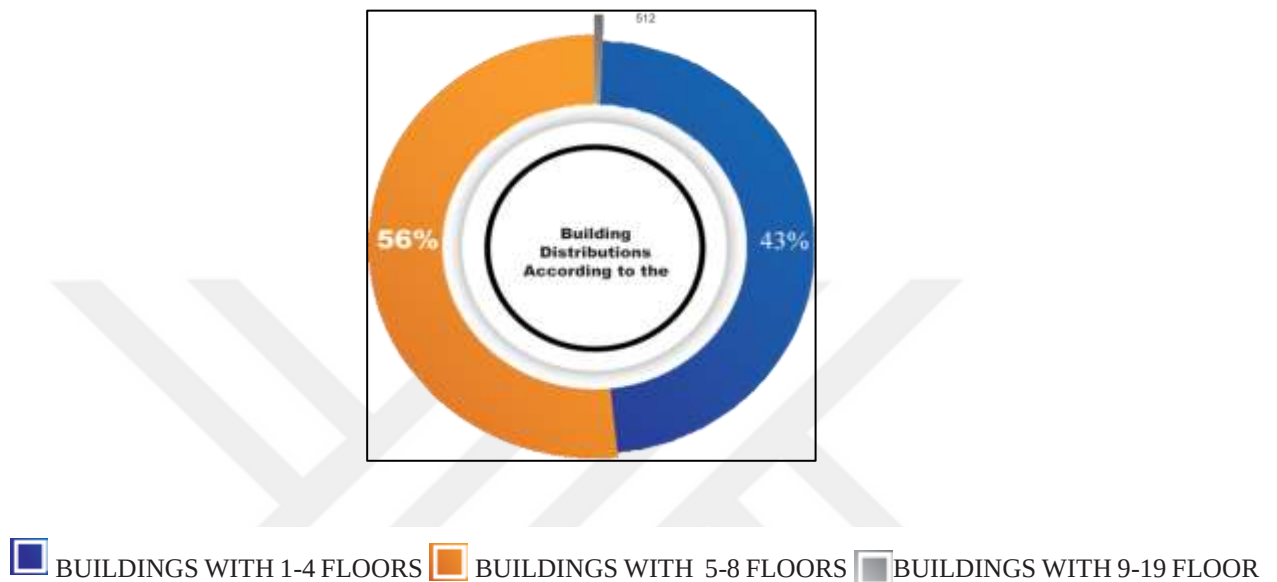


Figure 3.4: Building Distributions by the Number of Floors in Bağcılar District (
[https://8luvomezzsk.merlincdn.ne.\)](https://8luvomezzsk.merlincdn.ne.)

Figure 3.5 illustrates the distribution of buildings by the number of floors in the Bağcılar District. The distribution is as follows: prefabricated buildings constitute 0.1%, steel-framed buildings make up 0.2%, masonry buildings account for 4%, tunnel framework buildings represent 0.6%, reinforced concrete for 95%, and wooden buildings comprise 0.1% of the total.

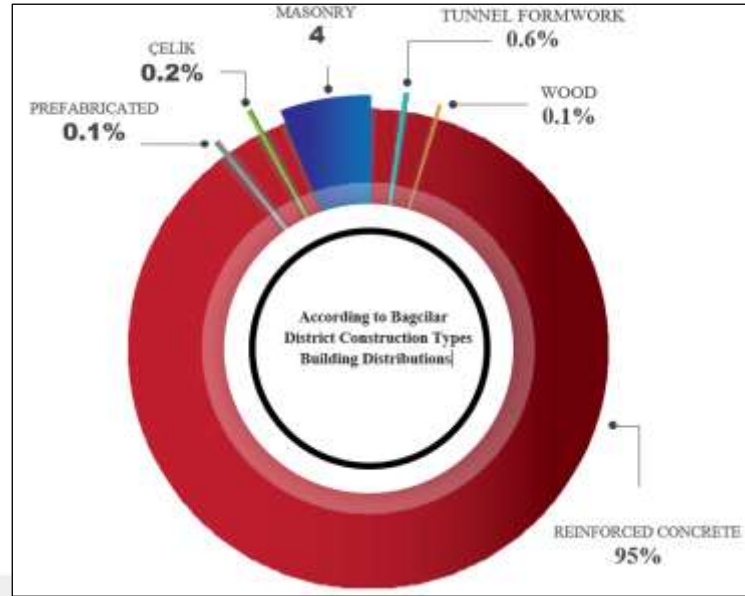


Figure 3.5: Building Distributions by Construction Types In Bağcılar District (<https://8luvomezzzsk.merlincdn.ne>.)

3.3 URBANIZATION CHALLENGES IN BAĞCILAR

Urbanization is the process by which a growing proportion of the population moves to urban areas, causing cities and towns to flourish and expand (Henderson, (2005)). This phenomenon is guided by a variety of factors, including industrialization, economic opportunity, increased access to services and facilities, and rural-urban migration. As people come to cities in search of jobs, education, and higher living standards, metropolitan areas see a fast population increase, and the creation of new infrastructure to meet the requirements of their citizens. However, urbanization brings with it issues such as overcrowding, inadequate housing, environmental deterioration, and social inequities (Gencer, (2016)). Effective urban planning and administration are required to solve these difficulties and guarantee that urbanization contributes to long-term development, economic growth, and a higher quality of life for urban dwellers. As discussed, Bağcılar is vulnerable to seismic hazards due to its proximity to major fault lines, such as the North Anatolian Fault. Therefore, the Urbanization process in Bağcılar aimed a variety of issues for controlling population growth, land use development, infrastructure expansion, and socioeconomic dynamics to mitigate seismic events and ensure resident safety and well-being (Munk, (2014)). Moreover, earthquake-risky building structure poses a huge problem for more

accurate urban planning. These structures, which are fragile in the face of seismic activities, pose a danger to residents as well as make the urban areas prone to failure.

Meticulous urban planning is aimed at overcoming multiple issues related to uncovering, evaluating, and completing the aerodynamic susceptibilities of the construction system (Figure 3.6). First and foremost, safety concerns should take priority as it is the planners' responsibility to ensure that everyone is safe by identifying the buildings that are at risk and implementing measures to make them more resilient. Nevertheless, the task is tricky given the complex nature of the different building types, ages, and building construction methods that occur in urban settings. What's more, the complexity requires thorough data analysis and proper resource distribution to achieve the goal of prioritizing the measures of mitigation.



Figure 3.6: Common Urbanization Challenges in Bağcılar.

4. PROPOSED METHODOLOGY

In this chapter, we address the problem of earthquake risk region identification and investigate the performance of different Machine Learning (ML) methods for regional risk prediction in neighborhoods of Bağcılar. To achieve this aim, we used Principal Component Analysis (PCA) (Abdi et al., 2010) with a K-mean clustering algorithm (Kanungo et al., 2000). K-means clustering divides the data set into K number of clusters, where the data points are repeatedly assigned to the clusters based on the minimum Euclidean distance to the centroids, and the centroids are moved to the arithmetic mean of the points in the clusters. It persists until the centroid of each cluster no longer changes much; that is, the variance within the clusters is as low as it can be. The PCA is inherently linear and used to remove noise and unnecessary features, increasing the robustness of clustering algorithms while making them computationally efficient. In addition to the speed-up of distance calculations, lower dimensionality also promotes more understandable outcome interpretations in terms of patterns and relationships among data points. It transforms a large set of variables into a set of orthogonal components within a space where each component has a maximal variance. They define the most important characteristics so they minimize the data abstraction, which is kept to the most necessary level. Further feature reduction improves clustering separation, solving the curse of dimensionality (Köppen et al., 2000) and addressing redundancy or correlation in features. Considering it, this chapter is categorized into five sections: (1) Data Collection and Pre-processing, (2) Feature Extraction (Already Available), (3) Feature Reduction using PCA, (4) Grouping using K-Mean Clustering, and (5) Performance Measures. These sequential steps produce dense and effective clusters that essentially capture the true structure of data and, thus, improve insensitivity to variations and noise. In general, feature reduction techniques are critical in improving the success of clustering and making high-dimensional data analysis easier.

4.1 PROPOSED CLUSTERING FRAMEWORK FOR URBAN PLANNING IN BAĞCILAR DISTRICT

The selected features were further used in K-mean Clustering to determine highly similar earthquake-prone regions in Bağcılar. The key objectives of the proposed methodology are listed below:

- i. Understanding for Bağcılar District and its region variability.
- ii. Finding the risky, medium and low Clusters by K-means clustering algorithm through the dataset used in the Bağcılar region consisting of 22 neighborhoods, where the most risky accurate clusters in the results will be chosen and this will be explained in the next chapter.
- iii. Developing urban planning strategies for the region after identifying the risk neighborhoods in the Bağcılar district and the neighborhoods with common risks to reduce the risk of earthquakes and minimize their impact on residential buildings and architectural buildings in the Bağcılar district
- iv. Estimating the optima risky clusters formed by K-means clustering algorithm using data from Bağcılar region evaluating it by two performance measures (1) Silhouette Score (Shahapure et al., 2020), and (2) Calinski-Harabasz Score (Ashari et al., 2023). And By calculating the average risk score for the Clusters formed through the data of the expected risk number for each neighborhood in the data set used. Considering the above-mentioned objectives, a working flow chart is shown in Figure 4.1.

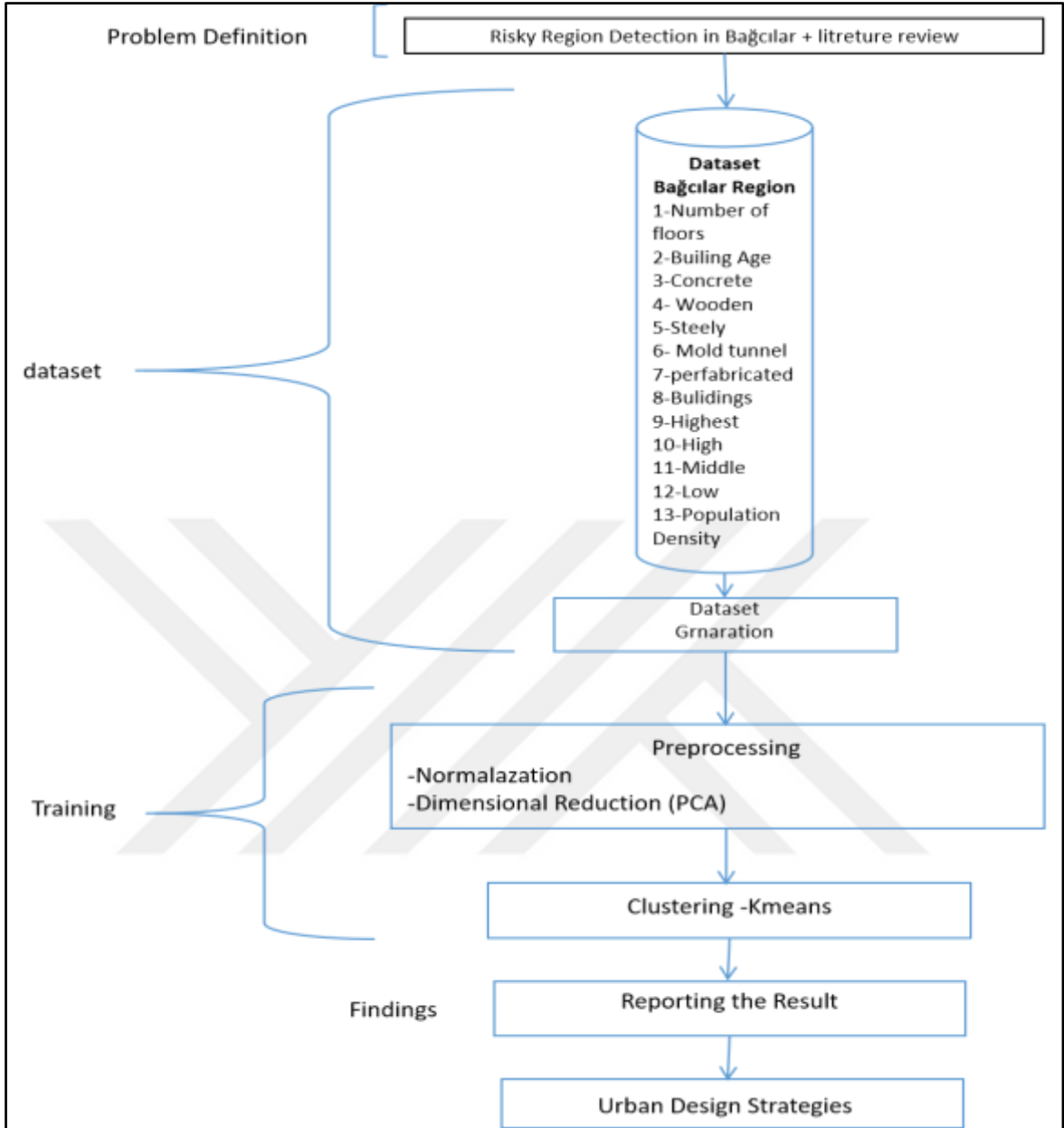


Figure 4.1: Working Diagram of the Proposed Clustering Framework for Urban Planning in Bağcılar District.

