

City Information Modeling for Water Management in Climate Adaptive Campus Design

A Thesis

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Doğa Bitik

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City Information Modeling for Water Management in Climate Adaptive Campus Design

Approved by:

Assistant Professor Doğa Dinemis Aman,
Advisor
Department of Architecture
Özyeğin University

Professor Orhan Hacıhasanoğlu
Department of Architecture
Özyeğin University

Professor Gülşen Aytaç
Department of Landscape Architecture
Istanbul Technical University

Date Approved: 24 May 2023



To my family...

ABSTRACT

Cities must deal with increasing disasters due to global climate change. University campuses are socio-ecological systems that can act like urban prototypes in which we can test self-sufficiency and resilience in their physical context. Current studies commonly look for smart city indicators and how to demonstrate them on university campuses, but most of them do not offer resilient planning and design strategies. This thesis focuses on proposing a resilient and sustainable smart campus design index. The proposed research methodology involves the determination of the index by integrating resilience and sustainability indicators, followed by a case study assessment with City Information Modeling (CIM) and climate analysis simulation with a particular attention on water. Simulation and modeling tools, including computer simulations, 3D modeling, and digital twins as part of "Smart," is used to evaluate the effectiveness of existing campus masterplan design guidelines and strategies for water related disaster resilience and sustainability. The simulation method created for this thesis can be extended and used for offering climate change adaptive design strategies of different typologies, capable of functioning for different types of hazards. The potential use of digital twin and smart city technologies in disaster-resilient university buildings and campus design is explored, and potential challenges and limitations are identified. Integrating smart city principles and resilient thinking is a major demand for the city's future sustainability. This research methodology contributes to the literature on adaptive and smart disaster-resilient urban design index. The proposed study can assist in climate change adaptation and help decision-makers support further comprehensive planning and design approaches.

ÖZETÇE

Şehirlerin küresel iklim değişikliği nedeniyle artan felaketlerle baş etmesi gün geçtikçe zorlaşmaktadır. Üniversite kampüsleri, sosyo-ekolojik sistemler olarak, kentsel prototipler gibi hareket ederler ve fiziksel bağlamda sürdürülebilirlik ve dirençlilik testlerinin yapılabileceği yerlerdir. Mevcut çalışmalar genellikle akıllı şehir göstergelerini sürdürülebilirlik anlamında araştırmakta ve bunları üniversite kampüslerinde nasıl uygulayabileceğimizi göstermeye çalışmaktadır ancak çoğu dirençli planlama ve tasarım stratejileri sunmamaktadır. Bu tez, bir sürdürülebilir ve dirençli kampüs tasarım endeksi önermeye odaklanmaktadır. Önerilen araştırma yöntemi, sürdürülebilirlik, dirençlilik ve akıllı şehir göstergelerinin entegrasyonu ile endeksin belirlenmesini içermektedir. Su konusuna özellikle önem vererek, Şehir Bilgi Modellemesi (ŞBM) ve iklim analizi simülasyonu ile birlikte bir vaka çalışması değerlendirmesi yapmaktadır. Bilgisayar simülasyonları, 3D modelleme ve "Akıllı" kavramına bağlı olarak dijital ikizler de dahil olmak üzere simülasyon ve modelleme araçları, mevcut kampüs genel planı tasarım rehberlerinin ve su ile alakalı afet direnci stratejilerinin etkinliğini değerlendirmek için kullanılmıştır. Oluşturulan simülasyon yöntemi, iklim değişikliğine uyumlu tasarım stratejilerini sunmak için genişletilebilir ve kullanılabilir. Afetlere dayanıklı üniversite binaları ve kampüs tasarımında dijital ikiz ve akıllı şehir teknolojilerinin potansiyel kullanımı incelenmiş, zorluklar ve sınırlamalar belirlenmiştir. Yapılan araştırma, sürdürülebilir ve dirençli kampüs tasarım endeksi ile literatüre katkıda bulunmaktadır. Önerilen çalışma, iklim değişikliği adaptasyonuna yardımcı olabilir ve akıllı şehir prensipleri aracılığıyla karar mekanizmalarının daha kapsamlı planlama ve tasarım yaklaşımlarıyla desteklenmelerine yardımcı olabilir.

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CHAPTER I

INTRODUCTION

Cities worldwide are increasingly vulnerable to disasters caused by climate change, making it crucial to develop resilient and sustainable strategies [1], [2]. Universities have the potential to serve as prototypes for testing self-sufficiency and resilience in urban areas [3], [4], yet existing studies on smart campus indicators often lack resilient planning and design strategies. This thesis aims to propose a sustainable and resilient campus design index that integrates smart city indicators together with resilient planning and design strategies. By leveraging Building Information Modeling (BIM), City Information Modeling (CIM) and simulations, the index will assist decision-makers in supporting comprehensive planning and design approaches for climate change adaptation, with a particular attention to the water. The study will explore the relationship between smart city indicators, resilient planning, and design strategies, evaluate existing campus design guidelines using simulations, and investigate the challenges and opportunities of integrating digital twin and smart city technologies. Employing a mixed-methods research methodology, including literature review, case study investigation, and simulation analysis, this research seeks to provide practical recommendations for designing disaster-resilient university buildings and campuses. The aim is to contribute to the development of resilient and sustainable planning and design strategies for universities, fostering a more sustainable and resilient future.

1.1 Problem Statement

Cities worldwide are experiencing the increasing threat of disasters resulting from climate change [1], [2], and universities have the potential to serve as prototypes for testing self-sufficiency and resilience in urban areas [3], [4]. However, existing studies on smart campus indicators in universities often need more resilient planning and design strategies. As a result, there is an urgent requirement to develop practical and effective design guidelines and strategies that integrate smart city principles with resilient thinking for disaster-resilient university buildings and campuses.

This Master of Science thesis aims to address this gap by proposing a sustainable and resilient smart campus design index to help decision-makers support comprehensive planning and design approaches. The thesis focuses on using Building Information Modeling (BIM) and City Information Modeling (CIM) to assess the climate-adaptive design of smart campuses, with a particular focus on integrating resilience and sustainability principles. The research involves the development of a CIM-based tool that can be used to evaluate the sustainability and resilience of campus buildings and infrastructure for water management, with a focus on their ability to withstand and recover from natural disasters. The tool will be tested on a case study of an existing campus to evaluate the resilience and sustainability of smart campus design for expected extreme drought and precipitation events due to climate change [5]. This research will contribute to developing practical and effective evaluation and design guidelines and strategies that integrate smart city principles with resilient thinking for disaster-resilient university buildings and campuses.

By leveraging the power of technology, this research can transform how decision-makers approach climate-adaptive smart campus design, promoting a more sustainable and resilient future for universities and the communities they serve.

1.2 Hypothesis

The impact of climate change is increasingly being felt globally [5]. As centers of research and education, universities have the potential to serve as catalysts for the development of sustainable and resilient approaches to addressing the impacts of climate change [4]. Integrating smart city indicators, resilient planning and design strategies, and City Information Modeling (CIM) and Building Information Modeling (BIM) can create a climate-adaptive smart campus design index, assisting decision-makers in supporting comprehensive planning and design approaches for climate change adaptation and sustainability [6]. By integrating City Information Modeling (CIM) and Building Information Modeling (BIM), smart city indicators [7], resilient planning and design strategies [8], it is possible to create a climate-adaptive smart campus design index that can assist decision-makers in supporting comprehensive planning and design approaches for climate change adaptation and sustainability for universities and the communities they serve.

This index will be developed using simulation and modeling tools, including computer simulations, 3D modeling, and digital twins. These tools will enable the evaluation of the effectiveness of existing campus masterplan design guidelines and strategies for disaster resilience and identify potential challenges and limitations in integrating digital twin and smart city technologies in the design and construction of disaster-resilient university buildings.

The proposed climate-adaptive smart campus design index will provide a comprehensive and practical tool for decision-makers to assess campus buildings and infrastructure sustainability and resilience, focusing on their ability to withstand and recover from natural disasters such as extreme drought and precipitation events.

Using simulation and modeling tools, this index can be evaluated, refined, and applied to existing and proposed campus projects, promoting a more sustainable and resilient future for universities and the communities they serve.

1.3 Aim of the Study

The primary aim of this thesis is to propose a resilient smart campus design index that integrates smart city indicators and resilient planning and design strategies to create a comprehensive tool for decision-makers to support climate change adaptation and sustainable planning and design for university buildings and campuses. To achieve this aim, the following objectives will be pursued:

The first objective is to identify the relationship between smart city indicators, resilient planning and design strategies for university campuses and propose a framework for integrating these concepts to create a sustainable and resilient smart campus design index. This involves reviewing the literature on smart city indicators, resilient planning, and design strategies in the context of university campuses and developing a framework for integrating these two concepts to create a comprehensive tool for decision-makers.

The second objective is to investigate the potential challenges and opportunities associated with integrating digital twin and smart city technologies in designing and adapting disaster-resilient university buildings, provide recommendations for addressing

these challenges to support climate change adaptation with a particular attention to water. This will involve examining the potential benefits and limitations of digital twin and smart city technologies in the context of disaster-resilient university buildings and developing recommendations for integrating these technologies into resilient planning and design strategies through the development of a sustainable and resilient campus index.

1.4 Research Questions

This thesis proposes 3 main research questions related to developing resilient and sustainable planning and design strategies for university buildings and campuses. The following research questions will be investigated in this study:

1. What is the relationship between smart city indicators, resilient planning and design strategies for university campuses, and how can these concepts be integrated to create a sustainable and resilient campus design index?
2. How can Building Information Modeling (BIM) and simulation, including digital twins, be used to evaluate the effectiveness of existing campus masterplan design guidelines in relation to water, and strategies for disaster resilience, and what are the potential benefits and drawbacks of these approaches?
3. What are the potential challenges and opportunities associated with integrating digital twin and smart city technologies in the design, construction and adaptation of disaster-resilient university buildings, and how can these challenges be addressed to support climate change adaptation and sustainable planning and design?

The first research question determines the relationship between smart city indicators and resilient planning and design strategies for university campuses and how these concepts can be integrated to create a resilient smart campus design index. To answer this question, the study reviews the literature on smart city indicators and resilient planning and design strategies in the context of university campuses and explore how these concepts can be integrated to create a comprehensive tool for decision-makers to support climate change adaptation and sustainable planning and design. This research will contribute to developing a practical and effective tool for evaluating the climate adaptability of smart campus designs.

The second research question investigates how Building Information Modeling (BIM), City Information Modeling (CIM) and simulation, including digital twins, can be used to evaluate the effectiveness of existing campus masterplan design guidelines and strategies for disaster resilience and what are the potential benefits and drawbacks of these approaches. To answer this question, the study examine how City Information Modeling (CIM) technology and simulation tools can be used to model and simulate the performance of campus buildings and infrastructure in response to natural disasters and other climate-related hazards.

The third research question explores the potential challenges and opportunities associated with integrating digital twin and smart city technologies in designing, constructing, and adapting disaster-resilient university buildings and how these challenges can be addressed to support climate change adaptation and sustainable planning and design. This question will examine the potential benefits and limitations of digital twin and smart city technologies in disaster-resilient university buildings and

develop recommendations for integrating these technologies into resilient planning and design strategies.

By investigating these research questions, this thesis aims to contribute to developing resilient and sustainable planning and design strategies for university buildings and campuses.

1.5 Research Methodology

The proposed Master of Science thesis employs a mixed-methods research methodology to investigate the problem of climate change and resilience in architectural and urban planning strategies and practices for disaster management in university campuses. The research methodology includes the following steps:

The research methodology for this thesis starts with a comprehensive literature review to identify the problem related to climate change and resilience in existing architectural and urban planning strategies and practices for disaster management in university campuses. This will involve reviewing the existing literature on climate change, resilience, sustainability, disaster management, risk assessment, Building Information Modeling (BIM), City Information Modeling (CIM), Digital Twins, Smart Cities and Smart Campuses. and architectural and urban planning strategies for university campuses.

The comprehensive literature review will follow the definition of a sustainable and resilient campus index. Later a case study analysis will be conducted to analyze the Özyeğin University campus and surrounding urban context to identify potential extreme

drought and precipitation risks. This analysis includes data gathering through site visits, interviews, and reviewing relevant documents.

Modeling and simulation tools are used to test and evaluate the existing campus masterplan design guidelines and strategies for disaster resilience, including 3D modeling, computer simulations, and digital twins as part of "Smart." Özyeğin University was chosen as the case study for this study due to its proximity to the Ömerli Dam, the largest dam in Istanbul. A virtual model of Özyeğin University Çekmeköy Campus is created on Rhinoceros 3D software [9], the topography of the area that surrounds the campus is exported through GIS. To conduct a water flow analysis of Çekmeköy Campus and surrounding context simulation algorithms are created in Grasshopper [10]. Since Building Information Modeling is a system that transfers building data to the model, different surfaces and roof types that can affect water retention are analyzed for further process as data on the created digital twin. These include water-permeable and impermeable surfaces, different roof types such as green roofs, pitched roofs, flat roofs, and streams available in the topography where the buildings sit.

The literature review for this research revealed that climate change reports on İstanbul, the location of Özyeğin University Çekmeköy Campus, identified extreme drought and precipitation events as one of the strongest risks in the coming years [5]. Therefore, the analysis for this research will focus on indicators related to water conservation, starting with a water flow simulation analysis. This methodological approach utilizes technology to evaluate the effectiveness of existing or designed university campuses in mitigating potential disasters related to climate change [5]. By conducting this analysis on water conservation indicators within the sustainable and

resilient smart campus index, a methodology for further analysis on other indicators present in the index can be developed.

Finally, the research concludes a summary of the findings and recommendations for designing and building disaster-resilient university buildings and campuses. The research highlights the strengths and limitations of the proposed CIM based virtual model simulation method and suggest areas for future research. This research methodology will employ qualitative and quantitative research methods, such as literature review, interviews, case study analysis, digital twinning, and simulations. The research aims to provide practical recommendations for designing and adopting disaster-resilient smart university buildings and campuses in the context of climate change and urban sustainability. By leveraging the power of modeling and simulation tools, this research can transform how decision-makers approach climate-adaptive smart campus design, promoting a more sustainable and resilient future for universities and the communities they serve.

Research Methodology

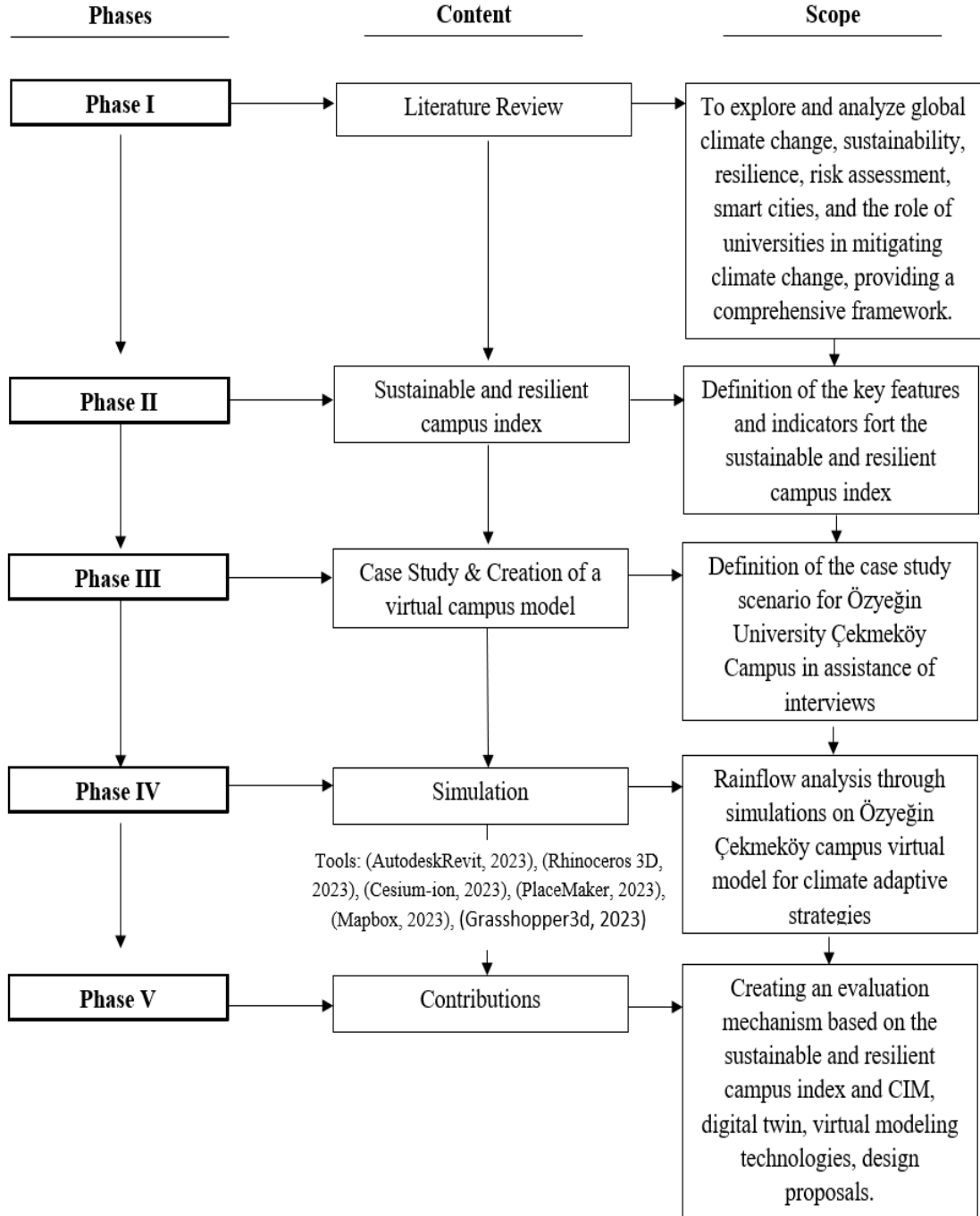


Figure 1: Research Methodology

CHAPTER II

THEORETICAL DISCUSSION

This chapter begins by examining the global impact of climate change, discussing its effects on ecosystems, weather patterns, and human populations. It also explores the predicted impact of climate change on Turkey, highlighting the country's specific challenge. Mitigation and adaptation strategies are essential in addressing climate change, emphasizing the importance of sustainability and resilience. The role of universities in promoting sustainability and resilience is crucial [11], emphasizing their contributions through research, education, and community engagement. The discussion then defines sustainability, resilience, and risk assessment, emphasizing their interconnectedness and significance in addressing climate change challenges. It also highlights risk assessment as a crucial tool for identifying and evaluating vulnerabilities.

The concept of smart cities and smart campuses is examined in detail, emphasizing their use of technology and data-driven approaches to enhance efficiency, sustainability, and quality of life. The unique characteristics and challenges associated with managing a smart campus are explored, focusing on the university campus as a micro-scale city. The adaptability of smart campuses to climate change is crucial, emphasizing the use of technological infrastructure and data analytics to develop climate-adaptive strategies. The importance of utilizing smart technologies for effective monitoring and response to climate change impacts is highlighted.

Finally, the role of BIM, digital twins, and smart technologies in climate-adaptive design is discussed. This includes the integration of data and design processes through Building Information Modeling (BIM) and City Information Modeling (CIM). The concept of digital twins, enabling virtual replicas for monitoring and analysis, is introduced. The discussion explores the application of information modeling and digital twins in enhancing sustainability and resilience.

2.1 Global Climate Change

Global climate change refers to the alteration of long-term weather patterns that define different regions of the world. Scientists assert without doubt that the Earth is undergoing a warming process. The observed trend cannot be solely attributed to natural climate variability. Human activities, particularly the combustion of coal and oil, have significantly elevated the concentrations of greenhouse gases in the atmosphere, resulting in a substantial warming effect on the Earth. [5] As humans continue to release increasing amounts of these gases into the atmosphere, the Earth is expected to experience even more warming in the coming decades and centuries. The most significant of these greenhouse gases (GHG) are carbon dioxide (CO₂), methane, nitrous oxide, and fluorinated gases. When it comes to mitigating climate change, the focus tends towards carbon dioxide (CO₂) emissions. However, human-induced emissions of non-CO₂ greenhouse gases (GHGs) are important contributors to global warming. These include methane (CH₄), nitrous oxide (N₂O), fluorinated greenhouse gases (HFCs, PFCs and SF₆) and ozone depleting substances. Other non-CO₂ emissions, such as aerosols (e.g. black carbon (BC)) and pollutants that function as aerosol or GHG precursors, contribute to changes in the atmosphere's energy balance. [12]. The increasing concentrations of

GHGs in the atmosphere result in a phenomenon known as the greenhouse effect. This phenomenon happens when greenhouse gases (GHGs) trap heat within the atmosphere, leading to an increase in the Earth's temperature. The impacts of warming can already be observed in many places, from rising sea levels to melting snow and ice to changing weather patterns. The impacts of climate change are already being observed in ecosystems, freshwater resources, and human health. [13].

2.1.1 The Global impact of Climate Change

The United Nations Intergovernmental Panel on Climate Change (IPCC) has warned that global warming could have significant and irreversible impacts on human societies and natural ecosystems.

Panel (c) Observed impacts on ecosystems and human systems attributed to climate change at global and regional scales [5]. Global assessments focus on large studies, multi-species, meta-analyses and large reviews. Regional assessments consider evidence on impacts across an entire region and do not focus on any country in particular. For human systems, the direction of impacts is assessed and both adverse and positive impacts have been observed e.g., adverse impacts in one area or food item may occur with positive impacts in another area or food item. Physical water availability includes balance of water available from various sources including ground water, water quality and demand for water. Global mental health and displacement assessments reflect only assessed regions. Confidence levels reflect the assessment of attribution of the observed impact to climate change. [5];

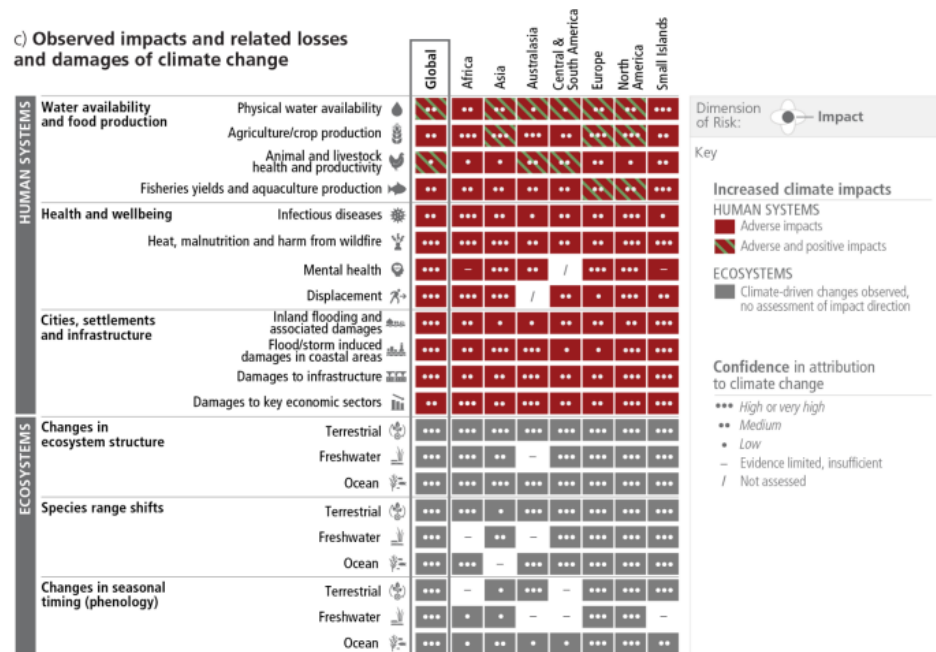


Figure 2: Observed Impacts and Related Losses and Damages of Climate Change

[5]

2.1.2 The Predicted Impact on Turkey

According to the research cited in IPCC 2023, the potential impact of climate change on Turkey is linked to disasters related to drought, excessive and irregular precipitation until 2030. [5] It is predicted that there will be a rapid temperature increase towards the end of the 2030s. [14] It is stated that the geography in which Turkey is located is at high risk especially in terms of agriculture and crop production, heat, malnutrition and harm from wildfire, mental health, displacement, flood/storm induced damages in coastal areas, changes in ecosystem structure, species range shifts and phenology [5].

Although it varies according to the regions, it has been observed that there will be an increase in the annual average temperature of Turkey between 2.5°C and 4°C. All provinces saw an increase in annual mean temperature, one of the main indicators of

climate change; over 30 years, the annual mean temperature has increased by 2 °C across the country. [5] The increase in annual maximum precipitation due to changes in the precipitation regime is another important indicator of climate change. Although there is an increase in precipitation in the eastern part of North Anatolia, precipitation is expected to decrease throughout Turkey. The annual number of extreme weather events is seen to have increased in each province except ,Sırnak, Siirt , Tunceli, and Bitlis, with provinces located along coastlines seeing the highest rates of increase. The number of dry months per year rose in 39 of the 81 provinces, indicating no general increase in the number of dry months across the country. [15];

All these will severely decrease our country's water resources, drought and desertification, loss of agricultural productivity, an increase in the number and impact of forest fires, and loss of biodiversity. [16]

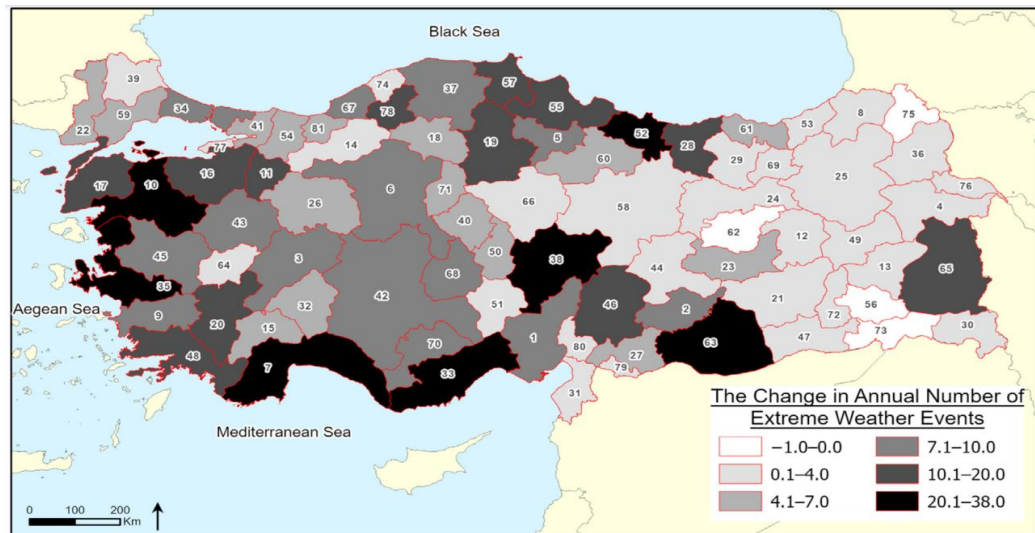


Figure 3: The change in the annual number of extreme weather events (comparison of 1990–1991 mean and 2018–2019 mean) [15];

2.1.3 Mitigation and Adaptation Strategies

Urgent action is required to address and mitigate the impacts of global climate change. This entails reducing greenhouse gas (GHG) emissions by transitioning to renewable energy sources and enhancing energy efficiency. It also requires adapting to the existing changes, such as constructing resilient infrastructure capable of withstanding the impacts of climate change. According to the United Nations Intergovernmental Panel on Climate Change, there are measures that can be taken to reduce and prevent the effects of global warming. Sustainable Development Goals (SDG) specified by IPCC were determined as 17.

These are as follows [5];

- No poverty
- Zero Hunger
- Good Health and Well-Being
- Quality Education
- Gender Equality
- Clean Water and Sanitation
- Affordable and Clean Energy
- Decent Work and Economic Growth
- Industry, Innovation, and Infrastructure
- Reduced Inequalities

- Sustainable Cities and Communities
- Responsible Consumption and Production
- Climate Action
- Life Below Water
- Life on Land
- Peace, Justice, and Strong Institutions
- Partnerships for the Goals

The figure presented in Panel (a) of IPCC'23 provides an overview of selected climate responses and adaptation options, as well as mitigation options and their estimated costs and potentials in 2030 [5]. The left-hand side of the panel shows climate responses and adaptation options evaluated for their feasibility at a global scale, in the near term, and up to 1.5°C global warming. The feasibility is assessed based on six dimensions, including economic, technological, institutional, social, environmental, and geophysical, and their synergies with mitigation. The right-hand side of the panel presents selected mitigation options and their net lifetime discounted monetary costs of avoided greenhouse gas emissions, as well as their potential for net greenhouse gas emission reduction relative to a specified emission baseline. The potential and costs are broken down into different cost categories.

However, it is important to note that feasibility at higher levels of warming beyond 1.5°C may change and is currently uncertain. Moreover, the mitigation potential is uncertain and depends on various factors such as the reference technology being displaced

and the rate of new technology adoption. Different options have different feasibilities beyond the cost aspects, which are not reflected in the figure. Furthermore, the expenses associated with incorporating variable renewable energy sources into electricity systems are projected to be relatively low until 2030 and have not been considered. Therefore, the figure should be interpreted with caution and consider the uncertainties and limitations of the assessments presented.

Global climate change is a complex and multifaceted issue that requires a coordinated effort across governments, businesses, and individuals to address. It is a critical challenge facing humanity today and will require sustained action and commitment to mitigate its impacts and ensure a sustainable and livable planet for future generations.

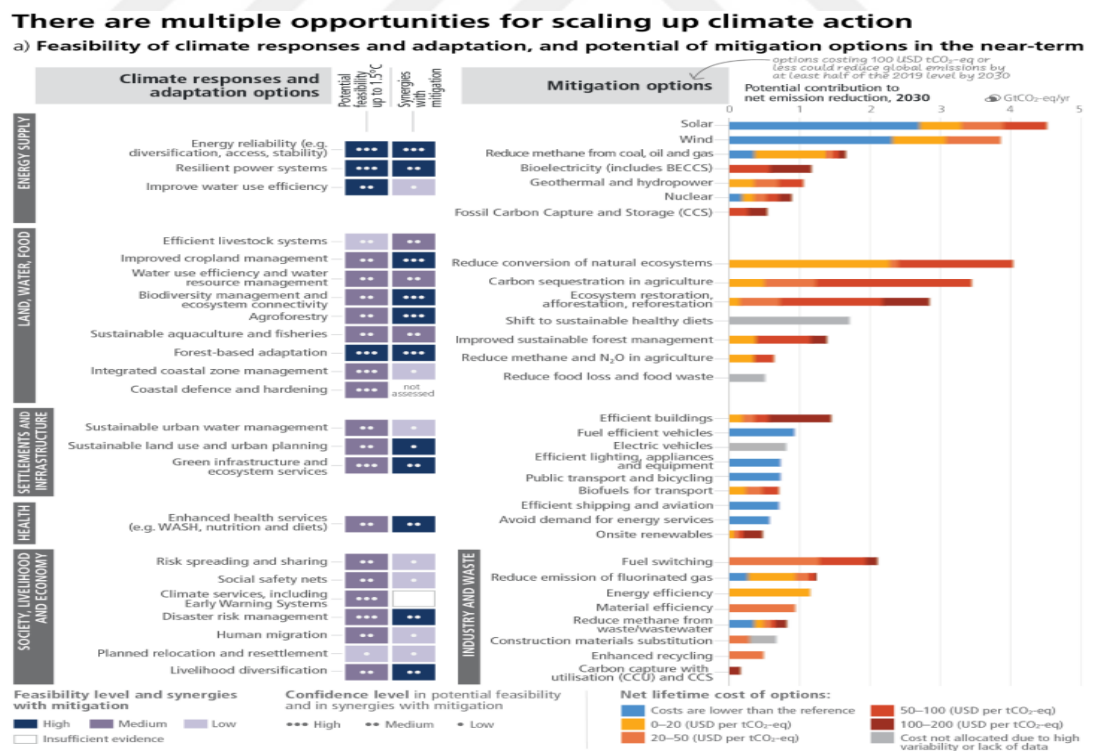


Figure 4: Observed Impacts and Related Losses and Damages of Climate Change

[5];

2.1.4 Universities' Role in Mitigating Climate Change

Institutions of Higher Education, particularly universities contribute immensely to the United Nations landmark 2030 agenda and the achievement of its Sustainable Development Goals—the SDGs. Universities are uniquely placed to broken links between different sectors through fostering cross-cutting approaches to achieving the climate change-related sustainable development goals [4].

Universities play a crucial role in mitigating climate change by undertaking research, implementing sustainable practices, and educating students on climate change mitigation strategies. Through research, universities provide vital knowledge and expertise to governments, industries, and communities to develop effective mitigation policies and solutions. Universities play a key role in this effort by targeting their emissions and working with other local actors to develop climate change mitigation programs, reducing their own carbon footprint by adopting sustainable practices, such as using renewable energy sources, promoting energy efficiency, and implementing sustainable transportation policies [17]. Universities can equip students with the necessary skills and knowledge to address climate change through relevant academic programs and courses, promoting sustainability initiatives, and encouraging student-led climate action. Universities' role in mitigating climate change is critical in addressing the global challenge of climate change and achieving a sustainable future.

2.2 Sustainability, Resilience and Risk Assessment

As the impacts of climate change continue to pose significant challenges to the world's cities, universities are playing an increasingly vital role in promoting sustainability,

resilience, and risk assessment. Cities are facing complex challenges in adapting to climate change, such as rising sea levels, extreme weather events, and water scarcity. Universities are well-placed to address these challenges through research, education, and community engagement. Sustainability refers to meeting the needs of the present generation without compromising the ability of future generations to meet their own needs, while minimizing the impact on the environment. [18]

Sustainability efforts can help reduce greenhouse gas emissions, promote renewable energy sources, and encourage sustainable transportation and building practices. Resilience is the ability to adapt and recover from disturbances or shocks, while maintaining basic functions and structures, with consideration to the environment [19]. Resilience measures can help cities adapt and recover from the impacts of climate change, ensuring continuity of services and infrastructure. Risk assessment is the process of evaluating the likelihood and potential consequences of a hazard, with respect to the environment, to determine appropriate actions to mitigate or manage the risk. [20] Risk assessment provides critical information on the likelihood and severity of climate impacts, enabling decision-makers to take proactive measures to reduce vulnerability and increase preparedness. Universities can collaborate with cities, governments, industry, and civil society to develop innovative solutions and foster sustainable and resilient communities. This integration of sustainability, resilience, and risk assessment into universities' core missions can play a critical role in mitigating the impacts of climate change and ensuring a sustainable future for cities and communities.

2.2.1 Defining Sustainability and Resilience

Sustainability and resilience are two distinct concepts that are critical in addressing the challenges posed by climate change. Sustainability refers to the practice of utilizing the critical functions of our natural surroundings in a manner that ensures their continuous availability. [21]. In simpler terms, sustainability is the ability to meet the needs of the present generation without compromising the ability of future generations to meet their own needs. [18] This definition highlights the importance of responsible consumption and utilization of natural resources. Sustainability also encompasses the concept of ecological balance, which involves the harmonious coexistence of human and natural systems. As such, sustainability aims to find ways for both systems to operate in a mutually beneficial manner that promotes the survival and prosperity of all species, both locally and globally. [22].

The focus of sustainability is on promoting a balance between economic, social, and environmental factors, ensuring that these factors are in harmony and do not compromise each other's viability. In sustainability, stability and balance are the norms, and the focus is on promoting long-term, predictable outcomes [23]. This entails establishing a system capable of adapting to environmental, economic, and societal changes while ensuring responsible and sustainable use of resources. On the other hand, Resilience recognizes that the future is uncertain, and that change is inevitable, so the emphasis is on building capacity to adapt to change and recover quickly from shocks. The focus of resilience is on promoting the ability of a system to cope with nonlinear, unpredictable change and chaos. [23].

Resilience is about adapting to change and being able to recover quickly from disruptions, ensuring that critical services and infrastructure continue to function. Resilience is a key principle associated with the four dimensions of energy that underpin sustainability. It refers to the capacity of a system to respond to disturbances and maintain its functions and structure. [19]. Resilience can be understood in multiple ways, including as a metaphor related to sustainability, a property of dynamic models, and a measurable quantity that can be assessed in studies of social-ecological systems. [24]. In the context of sustainability, resilience is central to understanding how ecosystems respond to strong perturbations and is related to other concepts such as resistance, recovery, vulnerability, stability, adaptive capacity, regime shift, and tipping point. [25]. Therefore, resilience is a critical component of sustainability, allowing systems to adapt and thrive in the face of change while maintaining their long-term viability.

Sustainability and resilience are both crucial concepts in addressing the challenges posed by climate change. Sustainability aims to balance economic, social, and environmental factors to preserve resources and systems over the long term. Resilience, on the other hand, focuses on a system's ability to withstand and recover from disturbances or shocks. Together, these concepts can promote a sustainable and resilient future for current and future generations by ensuring that natural resources and ecosystems are preserved while allowing for adaptation to changing circumstances. Assessing risks is critical for achieving sustainability and resilience goals by identifying potential threats and developing strategies to mitigate those risks.

Table 1: Sustainability: Definitions, Goals and Assumptions

	Sustainability
Definitions	Sustainability is the ability to meet the needs of the present generation without compromising the ability of future generations to meet their own needs. [18]
	Sustainability is defined as the use of the vital functions (possible uses) of our biophysical surroundings in such a way that they remain indefinitely available. [21]
	Sustainability seeks a way for human and natural systems to work together so that all species can survive and thrive over the long term, both locally and globally. [22]
Goals	Maintain and preserve resources and systems over the long term. [23]
Assumption	Stability & Balance are the norm (or at least possible). [23]

Table 2: Resilience: Definitions, Goals and Assumptions

	Resilience
Definitions	The ability to plan for, absorb, recover from, and adapt to adverse events that may happen in the future is a resilience principle associated with the four sustainability dimensions of energy. [19]
	Resilience has multiple levels of meaning: as a metaphor related to sustainability, as a property of dynamic models, and as a measurable quantity that can be assessed in field studies of SES. [24]
	Resilience is the central concept for understanding how an ecosystem responds to a strong perturbation and is related to other concepts used to analyze system properties in the face of change such as resistance, recovery, sustainability, vulnerability, stability, adaptive capacity, regime shift, and tipping point. [25]
Goals	Reducing vulnerability & increasing physical & social capacity for change, flexibility and redundancy. [23]
Assumptions	Non-linear & Unpredictable Change & Chaos are the norm. [23]

2.2.2 Defining Risk Assessment

Risk assessment plays a critical role in achieving sustainability and resilience goals, especially given the increasing challenges posed by climate change. Risk assessment is a process that involves examining potential hazards and evaluating the extent of the risks involved, considering existing precautions. Environmental risk assessment focuses

specifically on the examination of the risks posed by technology that threatens ecosystems, human beings, animals, and other natural resources. [26] This assessment evaluates the effects of environmental changes on a valued natural resource and interprets the significance of those effects considering the uncertainties identified in each component of the assessment process. [27] Through the risk assessment process, decision-makers can identify potential hazards and assess the associated risks, enabling them to take measures to minimize negative impacts and promote sustainable outcomes. [20] Risk assessment is a critical tool in advancing sustainability and resilience goals, as it enables decision-makers to make informed decisions that promote the long-term viability of natural resources and ecosystems while ensuring the well-being of current and future generations. By incorporating risk assessment into sustainability and resilience efforts, decision-makers can make informed choices that promote the long-term viability of natural resources and ecosystems, while also ensuring the well-being of current and future generations.

Risk assessment holds significant importance in the design and planning processes carried out by architects and urban planners. It involves identifying potential hazards, evaluating the likelihood and severity of associated risks, and identifying strategies to mitigate those risks. In urban planning, risk assessment may involve analyzing the potential impacts of climate change on a city's infrastructure, evaluating the vulnerability of infrastructure, and identifying strategies to improve resilience. In architecture, risk assessment may involve evaluating the potential risks associated with building materials, construction methods, and location, and designing the building accordingly. By conducting risk assessment, architects and urban planners can identify potential hazards

and assess the associated risks, enabling them to develop strategies to minimize negative impacts and promote sustainable outcomes.

Table 3: Risk Assessment

	Risk Assessment
Definitions	Environmental risk assessment is the examination of the risks resulting from technology that threaten ecosystems, human beings, animals, etc. [26]
	Risk assessment evaluates the effects of an environmental change on a valued natural resource and interprets the significance of those effects in light of the uncertainties identified in each component of the assessment process. [27]
	Risk assessment involves identifying the hazards present in any undertaking (whether arising from work activities or from other factors, e.g. the layout of the premises) and then evaluating the extent of the risks involved, taking into account existing precautions. [20]
Goals	Identification of potential hazards and evaluate associated risks to develop strategies to mitigate those risks and promote sustainable and resilient outcomes.
Assumptions	Potential hazards and associated risks can be identified and evaluated through a systematic and objective process.

2.2.3 Smart City and Smart Campus

The rapid urbanization and growth of cities worldwide have brought about many challenges, including population growth, increasing energy consumption, environmental degradation, and inefficient transportation systems [28]. To tackle these challenges and improve the quality of life for citizens, cities and campuses around the world are turning to smart technologies [29].

Smart cities and smart campuses are defined as places that use technology to improve the quality of life for residents and users, while also enhancing sustainability, efficiency, and safety. [30] The goal of smart cities and campuses is to use digital technology and data-driven insights to optimize the use of resources, reduce waste, and enhance the overall livability of the built environment. [31]

A smart city is an urban area that uses digital technology to manage its resources and services efficiently, often leveraging sensors, data analytics, and automation to improve everything from transportation and public safety to energy consumption and waste management. Examples of smart city initiatives include intelligent traffic management systems, smart parking solutions, and efficient waste management systems. [29].

Similarly, a smart campus is an academic environment that uses digital technology to enhance the learning experience for students, improve the management of campus resources, and support sustainable practices. Smart campus initiatives can include smart lighting, building automation systems, and mobile applications that provide real-time information about campus events, transportation, and other services [32].

Both smart cities and smart campuses share many of the same goals and strategies, including the use of data analytics and real-time insights to optimize the use of resources and enhance sustainability. Additionally, both smart cities and campuses are designed to provide a more livable and efficient built environment for their users, whether that is the residents of a city or the students, faculty, and staff of a campus.

One of the key benefits of smart cities and smart campuses is the ability to collect and analyze large amounts of data in real-time. This data can then be used to optimize the use of resources, improve safety, and enhance overall efficiency. For example, sensors in a smart city can provide real-time data on traffic patterns, enabling traffic management systems to adjust traffic flow to minimize congestion and reduce emissions. Similarly, sensors in a smart campus can provide real-time data on energy consumption and temperature, enabling building automation systems to adjust heating and cooling systems to optimize energy use.

In conclusion, smart cities and smart campuses represent an exciting new frontier in urban planning and campus management. Smart cities and campuses leverage digital technology and data analytics to enhance the quality of life for residents and users. These innovative designs prioritize sustainability, efficiency, and safety, ultimately creating environments that are more livable and enjoyable. As the world continues to urbanize, smart cities and campuses will play an increasingly important role in creating more livable, sustainable, and efficient built environments for everyone.

2.2.4 Definitions of Smart City and Smart Campus

As the world continues to face challenges posed by urbanization, climate change, and digital transformation, the concept of the smart city has emerged as a solution for modern

urban management. A smart city is a community in which stakeholders, including citizens, businesses, knowledge institutions, and municipal agencies, collaborate to achieve systems integration and efficiency, citizen engagement, and a continually improving quality of life [33]. Employing information and communication technologies, smart cities aim to improve the quality of life for their citizens, boost the local economy, improve transport, and traffic management, enhance the environment, and enable better interaction with government [30]. By using state-of-the-art technologies, the smart city concept aims to meet ecological standards, save resources, and achieve expected results [31].

Similarly, the concept of the smart campus has gained significant attention in recent years. A smart campus is defined as an entity that uses technology and infrastructure to support and improve its processes so people can use them better [34]. The smart campus concept is divided into three main categories: smart building, scope, and technology [35]. It represents a high level of digital campus and aims to improve efficiency, sustainability, safety, and student satisfaction. Smart campus technology includes intelligent energy management, lighting control, building automation, smart parking, and enhanced security, among others [36]. Both the smart city and smart campus concepts share the goal of improving the quality of life, ensuring efficient management of *resources*, and enhancing sustainability. Buildings are a major source of greenhouse gas emissions [15], and the smart city and smart campus concepts provide an opportunity to address this issue by using technology to increase energy efficiency, reduce carbon emissions, and minimize waste. By integrating sustainability and technology, both concepts aim to create smarter, more resilient communities for the future.

Table 4: Smart City and Smart Campus

	Smart City and Smart Campus
Definitions	A smart city can be understood as a community in which citizens, business firms, knowledge institutions, and municipal agencies collaborate with one another to achieve systems integration and efficiency, citizen engagement, and a continually improving quality of life. [33]
	Smart cities employ information and communication technologies to improve the quality of life for its citizens, the local economy, transport, traffic management, environment, and interaction with government. [30]
	The goal of the smart city concept is modern urban management using technical tools that offer state-of-the-art technologies, considering the applicable ecological standards while saving resources and achieving the expected results. [31]
	Smart campus is an entity of any kind that uses technology and infrastructure to support and improve its processes so people can use them better. [34]
	Tree main categories have been identified as defining the smart campus concept and these are smart building, scope, and technology. [35]
	Smart Campus is the high level of digital campus. [36]

2.2.5 University Campus as a Micro-Scale City

A university campus can be thought of as a micro-scale city because it shares many of the characteristics of a larger urban environment. [37] Universities are complex organizations that contain a diverse mix of people, buildings, facilities, and services. The campus serves as a place where students, faculty, staff, and visitors come together to work, learn, live, and socialize. Like a city, a university campus has its own infrastructure and governance systems. It includes housing, transportation, dining, recreation, and healthcare facilities, among others. Campus facilities range from classrooms, libraries, and laboratories to sports facilities, theaters, and art galleries. The campus is also a hub of social and cultural activities, with student organizations, clubs, and events playing a central role in campus life. [38]

Like a city, a university campus has its own unique identity and sense of community. Campus traditions, symbols, and events create a shared culture that brings people together and fosters a sense of belonging. The campus environment is a microcosm of the wider urban environment, with similar challenges and opportunities. For example, sustainability is an important issue for both cities and university campuses. Campuses can serve as testbeds for sustainable technologies and practices, such as energy-efficient buildings, renewable energy, and waste reduction. Moreover, the campus can serve as a living laboratory for interdisciplinary research and education, addressing sustainability issues that affect both the campus and the surrounding community.