4.2 DESCRIPTION OF THE ALGORITHMS

In this study, two types of algorithms: (1) Feature reduction, and (2) Clustering are used for earthquake risk identification. For feature reduction PCA and K-mean for clustering purpose are employed to determine similar regions in the Bağcılar. In the subsequent subsection, we have discussed the crisp properties of both algorithms so that reader can understand their working and correlate them in the proposed research study.

4.2.1 Feature Reduction

Dimensional reduction, also known as feature reduction, is an essential pre-processing step in the process of data analysis especially when applying clustering algorithms. This procedure includes feature selection from a group of relevant features or transforming the current ones into lower-dimensional space while preserving important information. Feature reduction is an important step that helps improve the efficiency of clustering algorithms to solve different problems associated with high-dimensional data. This approach decreases noise, increases computational efficiency, and provides better interpretable clustering results by removing unnecessary or repeated characteristics. Further, feature reduction helps in better cluster separation avoids the curse of dimensionality, and allows for working with more complex structures within the data. In general, the streamlined data representation with feature reduction enables more efficient clustering processes which are less computationally expensive and interpretable across a wide range of applications including data exploration to pattern recognition.

Here, we described PCA algorithm to minimize the irrelevant and redundant features from the neighborhoods.

Principal Component Analysis (PCA) is one of the most important linear feature reduction algorithms in ML while preserving the original information of the attributes. The key steps are given below:

- i. The procedure starts with the normalization of the data, in which all features are put on a common scale.
- ii. PCA computes the covariance matrix, which reflects the correlations between variables.
- iii. The Eigen decomposition of the covariance matrix results in eigenvectors and eigenvalues.
- iv. The eigenvectors arranged in descending order of their associated eigenvalues are the principal components.

However, the number of principal components to retain is an important decision, usually based on the cumulative explained variance. The chosen components are then used to build a projection matrix that allows projecting the original data into a lower-dimensional space. This derived dataset, which is referred to as the scores or loading, represents the major variations in the original data. The PCA is useful for tasks such as noise reduction,

visualization, and compressed representation of high-dimensional data that lead to better analysis and model performance.

4.2.2 Clustering Algorithm

Clustering algorithms are the core of data analysis whereby similar data points are clustered together based on some specific criteria. The first objective is to discover the inherent patterns and structures in the data. There are many domains where clustering is applied such as customer segmentation, anomaly detection, image segmentation, and document organization. It is useful in revealing hidden associations and can be an important part of data pre-processing before analysis. In this case, K-mean clustering algorithm was used to determine the similar neighborhoods in Bağcılar district.

K-means is a partitioning technique, which partitions a dataset into k clusters where the value of ‘ k ’ is provided by the user. The iterative algorithm minimizes the sum of squared distances between data points and their assigned cluster centroids. The steps are as follows:

- v. Initialization: Randomly choose k initial cluster centers.
- vi. Assignment: For each data point, assign it to the cluster with the closest centroid, usually calculated using Euclidean distance.
- vii. Update Centroids: Calculate new centroids for each cluster by taking the mean of points assigned to that cluster.
- viii. Repeat: Repeat steps 2 and 3 until convergence, where convergence happens when the centroids no longer change significantly.

K-means is also subject to centroid initialization and can arrive at local minima. It is computationally inexpensive but may not work well with non-spherical or clusters of different sizes.

4.3 DATA COLLECTION AND PREPROCESSING

In the proposed work, we collected building data located in various earthquake zones from the “Department of Earthquake Risk Management and Urban Improvement” repository entitled “For Disaster Resistant, Earthquake Safe and Livable Istanbul”. The dataset can be downloaded from the source depository (<https://8luvomezzzsk.merlincdn.net/wp-content/uploads/2021/01/Bağcılar.pdf>). This data consists of 22 regions with 17 properties

such as construction year, structural components, and clusters based on several floors. Here, three attributes, wooden, steel, and fabrications are very sparse (most of the entries are zero) therefore it is required to handle them carefully before clustering analysis. Moreover, the remaining 14 attributes are directly used in the analysis. A screenshot of the dataset is shown in Figure 4.2. In the following figures (4.3, 4.4, 4.5, 4.6, 4.7) show the data set of the Bağcılar region is represented which was used in the application of the K-means algorithm. In the following figures, the data set used in the Bağcılar District will be represented on the Bağcılar map to make it more clear.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	Region_Name	cluster(1-4)	cluster(5-8)	cluster(9-19)	B_age(1970)	B_age(1980)	B_age(2001)	Concrete	Wooden	steel	mold	tunnel	Prefabricated Buildings	Highest	High	Middle	low
2	Mahmutbey	3948	809	63	226	4162	412	4505	0	1	44	0	270	47	35.25	23.5	11.75
3	Eren	1702	1793	31	231	2021	774	3012	0	1	13	0	0	54	40.5	27	15.3
4	Göresh	822	1617	35	211	1542	518	2317	0	0	21	0	36	47	35.25	23.5	11.75
5	Bağlar	685	519	39	234	456	349	1141	0	0	27	0	99	36	27	18	9
6	Hariyet	585	920	27	417	712	383	1490	0	0	58	0	24	49	36.75	24.5	12.25
7	Bağlar	174	794	4	363	516	353	1119	0	0	4	0	49	36	27	18	9
8	Karataş	524	943	2	332	716	421	1410	0	0	1	0	58	46	24.5	23	11.5
9	Vide tepesi	583	1036	21	521	781	338	1562	1	0	13	0	84	67	50.25	33.5	16.75
10	Yeni Garı	174	724	1	221	509	319	886	0	0	0	0	11	24	18	12	8

Figure 4.2: Screenshot of the Dataset Used In The Analysis.

The following figure(4.3) shows a map of the Bağcılar district showing the percentages of floor heights in residential and architectural buildings in the Bağcılar district, which represent three types: (1-4) floors, (5-8) floors, (9-19) floors.

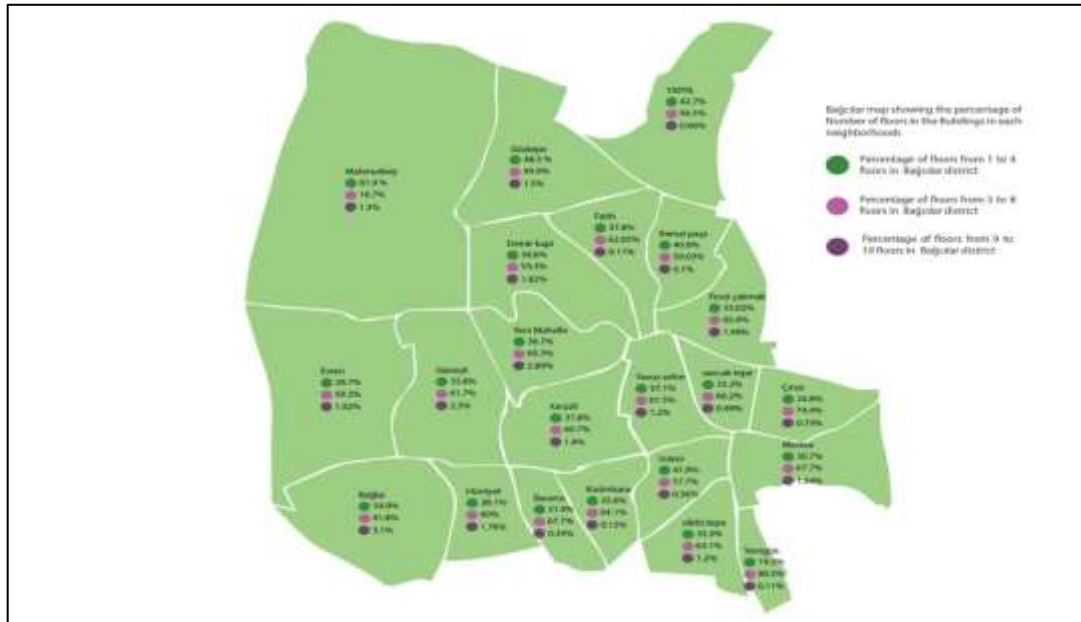


Figure 4.3: Bağcılar Map Showing The Percentage Of Number Of Floors In The Buildings In Each Neighborhoods.

The following figure(4.4) shows a map of the Bağcılar district showing the age ratios of residential and architectural buildings in the Bağcılar district, which represent three types of construction: pre-1980 construction, construction between (1980-2000), and construction after (2000).

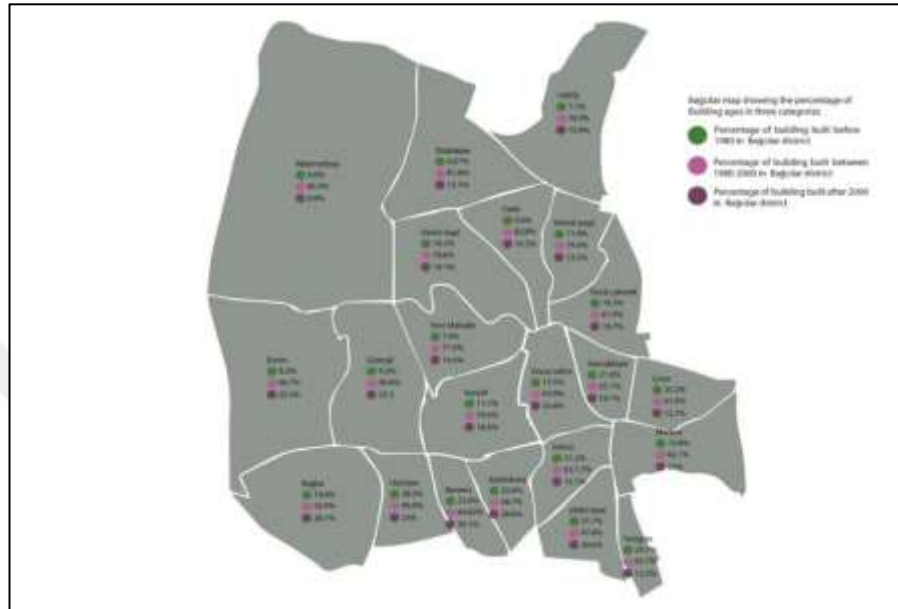


Figure 4.4: The Age Ratios Of Residential And Architectural Buildings In The Bağcılar District.