In conclusion, the university campus is a micro-scale city that provides a unique and vibrant environment for learning, research, and socialization. It shares many of the characteristics of larger urban environments, including infrastructure, governance, and a

sense of community. The campus also presents a valuable opportunity to address pressing urban issues, such as sustainability, in a controlled and innovative environment.

2.2.6 Smart Campus Adaptability to Climate Change

Smart campuses have the potential to adapt to climate change and its impacts, such as extreme weather events, sea-level rise, and temperature changes. By utilizing sensors, data analytics, and real-time monitoring, campuses can identify vulnerabilities and prioritize actions to increase resilience. Smart campuses can take measures to reduce energy consumption and carbon emissions, such as implementing renewable energy sources, optimizing building performance, and reducing water waste. They can also integrate green infrastructure, such as permeable pavement, green roofs, and bioswales, to manage stormwater and reduce the urban heat island effect. [39]

In addition to mitigating climate change impacts, smart campuses can also facilitate climate adaptation. They can improve emergency response and preparedness, such as by using sensors to monitor flood-prone areas or extreme weather conditions. Smart campuses can also provide real-time information to students, staff, and visitors on weather conditions and hazards, allowing them to adjust their activities and plans accordingly. [40]

Smart campus adaptability to climate change requires a collaborative effort between various actors, such as university administrations, researchers, students, and community partners. [41] This collaboration can result in innovative and effective solutions to address climate change and its impacts. By implementing smart technologies and taking a proactive approach to climate adaptation, campuses can create a sustainable and resilient environment for all its members.

2.3 BIM, Digital Twins and Smart Technologies

The construction industry has seen a major transformation with the introduction of Building Information Modeling (BIM), digital twins, and smart technologies. These cutting-edge technologies have revolutionized the way construction projects are designed, built, and managed, offering significant benefits in terms of efficiency, cost savings, and sustainability. BIM provides a collaborative platform for architects, engineers, and contractors to work together on a project by using digital models. [42] Digital twins are digital replicas of physical assets, providing real-time data and analytics to optimize performance and reduce maintenance costs. [43] Smart technologies such as the Internet of Things (IoT) and artificial intelligence (AI) are also being integrated into construction projects, providing real-time data on building performance, energy consumption, and resource utilization. [44] The integration of these technologies has the potential to transform the construction industry, offering significant benefits in terms of efficiency, cost savings, and sustainability, and creating a more sustainable and resilient built environment for current and future generations.

However, there is a lack of studies on the integration of resilience in architectural and urban projects. There is a pressing need for a mechanism that includes resilience as part of design decision-making processes to ensure that construction projects can withstand and recover from disturbances or shocks. BIM and digital twins can be used for building performance analysis and various assessments, such as energy consumption, indoor environmental quality, and water efficiency, providing a comprehensive view of a building's sustainability and resilience. [6]. Additionally, simulation techniques on digital twins can help predict building performance and identify potential risks, enabling

decision-makers to make informed choices that promote sustainability and resilience. [45] Therefore, integrating resilience into the design process through BIM, digital twins, and smart technologies can lead to a more sustainable and resilient built environment for current and future generations.

2.3.1 Introduction to BIM and CIM

Building Information Modeling (BIM) is an innovative approach to design, construction, and facility management that has revolutionized the architecture, engineering, and construction (AEC) industry. BIM involves creating a digital representation of the building process to facilitate the exchange and interoperability of information in digital format. [42] This digital model can encompass all aspects, disciplines, and systems of a facility, allowing all design team members to collaborate more accurately and efficiently than using traditional processes. [46] BIM provides a virtual process that allows stakeholders to share data, traceability, and the integrated management of the building or infrastructure life-cycle through a 3D informative virtual model. [47]

In recent years, the concept of BIM has expanded beyond individual buildings to include entire cities through the use of City Information Modeling (CIM). CIM, also known as Urban Information Modeling or Digital Urban Twin, produces a digital 3D model of a city that includes different types of information, such as geographic information system (GIS) data. [48] This information can be used for urban purposes that go beyond BIM, providing a comprehensive view of a city's infrastructure, transportation systems, utilities, and more. The use of CIM can improve urban planning and management, creating more sustainable and livable cities for future generations.

BIM and CIM are powerful tools that can help the AEC industry create better-designed, more sustainable, and resilient buildings and cities. By facilitating collaboration, data sharing, and traceability, these technologies can help make informed decisions that promote sustainability and resilience throughout the entire life-cycle of a building or city.

Table 5: Building Information Modeling (BIM)

	Building Information Modeling (BIM)
Definitions	Building Information Modeling (BIM) is a new approach to design, construction, and facility management in which a digital representation of the building process is used to facilitate the exchange and interoperability of information in digital format. [42]
	BIM can be viewed as a virtual process that encompasses all aspects, disciplines, and systems of a facility within a single, virtual model, allowing all design team members (owners, architects, engineers, contractors, subcontractors, and suppliers) to collaborate more accurately and efficiently than using traditional processes. [46]
	Building information modeling approach allows for data sharing among stakeholders, traceability, and the integrated management of the building or infrastructure life-cycle through a 3D informative virtual model. [47]

Table 6: City Information Modeling (CIM)

	City Information Modeling (CIM)
Definitions	City Information Modeling (CIM), also called Urban Information Modeling or Digital Urban Twin, can be used for urban purposes that go beyond BIM, by producing a digital 3D model of a city including different types of information such as geographic information system (GIS) data. [48]
	CIM was initially accepted as a form of BIM technology specifically applied to cities, later the CIM concept is extended to an intelligent city model. For this concept, the Internet of Things (IoT), BIM, and GIS are the primary technical support of CIM for collecting, storing, and processing large data. Advanced technology, such as cloud computing, big data, virtual reality (VR), and artificial intelligence (AI), has gradually been used for CIM to build smart cities. [49]
	CIMs are often cloud-based geospatial services and data repositories with one-way data connections, which differ from integrated and high-fidelity cyber-physical complex systems for digital twins (DTs). [50]

2.3.2 Introduction to Digital Twins

The concept of a digital twin is transforming the way we design and manage complex systems, such as buildings, infrastructure, and entire cities. A digital twin is a virtual representation of a physical object or process that can collect information from the real

environment to represent, validate, and simulate the physical twin's present and future behavior. [51] Digital twins are characterized by the seamless integration between the cyber and physical spaces, providing a comprehensive view of a system's performance and behavior. [43]

Digital twins are created using Building Information Modeling (BIM) software, which allows for the seamless integration of various types of data, including geographic information system (GIS) data, sensor data, and more. [52] This integration allows for a more accurate representation of a system's behavior and performance, enabling stakeholders to make informed decisions that promote sustainability, efficiency, and resilience.

Digital twins hold significant potential and find applications across various industries, including architecture, engineering, construction, and smart city management. Their capabilities offer valuable opportunities for enhancing efficiency, productivity, and decision-making processes. By providing real-time data on building performance, energy consumption, and resource utilization, digital twins can help identifying areas for improvement and optimize systems for greater efficiency. [53] Simulation techniques on digital twins can help predict performance and identify potential risks, enabling informed choices that promote sustainability and resilience. [54]

Digital twins are important for the advancement of smart cities, facilitating the management and optimization of intricate urban systems. Through their virtual representation of a city's physical infrastructure, digital twins enable real-time data management using technologies like the Internet of Things (IoT). By providing a virtual representation of a city's physical infrastructure, digital twins enable real-time data

management through the Internet of Things (IoT) and other technologies. This real-time data collection and analysis can help city officials and other stakeholders make informed decisions about how to manage and optimize city systems for greater efficiency, sustainability, and resilience. [54]

For example, a digital twin of a smart city's transportation system could collect and analyze data on traffic flow, public transit ridership, and other factors to identify areas for improvement and optimize the overall system for greater efficiency. [55] Similarly, a digital twin of a smart city's energy grid could provide real-time data on energy consumption and production, allowing city officials to identify areas where energy efficiency improvements could be made. [56]. Digital twins can also play an important role in emergency response and disaster management. By providing real-time data on the location and status of key infrastructure assets, such as power grids, water systems, and transportation networks, digital twins can help emergency responders and city officials quickly identify and respond to crises. [1]

Table 7: Digital Twins

	Digital Twins
Definitions	A digital twin is a virtual representation of a physical object or process capable of collecting information from the real environment to represent, validate and simulate the physical twin's present and future behavior. [51]
	Digital twins are characterized by the seamless integration between the cyber and physical spaces. [43]
	Digital twins are digital representations of real-world infrastructure using Building Information Modeling software. [52]

2.3.3 Information Modeling and Digital Twins for Climate-Adaptive Design

Buildings are major sources of greenhouse gas (GHG) emissions and contributors to climate change and global warming. [15]

As the climate change effects become increasingly visible, there is a growing need for building and infrastructure design to incorporate climate-adaptive features. Building Information Modeling (BIM), City Information Modeling (CIM), and digital twins are powerful tools that can be used to create more climate-adaptive designs for buildings and cities. [50], [54]

BIM can be used to simulate and analyze a building's energy performance, allowing designers to identify areas for improvement and optimize the building's design for greater energy efficiency. [46] CIM can be used to create a digital twin of a city, which can be used to simulate and analyze the city's performance under different climate

scenarios. [50] Using digital twins, designers and planners can simulate the behavior of buildings or infrastructure assets under different climate scenarios, helping to identify potential areas of vulnerability and develop strategies to improve resilience. [45] For example, simulations can help identify areas of a building that are prone to overheating or flooding and suggest design modifications to mitigate those risks. Similarly, simulations of a city's infrastructure can help identify critical systems that are most at risk during extreme weather events and identify opportunities to improve those systems. [40] By giving a more complete picture of a building or city's response to different climate scenarios, digital twins can help make more informed decisions and create more resilient and sustainable built environments.

CHAPTER III

METHODOLOGY

Cities worldwide are facing a growing number of disasters triggered by the impacts of global climate change. [5] In this context, university campuses have emerged as socio-ecological systems that hold great potential as urban prototypes for testing self-sufficiency and resilience within their physical contexts. However, while current studies often focus on identifying and demonstrating smart city indicators on university campuses, they frequently lack resilient planning and design strategies. Therefore, the first part of the thesis focuses on creating a sustainable e resilient smart campus index which integrates both resilience and smart city indicators to guide the development of disaster-resilient university campuses.

The proposed research methodology involves a comprehensive and systematic approach to investigate climate change and resilience in architectural and urban planning strategies for disaster management in university campuses. The methodology encompasses a range of key steps, including a literature review, case study analysis, interviews, simulation, and modeling tools to evaluate the effectiveness of existing campus masterplan design guidelines and strategies for disaster resilience.

The initial step of the research methodology is a comprehensive literature review, which serves to identify the existing problem related to climate change and resilience in architectural and urban planning strategies for disaster management on university campuses. This review encompasses a thorough examination of relevant literature on

climate change, resilience, sustainability, disaster management, and architectural and urban planning strategies specific to university campuses.

Subsequently, a case study analysis is conducted to explore the Özyeğin University campus and its surrounding urban context. The primary objective of this analysis is to identify potential extreme drought and precipitation risks. To achieve this, data gathering techniques such as site visits, interviews, and document reviews are employed to gain comprehensive insights into the campus's specific vulnerabilities.

To assess the effectiveness of existing campus masterplan design guidelines and strategies for disaster resilience, simulation and modeling tools are utilized. The research methodology leverages a suite of powerful tools to support the analysis and evaluation process. These tools encompass cutting-edge capabilities such as 3D modeling with integrated Geographic Information System (GIS) data for climate analysis, digital twinning, and computer simulations facilitated by Grasshopper [10]. In this regard, a Digital Twin of the Özyeğin University Çekmeköy Campus is generated using Rhinoceros 3D software [9], while the surrounding topography is obtained through GIS. A simulation algorithm is then developed in Grasshopper to conduct a water flow analysis of the Çekmeköy Campus and its surroundings. The created digital twin incorporates relevant data on different surfaces, roof types, water-permeability characteristics, and streams within the topography, all of which can impact water retention and mitigate potential climate-related disasters.

Given the location of the Çekmeköy Campus in Istanbul, climate change reports have identified extreme drought and precipitation events as significant risks in the coming years. [5] Therefore, the analysis for this research methodology places particular

emphasis on indicators related to water management, initiating with a water flow simulation analysis. This methodological approach leverages technological tools to evaluate the efficacy of existing or proposed university campuses in mitigating potential climate change-related disasters. The focus on water conservation indicators within the sustainable and resilient smart campus index serves as a foundation for developing a broader methodology to analyze additional indicators present in the index.

By employing a combination of qualitative and quantitative research methods, such as literature review, interviews, case study analysis, digital twinning, and simulations, this research methodology aims to offer practical recommendations for designing and adopting disaster-resilient smart university buildings and campuses within the context of climate change and urban sustainability. Leveraging the power of modeling and simulation tools, this research has the potential to transform decision-making approaches to climate-adaptive smart campus design, thereby fostering a more sustainable and resilient future for universities and the communities they serve.

3.1 Interviews with Sustainability Platform and HSE Department

The interviews conducted with the HSE department and the Sustainability Platform of Özyeğin University proved to be important in conducting a comprehensive and thorough research on the environmental and security policies of the university. Through these interviews, a deeper understanding of the university's approach to sustainability and resilience was gained, providing key insights into the criteria that contribute to a sustainable and resilient campus.

During the first stage of the interviews, the focus was on gathering information about the university's sustainability and safe living policies, as well as its water

management plan. The officials from the HSE department and the Sustainability Platform provided valuable insights into the various initiatives and measures taken by the university to promote sustainability and ensure the well-being of its community members. Questions were posed regarding waste management practices, energy conservation efforts, green infrastructure development, and strategies for mitigating environmental risks. Based on the recommendations and insights provided by the officials, the research was able to identify specific areas that required more attention and exploration. These areas included the implementation of renewable energy sources, the integration of sustainable transportation options, the promotion of eco-friendly practices in campus operations, and the enhancement of biodiversity conservation efforts. The focus of the research was thus refined to delve deeper into these key aspects, aiming to identify best practices and develop recommendations for further improvement.

During the second stage of the interviews, the findings from the initial research were discussed in detail. The officials provided their perspectives, insights, and suggestions based on the preliminary findings. This interactive discussion allowed for a comprehensive examination of the identified topics, enabling a deeper understanding of the challenges, opportunities, and potential solutions related to the university's environmental and security policies.

The engagement with the HSE department and the Sustainability Platform of Özyeğin University not only facilitated the collection of valuable information but also fostered a collaborative and participatory approach to research. The insights and recommendations provided by the officials served as a guiding framework for the research, helping to shape the research objectives and criteria. The interviews played a

pivotal role in ensuring that the research aligned with the university's goals and aspirations in terms of sustainability, environmental protection, and healthy living.

Overall, the interviews conducted with the HSE department and the Sustainability Platform of Özyeğin University enriched the research process and contributed significantly to the development of a comprehensive understanding of the university's environmental and security policies. The findings from these interviews, combined with other research methods, will inform the final outcomes of the research, including recommendations for enhancing sustainability practices and resilience in the university's operations and campus environment.

3.2 Developing a Sustainable and Resilient Campus Design Index

Sustainability and resilience are interrelated concepts that encompass a range of key features necessary for promoting a more sustainable and resilient future. Key sustainability features include renewable and efficient energy, water conservation, sustainable land use, green buildings, indoor environmental quality, access to transportation, and waste management. [57] These elements work together to promote ecological balance, protect natural resources and ecosystems, and enhance the well-being of individuals and communities. The Leadership in Energy and Environmental Design (LEED) certification system is an internationally recognized rating system that provides a framework for designing, constructing, and operating green buildings, and promotes sustainable building practices. [58] While green building certification programs such as LEED, do reduce the environmental footprint of the buildings, they must also be designed for resilience to withstand external stressors that may arise over the buildings' lifetime for it to be truly sustainable. [59]

Therefore, in addition to the key features of sustainability, such as renewable and efficient energy, water conservation, sustainable land use, green buildings, indoor environmental quality, access to transportation, and waste management, there are also key features of resilience that are essential for addressing the challenges posed by climate change. These include disaster preparedness, emergency management, continuity planning, risk assessment, infrastructure resilience, community engagement, and adaptive design.

The key features of resilience are closely connected to the key features of sustainability. For example, disaster preparedness and emergency management are essential for protecting natural resources and ecosystems, as well as ensuring the well-being of individuals and communities. Continuity planning ensures that essential services, such as energy, water, and transportation, continue to function during and after a crisis, promoting sustainability and resilience. Risk assessment is critical for identifying potential hazards and developing strategies to mitigate negative impacts, promoting sustainable outcomes. Infrastructure resilience, community engagement, and adaptive design all work together to promote ecological balance, protect natural resources and ecosystems, and enhance the well-being of individuals and communities.

Sustainability and resilience are interdependent concepts that require a holistic approach to achieve. By incorporating both the key features of sustainability and resilience into decision-making processes, the goal of creating a future that is equitable, safe, and sustainable for all can be achieved.

Table 8: Sustainability Features

	Sustainability
Features	Renewable and Efficient Energy: [60]
	This feature is crucial to reduce the carbon footprint of the campus and increase energy security, while supporting a sustainable and resilient campus design.
	Water Conservation: [60]
	Water is a limited and precious resource, and conserving it is essential for the sustainability and resilience of the campus, especially in areas prone to water scarcity or drought.
	Sustainable Land Use: [60]
	Proper management of land and natural resources is crucial for the sustainability and resilience of the campus, and for mitigating the impact of climate change.
	Green Buildings: [60]
	Buildings with green design features, such as energy efficiency, natural lighting, and sustainable materials, play a significant role in reducing the environmental impact of the campus while providing a healthier indoor environment for its occupants.
	Indoor Environmental Quality: [60]
	A healthy and comfortable indoor environment is important for the well-being and productivity of the campus community and is a key factor in the resilience of the campus during extreme weather events or other hazards.
	Access to Transportation: [60]
	A sustainable and resilient campus design requires an efficient and sustainable transportation system that reduces reliance on personal vehicles and encourages low-carbon transportation options.
	Waste Management: [60]
	Proper management of waste is essential for the sustainability and resilience of the campus, and for reducing its environmental impact.

Table 9: Resilience Features

	Resilience
Features	Disaster Preparedness: [61]
	Being prepared for natural or man-made disasters is essential for the safety and well-being of the campus community, and for the continuity of operations.
	Emergency Management: [62]
	In the event of a disaster, effective emergency management procedures and protocols are necessary to ensure a timely and coordinated response, minimizing the impact on the campus community and the environment.
	Continuity Planning: [61]
	A resilient campus design requires comprehensive continuity planning, ensuring that essential functions and operations can continue in the event of a disruption.
	Risk Assessment: [63]
	Conducting risk assessments is essential for identifying potential hazards and vulnerabilities, enabling the campus to develop appropriate risk management strategies and improve its resilience.
	Infrastructure Resilience: [64]
	The resilience of campus infrastructure is essential for the continuity of essential campus functions and operations, reducing the impact of disruptions on the campus community and the environment.
	Community Engagement: [61]
	A Engaging with the community and stakeholders is essential for developing a resilient and sustainable campus design, ensuring that their needs and concerns are addressed, and building a sense of ownership and commitment to sustainability.
	Adaptive Design: [64]
	A resilient and sustainable campus design must be flexible and adaptable to changing environmental and social conditions, ensuring that it can continue to meet the needs of the campus community and the environment in the long term.

3.3 Simulation

During the literature review, it became evident that our country is expected to experience more pronounced impacts of global warming in the next decade. Consequently, it is crucial to address the root causes of global warming and prepare for potential adverse effects of climate change. To assess the sustainability and resilience of university campuses in the face of climate change, the development of a sustainable and resilient smart campus index, based on the findings of the literature review, will play a significant role.

Technological advancements, particularly in urban planning and architecture, offer valuable tools for enhancing the structural sustainability and resilience of university campuses. Building Information Modeling (BIM) and City Information Modeling (CIM) present promising opportunities in this regard. At the building scale, BIM enables the integration of data related to building components, MEP systems, and construction processes, facilitating comprehensive analysis. This supports the renovation of existing buildings and the design of new ones, aiming to minimize environmental impact and maximize performance throughout their lifecycle.

CIM allows for the incorporation of physical land data and location-specific climate information into the model, enabling the simulation of weather phenomena's impact on the entire complex at the city or campus level. CIM models can calculate parameters such as airflow, air quality, water movement based on terrain characteristics, areas prone to water accumulation due to precipitation, shadowing effects, surface temperatures influenced by structures, energy consumption associated with materials, and temperature variations based on different building materials.

By conducting these calculations within CIM models, a comprehensive understanding of the complex's response to weather events can be achieved, encompassing the entire city or campus. This simulation-driven approach facilitates informed decision-making in urban and campus planning, ultimately enhancing the resilience and sustainability of the built environment in the face of climate change.

In addition to BIM and CIM models, the integration of digital twins further enhances the capabilities of these methods in enhancing the sustainability and resilience of university campuses. Digital twins are virtual replicas of physical assets or systems that enable real-time monitoring, analysis, and simulation.

By integrating digital twins with BIM and CIM methods, a more dynamic and accurate representation of the built environment can be achieved. Real-time data from sensors embedded in buildings and urban infrastructure can be fed into the digital twin, providing up-to-date information on energy consumption, occupancy patterns, environmental conditions, and other relevant parameters. This data can be used to perform predictive simulations, allowing for proactive decision-making and optimization of resource utilization. For example, a digital twin integrated with a BIM model can simulate and analyze the energy performance of a building based on real-time data, identifying areas of inefficiency, and suggesting energy-saving strategies. Similarly, a digital twin integrated with a CIM model can simulate and analyze traffic patterns in a city, optimizing transportation networks, reducing congestion, and improving overall mobility.

The integration of digital twins with BIM and CIM methods offers a comprehensive approach to sustainability and resilience. It enables continuous monitoring and analysis of the built environment, leading to improved efficiency, reduced

environmental impact, and enhanced user experience. This integration also supports long-term planning and management, allowing for adaptive strategies in response to changing environmental conditions. BIM and CIM simulations provide valuable tools for assessing sustainability and resilience in building and urban contexts. These simulations contribute to strategies that minimize environmental impact, optimize resource utilization, and enhance adaptability to climate change challenges.

3.3.1. Case Study

The creation of a case study is essential for testing the sustainable and resilient campus index as it allows for a comprehensive examination of the distinctive features and challenges of university campuses, akin to micro-scale cities. Recognizing the parallels between a campus and a larger urban environment enables researchers to explore how the index can be adapted and applied to meet the unique needs and complexities of campus settings. By taking a holistic view of the campus, encompassing its diverse infrastructure, governance systems, and services, a case study enables the identification of opportunities and obstacles for implementing sustainable and resilient practices. Moreover, the campus environment cultivates a sense of community and shared identity, making it an ideal setting to test and promote sustainable behaviors and initiatives. By delving into campus traditions, symbols, and events, researchers gain insights into integrating sustainability and resilience into the fabric of campus life. Furthermore, universities have the potential to serve as testbeds for sustainable technologies and practices, with the campus functioning as a living laboratory for interdisciplinary research and education. Through conducting a case study, researchers can assess the effectiveness and feasibility of implementing sustainable solutions within the campus environment, while considering their broader impact on the surrounding community. In conclusion, a case study approach

is crucial for testing the sustainable and resilient campus index as it recognizes the micro-scale city-like nature of university campuses. By comprehensively examining the campus as a whole and considering its distinct identity, infrastructure, and governance, researchers can tailor and refine the index to address the specific challenges and opportunities within the campus environment. This approach ensures that the index is practical, effective, and relevant in promoting sustainability and resilience in university campuses and beyond.

3.4 Macro Scale

3.4.1 Çekmeköy District

Çekmeköy, situated on the Asian side of Istanbul, holds a unique place within the city's geography. As a district with a rich history and natural beauty, it offers a refreshing escape from the bustling city life. Çekmeköy became an official district in 2009, encompassing the neighborhoods of Alemdağ, Taşdelen, and Ömerli, along with 17 other neighborhoods and 4 villages. With an area of 148.08 square kilometers and a population of 264,508, Çekmeköy is bordered by Beykoz, Şile, Ümraniye, and Sancaktepe. Çekmeköy is known for its lush forests, which contribute to the city's oxygen supply. The forests are teeming with diverse flora and fauna, offering a haven for plants, birds, insects, and other living creatures. The Bents and Alemdağı areas are particularly renowned for their pine trees, creating a picturesque landscape.

Throughout history, Çekmeköy has played a significant role in providing resources to Istanbul. During the Byzantine era, the region was covered in forests, and hunting grounds and monasteries were established. In the Ottoman period, the district supplied wood and coal to the city, while also serving as a hub for agriculture and animal

husbandry. One of the most remarkable features of Çekmeköy is the presence of the Ömerli basin, which is home to some of Istanbul's best spring waters. The basin boasts a diverse range of natural habitats, including oak forests, meadows, wetlands, and peatlands, supporting a wide variety of plant and animal species. Notably, the Ömerli basin hosts the largest juniper groves in Eastern Mediterranean and Eastern European countries, making it a rare and unique habitat. Geographically, Çekmeköy is located on the southwestern slopes of Keçiğalı Hill, within the Alemdağ forests. With an elevation of 100 meters above sea level, the district enjoys a mild climate due to its transitional location between the Mediterranean and Black Sea climates. Summers are hot and dry, while winters are mild and rainy. Çekmeköy, with its rich natural heritage, offers a serene living environment. Whether exploring the forests, enjoying the fresh spring waters, or appreciating the diverse wildlife, residents and visitors alike can experience the harmonious blend of nature and urban living that Çekmeköy has to offer. [65]

3.4.2 Nişantepe Neighborhood

Nişantepe Neighborhood, situated in the Alemdağ (Alemdar) district of Istanbul, Turkey, is a vibrant residential area that forms part of the Çekmeköy district. With its convenient location, the neighborhood can be found at approximately 41° 2' 37.1580" North and 29° 15' 59.3748" East GPS coordinates. It is just 8 kilometers away from the Çekmeköy district center, offering residents easy access to a range of amenities and services. Additionally, Nişantepe is approximately 24 kilometers away from Istanbul's bustling city center, providing a peaceful and suburban living environment while still being well-connected to the vibrant city life. In the heart of this thriving neighborhood is Özyeğin University, located at Orman Sk. No:13, 34794 Çekmeköy/İstanbul, Türkiye. The university's central location within Nişantepe allows students, faculty, and staff to enjoy

the serene surroundings and convenient amenities offered by the neighborhood. With its commitment to fostering a collaborative and engaging academic environment, Özyeğin University embraces its integration into the fabric of Nişantepe. The university's address at Orman Sk. No:13 reflects its dedication to providing students with easy access to educational facilities, cultural activities, and various resources within the vibrant community of Çekmeköy, Istanbul. [65]

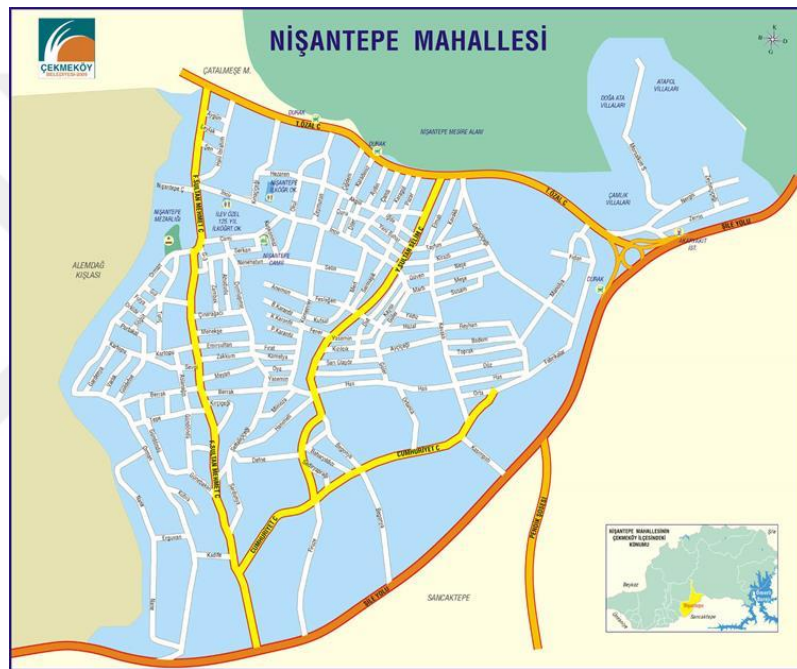


Figure 5: Çekmeköy District, Nişantepe Neighborhood Map [65]

3.4.3 Urban Development Through 1970-2022 in Çekmeköy and Nişantepe

For this thesis research, maps and satellite images created by the Istanbul Metropolitan Municipality (İBB) were examined to understand how the urbanization and geography of Özyeğin University campus surroundings have changed from its establishment year in 2007 to 2022. Satellite images are available from 1970 onwards, with images taken in 1970, 1982, 2006, 2011, 2013, 2014, 2015, 2017, 2018, 2020, 2021, and 2022. By comparing the satellite images, we can observe the functional development process of the

Ömerli Dam, which was completed in 1972. [66] From 1970 to 2006, we can also observe the development of the D016 road, which is the Şile Highway. In the 2006 map, the D020 road connecting Paşaköy to Nişantepe is visible, indicating this development. When examining the satellite images of 2015, we can see the construction works of the Northern Marmara Highway. The highway construction began in 2013 and was opened in 2020. [67] Between 2018 and 2021, residential projects were constructed in the eastern area adjacent to Özyeğin University. Furthermore, between 2018 and 2020, we can observe the deforestation of the wooded area on the hill west of Özyeğin University.

Additionally, in the satellite views from 1970 to 2013, it is evident that construction works were carried out in Köy Stream, an extension of Alemdağ Stream, within the Özyeğin University campus surroundings. These construction activities have resulted in alterations to the natural pathway of the stream over the years. The construction of highways, especially, has had a significant impact on diverting the course of the streams. This observation further emphasizes the influence of infrastructure development on the waterways in the area. The examination of maps and satellite images as part of this thesis research highlights the progression of infrastructure projects, road networks, and residential developments over the years. By analyzing these visual records, a comprehensive understanding of the transformations and their consequences for the local environment are gained.



Figure 6: Satellite view of Çekmeköy, 1970 [68]



Figure 7: Satellite view of Çekmeköy, 1982 [68]

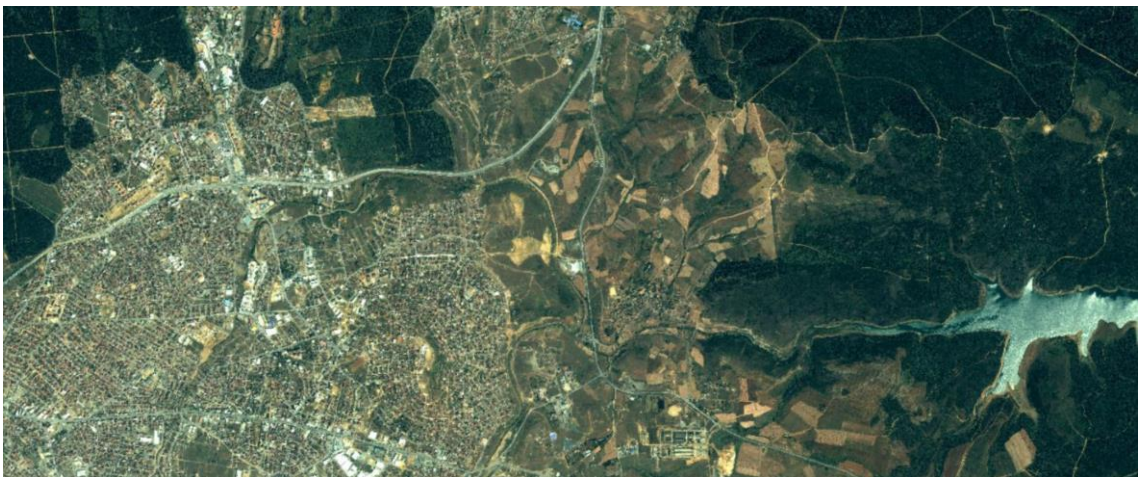


Figure 8: Satellite view of Çekmeköy, 2006 [68]



Figure 9: Satellite view of Çekmeköy, 2011 [68]



Figure 10: Satellite view of Çekmeköy, 2013 [68]



Figure 11: Satellite view of Çekmeköy, 2014 [68]

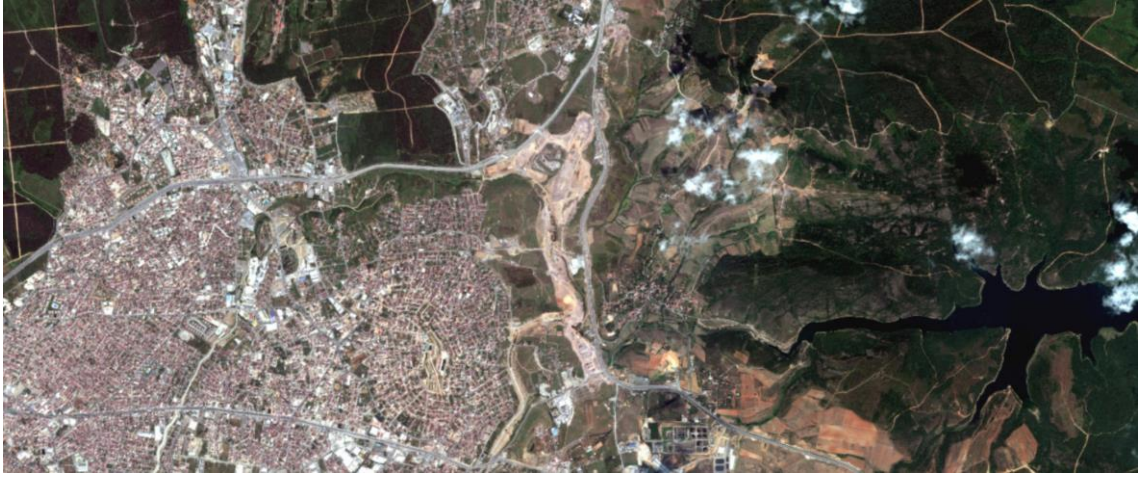


Figure 12: Satellite view of Çekmeköy, 2015 [68]



Figure 13: Satellite view of Çekmeköy, 2017 [68]

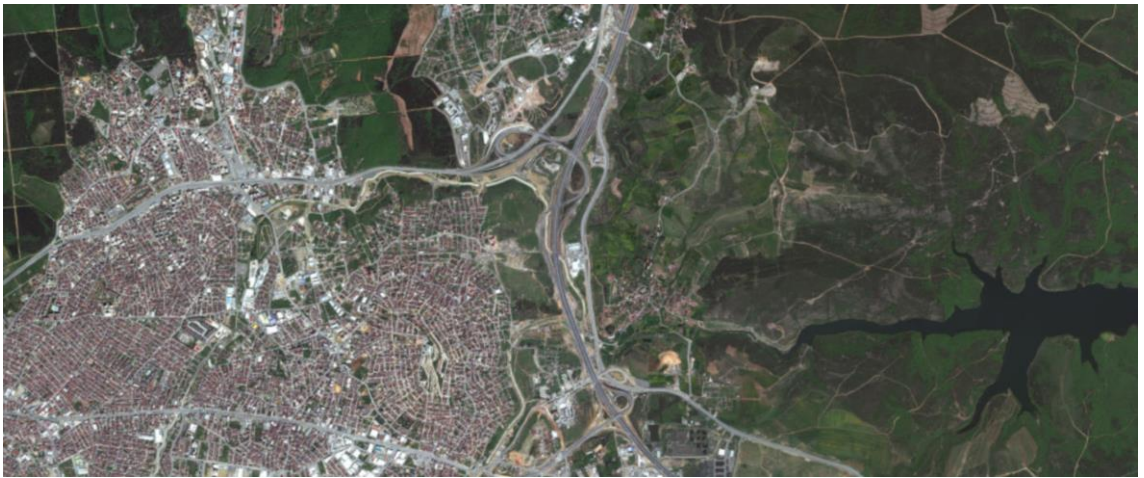


Figure 14: Satellite view of Çekmeköy, 2018 [68]



Figure 15: Satellite view of Çekmeköy, 2020 [68]



Figure 16: Satellite view of Çekmeköy, 2021 [68]



Figure 17: Satellite view of Çekmeköy, 2022 [68]



Figure 18: Satellite view of Nişantepe, 1970 [68]



Figure 19: Satellite view of Nişantepe, 1982 [68]



Figure 20: Satellite view of Nişantepe, 2006 [68]



Figure 21: Satellite view of Nişantepe, 2011 [68]



Figure 22: Satellite view of Nişantepe, 2013 [68]



Figure 23: Satellite view of Nişantepe, 2014 [68]



Figure 24: Satellite view of Nişantepe, 2015 [68]



Figure 25: Satellite view of Nişantepe, 2017 [68]



Figure 26: Satellite view of Nişantepe, 2018 [68]



Figure 27: Satellite view of Nişantepe, 2020 [68]



Figure 28: Satellite view of Nişantepe, 2021 [68]



Figure 29: Satellite view of Nişantepe, 2022 [68]

3.4.4 Basins and Treatment Facilities in Campus Surroundings

Özyeğin University's Çekmeköy Campus is crossed by the Köy Stream, which is an extension of the Alemdağ Stream. The topography of the area where Özyeğin University is located has a valley-like characteristic. By referring to the relief map published by Istanbul Metropolitan Municipality (IBB), it can be observed that the terrain slopes on both sides and the lowest point of the slope coincides with the stream [68]. According to interviews conducted with the HSE (Health, Safety, and Environment) and Sustainability Platform, it was mentioned that the water from this stream is directed by ISKI (Istanbul Water and Sewerage Administration) to the ISKI Paşaköy Wastewater Treatment Inlet Pumping Center in Paşaköy, where the water is treated and then transferred to the Ömerli Dam.

Özyeğin University's Çekmeköy Campus is located in close proximity to the Ömerli Dam. The Ömerli Dam is one of Istanbul's most important water reservoirs. It is situated on the Riva Stream, which is the largest basin opening to the Black Sea on the Anatolian side. Administratively, the basin is located within the boundaries of Istanbul and Kocaeli provinces. According to ISKI data, the maximum water surface area of the dam is 21,248,122 square meters, and the maximum water level is stated as 62.00 meters. The annual water yield is 220,000,000 cubic meters [66]. With these features, the Ömerli Dam holds great significance as one of Istanbul's main dams. As of May 11, 2023, the Ömerli Dam has the highest occupancy rate at 78.99% among all the dams in İstanbul. According to ISKI data from May 11, 2023, the Ömerli Dam accounts for 43.3% of the total water volume among the dams [66].

The presence of the Köy Stream within the Özyeğin University campus area and the proximity of the campus to the Ömerli Dam highlight the interconnectedness between water basins and treatment facilities in the area. The Köy Stream serves as a tributary to the larger Alemdağ Stream, and its water is directed to the Paşaköy Wastewater Treatment Inlet Pumping Center for treatment before being transferred to the Ömerli Dam. This integrated water management system ensures the sustainable utilization of water resources and contributes to the overall water supply for the region.

The Ömerli Dam, with its significant water storage capacity and strategic location, plays a crucial role in meeting the water needs of Istanbul. Its proximity to Özyeğin University's campus underscores the university's commitment to environmental sustainability and responsible water management. Özyeğin University was chosen as the case study for this study due to its proximity to the Ömerli Dam, the largest dam in Istanbul. The availability of such vital water infrastructure in the vicinity reinforces the campus's ability to operate in an environmentally conscious manner and promotes awareness among students, faculty, and staff about the importance of water conservation and preservation.

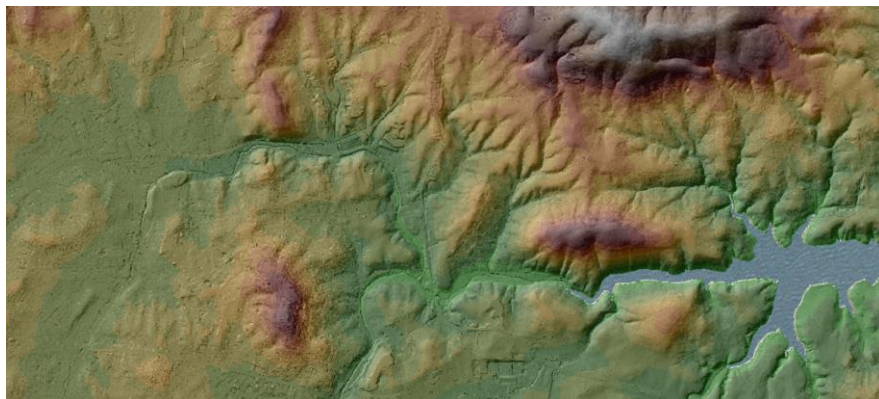


Figure 30: Çekmeköy Relief Map [68]

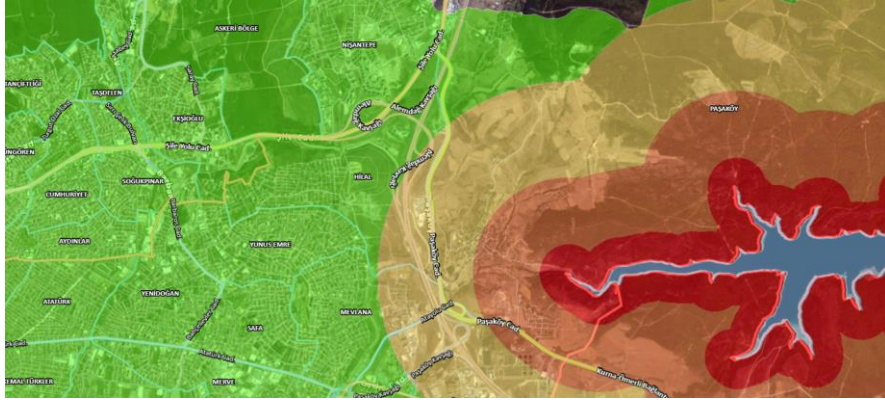


Figure 31: Çekmeköy Water Basin Map [68]

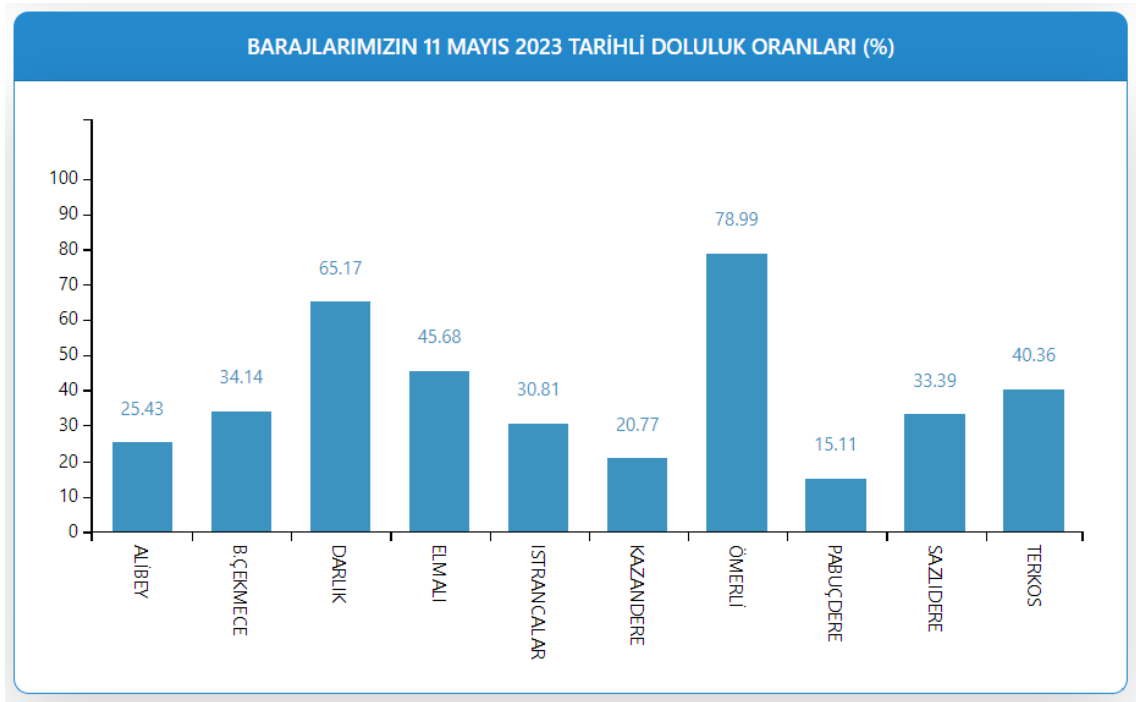


Figure 32: The fill rate (%) of our dams as of May 11, 2023 [66]