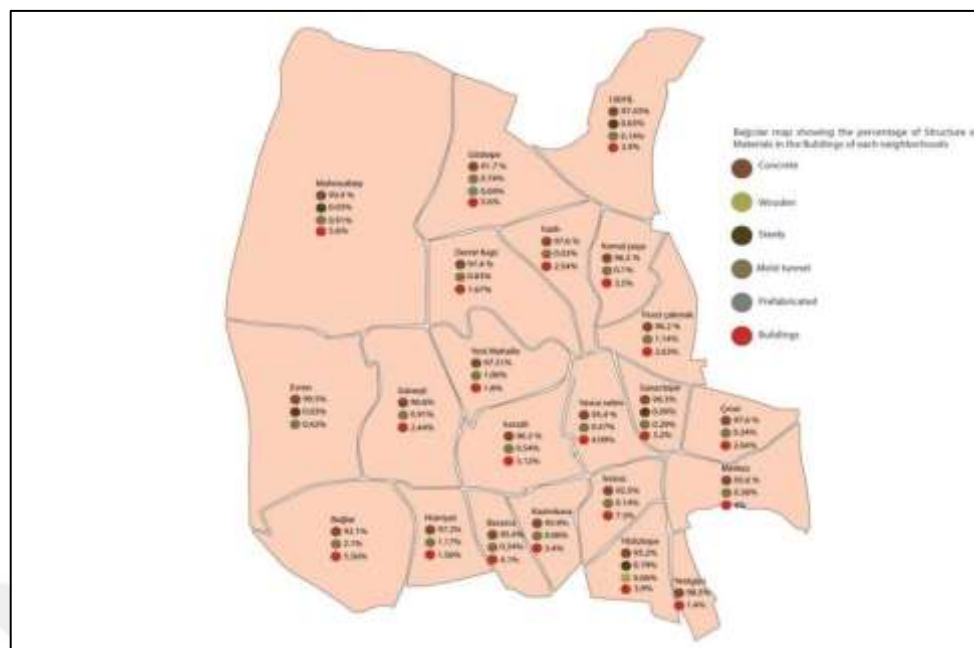


Figure 4.5: Bağcılar Map Showing The Percentage Of Structure Materials In The Bulidings Of Each Neighborhoods.

The following figure(4.6) shows a map of the Bağcılar region showing the expected risk figure in the event of an earthquake of magnitude 7.5 on the Richter scale occurring in the region, taken from the Istanbul Metropolitan Municipality for each neighborhood in the Bağcılar region and compliant with four types of risk including: high risk, risk , medium, and low risk.

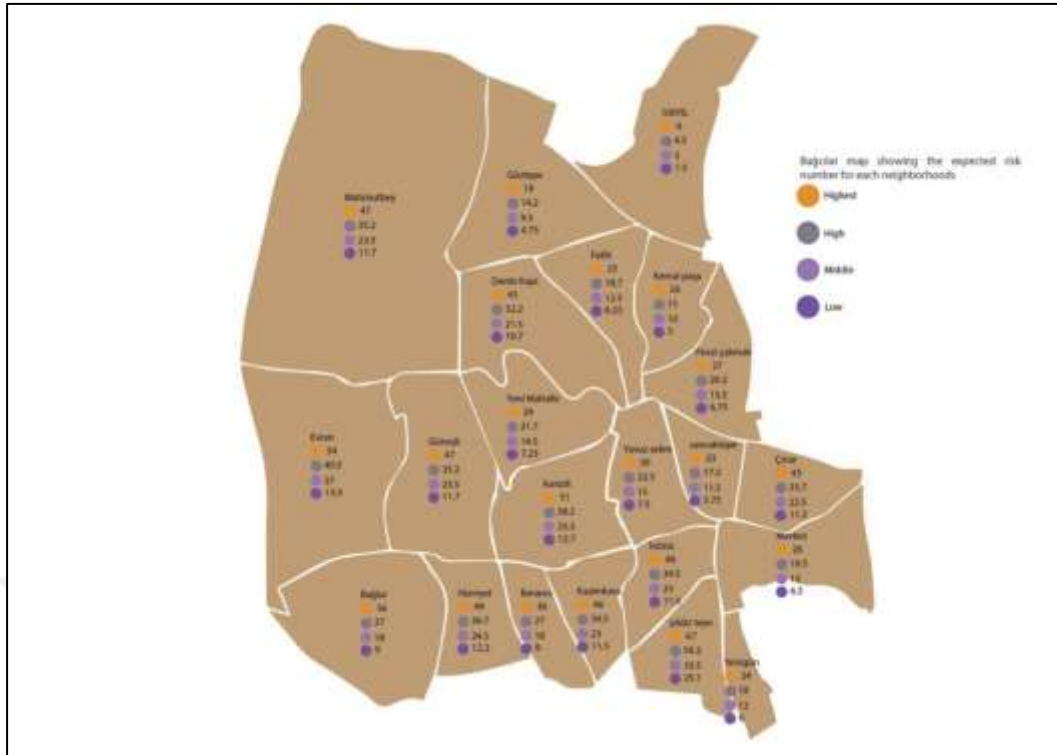


Figure 4.6: Bağcılar Map Showing The Expected Risk Number For Each Neighborhoods.

The following figure(4.7) shows a map of the Bağcılar district, showing the population density of each neighborhood.

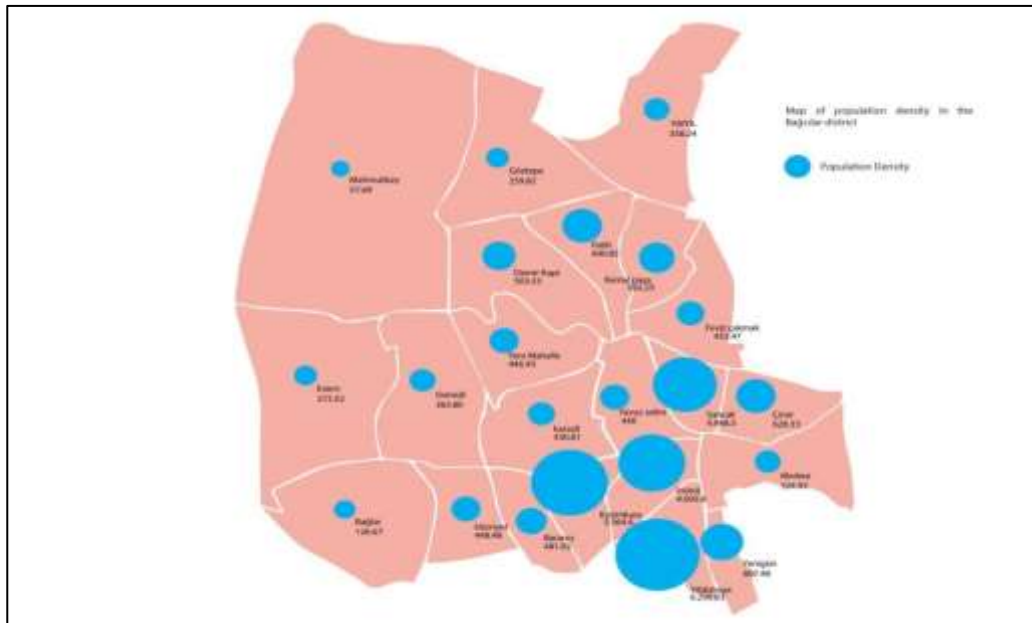


Figure 4.7: Map of Population Density In The Bağcılar District.

The previous figures that were explained represent the data set used in the Bağcılar region, and the steps for applying the K-means algorithm to the data of the Bağcılar region and the process of forming groups will be explained.

4.3.1 Data Filtering

In the building dataset, three columns (wooden, steel, and fabrications) were sparsely distributed because most of the entries were zero, therefore, directly eliminated from the dataset. These entries were not used in the analysis. Sparse data handling is always crucial in machine learning because it degrades the performance of the developed computational model and increases the over fitting issue.

4.3.2 Categorical Encoding

In the dataset, the first column (Region name) was given in “English” therefore it is required to encode this variable into numeric data. Since a very limited number of observations were in the samples, therefore, we manually allowed them numbers starting from 1 to 22 (since only 22 regions were available). Further, this observation is not used in the analysis because it worked as a region identifier and it didn’t have any role in building characterization. Moreover, this observation is used in the cluster visualization to identify specific regions.

4.3.3 Feature Reduction

The original dataset consists of 17 attributes with three sparse and one encoded features. Two minimize the over fitting risk, we avoided all sparse and encoded features. The list of employed featured are given below:

- a)Number of floors (1-4)
- b)Number of floors (5-8)
- c)Number of floors (9-19)
- d)Building Age before(1980)
- e)Building Age (1980)-(2000)
- f)Building Age after (2000)
- g)Concrete
- h)Mold Tunnel
- i)Buildings
- j)Highest
- k)High
- l)Middle
- m)Low

Total 13 features are used in the feature reduction phase

4.3.3.1 Application of pca in feature reduction

In the first experiment, PCA was implemented to rank all 13 features into transformed components. We plotted a graph between several selected components and the cumulative variance explained. The graph is shown in Figure 4.8. The transformed features were selected using a fixed threshold variance coverage ($=0.99$). The list of features is displayed below.

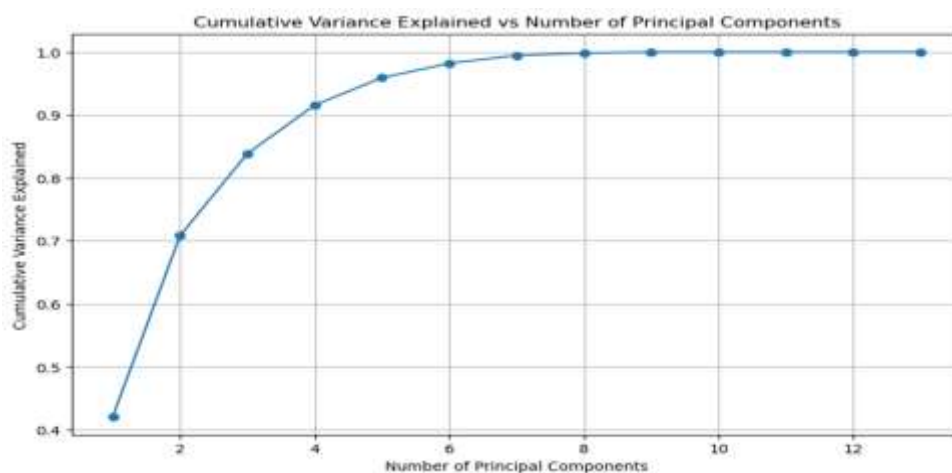


Figure 4.8: Visualization Graph Between Number Of Principle Components And Cumulative Variance Explained.

In our work, we plotted a graph between the number of selected features vs the correlation score in Figure 4.9.

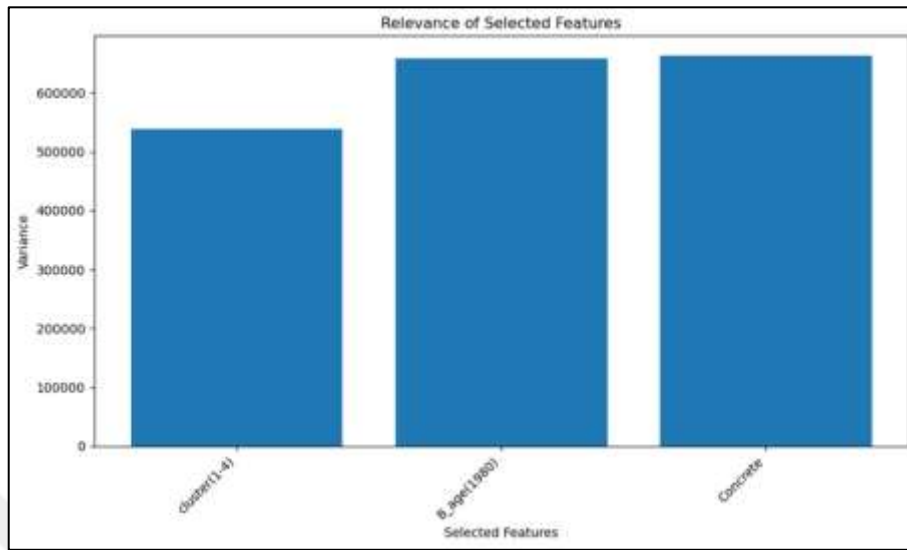


Figure 4.9: Visualization of Variance Scores Of The Selected Features.

In addition, I applied the heat map , heat map is a color-coded graphic used to visualize data related to various aspects of buildings such as age of construction, number of floors, and materials used in buildings. This technique helps urban planners and architects to estimate patterns, trends, and all the interests within the data set used I plotted the heat map among all the selected features in Figure 4.10 to show the coupling between selected attribute pairs. In this figure, the color of each cell correlates to its value, making patterns and trends easier to identify. Common color scales include gradients from low to high values (blue to red) and diverging scales with unique hues for positive and negative values.

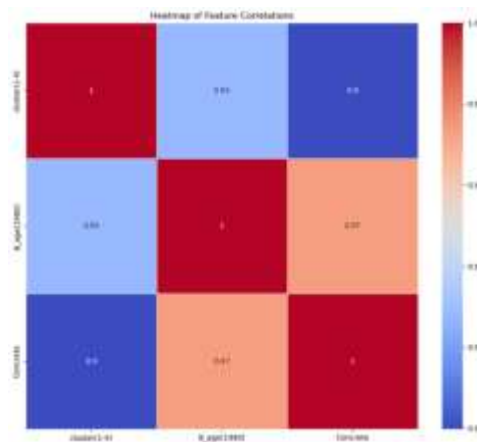


Figure 4.10: Heat Map of the Selected Features.

It can be easily observed that the attribute “B_age 1980” is maximally correlated (0.97) with variable concrete. That is, 1980 B-age, which represents the age of the building before 1980, has a maximum correlation with concrete, the rest is 0.97, and this represents a close limit to the strong correlation, i.e. it is not a low correlation value. As we notice, the correlation of Cluster (1-4), which corresponds to the number of floors of buildings from 1-4 floors, with concrete, has a maximum correlation of 0.9, i.e. it represents a low correlation value compared to the previous correlation that was between the age of buildings before 1980 and concrete. Using this heat map on the data set of the city of Bağcılar simplifies complex data, making it easier for architects and urban planners to make the right decision and avoid the risk and wrong decision that does not serve the interests of urban planning. Determining trends in using the heat map on the data set of the city of Bağcılar facilitates the concept of the impact of changes in building materials and the age of buildings, as happened in the correlation of the age of the building before 1980 with concrete, or facilitates changes in construction practices.

4.4 CLUSTERING

The clustering involves analyzing the main principal components of a data set for the Bağcılar district by PCA, and then the K-means algorithm is applied after obtaining the new main components resulting from the PCA analysis process to form clusters. The number of clusters depends on the number of K and these clusters include the neighborhoods of the Bağcılar district, which will be explained in following sections

4.4.1 K-Mean Clustering

K-means clustering is a very common unsupervised machine learning algorithm designed to divide the given dataset into many homogeneous groups or clusters. Here, we implemented K-Mean clustering to determine the optimal groups of the regions where buildings of different characteristics are located. Here, we have shown clusters for different values of ‘K’ and inbuilt parameters on the dataset having filtered features, obtained from feature extraction algorithms. Below, the graphical visualization for different algorithm pairs (feature extraction and K-Mean clustering) is shown.

4.4.1.1 PCA with k-mean clustering

The clustering solution is heavily influenced by the number of clusters (K), a factor. On changing the value of K from 2 to 5, we see a shift from the initial two distinctly separate clusters to clusters comprising more but smaller numbers (Figure 3.6). These clusters will now be characterized by a greater concentration of data points, which will be outlying from each other. It's quite difficult to unequivocally deduce the within-cluster variance from this visualization, but you might conclude it might grow a little with more clusters. . In the below figure 4.11 represents the number of K=(2,3,4,5) on Bağcılar District Map

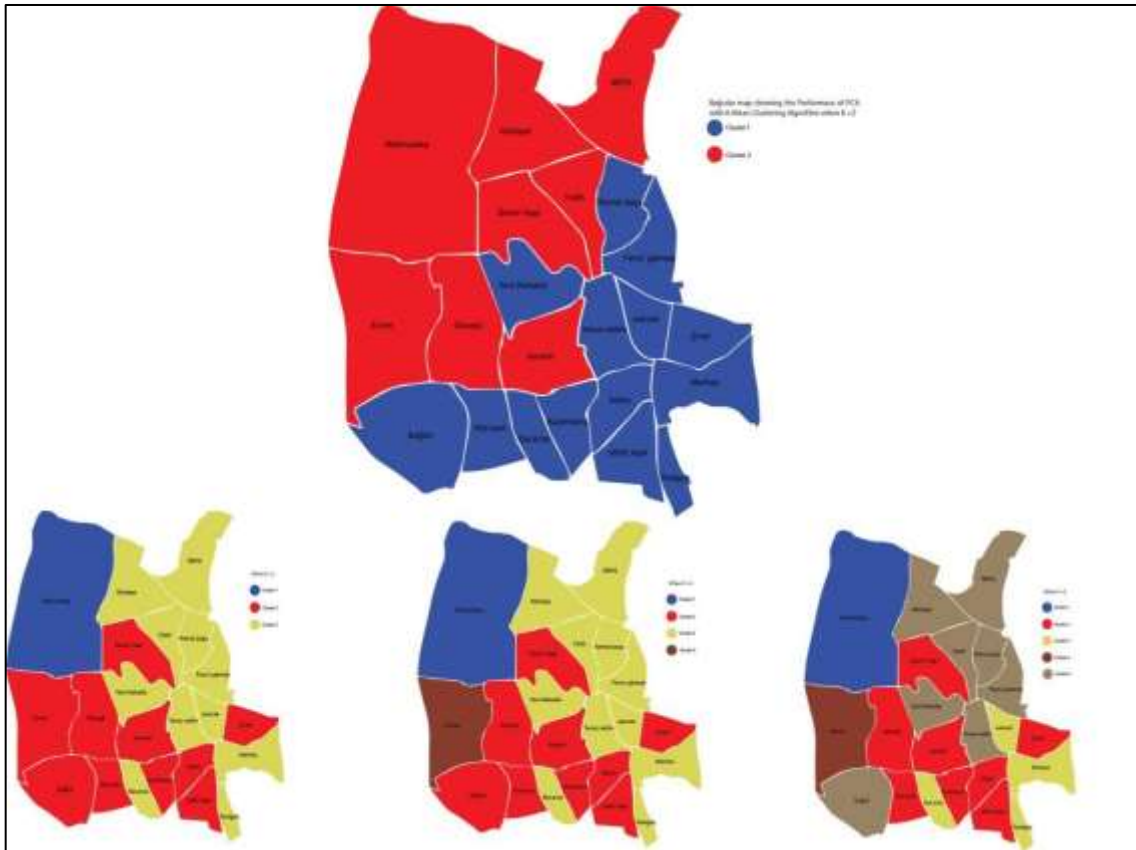


Figure 4.11: Applying the number of K=(2,3,4,5) on Bağcılar District Map

4.5 PERFORMANCE EVALUATION

In our study, various performance measures are used for comparing the performance of all the feature reduction algorithms and both clustering techniques. In addition, I calculate the risk factor for each neighborhood according to K=2. I have the expected number for each neighborhood from our dataset of Bağcılar district that is taken from the municipality of

Istanbul“Department of Earthquake Risk Management and Urban Improvement”
(<https://8luvomezzzsk.merlincdn.net/wp-content/uploads/2021/01/Bağcılar.pdf>)The details of all the used metrics are discussed below:

4.5.1 Silhouette Score

The Silhouette Score is a measure of the quality of clusters in unsupervised learning. It calculates the intro-cluster cohesion and also inter-cluster separation. In particular, it measures how far an object is from its cluster in comparison to other clusters. The value varies from -1 to 0, with a larger positive value showing that the object belongs well in its cluster and poorly to the other clusters. A score near 1 for the Silhouette Score indicates a clearly defined cluster with healthy inter-cluster distances, which is a very good measure of the overall structure and compactness of clusters.

4.5.2 Calinski-Harabasz Score (Variance Ratio Criterion)

Calinski–Harabasz score is a clustering performance measure that compares the ratio of between-cluster dispersion (BCSS) to the within-cluster dispersion (WCSS). The larger the Calinski-Harabasz Score, the clearer and distinct the clusters. The index is particularly useful for comparing various clustering algorithms and also estimating the best number of clusters. This metric offers a very important insight into the quality of clustering solutions by focusing on within-cluster tightness and also between-cluster separation.

$$WCSS = \sum_{i=1}^n \sum_{j=1}^k \delta_{ij}^2 \quad (4.1)$$

$$BCSS = \sum_{j=1}^n n_j \cdot ||C - C_j||^2 \quad (4.2)$$

where n is the total number of data points, k is the number of clusters, and δ_{ij} is the distance between data point i and the centrefold of cluster j . In addition, where n_j is the number of data points in cluster j , c_j is the centrefold of cluster j , C is the centrefold of the entire dataset and $||\square\square\square\square||$ denotes the Euclidean distance.

Regarding the Silhouette Score, the members of Cluster 2 have a much higher value than those of Cluster 1. This means the objects from Cluster 2 are more cohesive and internally homogeneous as they have a stronger association with their respective cluster centers and less overlap with neighboring clusters. On the other hand, although Cluster 1 has a

reasonable Silhouette Score, it is still a bit behind Cluster 2 which shows a lower degree of internal coherence on its data points. Finally, the Calinski-Harabasz Score shows that Cluster 2 comes out on top again with the highest value. This means that the clusters that are part of Cluster 2 are more different from each other and are distinctly separated in space. This suggests that there are clear boundaries between them, and a higher degree of separation between clusters in this case. However, just like Cluster 1 which with a good Calinski-Harabasz Score, Cluster 2 seems to be slightly lagged when it comes to distinctiveness and separation. This analysis confirms that Cluster 2's scores are usually denser, and more internally consistent, with clearer boundaries and better separation between clusters in comparison to Cluster 1. These discoveries can be critical for future optimization of the clustering algorithms or for the comprehension of the data structure itself.

4.5.3 Risk Factor Calculation

The risk factor in the Bağcılar region lies in calculating average Risk Score for two clusters consisting of the neighborhoods of the Bağcılar region, which I obtained after applying the K=2 algorithm because it is more accurate and clearer than the rest of the clusters, as the expected risk number was relied upon in each neighborhood in the event of an earthquake measuring 7.5 on the Richter scale on residential and architectural buildings in the Bağcılar region, and these expected numbers represent one of the data sets used in the Bağcılar region and approved by the Istanbul Metropolitan Municipality, and the earthquake number 7.5 constitutes a high risk on residential and architectural buildings and on the urban planning of the Bağcılar region.

The neighborhoods of the first cluster are in blue and the neighborhoods of the second cluster are in red. The average risk scores for all neighborhoods in the first and second clusters were collected and divided by the total number of regions in that clusters. Below will be explained the steps for calculating the risk score rate for both clusters in the Bağcılar region in the event of an earthquake :

Total Average expected risk number for each neighborhood in the cluster 1= Expected number for highest risk + Expected number for high risk + Expected number for medium risk + Expected number for low risk /4

Total Average Risk cluster1= Total average Risk for expected risk number for each neighborhood in the cluster 1

Average Risk Score for cluster 1 = Total average Risk for each neighborhood in the cluster 1
/ Number of neighborhoods for cluster1

Total expected risk number for each neighborhood in the cluster 2= Expected number for high risk + Expected number for high risk + Expected number for medium risk + Expected number for low risk / 4

Total Average Risk cluster 2= Total average Risk for expected risk number for each neighborhood in the cluster 2

Average Risk Score for cluster 2 = Total average Risk for each neighborhood in the cluster 2
/ Number of neighborhoods for cluster 2

This calculation is used to find the risk score for both Clusters including the neighborhoods of Bağcılar district which we obtained by applying the K-means clustering algorithm. In the next chapter, the results and discussions on developing urban planning strategies for Bağcılar district will be identified.