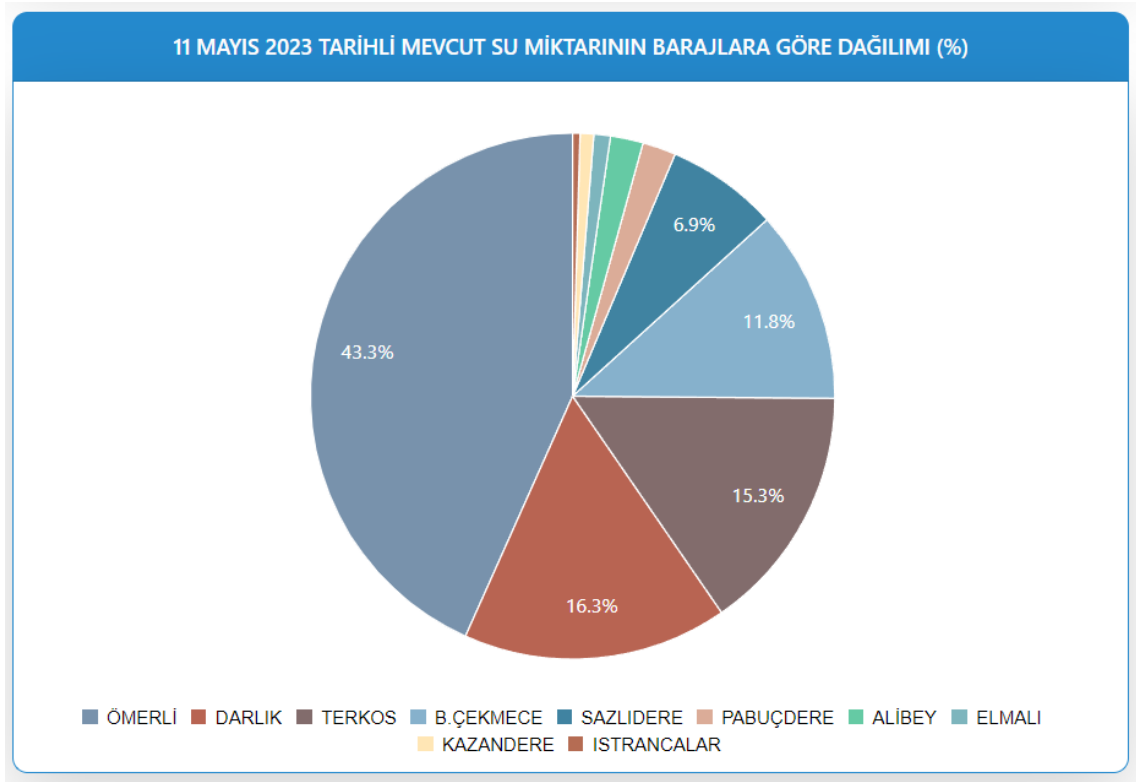


Figure 33: Distribution (%) of the current water quantity among the dams as of May 11, 2023 [66]

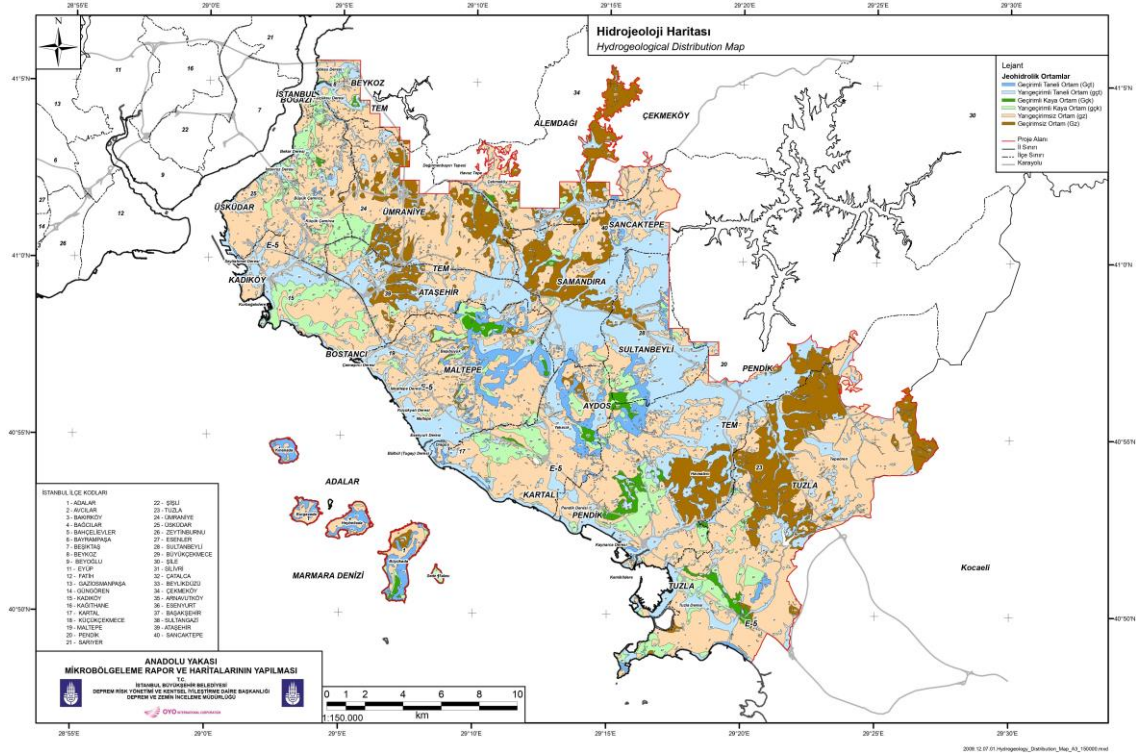


Figure 34: Istanbul Anatolia, Hydrogeological Distribution Map [68]

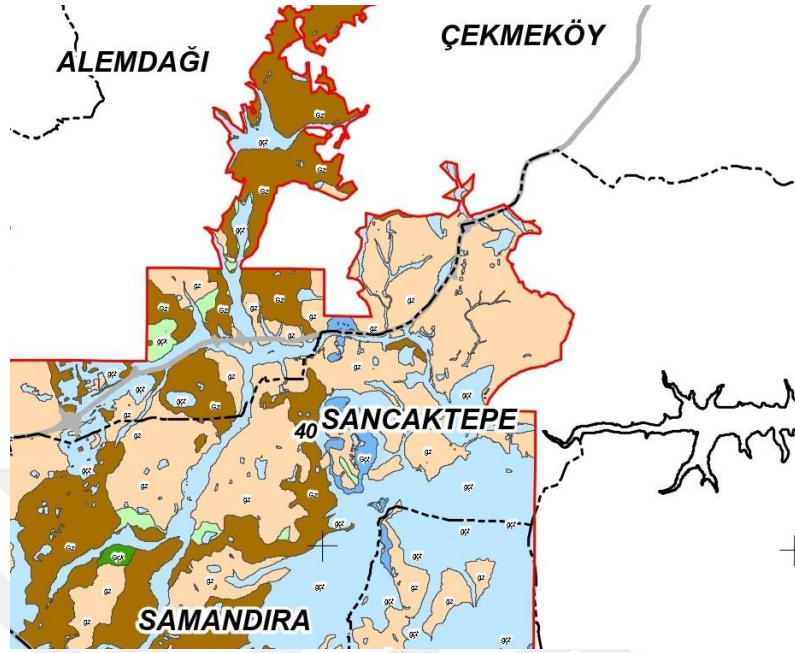


Figure 35: Istanbul Anatolia, Çekmeköy, Hydrogeological Distribution Map [68]

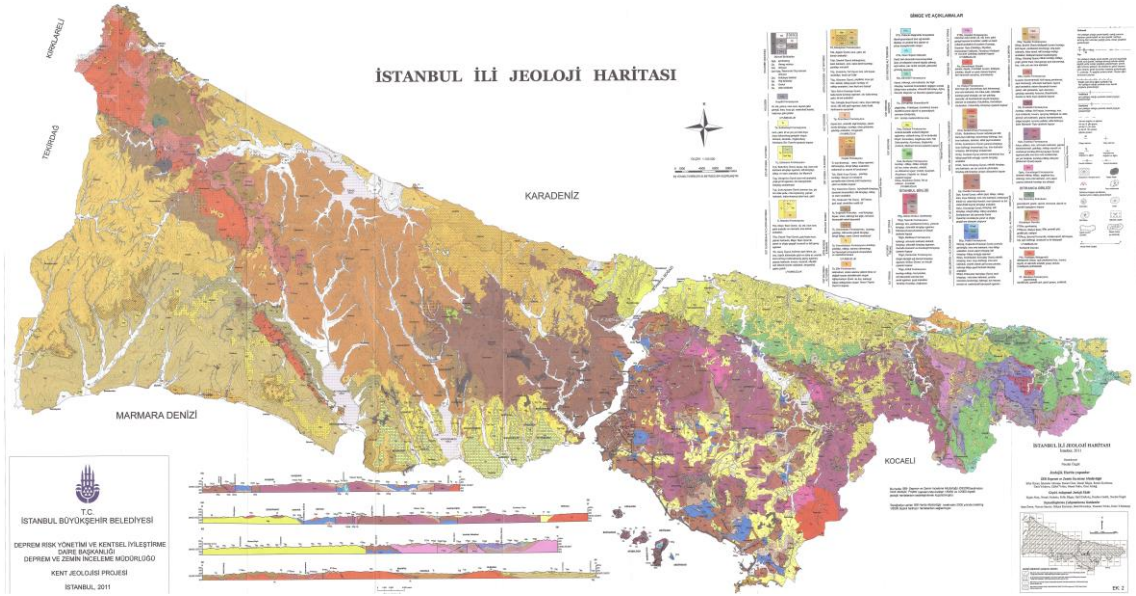


Figure 36: Istanbul geological map [68]

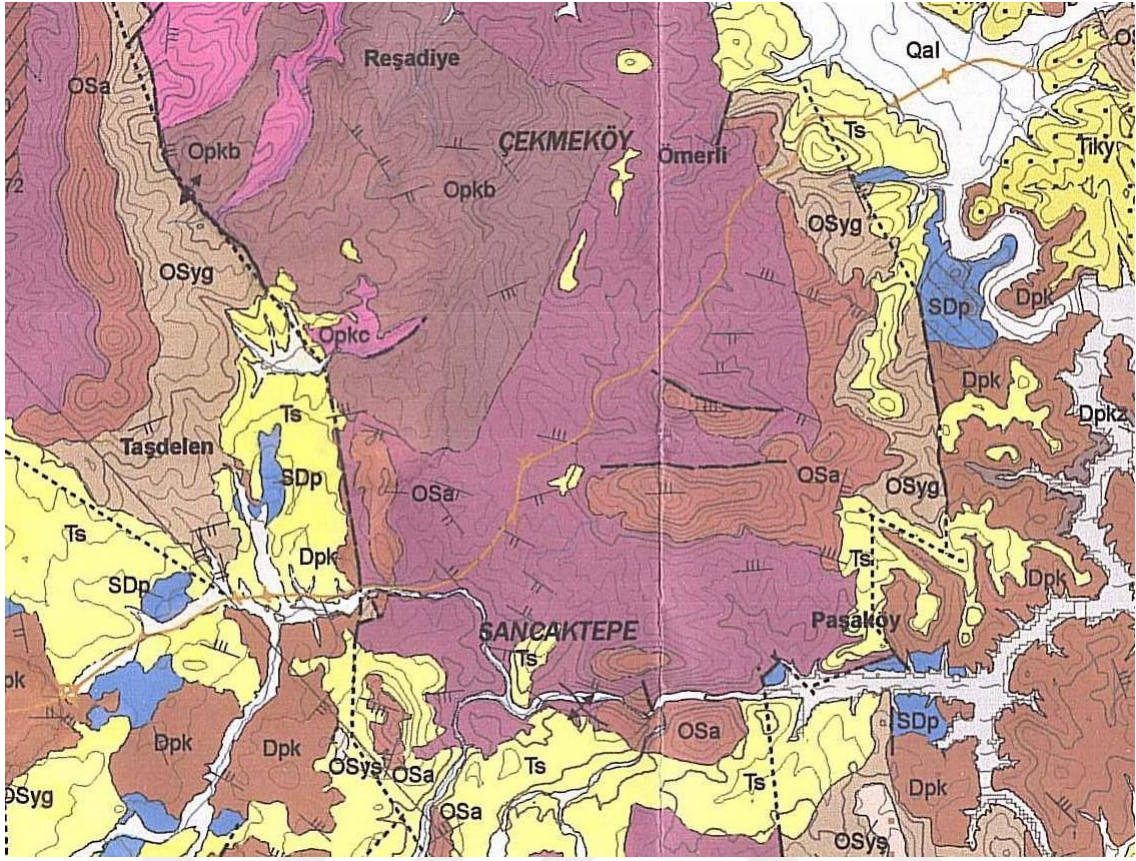


Figure 37: Istanbul geological map, Çekmeköy [68]

3.5 Micro Scale

3.5.1 Özyeğin University Çekmeköy Campus Design

The establishment of Özyeğin University began in the autumn of 2005, initiated by the Hüsnü M. Özyeğin Foundation. The foundation conducted extensive research involving business professionals, faculty members, university, and high school students, with over 500 individuals, as well as a study on "Developing Sectors and Professions in Turkey and the World." Based on the findings of these research efforts, design work led by ARAMA Participatory Management Consultancy was carried out, engaging various stakeholders to discuss the university's core values and vision. Through workshops and participation from business executives, faculty members, university students, and recent graduates,

Özyeğin University's vision was formulated. [69]

Officially established on May 18, 2007, Özyeğin University aimed to become a unique and socially impactful institution with a contemporary education system, innovative integration with real-life experiences, an education approach closely tied to industries, and relevant programs. The university welcomed its first students at the Altunizade Campus in Istanbul in September 2008 and transitioned to the Çekmeköy Campus in September 2011. [69]

The Çekmeköy Campus, designed by a world-renowned architectural firm that also worked on Cambridge and Princeton buildings, is Turkey's first LEED Gold-certified tranquil and peaceful university campus. Spanning a total area of 280,000 square meters, the campus offers quiet and comfortable study rooms, modern classrooms and laboratories, a 15,000 square meter sports center, a 2,825 square meter library, and two auditoriums with capacities of 350 and 372 people, respectively. The aim is to provide students with opportunities for academic growth as well as involvement in social, sports, and cultural activities. [69]

Özyeğin University, embracing the mission of a "research-based entrepreneurial university" even during its establishment phase, continued its journey with a focus on conducting impactful and value-creating work for society. Alongside publishing articles in international journals, faculty members have been actively involved in research projects with commercialization potential. [69]

With the goal of being a vibrant and entrepreneurial center of education closely integrated with life, Özyeğin University aims to produce graduates who make a difference in their surroundings and workplaces through their acquired knowledge, communication skills, information technology proficiency, practical experience, and entrepreneurial

mindset. The university is dedicated to nurturing graduates who are well-versed in emerging professions, possess a deep understanding of their fields, have a command of foreign languages, and are capable of making a difference in both their academic studies and the real world. Özyeğin University not only shapes "professionals" but also fosters "entrepreneurs." [69]

Believing that every successful student should have access to quality education regardless of their circumstances, Özyeğin University offers scholarships to 90.4% of its registered undergraduate students. The university provides education through six faculties, three institutes, and two vocational schools, offering a total of 23 undergraduate and 10 doctoral programs. With its campus located in Çekmeköy, the university prepares its students for life within a total area of 283,000 square meters. [69]

The Özyeğin University Çekmeköy Campus, designed by the prestigious architectural firm RMJM, stands as a testament to innovative design and sustainability. RMJM has an impressive portfolio, having crafted campuses and structures for renowned universities worldwide. Notable projects include Columbia University Medical Center, Cambridge University William Gates Building, Princeton University Bowen Building, Oxford University Chemistry Research Building, and the University of West Scotland Ayr Campus. [69]

At the heart of Özyeğin University Çekmeköy Campus lies its distinct architectural features of light and transparency. The integration of natural materials further enhances the campus's aesthetics and environmental consciousness. The design adopts a flexible and modular approach, providing a harmonious balance between functionality and sustainability. [69] [70]

Özyeğin University Çekmeköy Campus showcases its commitment to sustainability by optimizing the use of resources and minimizing operational costs. The campus serves as a prime example of responsible construction, demonstrating how a harmonious blend of design and eco-friendly practices can create a thriving and environmentally conscious educational environment. [70]

3.5.1.1 Student Center

The student center, a remarkable architectural creation by ARK-itecture and B-Design, stands proud with its prestigious LEED Gold certification. Positioned strategically as a "transition area," bridging the main square, campus valley, and residential connection levels, the student center takes center stage as a vital component of the esteemed "academic spine," serving as the vibrant epicenter of social and academic life. [71]

The innovative concept of utilizing stacked masses on the challenging topography, departing from conventional urban development norms, emerged as a reimagined and elevated architectural expression. The distinct massing of the student center sets it apart from its counterparts, with 16 modules measuring 16x16 meters merging seamlessly at varying angles and elevations, forging a tangible link between the academic spine and the enchanting campus valley. [71]

Comprising an array of facilities, the student center caters to diverse needs, housing a captivating library, a bustling cafeteria, dynamic student clubs, an engaging forum area, and various campus support spaces. The forum area extends gracefully from the entrance axis towards the mesmerizing valley, seamlessly connecting all other functions. Designed to foster student gatherings, intellectual discussions, and fruitful collaborations throughout the academic year, this space pulsates as a dynamic hub of

interaction. The library boasts distinct zones tailored for diverse uses, offering a tranquil study space adorned with sweeping vistas of the main square. The café area, complemented by an inviting terrace, provides students with a social haven to engage in a myriad of activities, no matter the season. The cafeteria, thoughtfully designed to maximize natural light, caters to the culinary needs of up to 800 students, offering panoramic views of the picturesque valley and the serene inner courtyard. At the heart of the campus's main entrance square, a captivating pavilion structure materializes, an architectural marvel exquisitely crafted as a transparent glass cube. Embracing visitors with open arms, this remarkable edifice serves as a gracious gateway to the campus, offering an alternative entrance to both the parking area and the bustling student center. Additionally, the pavilion houses captivating temporary exhibition spaces, fostering artistic expression within its walls. [71]

Embracing sustainability as a guiding principle, the student center's LEED Gold certification stands as a testament to its environmentally conscious design. The utilization of perforated metal mesh as the secondary façade elegantly harmonizes with the surrounding academic buildings. Drawing inspiration from the enchanting natural landscape, the color palette of the metal mesh panels evokes a harmonious visual dialogue with the environment, accentuating the allure and tranquility of the campus's ambience. [71]

3.5.1.2 SCOLA

Özyeğin University's School of Foreign Languages (ScOLa) Building has gained recognition as a remarkable project at the EKODesign Conference, positioning itself as one of Turkey's leading energy-efficient structures. Serving as the implementation

building for the NEED4B: Energy Efficiency in New Buildings project, a 7th Framework Program initiated by the European Union, the Özü ScOLa building has been instrumental in showcasing innovative and integrated energy applications, surpassing the project's consumption target with a rate of 45 kWh/m². [72]

Since 2012, Özyeğin University's Energy, Environment, and Economy Center (EÇEM) has actively participated in the NEED4B project, collaboratively undertaken by seventeen institutions from five countries, under the coordination of the CIRCE Energy Center at the University of Zaragoza in Spain. This initiative aims to implement energy efficiency practices in diverse climatic regions, incorporating various construction cultures. As part of this venture, the Özü School of Foreign Languages (ScOLa) building was constructed in collaboration with FİBA Holding and B-Design, led by EÇEM. The ScOLa building, which adopts innovative and integrated energy applications, occupies a significant position within Özyeğin University's Çekmeköy Campus. It forms an integral component of the educational spatial network, alongside other LEED Gold-certified buildings. [72]

Covering a gross area of 17,715 square meters, the ScOLa Building has been operating as the School of Foreign Languages since 2013, catering to approximately 1450 students, supported by 125 academics and 10 administrators. Notably, the building exemplifies one of Turkey's most efficient and sustainable structures. It incorporates a combination of transparent and opaque surfaces, an advanced automation and lighting system that achieves an impressive efficiency rate of over 65%, natural ventilation mechanisms, and the seamless integration of renewable energy sources. [72]

3.5.1.3 *Özü X*

Özü-X, inspired by the global trend of digitalization and symbolizing technology and innovation, serves as Özyeğin University's hub for entrepreneurship and innovation. It aligns with the vision of OpenFab, the sharing center that supports maker culture and hardware entrepreneurship in the field of educational technologies. Established in 2015, OpenFab showcases the accessibility of technology to everyone by demonstrating how applications, tools, and devices can be created. Through maker workshops on coding, 3D modeling, electronic prototyping, and robotics, OpenFab engages diverse audiences and fosters creativity and innovation. [73]

Located within Özü-X, the Technology Transfer Office (Özü TTO) plays a vital role in promoting innovation and economic development. Since its establishment in 2013, Özü TTO has been supporting researchers in their journey from idea to product. By facilitating project development, industrial collaborations, intellectual property rights, and commercialization, Özü TTO enhances the impact of research projects and contributes to technological advancements and knowledge transfer. [73]

To further support sustainable development, Özyeğin University partnered with the Turkish Industry and Business Association (TÜSİAD) to establish the Sustainable Development Forum (SKF). The SKF actively monitors international efforts in sustainable development, including the United Nations Sustainable Development Goals. By evaluating their impact on the Turkish business world, the SKF provides a platform for dialogue and collaboration. It develops innovative approaches and methods, particularly in the realm of circular economy, to minimize environmental impact while promoting sustainable growth and smart industrialization. Additionally, the SKF

conducts research, evaluations, and shares valuable insights with stakeholders and the public to shape informed policies and strategies. [73]

ÖzÜ-X, as integral parts of Özyeğin University's ecosystem, embody the university's commitment to innovation, entrepreneurship, and sustainable development. They provide a nurturing environment where ideas can thrive, technologies can be shared, and students can find the support they need to succeed. With their collaborative approach and focus on creating a positive impact, ÖzÜ-X contribute to the advancement of knowledge, the development of entrepreneurial ventures, and the promotion of sustainable practices within and beyond the university community. [73].

3.5.1.4 Sport Center

The sports center is located on a steep terrain within the Özyeğin University Campus. There are pedestrian and vehicle accesses from the campus center, dormitories, and the surrounding ring road. The mass design is gradually constructed using the topographic data to accommodate the slope. Due to the steepness of the slope, the given program does not allow for additional levels, so the building facade is elevated from the supporting ground. Terracing is created in between, forming an activity landscape. This area is dedicated to floor gardens and sports activities such as climbing walls and streetball.