5. RESULTS AND DISCUSSION

This chapter includes findings obtained from the experiments conducted to determine the true patterns associated with buildings of different neighbors of the Bağcılar district. Further, a detailed discussion on observed patterns, trends, correlations, and various expected outcomes is included.

5.1. NEIGHBORHOOD SIMILARITY ESTIMATION IN BAĞCILAR

We applied a popular clustering “K-mean” algorithm to compute the optimal number of clusters and associated neighbors of Bağcılar. Here, the algorithm computes the similarities between each observation and two different center points. Further, the closest data points are placed in the respective cluster center. Here, we employed “K-mean” clustering for $K = 2$ means there are two centers (C1, C2) used to compute the Euclidean distance (d) between both centers and each data point. The distribution of all 22 neighbors is shown in **Figure 5.1**. The details of performance measures for both clusters are given in Table 4.1. Given scores give information about the quality and features of both clusters, Cluster 1 and Cluster 2.

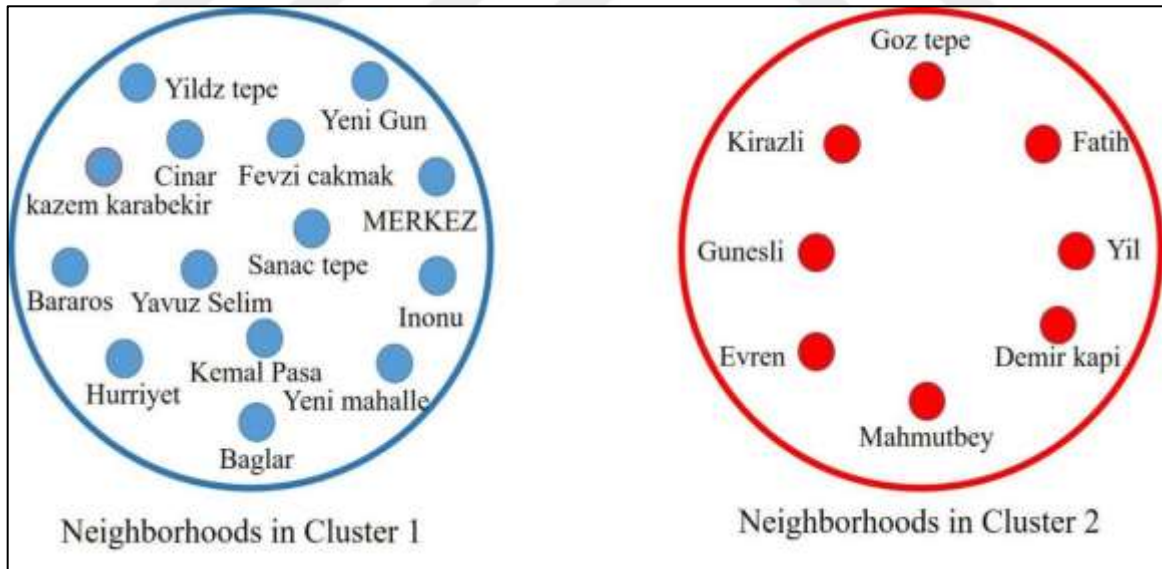


Figure 5.1: K-mean Clustering Implementation on the Dataset. Here, Each Bubble Indicates The Individual Neighborhood Of The Bağcılar District. In The First Cluster, There Are A Total Of 14 Regions While In The Second Cluster, The Remaining 8 Regions Are Located.

5.1.1 Estimating The Risk Of Neighborhoods In Bağcılar District For Urban Planning Strategies

The analysis of the k-means clustering results for the Bağcılar region reveals significant insights into the risk factors associated with various neighborhoods. The dataset utilized for this analysis considered critical elements such as building age , the number of floors in each building, and population Density leading to the identification of two distinct clusters. Cluster Analysis:

Cluster 2 is identified as the higher risk group, characterized by three primary risk factors (Building age , Number of floors and population Density) . This cluster is visually represented using a light red color gradient for risk areas and a dark red gradient for high-risk areas.

In contrast, Cluster 1 encompasses neighborhoods with relatively lower risk levels. These areas are depicted using a dark blue color gradient for areas of moderate risk and a light blue gradient for low-risk zones.

The findings indicate that Cluster 2 poses a greater danger compared to Cluster 1. Each neighborhood within the Bağcılar region has been assessed, detailing the specific reasons and degrees of risk associated with them. This comprehensive evaluation provides a clearer understanding of the risk landscape in Bağcılar, allowing for targeted interventions and resource allocation based on the identified risk factors.

In Cluster 1, I have identified 14 neighborhoods, ranging from those close to risk to those with lower risk levels. Below is an overview of each neighborhood in the Bağcılar district, organized from lower to higher risk based on the k-means results and the dataset used

Merkez: This neighborhood is classified as low-risk due to its modern residential and architectural buildings constructed after 2000, which adhere to earthquake-resistant standards. Additionally, many older buildings have been renovated to enhance their earthquake resilience, contributing to its low-risk status.

- i. Bağlar: Similar to Merkez, Bağlar is considered low-risk. The presence of new and renovated buildings, along with available vacant spaces for future development, allows for the construction of earthquake-resistant structures. This makes Bağlar a safe neighborhood according to the k-means analysis.
- ii. Fevzi Çakmak: This neighborhood features a significant number of new and renovated buildings, with approximately 350 constructed after 2000. The potential for further urban development reinforces its classification as low-risk compared to other areas.
- iii. Bararos: Bararos is also deemed low-risk, with about 33% of its buildings constructed after 2000. This modern infrastructure reduces its overall exposure to risk, as indicated by the k-means results.
- iv. Hürriyet: This neighborhood is classified as relatively low-risk, primarily due to its low levels of earthquake risk factors and the presence of low-rise residential buildings. These characteristics contribute to its safety compared to other neighborhoods
- v. . Yavuz Selim: Yavuz Selim is considered low-risk, as it has fewer risk factors than other neighborhoods. The residential buildings here are predominantly low-rise, with 1 to 4 floors, making them less vulnerable to earthquake damage.
- vi. Kazım Karabekir: While this neighborhood is relatively close to risk, it does not pose a high threat like those in Cluster 2. Approximately 30% of its buildings were constructed after 2000, but high population density raises concerns about potential risks during an earthquake.
- vii. Yeni Mahalle: This neighborhood is near the risk zone due to older buildings constructed before 1980. However, over 1,400 buildings built before 2000, most of which are earthquake-resistant, mitigate the overall risk.
- viii. İnönü: İnönü is relatively close to danger due to the presence of older buildings that lack earthquake resistance. High population density further exacerbates the risk, although many buildings have been renovated or constructed after 2000

- ix. .Sancaktepe: This neighborhood is close to the danger zone, with about 67% of its older buildings posing medium-high risk. The high population density of approximately 500,000 per square kilometer adds to its vulnerability.
- x. Çınar: Çınar is considered relatively close to danger due to the presence of older buildings constructed before 1980, which make up about 25% of the total structures in the area.
- xi. Yenigün: This neighborhood is near the relative risk level, primarily due to high population density and over 220 buildings constructed before 1980.
- xii. Kemal Paşa: Kemal Paşa is close to the risk level, with about 30% of its buildings constructed before 2000 and 12% before 1980. This makes it a relatively risky area, though not classified as high-risk
- xiii. Yıldıztepe: This neighborhood is close to the relative risk level, characterized by multi-story buildings (5-8 floors) and a significant percentage (31.7%) of structures built before 1980. The high population density of approximately 6,290 per square kilometer further contributes to its risk profile. This assessment provides a detailed overview of the risk levels associated with each neighborhood in Bağcılar, highlighting the importance of modern construction and urban planning in mitigating earthquake risks.

In Cluster 2, we have identified 8 neighborhoods that are considered risky. Below is an overview of each neighborhood in the Bağcılar district, ranked from the highest risk to medium risk:

- xiv. Mahmutbey: Mahmutbey is recognized as one of the highest-risk neighborhoods due to various risk factors. The primary concern is the presence of old residential and architectural buildings constructed before 2000, which significantly elevates the risk level according to the k-means analysis and the dataset utilized.
- xv. Fatih: Fatih follows Mahmutbey as the second most at-risk neighborhood. It features a large number of residential and older architectural buildings that were constructed in outdated styles, with many lacking earthquake-resistant features. There are over 2,500 such buildings, although a few have been retrofitted for safety.

- xvi. Göztepe: Göztepe is classified as a risky neighborhood due to several high-risk factors, including a relatively high number of floors in its buildings and the presence of older structures that do not comply with earthquake-resistant standards.
- xvii. Güneşli: This neighborhood is categorized as medium-risk, primarily because it contains residential and architectural buildings built before 2000. Additionally, it has high-rise buildings exceeding 9 floors that were constructed using outdated methods, which poses a risk during an earthquake.
- xviii. 100Yıl: The 100Yıl neighborhood is also deemed medium-risk, with approximately 77% of its buildings constructed before 2000 and featuring 5 to 8 floors. This substantial proportion of older structures contributes to the neighborhood's risk profile in the event of an earthquake.
- xix. . Demir Kapı: Demir Kapı is considered medium-risk due to a lack of new or renovated buildings relative to the total number of structures in the area. It has over 1,000 buildings constructed before 2000, which raises concerns about safety during an earthquake.
- xx. Karazlı: This neighborhood is classified as medium-risk because it has a mix of newer and modern buildings compared to other risky neighborhoods. Additionally, it features an adequate number of low-rise buildings, which helps lower the overall risk level.
- xxi. Evren: Evren is also rated as medium-risk, primarily because of the presence of older buildings. Approximately 10% of the structures were built before 1980, and around 33% were constructed before 2000 without renovations, contributing to its risk profile according to the k-means analysis.

This assessment highlights the varying levels of risk across neighborhoods in Bağcılar, emphasizing the significance of modern construction and renovations in mitigating vulnerability to earthquakes. The figure 5.3 shows the high-risk and low-risk neighborhoods in the Bağcılar district.

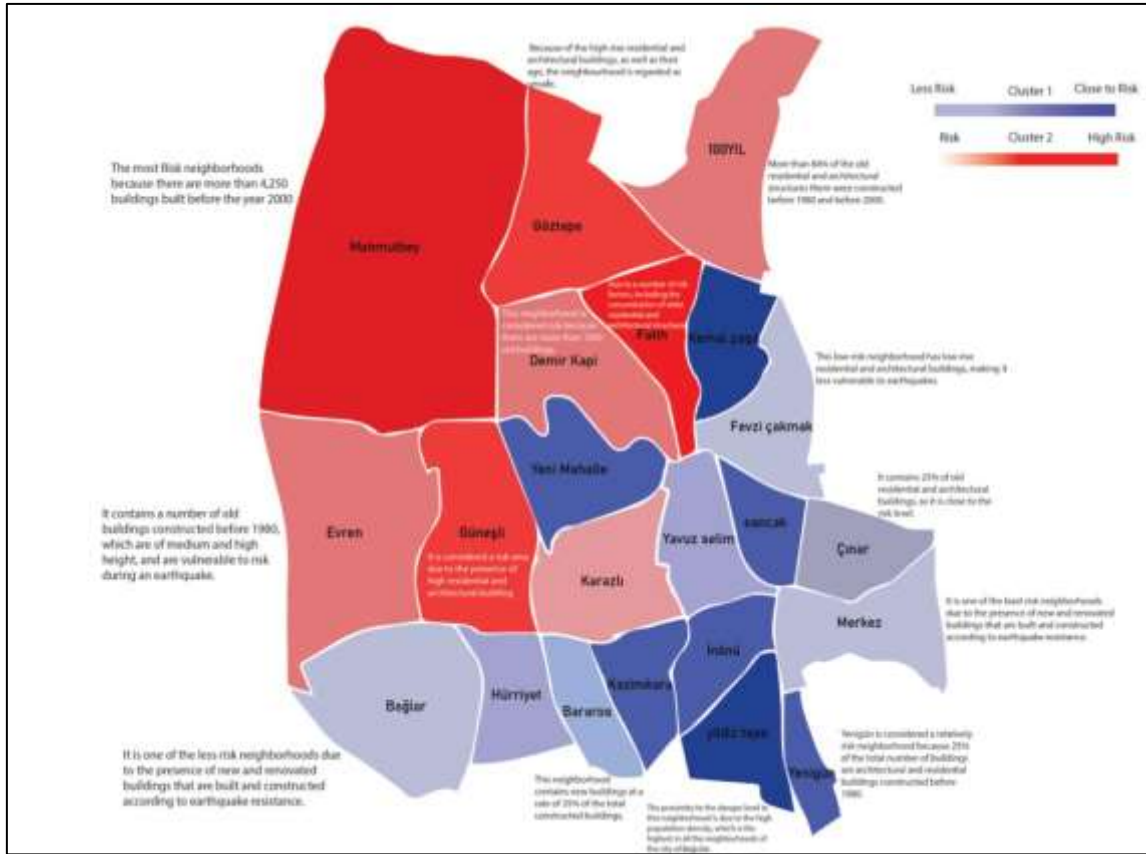


Figure 5.3: The Map Shows The High-Risk And Low-Risk Neighborhoods In The Bağcılar, District.

5.1.2 Common Risks Neighborhoods In Bağcılar District

The neighborhoods in the Bağcılar district are not devoid of risks, and several of them share similar vulnerabilities. For instance, both Mahmutbey and Fatih neighborhoods feature old architectural and residential buildings. Similarly, Göztepe, Güneşli, and Evren neighborhoods contain medium- to high-rise buildings, contributing to their risk profiles. Additionally, many neighborhoods experience high to medium population densities, which further exacerbates the risk to the urban fabric of the area.

Given these concerns, it is crucial for urban planners to recognize these risks and take proactive measures to address them. It is essential to implement strategies aimed at mitigating potential dangers, particularly in the event of an earthquake.

To illustrate these findings, we will present a map that represents the results for the 22 neighborhoods in the Bağcılar district, highlighting the common risks identified in both the

first and second groups according to the k-means analysis and the dataset used. Furthermore, I will provide a table outlining proposed urban planning strategies tailored for the neighborhoods sharing similar risks. This figure 5.4 shows the map of commons risk characteristics of the neighborhoods of Bağcılar district for both Clusters and gives recommendations through urban planning strategies in Bağcılar district.

Figure 5.4: This Figure Shows The Map Of Commons Risk Characteristics Of The Neighborhoods Of Bağcılar District For Both Clusters And Gives Recommendations Through Urban Planning Strategies In Bağcılar District.

Table 5.1: This Table Shows The Map Of Commons Risk Characteristics Of The Neighborhoods Of Bağcılar District For Both Clusters And Gives Recommendations Through Urban Planning Strategies In Bağcılar District.

Color	Cluster1	Common risk	Urban planning Strategies	Color	Cluster2	Common risk	Urban planning Strategies
Yellow	Kemal Paşa, Yeni Mahalle, Çınar	Neighborhoods near the risk zone are taken into consideration due to the presence of aging, unrenovated, and structurally weak buildings, along with a moderate population density.	Rehabilitation of buildings according to urban planning and distribution of population density in a way that reduces the risk	Blue	Göztepe, Erenköy, Güneşli	Risk neighborhoods with high-rise buildings and residential buildings	Decreasing the number of high-rise buildings is essential, as they present a significant risk in the event of an earthquake.
Turquoise	Sancaktepe, İnönü, Yıldıztepe, Yenigün, Kazım Karabekir	This neighborhood is regarded as one of the areas at risk due to its extremely high population density. The existing medium- and high-rise buildings are inadequate to support this population,	Rehabilitating existing buildings or constructing new ones in different neighborhoods within the urban planning framework of the Bağcılar area can help redistribute population density, thereby reducing risk.	Red	Mahmutbey, Fatih	The neighborhoods with the highest risk levels are characterized by a large number of old buildings constructed before 1980, as well as structures that have not been renovated since before 2000.	Restoring or demolishing old buildings that lack earthquake resistance.

Table 5.1: This Table Shows The Map Of Commons Risk Characteristics Of The Neighborhoods Of Bağcılar District For Both Clusters And Gives Recommendations Through Urban Planning Strategies In Bağcılar District." Table Continued"

		posing a significant danger in the event of an earthquake.					
Pink	Bağlar , Merkez, Fevzi çakmak	This neighborhoods are deemed low-risk because it features newer residential and architectural buildings at a higher standard compared to other areas, along with available vacant spaces within its urban planning.	Developing residential and architectural complexes within urban planning that incorporate modern earthquake-resistant systems.	Green	Demir kapı, 100Yıl , Karazli	These neighborhoods are classified as high-risk areas, featuring non-renewable architectural and residential buildings constructed before 2000, with 60% of them being of medium to high height.	consider reducing these non-resistant buildings by either demolishing them or renovating them to meet earthquake-resistant standards.
	Hürriyet, Bararos , Yavuz Selim	Bronze	Constructing new buildings and rehabilitating existing ones to ensure a relatively low risk during an earthquake.				

5.2 PATTERNS IN CLUSTER 1 AND CLUSTER 2

K-mean clustering decomposed the input dataset into two different clusters ($K=2$, Figure 4.1). In Figure 5.5, we showed the variance level of each feature in both clusters. Here, we refer to columns of cluster 1 as a_i and b_i for cluster 2. It can be easily observed that for

cluster 1, variable a_1 to a_7 and a_{12} to a_{16} are showing similar patterns with b_1 to b_7 and b_{12} to b_{16} . In addition, columns 5 and 7 show the top two variance levels which indicate that urbanization had more impact in the 1980s and various types of concrete material were used in building construction. In addition, we can understand the significance of these two features (B_age and Concrete) in terms of two assumptions: (1) Structural Variability, and (2) Risk Assessment. The structural characteristics of the buildings in the dataset may exhibit notable variability, as indicated by features with high variance levels. When a dataset contains a wide variety of building types and designs, for instance, characteristics of building materials, construction methods, or architectural designs may show significant variance. The observed column of "Number of buildings developed in the 1980s" across a sample size of 14 regions for a dataset of earthquake-prone buildings had an extremely high variance, which essentially means that there were diverse patterns in new building development during this period. This variation can be attributed to a variety of things, which can have an impact on construction activities and urban growth across different areas. For instance, the figure could illustrate demographic and economic trends that were valid for each region in the 1980s such as the growth of population, urbanization rates, and level of economic prosperity which could have influenced the needs for different construction works in the particular regions. Those regions with fast-growing urbanization or industrialization may have seen a sudden surge of building development, increasing the busyness and variance levels.

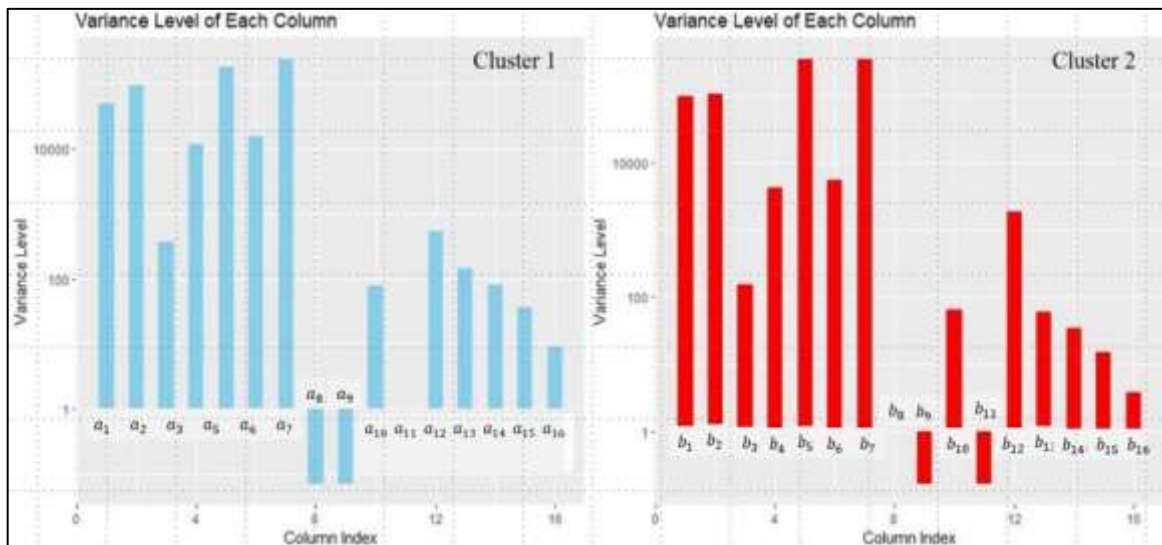


Figure 5.5: Variance Level Of All Features In Both Clusters.

Table 5.2: The Table Show The Dataset For Each Cluster In The Figure 5.3.

Cluster 1 symbol	Symbol	Meaning
a_1	b_1	Number Of floors (1-4)
a_2	b_2	Number Of floors (5-8)floors
a_3	b_3	Number Of floors (9-19)floors
a_4	b_4	Building Age before(1980)
a_5	b_5	Building Age between (1980-2000)
a_6	b_6	Building Age After(2000)
a_7	b_7	Concrete
a_8	b_8	Wooden
a_9	b_9	steely
a_{10}	b_{10}	mold tunnel
a_{11}	b_{11}	Prefabricated
a_{12}	b_{12}	Buildings
a_{13}	b_{13}	Highest
a_{14}	b_{14}	High
a_{15}	b_{15}	Middle
a_{16}	b_{16}	Low

Similarly, the previous observation of considerable variations in the column that represents the consumption of concrete in 14 earthquake-prone regions identically has comparable implications regarding earthquake resilience, the construction processes, and earthquake risk mitigation efforts. The high variance demonstrates either the variety in the distribution of concrete or the amount and way that concrete is used as a building material in different regions, which is the result of various factors influencing construction styles and the amount of infrastructure.

The first reason for this might be the existence of various functions of concrete, i.e. it depends on the local preferences of the design of buildings, the construction technologies applied as well as the availability of materials. Concrete can be a frequent choice for

construction in regions where it has significantly high structural strength, durability, and cheapness. High-rise buildings or infrastructure projects in the cities are good examples of these. However, parts of the region having narrow possibilities to the concrete provisions or the alternative construction technologies may present a low utilization rate which results in greater variance. Moreover, the issue of diversity of regulations, rules, building codes, and earthquake design standards are the key factors that influence the implementation of concrete in the building industry. Earthquake ally active zones with stringent regulations requiring earthquake-resistant construction or encouraging the application of sustainable building materials will be characterized by the use of concrete portions which could be the preferred way of improving the building strength and earthquake restrictions. Some regions with lax or obsolete legislative frameworks may register low adoption rates, hence these areas will have a greater degree of dispersion. Furthermore, socioeconomic factors like construction industry expertise, labor skills, and financial capacity have a certain influence on the possibility and implementation of different construction methods in concrete construction. Localities that have a robust construction preponderance, possess the necessary skills, and spend heavily on the construction of essential infrastructures may choose concrete-based construction because of its technical features and enduring benefits in earthquake-affected regions. However, concrete usage can be very different in regions with limited economic opportunities or without infrastructure investments thus those regions may turn to substitute building materials or traditional construction techniques alternatively.

In this regard, urban planners have to take these aspects into consideration before making decisions about zoning regulations, city planning codes, and large scale building projects so that construction materials are suitable, affordable, and do not waste natural resources. Beyond that, the referencing of tall buildings and large-scale infrastructure projects in the urban areas points out how city planners deal with urban growth, the density, the development of the urban areas considering the structural integrity, longevity, and costs of the building materials such as the concrete. This paragraph presents the overlapping aspect of construction materials, metropolitan development, and city planning which is critical in creating a living environment that satisfies the needs of people.