The building program includes a multipurpose sports hall, a semi-Olympic swimming pool, and studios for fitness, squash, pilates, etc. Later, a daycare center was added for the children of faculty members. Despite being within the same structure due to the advantage of the terraced mass, the daycare center can function independently from the sports center. [74]

The most significant advantage provided by the planning is its compact design approach. Circulation areas such as corridors are minimized, and the orientation is simplified. The large volumes such as the sports hall, pool, and fitness areas, are integrated. This integration allows for relationships between spaces, enhancing the spatial richness and providing a holistic experience within the building. [74]

The entrance facade of the structure features two different levels of squares. The lower square is the first welcoming space for campus visitors. The daycare center entrance and shops open onto this square. The daycare entrance is also considered an alternative entrance for people with disabilities. The stairs connecting this square to the upper square, where the main entrance of the sports center is located, behave like a landscape element and provide seating areas to enjoy the vibrancy of the lower square. The upper square forms the main entrance area of the sports center. It surrounds the building like a podium with terraces extending along the side facades, encompassing all entrances, exits, and approaches. It also divides the mass of the building, providing a lightening effect. A 10-meter console housing the fitness area creates a canopy over this main entrance. This console is a large window from which one can have a panoramic view of the entire campus. It offers sports enthusiasts the opportunity to experience such a breathtaking panorama. [74]

3.5.1.5 Dorm 2 - 4 - 6

The Özyeğin University dormitory buildings at the Çekmeköy Campus exemplify the university's dedication to providing exceptional support to its students. Designed with meticulous attention to detail, these buildings have a total capacity of 2,479 individuals. Offering a range of accommodation options, from single rooms to three and four-person

suites, the dormitories ensure that students feel a sense of comfort and belonging. Each room is equipped with an en-suite bathroom, a refrigerator, and a television, providing a convenient and enjoyable living experience. [75]

The common areas within the dormitory buildings are thoughtfully designed to cater to students' various needs. Students have access to a free laundry room, group study rooms, and a welcoming lounge area where guests can be received. For entertainment purposes, there is a cinema hall and a TV lounge, along with game areas for recreational activities. To fulfill students' culinary needs, the dormitories feature a cafeteria, a market, and other food and beverage establishments. [75]

The well-being and safety of students are of utmost importance, and the dormitory buildings are equipped with essential facilities to ensure this. A comprehensive security system, including surveillance cameras, is in place to safeguard the premises. Central heating provides a comfortable living environment throughout the year, while continuous hot water is available for the residents. Additionally, the dormitories offer an ambulance service for any medical emergencies that may arise. [75]

In line with the needs of modern students, wireless internet access is provided, enabling connectivity and facilitating academic and personal endeavors. Recognizing the importance of physical fitness and leisure, the dormitory complex offers recreational facilities such as a football field, basketball and volleyball courts, a tennis court, and a fitness gym. These amenities encourage students to lead active and healthy lifestyles while enjoying their free time. To ensure the smooth operation and continuous support, the Accommodation Services Directorate operates 24/7. It is divided into three separate

offices, namely Yurt 3, Yurt 4-5, and Yurt 6, which are readily available to address any inquiries or assistance needed by the residents. [75]

Overall, the Özyeğin University dormitory buildings at the Ekmeköy Campus provide a vibrant and comfortable living environment, fostering a sense of community and enhancing the student experience. [75]

3.5.1.6 Architecture faculty

The Özyeğin University Faculty of Architecture and Design is a testament to the university's commitment to creating an inspiring learning environment. Designed collaboratively by BG Architects and ARK-itecture, this modern structure is the culmination of meticulous planning and design. [76]

As a part of the Çekmeköy Campus project, the Faculty of Architecture and Design holds a special significance. It embodies the vision and aspirations of Özyeğin University, marking the beginning of an exciting chapter for young designers who will shape the future of architecture and design. [76]

The building aims to establish a strong connection with the campus's main square, seamlessly integrating the connection into its facade and interior design. By incorporating various levels and functions, it creates a flow that enhances the spatial experience. The open loft-style studio and collaborative workspaces foster visual interaction among students, promoting creativity, collaboration, and engagement with the surrounding landscape. [76]

The west facade of the faculty building is particularly notable. It protects the interior spaces from the intense western sun while allowing controlled natural light to

illuminate the building. The use of materials like corten steel and basalt creates a visually captivating appearance that harmonizes with the adjacent forest landscape. Inside, every space is carefully designed to foster creativity and self-expression. From the welcoming entrance lobby to the interconnected circulation areas, the design ensures functional flexibility. The shared spaces accommodate various activities, encouraging new modes of interaction and supporting evolving learning habits. The faculty building provides dynamic and inspirational settings that promote exploration, experimentation, and the exchange of ideas. [76]

3.5.2 Certification

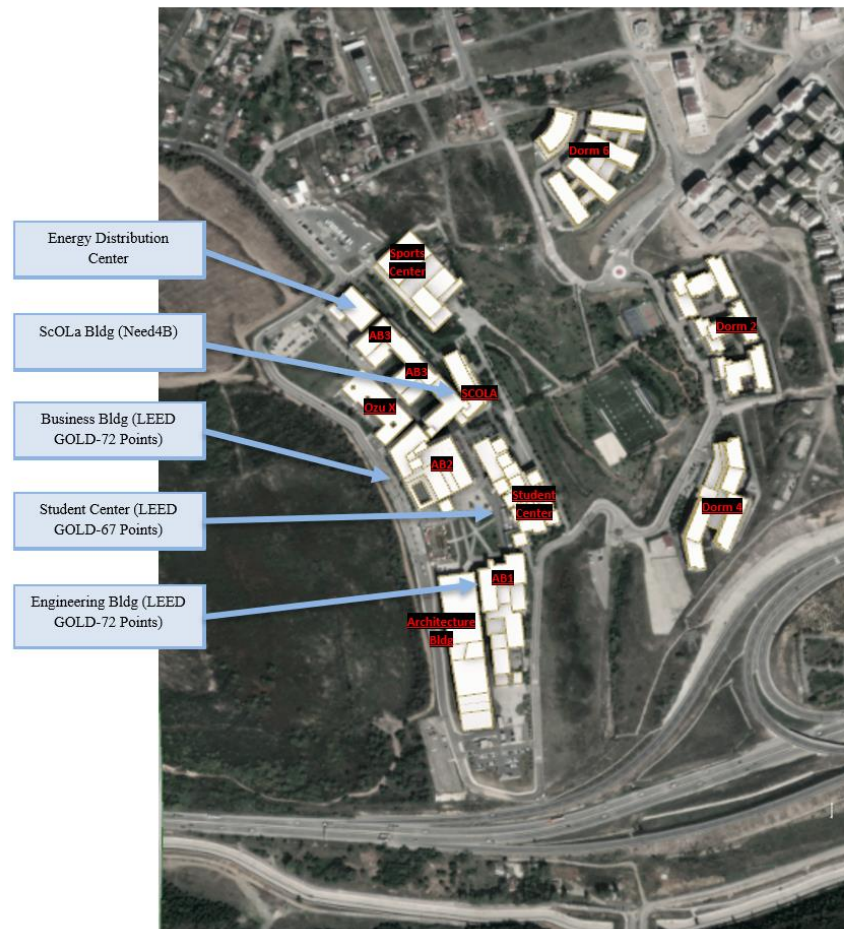


Figure 38: Özyeğin University Certifications [77]

1. LEED Gold Certificate for the AB1 and SC buildings - February 2013
2. LEED Gold Certificate for the AB2 Building - August 2014
3. NEED4B Project-SCOLA- October 2014
4. ISO 14001 Environmental Management System Standard - March 2014
5. ISO 45001 Occupational Health and Safety Management System Standard - March 2014
6. Zero Waste Certificate -February 2020



Figure 39: 1-Ozyegin University Academic Building 1 (Engineering) LEED Gold Certificate [78]



Figure 40: 1-Ozyegin University Student Center LEED Gold Certificate [78]



Figure 41: 2-Ozyegin University Second Academic Building LEED Gold Certificate [78]



Certificate of Registration

ENVIRONMENTAL MANAGEMENT SYSTEM - ISO 14001:2015

This is to certify that:

Özyegin Universitesi
Çekmeköy
Nisantepe Mah. Orman Sk.
Istanbul
Istanbul (Asia Side)
34794
Turkey

Holds Certificate No:

EMS 608192

and operates an Environmental Management System which complies with the requirements of ISO 14001:2015 for the following scope:

Higher Education Activities, Social and Administration Services

For and on behalf of BSI:

Andrew Launn, EMEA Systems Certification Director

Original Registration Date: 2014-03-13
Latest Revision Date: 2020-03-10

Effective Date: 2020-03-13
Expiry Date: 2023-03-12

Page: 1 of 1



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BSI Assurance UK Limited, registered in England under number 7805321 at 389 Chiswick High Road, London W4 4AL, UK.

Figure 42: Certificate of Registration Environmental Management System - ISO 14001:2015 [78]



Certificate of Registration

OCCUPATIONAL HEALTH & SAFETY MANAGEMENT SYSTEM - ISO 45001:2018

This is to certify that:

Özyegin Universitesi
Çekmeköy
Nisantepe Mah. Orman Sk.
İstanbul
İstanbul (Asia Side)
34794
Turkey

Holds Certificate No:

OHS 608191

and operates an Occupational Health and Safety Management System which complies with the requirements of ISO 45001:2018 for the following scope:

Higher Education Activities, Social and Administration Services

For and on behalf of BSI:

Andrew Launn, EMEA Systems Certification Director

Original Registration Date: 2014-03-13

Latest Revision Date: 2020-03-10

Effective Date: 2020-03-13

Expiry Date: 2023-03-12

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BSI Assurance UK Limited, registered in England under number 7805321 at 389 Chiswick High Road, London W4 4AL, UK.

Figure 43: Certificate of Registration Occupational Health & Safety Management System - ISO 45001:2018 [78]



T.C.
İSTANBUL VALİLİĞİ
Çevre ve Şehircilik İl Müdürlüğü



Belge No: TS/34/B2/6/1

Tarih: 14/02/2020

SIFIR ATIK BELGESİ
(Temel Seviye)

Adı : ÖZYEGİN ÜNİVERSİTESİ
Adresi : NİŞANTEPE MAHALLESİ ORMAN SOKAK NO:34-36, ÇEKMEKÖY, İSTANBUL
Vergi No : 7170240129

12/07/2019 tarihli ve 30829 sayılı Resmi Gazete'de yayımlanarak yürürlüğe giren Sıfır Atık Yönetmeliği'nce Sıfır Atık Yönetim Sistemi'ni kurarak **Sıfır Atık Belgesi**'ni almaya hak kazanmıştır.



Belge Son Geçerlilik Tarihi: 14/02/2025

Hacı Mehmet GÜNER
Çevre ve Şehircilik İl Müdürü

Not: 5070 sayılı Elektronik İmza Kanunu gereği bu belge elektronik imza ile imzalanmıştır.
Evrak Doğrulama Kodu: LNLBXDMA Evrak Takip Adresi: <https://www.mukye.gov.tr/cevre-ve-sehircilik-bakanligi>

Figure 44: Zero Waste Certificate [78]

Özyeğin University has embraced its commitment to environmental sustainability since its inception, making it an integral part of the university's initial strategic plan. As a testament to this dedication, three buildings on the campus have achieved LEED Gold Certification, following assessments by the U.S. Green Building Council. Notably, the AB3: ScOLa building stands as one of the most energy-efficient academic structures in Turkey. Developed under the NEED4B project, which received funding from the European Union's 7th Framework Program, and executed by ÖzÜ's Energy, Environment, and Economy Center (EÇEM), ScOLa consumes approximately 20% less energy compared to the average academic building in the country. The NEED4B project, stands as the most substantial energy project awarded to a university in Turkey. Another notable achievement by EÇEM is the TRIBE Project, the first initiative supported by the

European Union's Horizon 2020 program in Turkey. Launched in 2015, TRIBE aims to enhance the energy efficiency of Özü's AB1 building by incorporating user options and leveraging the Internet of Things concept. [70]

Beyond LEED certifications, Özü has secured ISO 14001 Environmental Management System and OHSAS 18001 Occupational Health and Safety certifications, marking a significant milestone as the first Turkish university to achieve both. ISO 14001 encompasses an environmental management system that enables effective environmental performance management and improvement. On the other hand, OHSAS 18001 is a certification that focuses on workplace health and safety, providing a comprehensive framework for identifying, controlling, and minimizing risks in the work environment. [70]

In addition to these achievements, the university has collaborated with Fina Enerji to install 376 kW-e solar panels and establish seven green roofs. These initiatives align with Özü's continuous efforts to optimize energy consumption and minimize environmental impact. The Energy Distribution Center, operational since the university's inception, plays a vital role in monitoring all energy production and consumption across the campus. With its detailed building automation applications, well-organized water management practices, and waste management initiatives, the center embodies Özü's commitment to sustainable practices and responsible resource usage. [70]

The LEED certification serves as a commendation for structures that adhere to the core principles of sustainability, ensuring harmony with the natural environment while minimizing ecological disruption. A comprehensive evaluation is conducted in Özü, considering various sustainability requirements, to determine the performance score of a

building seeking LEED certification. This performance score acts as the basis for awarding different levels of certification: LEED Certified (40-49), LEED Silver (50-59), LEED Gold (60-79), and LEED Platinum (80+). To attain the LEED certified status, all buildings must achieve a minimum performance score of 40. Özyeğin University has proudly earned the esteemed LEED GOLD certification for its AB1, AB2, and SC buildings, signifying their exceptional sustainability practices and commitment to environmental stewardship. [70]

Recognized for its groundbreaking and integrated approach to energy management, the ScOLa (School of Languages) edifice at Özyeğin University, fondly referred to as OzU ScOLa, stands as a symbol of excellence. This remarkable building was constructed as a demonstration project in Istanbul, Turkey, under the NEED4B initiative: New Energy Efficient Demonstration for Buildings. The project received co-financing from the European Union through the Seventh Framework Programme (FP7) and was executed by the esteemed Center for Energy, Environment, and Economy (CEEE) at Özyeğin University. [70]

Impressively spanning an expansive 17,715 square meters of gross area, the ScOLa building is nestled within the picturesque Çekmeköy Campus of Özyeğin University. Since its inauguration in 2013, the buildings of ScOLa are home to the esteemed School of Languages, catering to a vibrant community comprising approximately 1,450 students, 125 tutors, and 10 managers. Celebrated as one of Turkey's leading exemplars of energy efficiency and sustainability, the ScOLa building boasts an array of cutting-edge features. Its state-of-the-art automation and lighting systems have been thoughtfully designed to achieve a remarkable efficiency rating of 65 percent, harnessing the power of both transparent and opaque surfaces. Additionally, the building

embraces a natural ventilation system, promoting a harmonious blend of comfort and environmental consciousness. In its commitment to renewable energy, the ScOLa building has seamlessly integrated sustainable resources, further enhancing its status as a pathfinder of eco-friendly design and functionality. [79]

In 2014, Özyeğin University successfully obtained the ISO 14001 Environmental Management System Standard, ensuring compliance with the stringent requirements of this system. The functionality of the system is regularly assessed through both internal and external reviews, ensuring its continuous effectiveness. Each year, the certificates are renewed, reflecting the commitment to maintaining high environmental management standards. The Environmental Management System (EMS) is a comprehensive framework designed to methodically mitigate and, whenever feasible, eradicate the adverse environmental impacts caused or potentially caused by organizations. Its primary objective is to foster the creation of a sustainable and flourishing environment for future generations. By implementing the EMS, organizations proactively address environmental concerns, identify areas of improvement, and adopt measures to minimize their ecological footprint. Through a systematic approach, the EMS empowers organizations to achieve environmental sustainability and contribute to the preservation and enhancement of our planet's well-being. [78]

ISO 14001 Environmental Management System [78]:

- Minimizes waste.
- Reduces energy consumption.
- Makes it easier to obtain permits and licenses.

- Ensures compliance with national and international legal requirements.
- Facilitates accurate use of natural resources and thus reduces expenditures and increases efficiency.
- Analyzes potential threats and thus minimizes accidents and losses.
- Increases trust and commitment as it guarantees stakeholders that all activities are carried out in accordance with environmental obligations.

To guide their actions and demonstrate their dedication to environmental stewardship, the University has published several essential documents. Our Environment Policy outlines the institution's overarching environmental goals and principles. Additionally, the Environmental Management Plan details the specific practices, roles, responsibilities, and key concepts that govern their environmental management efforts. Recognizing the importance of responsible resource usage, the University has also released User Guidelines for Campus Energy and Water Resources. These guidelines offer detailed instructions on maximizing the efficient utilization of energy and water resources available on campus while emphasizing the crucial considerations for environmental protection. Moreover, Özyeğin University takes waste management and environmental responsibility seriously, as reflected in the Özyeğin University Waste Management Plan and Environmental Lifecycle documents. These comprehensive plans outline our strategies for minimizing waste generation, promoting recycling and proper disposal practices, and ensuring a sustainable approach to managing our environmental impact throughout the lifecycle of our operations. Through the implementation of these documents and the continuous improvement of our environmental management practices,

Özyeğin University remains committed to fostering a sustainable future and fulfilling our environmental responsibilities. [78]

In 2014, Özyeğin University successfully achieved compliance with the ISO 45001 Occupational Health and Safety Management System Standard, demonstrating their commitment to ensuring a safe and healthy work environment. They diligently fulfill the requirements outlined by this management system, consistently maintaining the functionality and effectiveness of their occupational health and safety practices. To ensure ongoing adherence to the ISO 45001 standard, they conduct regular internal and external reviews of our system's functionality. These periodic assessments allow them to identify any areas for improvement and make necessary adjustments to enhance our occupational health and safety performance. Furthermore, their certifications are renewed on an annual basis, validating our commitment to maintaining high standards in health and safety management. In alignment with their dedication to occupational health and safety, they have established robust policies within the organization. The Health & Safety Policy outlines their institutional commitment to promoting a safe and healthy work environment for all employees. Additionally, their Emergency Response Policy details the procedures and protocols in place to effectively respond to emergency situations, ensuring the well-being of the staff and stakeholders.

Complementing their policies, they have developed comprehensive Health & Safety and Emergency Response Plans. These plans provide a clear framework for implementing best practices, defining roles and responsibilities, and fostering a culture of safety throughout their organization. They cover a wide range of relevant concepts, from hazard identification and risk assessment to incident reporting and emergency preparedness. [78]

By consistently adhering to the ISO 45001 standard, implementing their institutional policies, and following their Health & Safety and Emergency Response Plans, they strive to create a secure and healthy work environment for all individuals associated with the organization. They remain committed to upholding the highest standards of occupational health and safety, continuously improving our practices, and ensuring the well-being of the workforce. The ISO 45001 Occupational Health and Safety Management System is a comprehensive framework developed to address and mitigate risks within the organization, ensuring the establishment and maintenance of a secure and healthy working and living environment. By adhering to relevant legislation and industry standards, this management system aims to systematically identify, assess, and minimize occupational health and safety hazards. The primary objective of ISO 45001 is to prevent workplace accidents, injuries, and illnesses, fostering a culture of safety and well-being for all individuals within the institution. Through the implementation of this system, organizations can proactively identify potential risks, develop effective controls, and continuously monitor and improve occupational health and safety performance. In alignment with this standard, the institution has developed and implemented the Occupational Health and Safety Management System, which adheres to the principles and requirements of ISO 45001. This system is regularly reviewed and audited to ensure its ongoing effectiveness and compliance with legal obligations. [78]

By integrating this management system into the operations, they strive to provide a secure and healthy environment for employees, students, visitors, and all stakeholders. Through the systematic identification and control of occupational hazards, the institution demonstrates its commitment to the well-being and safety of all individuals associated with our organization. Furthermore, the institution maintains a culture of continuous

improvement by regularly monitoring performance indicators, conducting risk assessments, and implementing appropriate corrective and preventive measures. By fostering a proactive approach to occupational health and safety, they aim to create an environment where everyone can thrive and contribute to the success of the organization while minimizing potential risks and ensuring compliance with legal requirements. [78]

ISO 45001 Management System [78]:

- Minimizes occupational accidents and diseases, and prevents labor loss,
- Facilitates a better work environment and thus ensures employee satisfaction.
- Proves the institution's commitment to occupational safety to the legal authorities,
- Offers competitive advantage by increasing the institution's reputation.
- Prevents production delays or downtimes due to accidents or diseases; minimizes compensation, penalty, and indemnity amounts; and reduces operational costs.
- Enables potential reduction in downtime and associated costs.
- Ensures the systematic dissemination of occupational health and safety practices within the institution.
- Helps the institution demonstrate compliance with national and international laws and regulations on occupational health and safety.

The concept of "Zero Waste" is a waste management philosophy that aims to eliminate waste generation by promoting waste prevention, resource efficiency, and separate collection and recycling of waste at its source. It involves a comprehensive approach to minimize waste and make efficient use of resources. The "Zero Waste

Certificate" is a recognition granted by the Ministry of Environment and Urbanization to local administrations, institutions, and places that have established effective zero waste systems. The criteria for obtaining this certificate are outlined in the Rules and Regulations for Zero Waste Attachment, which includes the Özyeğin University campus and dormitories. The specific scope of the certificate is determined by the Ministry. Özyeğin University proudly became the first university in Turkey to receive the prestigious "Zero Waste Certificate" on February 14, 2020. This achievement highlights the university's commitment to sustainable waste management practices and its dedication to creating a waste-free environment. [78]

The Zero Waste Certificate's benefits for Özyeğin University [78]:

- Having obtained the zero waste certificate within the scope of the ISO 14001 Environmental Management System which we are using will serve as a positive reference in HSE Management Systems reviews.
- With the ISO 14001 Environmental Management System, the requirements of the Rules and Regulations for Zero Waste had been fulfilled to a large extent. This way, OzU was able to quickly apply for the basic level zero waste certificate. OzU currently has the necessary infrastructure to apply for the silver, gold, and platinum level certificates specified in the rules and regulations. With the support of management, and in particular, by increasing the active participation of all stakeholders in fulfilling the requirements of the University's environmental policy and environmental management procedures, it is foreseen that the University may also apply for advance level certifications in the future.

- The Zero Waste Certificate brought OzU's name to the fore for the Ministry of Environment and Urbanization and relevant public bodies to the extent that OzU submitted a report to serve as a best practice example upon the request of the Ministry of Environment and Urbanization.

3.5.3 Özyeğin University Sustainability Platform and HSE Initiative

The Health, Safety, and Environment (HSE) Department and the Sustainability Platform at Özyeğin University are committed to promoting a culture of health, safety, environmental responsibility, and sustainable practices. The HSE Department has a vital role in ensuring compliance with regulations, creating a safe work environment on campus, and providing guidance and consultancy on HSE issues. Their mission is to raise awareness among stakeholders about the basic requirements of civic life and instill a strong HSE culture within Özyeğin University. By keeping track of legislations and implementing effective policies, the department has helped the university become the first in Turkey to receive ISO 14001 Environmental Management System and OHSAS 45001 Occupational Health and Safety Management System Certifications. Through their Safety, Environment, and Emergency Response policies, the HSE Department sets goals and objectives, providing guidance to all departments. [80]

On the other hand, sustainability is deeply ingrained in the values and strategy of Özyeğin University. The university aims to minimize the adverse environmental, social, cultural, and economic impacts of its activities and lead society towards a sustainable lifestyle. To achieve this, Özyeğin University has established the Sustainability Platform (OzU-SP), which serves as a comprehensive and integrated model. The platform is designed to identify sustainability goals, conduct multidisciplinary research, integrate

sustainability education, maintain campus sustainability, and foster collaborations among stakeholders. OzU-SP operates in alignment with the university's vision, mission, and code of ethics. [77]

Together, the HSE Department and the Sustainability Platform work towards mitigating environmental issues, promoting health and safety, and advancing sustainable practices within Özyeğin University. Through their efforts, they create a multidisciplinary and transdisciplinary environment where knowledge about sustainability is developed, awareness is raised, and collaborations are fostered among faculty, staff, students, public bodies, and the private sector. These initiatives reflect Özyeğin University's dedication to being a leading institution in promoting health, safety, environmental responsibility, and sustainability.