Observation of the repeated pattern of low variation in the variables "Wooden" and "Steely" among the 14 cities under consideration of an earthquake-like structure in the dataset enables

the understanding of the urbanization processes, brought by diversified materials and construction techniques. Instantly, in the areas undergoing rapid urbanization, the number of warehouse and steel buildings is significantly lower than the concrete ones, due to the main factors, which are related to the urban development system.

Firstly, in cities, the density of the region is often increased as well as the height of new buildings goes up transforming the ethos of building materials from wood and steel to those that are more durable and load-carrying such as concrete. The acute land proportions and demand for prime urban space in multi-property buildings and skyscrapers mainly use concrete, which has high tensile strength, is fire resistant, and is therefore impractical for high-density construction. In the end, materials more common in urban regions vary, with the wooden, steely, and concrete structures exhibiting less variance when they have concrete as the primary choice for vertical construction. Moreover, a regulatory framework and provisions in the urbanized towns and regions generally pay attention to the standards of safety and resilience so the improved materials with better structural reliability and earthquake withstanding ability are adopted. Tough, it being combined with innate toughness and durability, is reportedly mandated or rewarded by the construction laws in the quake-affected urban areas but they (wooden or steel structures in contrast) are to be inspected very thoroughly or even may be liable to be refused b/c of they being believed to be vulnerable to earthquake forces and fires. As a consequence, both urbanized and non-urbanized areas may show lower deviation trends of wooden and steel structures as the stricter implementation of building codes positively contributes to the spread of concrete in structure practice.

Moreover, the number of construction materials in the market, the developed methods, and the number of professionals in the cities will surely affect the kind of materials utilized and the construction strategies. Urban areas usually enjoy freedom of choice from a variety of construction methods, materials, and expert personnel that provide opportunities to reduce the exploitation of modern open-cast concrete mining for the satisfaction of urban development projects. However, the utilization of life-supporting but fragile structures like wooden and steel structures is hindered by issues of material availability, construction cost, and technology and therefore has a lower variance level as regards its usage across urbanized settings. Taking into account these relationships are the basis of the solutions for the urban

planning strategies which include sustainability in the building countries and the community's resilience in the cities which are prone to earthquakes.

5.3 SPATIAL DENSITY OF BUILDING COMPONENTS

Spatial density estimation is the process of measuring the distribution and concentration of particular structural characteristics or materials within a given geographic area, such as a city, region, or neighborhood. The purpose of this analysis is to comprehend the spatial patterns of building materials, such as steel, concrete, wood, and other materials, throughout the study area. When estimating the spatial density of points or events in a continuous geographic space, statisticians frequently employ Kernel Density Estimation (KDE). By examining the spatial distribution of individual building components within the study area, KDE can be used to calculate the spatial density of each component. In Figure 5.6, KDE maps of all 16 structural components are shown for both clusters. Here symbol is used to denote component of cluster 1 and refers to component of cluster 2. In cluster 1, It can be easily observed that patterns for components and are similar. The close resemblance between the KDE maps of the two construction elements, Wooden and Steely, allows us to derive the urbanization process of all 14 regions from cluster 1. In our case both KDE maps a statistics show that both wooden and steel structures are well distributed across the urban scape that has some urban structure or pattern. The urbanization process in the first cluster of Bağcılar is a broad process related to rapid construction and that these wooden and metal components are used locally within the urban environment of this group, meaning that steel is used extensively in the case of modernizing buildings within the urban fabric to reduce the risk. On the other hand, the use of wood in urban areas refers to the historical and archaeological buildings within the urban fabric of Bağcılar and is important in developing a strategy to preserve historical buildings in the face of risk.

In Cluster 2, a sudden drop to zero in the Kernel Density Estimation (KDE) for the use of wooden structures across various regions indicates a limited presence of wooden buildings. This finding highlights the connection between urbanization and the dynamics of urban development, as well as the spatial distribution of construction materials. The absence of wooden structures in certain areas, reflected by the zero KDE values, may result from specific urbanization patterns influenced by socioeconomic factors, cultural preferences, or regulations.

In economically advancing towns characterized by modernity and industry, the low or zero presence of wooden elements often suggests a shift towards alternative materials like concrete or steel. This shift may be driven by technological advancements, building codes, or the aesthetic preferences of city planners. Areas with zero KDE values are likely to coincide with urban centers, shopping districts, or densely populated residential neighborhoods where modern construction materials are prioritized due to land scarcity and high population density.

Moreover, the limited use of wood in certain regions may also reflect historical influences that shaped city landscapes. Regions with zero wooden components are often associated with contemporary planning and architectural practices, including parks and green spaces, which favor modern materials and designs over traditional construction methods.

The symbolic representation of a_i (used in Cluster 1) and b_i (used in Cluster 2) are given in Tables 5.3.

Table 5.3: Description Of Variables Used In Kernel Density Estimation For Cluster 1 AND 2.

Cluster 1 symbol	Symbol	Meaning
a_1	b_1	Number Of floors (1-4)
a_2	b_2	Number Of floors (5-8)floors
a_3	b_3	Number Of floors (9-19)floors
a_4	b_4	Building Age before(1980)
a_5	b_5	Building Age between (1980-2000)
a_6	b_6	Building Age After(2000)
a_7	b_7	Concrete
a_8	b_8	Wooden
a_9	b_9	steely
a_{10}	b_{10}	mold tunnel
a_{11}	b_{11}	Prefabricated
a_{12}	b_{12}	Buildings

Table 5.3: Description Of Variables Used In Kernel Density Estimation For Cluster 1
AND 2. "Table Continued"

a_{13}	b_{13}	Highest
a_{14}	b_{14}	High
a_{15}	b_{15}	Middle
a_{16}	b_{16}	Low

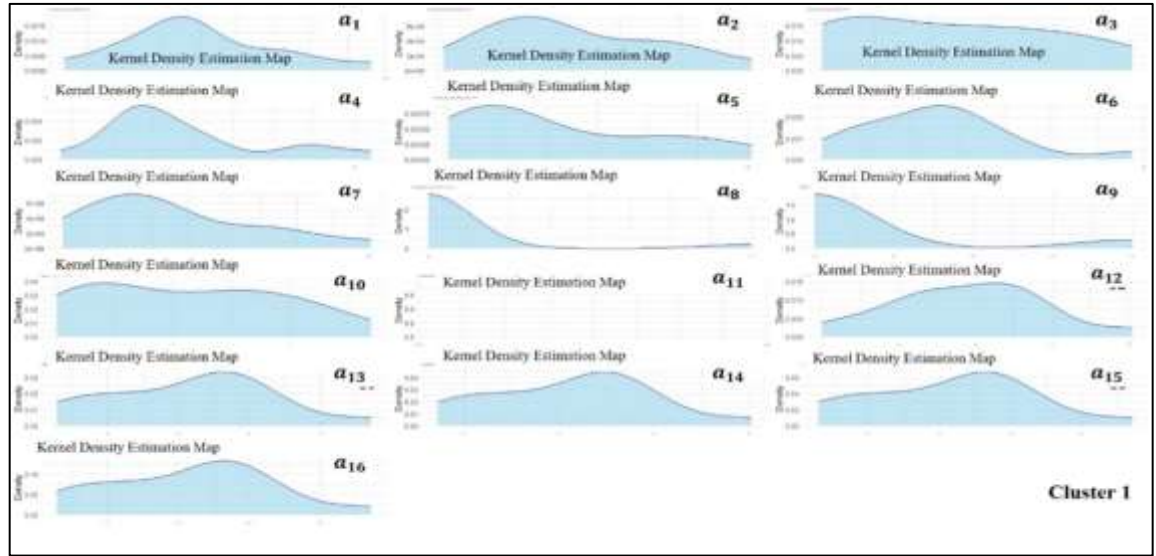


Figure 5.6: Regional Density Estimation Based On Individual Parameters For Clusters 1 And 2.

5.4 ROLE OF FINDINGS IN URBAN PLANNING

In this research study, we performed K-mean clustering on 22 neighborhoods of Bağcılar regions. According to the K-mean clustering, the “buildings constructed in the 1980s”, the construction material “Concrete”, the number of floors (1 to 4), and the number of floors (5 to 8) were four more prominent components that can be used in the urban planning of Bağcılar region. However, buildings put up in the 80s form a substantial part of the area’s built environment. Retrofitting and reinforcing these old buildings to meet modern earthquake standards will greatly increase their resistance to earthquakes. This improvement may result in to construction of more resilient but small buildings in the regions in respective clusters. Urban planners can work in tandem with architects and engineers to evaluate and

reinforce the structural integrity of these buildings by adding shear walls, strengthening foundations, and upgrading connections. With the earthquake retrofitting of buildings constructed in the 1980s, Bağcılar could decrease earthquake failure risk and decrease casualties during earthquake events.

The broad use of concrete as a building material in construction also clearly shows how much concrete is a key factor in the construction of earthquake-resistant buildings. Concrete provides excellent compressive strength and ductility of the structures which is a vital earthquake load-carrying capacity. The task of urban planners and architects is to push in urban communities for the adoption of earthquake design principles that encompass reinforced concrete frames, shear walls as well as moment-resisting frames in the construction of buildings. In addition, utilization of high-strength concrete mixes which are resilient, and earthquake and strengthen the durability of the structures in Bağcılar can also improve the earthquake reliability of these structures. By encouraging the incorporation of concrete in earthquake-resistant construction, the region can therefore enhance its earthquake security level.

The segmentation of buildings into 1-4-story referred to humans as earthquake-resistance urban planning and building construction strategies. Low-rise buildings, as a rule, have fewer stories; hence, the possibility of their destruction in case of an earthquake is lower compared to taller structures. Urban architects may acknowledge the application methods of earthquake design measures, such as base isolation and damping systems, in mid-rise and high-rise structures to decrease the negative impact of ground motions. However, it is not advised to construct buildings with more than 8 stories. Through the ability of Bağcılar to evaluate the earthquake vulnerability of buildings dependent on their height and occupancy, it is possible to form the needed earthquake-resistant building codes and land use regulations which will permit the reduction of the possibilities for loss of life and property.

5.4.1 Comparison Of Urban Planning Strategies In Bağcılar District

The 2002 studies by the Japan International Cooperation Agency (JICA) confirmed that the Bağcılar district is 90% earthquake resistant. The urban planning strategy used in this Japanese study on the Bağcılar district was concrete frame structures (Balamir et al. 2005). The district was expanded with modest residential blocks of four to eight floors in the middle

of the residential neighborhoods including some small business and manufacturing outlets on the ground floor as shown in Figure 5.7 (1). The red areas represent redevelopment areas such as Fatih, Kemalpaşa, Yıldıztepe, Yenigün, Kazım Karabakir and Sancaktepe, the green areas represent improved areas, the white areas represent urban renewal areas, and the gray area represents unprocessed zone .