The HSE Department plays a vital role in guiding and auditing processes related to health, safety, and the environment. They have developed comprehensive plans such as the Health & Safety and Environment Plan, the Emergency Response Plan, and the Environmental Management Plan, which are regularly updated and improved. Risk assessments are conducted, and necessary actions are taken to mitigate identified risks. The department provides stakeholders with valuable information, training, and seminars, awarding certificates of participation and achievement. They also establish emergency response teams and offer a range of mandatory and elective courses to students throughout the year. In terms of emergencies, the department takes charge of developing emergency measures, preparedness, recovery, communication, and drills. They are committed to preventing environmental accidents, promoting resource conservation, improving energy efficiency, and managing waste effectively. Additionally, the department conducts inspections and reports on subcontractor performance, monitors on-campus maintenance

and construction works, ensures the proper placement of signs and signage, and collaborates with security staff for managing parking facilities. They represent the university during external audits conducted by relevant authorities and take measures to address winter weather challenges, keeping campus access roads clear. The HSE Department is dedicated to upholding high standards and promoting a safe and sustainable environment at the university. [81]

The HSE department is responsible for keeping track of legislations, creating a safe work environment on campus in compliance with effective laws, and providing guidance/consultancy pertaining to the HSE issues. Through the efforts of the HSE Department, Özyeğin University has become the first university in Turkey that is concurrently awarded both ISO 14001 Environmental Management System and OHSAS 45001 Occupational Health and Safety Management System Certifications. To this end, the Department has published three policies: objectives in these policies and continues to provide guidance to all departments. [81]

Özyeğin University established an official Occupational Health and Safety Committee, which was later expanded and transformed into the Health Safety and Environment Committee in recognition of environmental requirements. In addition to administrative representatives legally required to be on the committee, the committee was expanded to include also academic and student representatives. All members of the committee have the opportunity to analyze and contribute to campus processes from the perspective of health, safety and environment. Members periodically meet and present their formal recommendations to senior management. The HSE Community is a student community dedicated to developing and promoting environmental responsibility and safety consciousness among students as required by the HSE management systems. The

HSE Community is actively involved in maintaining the internationally recognized health, safety, and environment (HSE) culture on campus. To this end, the HSE Community offers a series of events to provide students with insights as to how to maintain health, safety, and environmental consciousness. Events are scheduled for specific weeks and planned collectively during meetings. The HSE Community at Özyeğin University organizes a wide range of events to promote health, safety, and environmental awareness on campus. These events include HSE orientation sessions for new students during the Orientation Day, mandatory and elective SEC 101 classes to educate students on HSE principles, and the implementation of HSE rules throughout the campus. Waste management initiatives are also conducted, along with specific HSE practices focused on engineering and construction sites. Traffic training and first aid training are provided to enhance safety knowledge and skills. Additional events such as breathing exercises, a Red Crescent blood donation event, an addictions seminar, search and rescue training, seat belt simulations, and observance of important days like Environment Day, Water Day, and International Farmers' Day are organized. The community also conducts active drill observations to ensure preparedness in emergency situations. These events collectively contribute to fostering a culture of health, safety, and environmental responsibility within the university community. [82]

Özyeğin University's HSE (Health, Safety, and Environment) and Sustainability Platform policies are driven by their commitment to prioritize the physical and psychological well-being and occupational safety of all individuals within the university community. They proactively take measures, provide necessary resources, and meet requirements to prevent health issues and continuously enhance their occupational health and safety performance. The HSE department meticulously assesses and mitigates

potential risks, ensuring compliance with regulations and creating healthy and safe working conditions. They encourage consultation, comply with legislation, and continuously improve their Occupational Health and Safety Management System.

3.5.4 Özyeğin University Policies

3.5.4.1 Özyeğin University Water Management Policies

Özyeğin University has implemented comprehensive water management policies aimed at promoting sustainable and efficient water use on its campus. These policies encompass various initiatives, such as rainwater and greywater management and reuse systems, which enable the collection and utilization of water from precipitation and non-potable sources. This reduces the reliance on freshwater resources and minimizes water wastage. Additionally, the university has installed high-efficiency faucets that conserve water without compromising functionality. These faucets incorporate innovative technologies to optimize water flow and decrease overall water consumption. Another water-saving measure is the adoption of "dual-flush" toilets throughout the campus, providing users with the option to select a lower water volume for liquid waste and a higher volume for solid waste. This design significantly reduces water usage compared to traditional single-flush toilets. Furthermore, Özyeğin University emphasizes the importance of water recycling systems, as discussed during interviews with the Sustainability Platform and HSE members. Given the presence of Köy Stream, which is one of the branches of Alemdağ Stream, is in the stream operation band, passing through the campus area, the university paid particular attention to their integration into the natural context during the design and construction phase. Collaborating with ISKI, measures were taken to manage stream flow by implementing specific surface floors beneath the riverbed to control water

flow and prevent erosion. These efforts contribute to the overall water management and conservation practices of Özyeğin University, promoting a sustainable and environmentally conscious campus. [83]

3.5.4.2 Health and Safety Policy

Health and safety are integral aspects of Özyeğin University's mission and principles. The university takes all necessary measures, meets requirements, and provides the resources needed to ensure the physical and psychological well-being and occupational safety of its faculty, staff, students, and neighbors. Occupational health and safety risks are carefully analyzed, and proactive measures are taken to bring them to acceptable levels. Compliance with laws and regulations is a top priority, and Özyeğin University strives to serve as a role model with best practices in health and safety. Extensive training sessions, seminars, events, and other activities are organized to promote a culture of health and safety awareness. [84]

Özyeğin University aims to maintain its position as a prestigious and pioneering institution in Turkey by prioritizing the health, safety, and well-being of its community. Through its Emergency Policy and comprehensive approach to risk management, the university seeks to prevent emergencies and ensure preparedness for any unforeseen events. By continuously monitoring and improving its emergency management system, Özyeğin University strives to increase its effectiveness and efficiency in emergency response. Continuous monitoring and improvement of their health and safety management system is a priority for Özyeğin University. They develop and track key performance indicators to assess and enhance system performance. Regular reviews and audits are conducted to evaluate adherence and take necessary actions. Their commitment

to diligence ensures compliance, fosters a culture of safety, and drives ongoing improvement in health and safety practices. [84]

The university's commitment to continuous improvement is evident in its monitoring and evaluation processes. Key performance indicators are established to assess the effectiveness of its emergency management, waste management, and energy efficiency efforts. Reviews and audits are conducted to ensure compliance with regulations and identify areas for enhancement. Özyeğin University takes prompt action to address any issues and achieve its set goals, maintaining a safe, sustainable, and resilient environment for all. Özyeğin University's commitment extends to health protection, public awareness, sustainability, and change management. They establish guidelines, conduct regular medical examinations, and analyze collected data for preventive measures. The university actively engages with stakeholders, offers comprehensive training, and raises public awareness through campaigns. They also evaluate the potential impact of changes and conduct reviews and audits to ensure compliance and drive continuous improvement. Hazardous waste generated from construction, academic, and administrative activities is identified, collected, transported, and disposed of using safe and appropriate methods to ensure the protection of human health and the environment. All waste produced within the university facilities is sorted and disposed of properly. [84]

Additionally, the university places a strong emphasis on environmental sustainability and waste management. It is committed to minimizing waste, promoting recycling and reuse, and complying with relevant laws and regulations. Özyeğin University prioritizes energy efficiency and renewable energy sources, aiming to reduce its environmental impact and contribute to a sustainable future. By fostering

environmental awareness among students, faculty, staff, and stakeholders, the university aims to create a culture of responsible environmental stewardship. Through effective communication and awareness management, Özyeğin University ensures that all members of its community are well-informed about emergency response procedures, waste management practices, and energy efficiency initiatives. Training programs, seminars, and campaigns are organized to raise awareness and promote active participation in these areas. [84].

3.5.4.3 Environment Policy

Özyeğin University Çekmeköy Campus Facilities, guided by its mission and principles, urges all members of its community and stakeholders to take action, meet requirements, and provide the necessary means and resources to protect the environment. The university is committed to assessing potential environmental hazards in all activities and reducing environmental risks to acceptable levels, while satisfying the requirements of internal and external authorities. It strives to protect the environment, reduce pollution, enhance energy efficiency, comply with legislation, meet compliance requirements, and continuously improve its environmental management system for increased environmental protection. [84]

Environmental protection and risk management are integral to Özyeğin University's decision-making processes, considering environmental criteria in investment decisions and being cautious of potential environmental impacts in all activities. The campus features green buildings, and environmental hazards are identified and mitigated in all activities. Waste management focuses on minimizing waste and promoting recycling. Stakeholders actively support environmental projects and promote awareness.

The university places great importance on informing and involving all stakeholders, including students, subcontractors, on-campus businesses, faculty, and staff, in its environmental protection and waste management efforts. Their active participation is encouraged as they assume their share of environmental responsibility. Sustainable resource use is a key aspect of environmental protection, encompassing recycling, water and air quality emphasis, climate change mitigation, and the preservation of biodiversity and ecosystems. Senior management at Özyeğin University guarantees their commitment to fulfilling these responsibilities, leading the Environmental Management System, and ensuring quality assurance throughout the processes. [84]

The university prioritizes eco-friendly materials and systems while communicating with third parties about potential environmental impacts. The Özyeğin University community, including students, faculty, and staff, actively engages in promoting energy efficiency through actions like closing doors and turning off lights. Özyeğin University supports the organization of training programs, seminars, events, and similar activities to increase environmental awareness. Additionally, the university utilizes passive strategies such as employing energy-efficient equipment, lighting, facilities, and infrastructure to maximize energy conservation. Özyeğin University is dedicated to minimizing, reusing, and recycling waste to prevent environmental pollution. Special consideration is given to the selection of materials, systems, and methods that promote energy efficiency and waste reduction at the source. Waste is managed in accordance with applicable laws and regulations, and the university closely monitors technological advancements to identify the best waste management practices. Energy efficiency is prioritized at Özyeğin University, with an energy management system in place to monitor and optimize administrative decisions and end-user behavior. Renewable

energy resources are given priority, and students, faculty, and staff are encouraged to contribute to energy efficiency through simple actions such as closing doors and turning off lights. The university also utilizes energy-efficient equipment, lighting, facilities, and infrastructure. [84]

Environment policies are designed to be easily adopted by students, faculty, and staff and integrated into their daily lives. Continuous development and incorporation of the latest global and technological advancements ensure the system remains rational, practical, and responsive to evolving environmental challenges. Before implementing any changes that may affect current processes and services, Özyeğin University carefully considers their environmental impact. Rules are established and implemented to review, replace, or terminate risk controls that are no longer effective due to operational, locational, or activity changes. Effective communication and awareness management are vital components of Özyeğin University's environmental practices. The university establishes an organizational structure to share information and gather feedback from stakeholders, taking necessary actions based on their insights. Training programs are offered to educate students, faculty, staff, subcontractors, and on-campus businesses on their roles and responsibilities in implementing the environmental management system. Technological developments and environmental protection initiatives are closely followed, and efforts are made to raise public awareness through campaigns, events, posters, and brochures. [84]

The university actively monitors and improves its environmental performance by developing and tracking key performance indicators. Objective and guiding indicators are selected to assess the impact of processes and the effectiveness of the environmental management system. Regular reviews and audits are conducted to ensure compliance with

established rules. Authorized staff objectively record and evaluate the results of these reviews and audits. Necessary actions are taken diligently to address identified issues and achieve established goals, ensuring continuous improvement in environmental performance. Özyeğin University's comprehensive approach to waste management, energy efficiency, sustainability, communication, and change management, combined with its commitment to monitoring and improving environmental performance, contributes to a greener and more sustainable university environment. [84]

3.5.4.4 Emergency Policy

The Özyeğin University Çekmeköy Campus Facilities prioritize the safety and well-being of all members of the university community in emergency situations. Their comprehensive Emergency Policy aims to save lives, minimize loss, and ensure business continuity by implementing effective emergency response procedures. Özyeğin University is committed to taking necessary actions, meeting requirements, and providing the resources needed to prevent, prepare for, and recover from emergencies. The senior management of Özyeğin University is fully dedicated to fulfilling the commitments outlined in their Emergency Policy. They take the lead in establishing and maintaining the necessary systems and ensuring quality assurance throughout the emergency management processes. The Emergency Policy is closely aligned with the Health & Safety Policy and the Environment Policy, reinforcing the university's holistic approach to safety and well-being. [84]

Prevention is a key aspect of the Emergency Policy, and Özyeğin University plans and implements necessary precautions to identify and address potential threats. The university follows a risk management system that covers all stages of emergency

preparedness, including prevention, preparation, response, and post-emergency. Emergency response plans are developed, considering the expansive campus area and the diverse types of emergencies that may occur. Subcontractors are expected to adhere to Özyeğin University's emergency action plans while developing their own plans. The university encourages all members of the university community to contribute to the prevention of emergency situations and provides avenues for feedback and suggestions. [84]

Preparation is essential for effective emergency management, and Özyeğin University ensures that stakeholders are informed about emergency response plans and trained in their implementation. All individuals associated with the university, including faculty, staff, students, visitors, and on-campus businesses, receive proper education on emergency response procedures and are familiarized with the location and use of emergency response equipment. Regular checks and assessments are conducted to ensure that emergency exits, signage, lighting, and equipment are in working order. Special attention is given to the needs of individuals with specific requirements. The university analyzes and improves the performance of its emergency management system through regular controls, tests, and drills. [84]

During emergency situations, the main objective is to recover with minimum damage to human health and the university itself. Emergency response teams, consisting of students, faculty, and staff, are responsible for providing accurate and timely information, guidance, and necessary assistance. After each emergency, teams come together to review their performance and identify opportunities for improvement. [84]

Post-emergency recovery and communication are crucial for maintaining business continuity and ensuring effective information flow. Özyeğin University prepares alternative arrangements and IT systems to ensure continuous operation. Open and honest relationships are established with institutions and stakeholders to create a reliable and supportive environment. Clear communication channels are established at each level of emergency to provide stakeholders with accurate and timely information. [84]

To ensure the sustainability of on-campus safety and contribute to the HSE culture, Özyeğin University encourages its stakeholders to play an active role in reporting any threats, hazards, or problems they may observe on campus. The Solution Center has been established as a dedicated platform for immediate support and assistance in addressing these issues. Stakeholders are encouraged to utilize the Solution Center to submit their requests, recommendations, and opinions regarding all the amenities offered at the university. The HSE Department will ensure that these inputs are promptly forwarded to the relevant units for appropriate attention and action. Özyeğin University values the active participation and engagement of its stakeholders in maintaining a safe and sustainable environment on campus. By working together, we can create a campus community that prioritizes health, safety, and environmental responsibility. [84]

Özyeğin University is committed to monitoring and improving the performance of its emergency management system. Key performance indicators are developed and tracked to assess the effectiveness and efficiency of the system. Reviews and audits are conducted to ensure compliance with established rules, and necessary actions are taken to address identified issues and achieve set goals. The university places a strong emphasis on a proactive approach to incident and accident prevention. They actively monitor and report threats, near misses, and incidents, involving key stakeholders in the risk

identification process. Risk management is carefully planned, and safer options are preferred in material and equipment selection. Regular checks and assessments are conducted to evaluate the effectiveness of threat detection and risk management activities. Communication channels are established to encourage reporting of any issues or hazardous situations.

3.5.5 Documentations

3.5.5.1 Sustainability and Environmental Management Documentation

- Özyeğin University ISO 14064-1 Standard Corporate Greenhouse Gas Inventory Report, Reporting Period: 2018-2020

This comprehensive study serves multiple purposes, including the calculation of our university's impact on climate change, ensuring preparedness for current and future regulatory requirements, and identifying potential risks and challenges in carbon management. It also adheres to the reporting guidelines of ISO 14064-1, allowing them to accurately report their greenhouse gas emissions. Furthermore, this report contributes to developing the Campus Environmental Management Plan and plays a crucial role in raising awareness regarding climate change, energy efficiency, and sustainability in university campus. By undertaking this study, they anticipate numerous benefits for Özyeğin University. Internally, it provides transparency on the resource consumption, emissions, and energy use, enabling the identification of opportunities for emission reduction and increase internal awareness. Externally, this report reinforces their commitment to sustainability and promotes their environmental identity, solidifying their position as a pioneer in the sector. [85]

- Campus Environmental Management Plan, 27.01.2021

This comprehensive study conducted by Özyeğin University serves multiple purposes, such as calculating the university's impact on climate change, ensuring compliance with regulatory requirements, and identifying risks and challenges in carbon management. The report follows ISO 14064-1 guidelines, ensuring accurate reporting of greenhouse gas emissions. It also contributes to the development of a Corporate Carbon Management Plan and plays a vital role in raising awareness among employees about climate change, energy efficiency, and sustainability. The study is expected to bring numerous benefits to the university, including increased transparency on resource consumption and emissions, identification of emission reduction opportunities, and enhanced internal awareness. It serves as a foundation for the Greenhouse Gas Management Plan and reinforces the university's commitment to sustainability, positioning it as a pioneer in the sector. [86]

- Özyeğin University Environment Policy, 27.01.2021

Özyeğin University is committed to protecting the environment and promoting sustainable practices, as outlined in its comprehensive Environment Policy. The university encourages everyone associated with its Çekmeköy Campus Facilities, including faculty, staff, students, visitors, businesses, neighbors, subcontractors, and suppliers, to actively contribute to environmental protection. Environmental hazards are carefully evaluated to mitigate risks and comply with internal and external regulations. Özyeğin University is dedicated to reducing environmental pollution, increasing energy efficiency, and continuously

improving its environmental management system. The policy emphasizes sustainable resource use, including recycling, preserving water and air quality, mitigating climate change, and protecting biodiversity and ecosystems. Senior management takes responsibility for leading the Environmental Management System and ensuring the quality of environmental protection processes. The policy covers various aspects such as environmental protection and risk management, waste management, energy efficiency, sustainability, communication, awareness management, change management, monitoring and improvement of environmental performance, and conducting regular reviews and audits. Özyeğin University is committed to fulfilling its commitments and being a leader in environmental protection and sustainability. [87]

• Campus Energy and Water Resources User Manual, 10.12.2018

The Özyeğin University Campus Energy and Water Resources User Manual serves as a comprehensive guide to promote the effective use of on-campus energy and water resources. The rules for energy efficiency and environmental protection which must be observed by all students, faculty and staff are further explained in detail in Campus Energy and Water Resources User Manual. As part of the university's commitment to sustainability, it is essential for students, faculty, and staff to take responsibility and actively support the campus energy management policy of "Reduce-Reuse-Recycle." The manual provides information on carbon footprints, emphasizing the importance of reducing carbon emissions and high energy costs through energy-saving practices and efficient resource utilization. It highlights the significance of energy efficiency in reducing carbon footprints and the importance of developing alternative

energy resources. The manual also mentions the European Union's goals for renewable energy, carbon emission reduction, and energy efficiency, as well as the role of the Kyoto Protocol in combating climate change. While Özyeğin University has made significant strides with LEED-certified buildings and self-generated clean energy resources, there is still potential for further energy savings on campus. Therefore, the manual emphasizes the crucial need for effective management and responsible use of energy and water resources across all academic and dormitory buildings. [83]

- Campus Waste Management Plan, 25.12.2019

Özyeğin University has developed a comprehensive Waste Management Plan to ensure responsible and conscious consumption across the campus. The plan covers various waste categories, including organic waste, domestic waste, waste from cafes and dining halls, metal waste, glass waste, plastic waste, paper and packaging waste, as well as other recyclable waste such as furniture and scrap. The university encourages users to dispose of waste in designated recycling bins, which are monitored by relevant organizations. Municipal collection takes place on a weekly basis to ensure proper disposal and recycling. Hazardous waste, such as lab chemicals, is carefully managed, with secure storage in PE drums and a dedicated temporary storage area. The university also addresses specific waste streams, such as vegetable oil waste, electronic waste, batteries, medical waste, waste oil, bulbs and ballasts, garden waste, bag filters of air conditioning units, textiles and clothing, and contaminated waste. The Waste Management Plan emphasizes conscious consumption, proper disposal practices, and regular monitoring by technical and operation officials. This proactive approach to

waste management contributes to Özyeğin University's commitment to sustainability and environmental responsibility. [88]

- Table of Amounts of Waste Generated at Özyeğin University in 2021

The Table of Amounts of Waste Generated at Özyeğin University in 2021 provides valuable insights into the university's waste generation patterns. Among the various waste categories, Packaging Waste, including paper, plastic, metal, and glass, emerged as the largest contributor, accounting for 28.30% of the total waste generated in 2021. Following closely behind is Organic Waste/Trash, representing 24.72% of the total waste. Electronic Waste also had a significant presence, comprising 24.28% of the overall waste. These figures highlight the importance of addressing packaging waste and promoting sustainable practices in waste management. Furthermore, it emphasizes the need for effective strategies to manage organic waste and electronic waste, ensuring proper disposal and recycling to minimize their environmental impact. Özyeğin University recognizes these waste streams as key areas for improvement in its ongoing efforts towards sustainability and waste reduction. [89]

3.5.5.2 *Disaster Management Documentation*

- Campus Emergency Policy, 27.01.2021

The Özyeğin University Emergency Policy is designed to ensure the safety and well-being of everyone within the Çekmeköy Campus Facilities. It emphasizes the importance of implementing emergency response procedures and taking appropriate actions during emergency situations to protect lives, minimize

losses, and maintain business continuity. With a commitment to its mission and principles, Özyeğin University takes proactive measures, meets necessary requirements, and provides resources to prevent, prepare for, and recover from emergencies. Compliance with relevant laws and regulations is guaranteed, and the university continuously improves its emergency management system through regular controls, tests, and drills. Senior management takes responsibility for upholding the commitments outlined in the policy, overseeing the installation and operation of essential systems, and ensuring the quality of all processes. The Emergency Policy is closely linked with the Health & Safety Policy and the Environment Policy, forming an integrated approach to emergency preparedness and response. Key aspects of the policy include prevention, emergency response, post-emergency recovery and communication, monitoring and improvement of emergency management performance, as well as reviews and audits. [90]

- First Aid Seminar Booklet

The Özyeğin University First Aid Booklet, prepared in collaboration with Acıbadem, is a valuable resource aimed at enhancing the knowledge and skills of students, faculty members, and employees in the field of first aid. This comprehensive booklet provides detailed information on emergency response procedures and life-saving techniques, equipping individuals with the necessary tools to handle critical situations effectively. Acıbadem's expertise and guidance in developing the booklet ensures that the content is accurate, reliable, and up-to-date. By utilizing the information and techniques presented in the booklet, individuals can gain a deeper understanding of first aid principles and develop

practical skills that can be applied both on campus and in real-life scenarios. This collaborative effort highlights Özyeğin University's dedication to promoting the health and well-being of its community and instilling a culture of safety and care. The First Aid Booklet serves as an essential guide, empowering individuals to respond swiftly and confidently in emergencies, ultimately creating a safer and more prepared campus environment. [91]