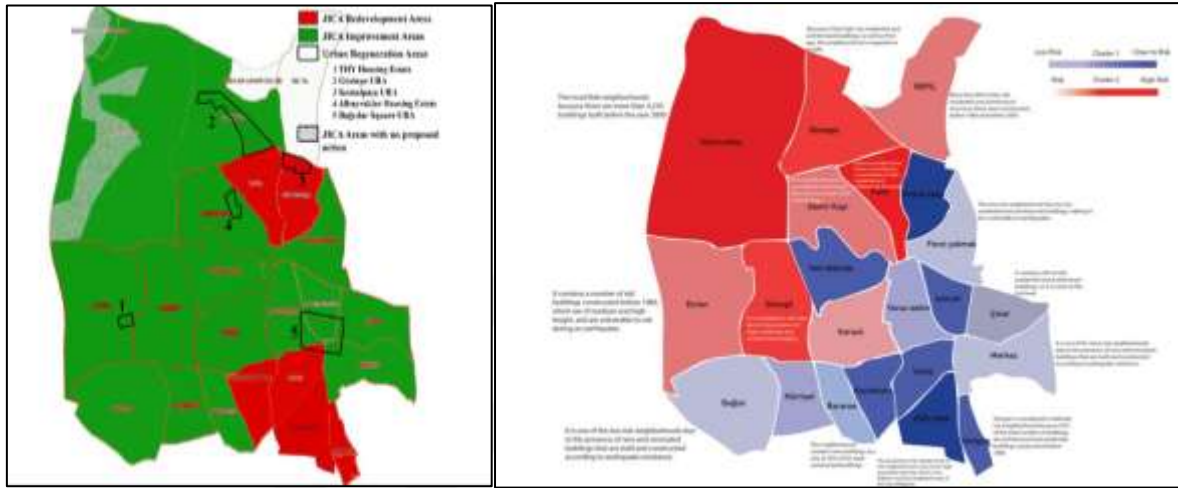


Figure 5.7: (1) Urban Growth And High-Risk Neighborhoods In Bağcılar (Balamir, (2005).

(2) The Map Shows The High-Risk And Low-Risk Neighborhoods In The Bağcılar, District.

Bağcılar was shown as one of the most risk district in Istanbul against the possibility of a random earthquake and it was estimated that 7,000 buildings, or 20% of the total area, would suffer severe or moderate damage and the death toll was estimated at more than 5,000 people and more than 7,000 people injured (Balamir et al. 2005). This research highlighted the urgent need in all 22 neighborhoods for deepening or redevelopment in this order.

The strategy of this thesis was applied by using K-means clustering algorithm on the data used for the Bağcılar district consisting of 22 neighborhoods. Two clusters were formed through K-means clustering. The first group in blue and its color gradient has the lowest risk and includes 14 neighborhoods. The second cluster in red and its color gradient has the highest risk and includes 8 neighborhoods as shown in Figure 5.7 (2). The neighborhoods in the blue areas represented close to low risk and the neighborhoods in the red areas

represented high risk to risk areas. Mahmutbey and Fatih neighborhoods are among the most risky neighborhoods in the Bağcılar district because they contain a large number of old residential and architectural buildings. Bağlar, Merkez and Fevzi çakmak neighborhoods are low risk neighborhoods because they contain modern buildings and vacant spaces at a higher rate than the rest of the neighborhoods according to the results of K-means and the data set used.

The strategy of this thesis emphasized the rehabilitation of residential and architectural buildings in the urban planning of the neighborhoods of this region such as Mahmutbey, Evren, Göztepe, 100Yıl, Fatih and Kemalpaşa. It emphasized the distribution of population density to the rest of the neighborhoods with low density and the redevelopment of buildings that suffer from weak earthquake resistance such as Yenigün, Yıldıztepe, Kazım Karabakir, İnönü, Sancaktepe and the rest of the neighborhoods where the urban planning strategies were given previously for this thesis through Table 5.1. This explained the comparison between the two strategies that worked on analyzing the Bağcılar region through the data set and the urban fabric represented by residential and architectural buildings and gave urban planning strategies on how to redevelop and rehabilitate the dangerous neighborhoods in this seismically active region.

5.6 LIMITATIONS OF THE STUDY

The key limitations of our approach are mentioned below:

- i. **Small Sample Size:** In urbanization, it is common to analyze data from various big data sets because of the huge variation and complexity of urban systems. A dataset with only 22 observations can lead to potential mere over fitting of the data beyond the current population, thus restraining the external validity of the study. This is especially so in urban planning where a variety of data is needed to make change and resilience-oriented designs.
- ii. **Limited Variability:** Whereas in the studies of urbanization and urban design, it is crucial to identify significant variance to appreciate the various types of urban settings, people living in these environments, and related environmental features. A small dataset means that the variability may be insufficient which can lead to an improper interpretation or creating the wrong number of clusters. This may lead to the development of some design or plan that neglects the crucial needs of different urban areas. The dataset we have

used is sufficient for this study; however, modifications in the dataset will impact the results.

- iii. **Reduced Robustness:** Most of the numeracy data for urbanization include distributions and noise, which differ in regions. If PCA is applied subsequently to validate K-means clustering with a restricted sample, differences such as these may well not be detected, by PCA essential for arriving at more credible results. This lack of robustness may considerably affect the reliability of the strategies of the urban design at a higher scale or across different urban settings.
- iv. **Dimensionality Reduction Issues:** It can also be said that PCA, with its focus on variance might distort urban typologies or patterns inherent within urban data, and thus not necessarily reveal the best inherent clusters. This misalignment could also lead to urban design interventions which may miss out on some of the key characteristics of urban form or function, and hence be less effective, or misaligned.
- v. **Sensitivity to Outliers:** This is so because the process of data collection may contain some unusual data on urban status or some abnormal urban circumstances. One disadvantage of using K-means and PCA is that it can be susceptible at times to outliers which could mislead the experiment in developing an appropriate K-value and hence the design. For example, a few atypical urban areas could drastically give results that are not very relevant to most urban design settings.
- vi. **Assumption of Linear Relationships:** Urban systems are not linear which means that the changes could be exponential, this is most probably true. Through the assumption of linearity, PCA might result in a wrong analysis of the non-linear data in the urban areas. Such a situation could lead to the development of measures that would not meet basic aspects of urban development such as the interconnection of infrastructure, population, and the environment

6. CONCLUSION AND FUTURE WORK

6.1 CONCLUSION

The study addressed several theoretical and experimental challenges in detail to determine the interconnection of urban planning policies and architectural structures and earthquake resistance in Bağcılar. The close examination holds the complex interaction between urban planning instruments and architectural projects for earthquake immunity in Bağcılar Building on a consolidated database that encompasses spatial perspectives and a variety of machine learning algorithms and spatial analytics, the study has discovered vital information with far-reaching developmental impacts for the upcoming years. Furthermore, spatial density estimation approaches such as Kernel Density Estimation (KDE) maps have become essential tools in the creation of detailed spatial distribution pattern maps of building materials in the study area. From now on these maps have revealed spatial trends and also factors that influence the city development dynamics, including construction materials, urbanization rates, and even historical influences. These types of data are irreplaceable during the making of evidence-based decision processes in urban planning and architecture design, allowing stakeholders to develop robust and environmentally friendly strategies that are uniquely adaptable to the living conditions of Bağcılar

The k-means clustering analysis of the Bağcılar district has provided valuable insights into the risk factors present in various neighborhoods. The neighborhoods in Cluster 2, marked in shades of red, demonstrate higher risk due to factors such as the age of buildings and their resilience to earthquakes. In contrast, neighborhoods in Cluster 1, marked in shades of blue, present lower risk levels. The detailed assessment of each neighborhood, considering the age of buildings, their architectural style and height, and population density, helps in understanding the specific risk factors and their severity. These insights are fundamental for urban planners to prioritize interventions, allocate resources effectively, and develop strategies to mitigate the identified risks. This comprehensive study underscores the significance of modern construction practices and urban planning in reducing earthquake risks, contributing to safer, more resilient urban spaces in the Bağcılar district.

The study has also pointed to significant factors that influence the residential development direction in Bağcılar such as population factors, economic frameworks, governing policies,

and preferences of society. The wave of concrete construction in urban areas was a summary of factors as composite strength, durability, as well as meeting building code requirements for earthquake resistance. With this knowledge, urban planners and architects can use proactive measures to address that problem, Mitchell architectural engineering, which is important as it helps prevent the harm of earthquakes to buildings and graffiti infrastructure and maintain people's livelihoods in Bağcılar. Observation of the repeated pattern of low variation in the variables "Wooden" and "Steely" among the 14 cities under consideration of an earthquake-like structure in the dataset enables the understanding of the urbanization processes, brought by diversified materials and construction techniques. Instantly, in the areas undergoing rapid urbanization, the number of warehouse and steel buildings is significantly lower than the concrete ones, due to the main factors, which are related to the urban development system.

In summary, the results from this study indicate the importance of properly combining urban planning practices with architectural design for indoor reinforcement purposes for places like Bağcılar which are extremely vulnerable to earthquakes. Therefore, from this moment, the direction of future urban development prescriptions must focus on using environmentally friendly building methods, making earthquake hazard-resistant infrastructure investments, and the participation of the community to efficiently manage earthquake threats and ensure the long-term sustainability of the region. Also, cluster 2, having 8 neighborhoods, is relatively risky compared to cluster 1 which shows that urban planners should avoid the planning schemes implemented in those regions. Also, concrete can be a frequent choice for construction in regions where it has significantly high structural strength, durability, and cheapness. Through the optimization of a synergistic model of urban planning and design, groups of stakeholders make it possible for residents of Bağcılar to lead safer, more robust, and eco-friendly lives in the future.

6.2 FUTURE SCOPE OF THE STUDY

The study of how neighborhood quake-resilient architectural structures contribute to urban planning strategies in Bağcılar has opened new paths for further research and applications. The present study provides enough background to undertake further investigation to provide more depth and insights into the aspect of the topic on which the study was done and inform future processes. Moving ahead in the research milieu, this study

will deal with a series of aspects that involve improving methodological approaches to meeting urban planning and disaster risk reduction challenges.

One of the most potent future research directions is the handling and integration of artificial intelligence and altered visual methodologies to get rid of model bias and improve the reliability and robustness of predictive models in the context of earthquake risk assessment. Researchers can surpass existing methods through the use of advanced analytical techniques and involve other data sources representing socioeconomic, environmental, and geological impacts on risk assessment frameworks. These frameworks provide the urban planner, policymaker, and stakeholder with relevant information for decision-making and mitigation. However, such an intervention and sustainability measures will benefit from these longitudinal studies to track progress and influence adjustments over time. By tracking the data over time through the process of data collection and analysis, one can determine the building pattern changes, infrastructure resilience, and the community's resilience. Thus, the researchers make a real-time assessment of impact and identify areas that need further development.

Other vigorous avenues of future research can be found in the application of advanced spatial technology tools, e.g. remote sensing techniques, geographic information systems (GIS), and LiDAR (Light Detection and Ranging) to improve the precision and granularity of the Geo spatial data analysis and routine monitoring. These technologies can give in-depth information about land uses, urban form, and infrastructure risk. Planning officials will now therefore be able to make more informed decisions based on the insight given. Increasing demand for multi-disciplinary cooperation between the urban planners, architects, engineers, social researchers, and stakeholder community in the quest for all-inclusive and locale-specific strategies to develop earthquake resilience in Bağcılar and other high earthquake areas is the other essential point. Through cross-disciplinary collaboration and exchange of knowledge, researchers thus can explore the rich perspectives and combined expertise available and join forces in the quest to develop powerful solutions, which often incorporate the socio-technical intricacies present in planning for urban resilience.

Besides all that, the authorities should provide several urban planning programs and knowledge transfer to assist community people with associated skills, resources, and tools needed to work together for reduction of the disaster risks and building resilience. These

community-led ways that incorporate local traditions, cultural values, and social networks produce a stronger resilience and bring a feeling of responsibility and ownership to the people. It also promotes the ability to foster such collective community values. Not only that, policy advocacy and governance reforms should be prioritized by making resilience considerations a cross-cutting issue in urban development plans, strategies, regulations, and policies. By adopting these principles of resilience, sustainability, and equity into the way we do policy making, policymakers can create a conducive environment for resilient urban development and ultimately be able to provide the appropriate needs and priorities of the vulnerable community. In conclusion, this study's future objective comprises a plenitude of significant research proposed about the interrelations between urban planning, architecture, and earthquake resilience in the Bağcılar neighborhood. Through the use of the multidisciplinary and participatory approach researchers and practitioners will longitudinally work with policymakers to achieve the building of resilient, participatory, and sustainable cities that are best valorized to withstand the challenges of the twenty-first century.

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