• Campus Health & Safety Policy, 27.01.2021

The Health & Safety Policy of Özyeğin University Çekmeköy Campus Facilities is deeply rooted in its mission and principles, prioritizing the physical and psychological well-being and occupational safety of all individuals within its community. Through comprehensive measures, adherence to requirements, and provision of necessary resources, the university is committed to preventing health issues and continuously improving occupational health and safety performance. By carefully assessing potential risks and striving for compliance with internal and external regulations, Özyeğin University ensures that occupational health and safety are maintained at acceptable levels. The university guarantees a healthy and safe working environment, promotes employee consultation and participation, complies with legislations, and leads in occupational health and safety through best management practices. With the commitment of senior management, the Occupational Health and Safety Management System is upheld, and all processes are subjected to quality assurance. The policy encompasses various aspects such as cultivating an occupational health and safety culture, risk management, communication and awareness, health protection, sustainability, and change management. Regular

reviews and audits further strengthen the university's commitment to maintaining a safe and healthy environment for all. [92]

- Health & Safety Management Plan, 27.01.2021-27.01.2027

The Health & Safety Policy of Özyeğin University Çekmeköy Campus Facilities is deeply ingrained in the core values and mission of the institution, placing utmost importance on the physical, psychological, and occupational well-being of all community members. The university employs a holistic approach to health and safety, implementing comprehensive measures, adhering to regulatory requirements, and allocating necessary resources to prevent health issues and continually enhance occupational health and safety performance. Through meticulous risk assessments and diligent compliance with internal and external regulations, Özyeğin University ensures that occupational health and safety are maintained at acceptable levels. The university is dedicated to providing a healthy and safe working environment by fostering employee consultation and active participation, complying with legislative requirements, and pioneering best practices in occupational health and safety management. With the unwavering commitment of senior management, the Occupational Health and Safety Management System is diligently upheld, and all processes undergo rigorous quality assurance. The policy encompasses a wide range of areas, including fostering an occupational health and safety culture, effective risk management, proactive communication and awareness, safeguarding employee health, promoting sustainability, and embracing change management. Regular reviews and audits further reinforce the university's dedication to upholding a safe and healthy environment for all members of its community. [93]

- General Chemistry Lab Safety, 01.08.2014

The General Chemistry Lab Safety in Özyeğin University emphasizes the importance of maintaining a safe and secure environment within the laboratory setting. While the laboratory is a space for exploration and education, it also presents potential risks if proper precautions are not taken. Although efforts have been made to minimize the use of hazardous substances, it is inevitable that the use of various chemicals and glassware may pose certain risks. It is crucial for all students to familiarize themselves with and strictly adhere to the general safety guidelines provided. These guidelines are in place to ensure the well-being of both individuals conducting experiments and those in proximity. Furthermore, specific safety measures will be communicated before any experiments involving potential hazards. Non-compliance with safety regulations may result in consequences such as removal from the lab or grading penalties. By prioritizing safety and following established protocols, a secure and productive laboratory environment can be always maintained. [94]

- Occupational Health and Safety Hazard-Risk Assessment Table

The Occupational Health and Safety Hazard-Risk Assessment Table in Özyeğin University serves as a crucial tool for systematically identifying, evaluating, and controlling workplace hazards and risks. It aims to create a safe and healthy work environment for all members of the university community. By conducting thorough assessments, the university can prioritize and implement appropriate control measures to prevent accidents, injuries, and occupational illnesses. The table promotes communication and collaboration among different departments,

acting as a central reference for documenting hazards, risk assessments, and control measures. It ensures compliance with occupational health and safety regulations and demonstrates the university's commitment to a safe learning and working environment. Regular review and updates allow for monitoring, evaluation, and improvement of control measures. The Hazard-Risk Assessment Table is an integral part of Özyeğin University's overall occupational health and safety management system, fostering a culture of safety and continuous improvement. [84]

- Environmental Impact Assessment Table

The Environmental Impact Assessment (EIA) Table at Özyeğin University serves as a crucial tool for evaluating and managing the environmental impact of the university's activities. It systematically identifies and assesses potential environmental risks and impacts, allowing the university to develop strategies and measures to mitigate its environmental footprint. The table acts as a centralized reference point, documenting and monitoring environmental impacts and facilitating collaboration among stakeholders. Regular review and updates help track progress, evaluate effectiveness, and identify areas for improvement. The EIA Table demonstrates Özyeğin University's commitment to environmental stewardship and sustainable development, aiming to minimize its ecological footprint, protect natural resources, and contribute to a more sustainable future. [84]

- Security Services Procedure, 11.07.2017

The Security Services Procedure at Özyeğin University is established to outline the security practices implemented at the entrance and exit points, on-campus traffic regulations, disciplinary procedures, and the principles and procedures for security checks and inspections on the Çekmeköy Campus. The procedure applies to all individuals entering or exiting the Özyeğin University campus, ensuring the safety and security of everyone within the university community. By providing clear guidelines and protocols, the procedure aims to maintain a secure environment for all members of the university campus. [95].

CHAPTER IV

SUSTAINABLE AND RESILIENT SMART CAMPUS INDEX

The sustainable and smart campus index is a valuable tool for promoting sustainability and resilience in university campuses. Key features of the index include renewable and efficient energy, water conservation, sustainable land use, green buildings, disaster preparedness, and community engagement. By implementing these features, universities can create environmentally friendly campuses that can adapt and recover from potential hazards and disruptions. The Özyeğin University Çekmeköy Campus in Turkey is a prime example of a campus that prioritizes sustainability and resilience, being the first LEED-certified campus in the country. The sustainable and smart campus index is a vital step towards creating campuses that promote a better future for both current and future generations. In defining sustainability and resilience features, sustainability aims to maintain and preserve resources and systems over the long term, while resilience is about withstanding and recovering from disturbances or shocks. The index includes 14 features that form its foundation. Implementing these features is crucial for managing land and natural resources, reducing carbon footprints, conserving water, and mitigating the impact of climate change. By prioritizing sustainability and resilience in campus design and management, universities can create safe and efficient environments that meet the needs of both students and the environment.

Table 10: Sustainable and Resilient Smart Campus Index- Sustainability Indicators
(references based on table 4 and 5)

	Sustainability						
	Water Management	Sustainable Land Use	Green Buildings	Waste Management	Renewable and Efficient Energy	Access to Transportation	Indoor Environmental Quality
Features / Identification	Rainwater harvesting systems	Implementation of green infrastructure for stormwater management	Water-efficient plumbing fixtures and fittings	Use of refillable water bottle stations	Smart building automation systems	Education and awareness programs for sustainable transportation	Use of low-toxicity building materials
	Use of permeable paving and green infrastructure for stormwater management	Use of permeable surfaces for improved soil health	Green roofs and living walls	Implementation of waste reduction strategies	Use of energy-efficient HVAC systems	Bike-sharing and bike storage facilities	Use of non-toxic cleaning products
	Use of low-flow showerheads and toilets	Green roofs and living walls	Use of low-toxicity building materials	Use of sustainable purchasing policies	Net-zero energy buildings	Campus shuttle buses and vanpools	Use of natural light and ventilation
	Greywater recycling systems	Integration of green spaces into campus design	Use of non-toxic cleaning products	Waste audits and assessments	Renewable energy credits and carbon offsets	Car-sharing and carpooling programs	Education and awareness programs for occupant health and well-being
	Efficient plumbing fixtures and fittings	Use of sustainable landscaping practices	Energy-efficient HVAC systems	Use of zero-waste events and practices	Energy management systems for monitoring and control	Electric vehicle charging stations	Use of low-VOC paints and finishes
	Water-efficient landscaping and irrigation systems	Preservation of natural areas and ecosystems	Use of net-zero energy building design	Education and awareness programs for waste reduction and recycling	Power-saving measures for computer labs and data centers	Promotion of alternative transportation modes	Use of air filtration systems
	Water audits and assessments	Sustainable agriculture and food production practices	Use of building automation for heating and cooling control	Provision of clearly marked recycling and composting bins	Use of geothermal heating and cooling systems	Use of sustainable transportation options for field trips and excursions	Use of indoor air quality monitoring and control systems
	Use of water-efficient appliances and equipment	Sustainable waste management practices	Smart building automation systems	Use of electronic communication and document management to reduce paper waste	Energy audits and assessments	Development of pedestrian-friendly campus design	Implementation of indoor humidity control
	Leak detection and repair programs	Use of non-toxic pest control methods	Use of natural light and ventilation	Use of reusable dining ware and utensils	Demand response systems	Provision of sidewalks and crosswalks	Use of acoustic design to minimize noise pollution
	Education and awareness programs for water conservation	Management of hazardous materials and pollutants	Use of energy-efficient windows and insulation	Implementation of source separation of waste	Solar panels and other renewable energy sources	Safe and accessible pedestrian and bicycle routes	Use of daylighting strategies to promote occupant health
	Water-efficient dishwashing and laundry systems	Use of native plants for landscaping	Use of solar shading and daylighting strategies	Donation and reuse programs for unwanted items	Battery storage for renewable energy	Implementation of traffic calming measures	Integration of plants and greenery into indoor spaces
	Use of drought-resistant plants and landscaping materials	Use of sustainable building materials	Use of sustainable and locally-sourced building materials	Recycling and composting programs	Energy-efficient lighting and appliances	Use of public transportation passes or discounts	Use of ergonomic furniture and equipment
	Cooling tower water treatment and management	Green procurement policies for campus purchases	Use of smart power outlets and power strips	Use of waste reduction and recycling certification programs	Use of microgrids for distributed energy generation	Integration of transportation options into campus technology platforms	Implementation of thermal comfort standards
	Water metering and monitoring systems	Preservation of historic buildings and landmarks	Use of energy-efficient building design and systems	Implementation of waste reduction and recycling signage	Campus-wide energy conservation programs	Provision of secure and covered bike parking	Use of flexible workspace design for employee well-being
	Use of reclaimed water for non-potable uses	Energy-efficient street lighting and signage	Use of indoor air quality monitoring and control systems	Development of partnerships with local recycling and waste management companies	Use of energy-efficient windows and insulation	Coordination with local transportation providers	Use of indoor environmental quality certification programs

Table 11: Sustainable and Resilient Smart Campus Index- Sustainability Indicators
(references based on table 4 and 5)

Resilience						
Infrastructure Resilience	Risk Assessment	Adaptive Design	Disaster Preparedness	Emergency Management	Continuity Planning	Community Engagement
Resilient water supply and treatment systems	Identification of key risk indicators	Use of green roofs and living walls	Adequate fuel and water supply	Resilient building design and construction	Executive leadership and support	Establishment of student-run organizations and initiatives
Resilient landscaping and green infrastructure	Regular risk assessments	Use of resilient landscaping and green infrastructure	Flood prevention and mitigation measures	Automated emergency response systems	Business continuity plan	Regular communication with stakeholders
Climate-adaptive infrastructure design	Identification of key risks and vulnerabilities	Design for reduced water use and waste generation	Real-time weather monitoring and analysis	Centralized monitoring and control systems	Crisis management team	Collaborative decision-making processes
Smart building automation systems	Prioritization of risk mitigation strategies	Flexibility in building design and layout	Hazard-resistant building design and construction	Effective and reliable communication systems	Alternate work locations	Use of feedback mechanisms
Energy-efficient buildings and facilities	Quantification of potential impact and likelihood of risks	Building orientation and shading to minimize energy use	Early warning systems for natural disasters	On-site security personnel and emergency responders	Data backup and recovery systems	Public outreach and education programs
Resilient waste management systems	Continuous monitoring of risk landscape	Use of sustainable and resilient materials	Effective communication protocols and systems	Access control and surveillance systems	Dual power and data feeds	Partnership development with local organizations and businesses
Hazard-resistant infrastructure design and construction	Establishment of risk management framework	Use of passive heating and cooling strategies	On-campus emergency generators	Mass notification systems	Cybersecurity measures	Volunteer and community service opportunities
Robust IT and communication infrastructure	Use of risk assessment tools and techniques	Accessibility for people with disabilities	Robust IT infrastructure to support emergency response	Incident reporting and tracking systems	Emergency funds and resources	Participatory planning and design processes
Backup and recovery systems	Integration of risk assessment into decision-making processes	Energy-efficient building design and systems	Redundant power and data systems	Incident command and control center	Supply chain continuity plan	Public meetings and forums
Sustainable transportation options	Coordination with external partners and stakeholders	Multi-purpose spaces and facilities	Regular emergency preparedness drills and exercises	Integration with local emergency services	Scenario planning and simulation exercises	Use of social media and digital communication channels
Disaster recovery plan	Risk communication plans	Incorporation of natural light and ventilation	Comprehensive emergency management plan	Dedicated emergency operations center	Communication plans for stakeholders	Campus events and activities that promote engagement
Redundant power and data systems	Regular review and update of risk assessments	Smart building automation systems	Integration with local emergency management agencies	Redundant power and data systems	Legal and regulatory compliance	Cultivation of a sense of community and shared responsibility
Coordination with local utilities and service providers	Involvement of senior leadership in risk management	Integration of technology infrastructure into building design	Stockpiles of essential supplies	Regular training and drills for emergency response teams	Coordination with external agencies and partners	Support for diversity and inclusion
Resilient critical infrastructure components	Training and education programs for risk management	Design for future expansion and growth	Well-defined roles and responsibilities for key personnel	Shelter-in-place facilities	Recovery and restoration plan	Use of surveys and polls to gather feedback
Regular infrastructure inspections and maintenance	Use of risk appetite and tolerance statements	Use of modular and adaptable building components	Shelter-in-place facilities	Integrated IT and physical security systems	Continual monitoring and improvement	Involvement of students in campus decision-making

4.1 Water Management

The listed features of water management are integral to creating a sustainable smart campus. Efficient plumbing fixtures and fittings, including low-flow showerheads and toilets, minimize water consumption while maintaining functionality. Greywater recycling systems and rainwater harvesting systems capture and treat water from various sources, reducing reliance on freshwater supplies. Water-efficient landscaping and irrigation systems optimize water usage in outdoor spaces. Water audits and assessments help identify areas for improvement and guide water conservation strategies. The use of water-efficient appliances and equipment further reduces water waste. Leak detection and repair programs ensure timely resolution of leaks, preventing unnecessary water loss. Education and awareness programs promote water conservation practices among the campus community. Water-efficient dishwashing and laundry systems minimize water usage in these facilities. Incorporating drought-resistant plants and landscaping materials conserves water in landscaping design. Cooling tower water treatment and management systems reduce water consumption in cooling processes. Permeable paving and green infrastructure for stormwater management facilitate natural water filtration and absorption, mitigating stormwater runoff. Water metering and monitoring systems provide real-time data on water usage, enabling efficient monitoring and control. Finally, the use of reclaimed water for non-potable uses, such as irrigation or toilet flushing, helps conserve freshwater resources. Together, these features contribute to a sustainable smart campus that optimizes water usage, reduces water waste, and promotes responsible water stewardship, ensuring a resilient water management system for the campus and surrounding environment.

4.2 Sustainable Land use

The listed features of sustainable land use play a crucial role in creating a sustainable smart campus. Preservation of natural areas and ecosystems helps maintain biodiversity and supports the campus's ecological balance. Sustainable landscaping practices promote the use of native plants, reduce water consumption, and minimize the need for chemical fertilizers or pesticides. Utilizing permeable surfaces improves soil health, enhances groundwater recharge, and reduces stormwater runoff. Green roofs and living walls not only provide aesthetic appeal but also contribute to energy efficiency and air quality improvement. Integrating green spaces into campus design creates a harmonious blend of nature and built environments, enhancing the overall campus experience. Implementing green infrastructure for stormwater management reduces the impact of heavy rainfall events and helps prevent water pollution. Sustainable agriculture and food production practices promote local sourcing, organic farming, and waste reduction in campus dining facilities. Proper management of hazardous materials and pollutants ensures a safe and healthy environment for the campus community. Non-toxic pest control methods minimize harm to the ecosystem and human health. Energy-efficient Street lighting and signage reduce energy consumption and light pollution. Preservation of historic buildings and landmarks honors the campus's heritage while promoting sustainability through adaptive reuse. Using sustainable building materials reduces the environmental impact of construction and improves indoor air quality. Green procurement policies for campus purchases prioritize environmentally friendly products and services. Sustainable waste management practices include recycling, composting, and waste reduction initiatives, minimizing landfill contributions. By incorporating these features, a sustainable smart campus establishes a harmonious relationship between the built environment and nature,

fostering a vibrant and resilient campus that supports ecological integrity, resource efficiency, and the well-being of its community.

4.3 Green Buildings

The listed features of green buildings are essential components of a sustainable smart campus. By incorporating energy-efficient building design and systems, campuses can significantly reduce energy consumption and minimize their carbon footprint. The use of sustainable and locally-sourced building materials promotes resource conservation and supports local economies. Smart building automation systems optimize energy usage by intelligently controlling lighting, heating, and cooling systems. Maximizing natural light and ventilation not only reduces energy demand but also enhances occupant comfort and well-being. Green roofs and living walls not only provide aesthetic appeal but also offer insulation, stormwater management, and biodiversity benefits. Water-efficient plumbing fixtures and fittings contribute to water conservation efforts. Using low-toxicity building materials and non-toxic cleaning products promotes a healthier indoor environment. Energy-efficient windows and insulation improve thermal performance and reduce energy loss. Solar shading and daylighting strategies optimize natural light while minimizing heat gain. Energy-efficient HVAC systems enhance comfort while reducing energy consumption. Smart power outlets and power strips enable efficient power management and reduce standby power usage. Net-zero energy building design aims to generate as much energy as it consumes, further minimizing environmental impact. Building automation systems for heating and cooling control ensure optimal temperature control and energy efficiency. Indoor air quality monitoring and control systems promote a healthy environment by monitoring and maintaining air quality parameters. By

implementing these features, a sustainable smart campus creates buildings that are energy-efficient, environmentally friendly, and conducive to occupant well-being, ultimately fostering a sustainable and healthy learning and working environment for the campus community.

4.4 Waste Management

The listed features of waste management are essential components of a sustainable smart campus, aiming to minimize waste generation and promote responsible disposal practices. Implementation of waste reduction strategies focuses on minimizing the overall amount of waste produced on campus through efficient resource usage and mindful consumption. Recycling and composting programs provide convenient and clearly marked bins for the separation and proper disposal of recyclable and organic waste, diverting materials from landfills. Waste audits and assessments help identify areas for improvement and measure the effectiveness of waste management initiatives. Zero-waste events and practices aim to eliminate waste sent to landfills during campus events, encouraging the use of reusable or compostable materials. Refillable water bottle stations reduce the consumption of single-use plastic bottles. Electronic communication and document management systems minimize paper waste by promoting digital alternatives. Use of reusable dining ware and utensils in campus dining facilities reduces single-use plastic waste. Implementation of source separation of waste ensures that different types of waste are properly segregated for appropriate recycling or disposal. Donation and reuse programs provide opportunities for unwanted items to find new homes or purposes, reducing waste and promoting a circular economy. Sustainable purchasing policies guide procurement decisions towards environmentally friendly and recyclable products. Waste reduction and recycling

certification programs provide guidelines and recognition for campuses that excel in waste management practices. Education and awareness programs raise awareness among the campus community about waste reduction, recycling, and responsible disposal practices. Waste reduction and recycling signage help individuals make informed choices when disposing of their waste. Development of partnerships with local recycling and waste management companies ensures proper and efficient waste handling and disposal. By implementing these features, a sustainable smart campus fosters a culture of waste reduction, recycling, and responsible waste management, contributing to environmental conservation and promoting a circular economy.

4.5 Renewable and Efficient Energy

The listed features are critical for a sustainable smart campus as they focus on renewable and efficient energy sources and practices. Solar panels and other renewable energy sources, such as wind turbines, allow campuses to generate clean and sustainable energy, reducing reliance on fossil fuels and lowering carbon emissions. Energy-efficient lighting and appliances help minimize energy consumption, while smart building automation systems enable efficient control and optimization of energy usage. Energy management systems provide real-time monitoring and control, allowing campuses to identify and address energy inefficiencies promptly. Power-saving measures for computer labs and data centers help reduce energy waste in high-demand areas. The use of energy-efficient HVAC systems and geothermal heating and cooling systems ensures optimal energy usage and reduces reliance on traditional heating and cooling methods. Energy audits and assessments help identify areas of improvement and guide energy-saving strategies. Net-zero energy buildings aim to produce as much energy as they consume, making them

highly sustainable. Demand response systems allow campuses to adjust energy usage during peak demand periods, contributing to grid stability. Battery storage facilitates the storage and utilization of excess renewable energy, promoting energy resilience. Renewable energy credits and carbon offsets further support sustainability goals by offsetting carbon emissions. Campus-wide energy conservation programs encourage behavioral changes and promote energy-saving practices among the campus community. The use of energy-efficient windows and insulation enhances thermal comfort and reduces energy loss. Microgrids enable distributed energy generation, improving energy efficiency and reliability. Collectively, these features create a sustainable smart campus that prioritizes renewable energy, energy efficiency, and environmental stewardship, contributing to a greener future for both the campus and the broader community.

4.6 Access to Transportation

The listed features of access to transportation contribute to creating a sustainable smart campus that prioritizes efficient and eco-friendly mobility options for its community. Bike-sharing and bike storage facilities promote active transportation, reducing reliance on cars and promoting physical fitness. Campus shuttle buses and vanpools provide convenient and shared transportation options, reducing the number of single-occupancy vehicles on campus. Car-sharing and carpooling programs encourage carpooling and shared vehicle usage, reducing congestion and emissions. Electric vehicle charging stations support the adoption of electric vehicles, contributing to reduced carbon emissions. Promoting alternative transportation modes, such as walking and public transit, encourages sustainable commuting choices. Sustainable transportation options for field trips and excursions further minimize environmental impact. Development of

pedestrian-friendly campus design prioritizes the safety and comfort of pedestrians, fostering walkability. Provision of sidewalks, crosswalks, and accessible pedestrian and bicycle routes enhances safety and accessibility for active transportation. Implementation of traffic calming measures improves safety and encourages lower speeds. Use of public transportation passes or discounts encourages the use of public transit, reducing the reliance on private vehicles. Integration of transportation options into campus technology platforms facilitates easy access to transportation information and services. Provision of secure and covered bike parking promotes cycling as a viable transportation choice. Coordination with local transportation providers enables seamless connections to the wider transportation network. Education and awareness programs raise awareness about sustainable transportation options and their benefits, encouraging the campus community to make environmentally conscious choices. By implementing these features, a sustainable smart campus fosters a culture of sustainable transportation, reducing traffic congestion, emissions, and promoting healthier and more sustainable commuting options for students, faculty, and staff.

4.7 Indoor Environmental Quality

The listed features of indoor environmental quality contribute to creating a sustainable smart campus that prioritizes the well-being and comfort of its occupants. By utilizing natural light and ventilation, campuses can reduce reliance on artificial lighting and mechanical ventilation systems, resulting in energy savings and improved occupant satisfaction. The use of low-toxicity building materials and non-toxic cleaning products ensures a healthy indoor environment by minimizing the presence of harmful chemicals. Low-VOC paints and finishes further reduce indoor air pollution and promote better air

quality. Air filtration systems enhance indoor air quality by removing pollutants and allergens from the air. Indoor air quality monitoring and control systems continuously monitor air parameters and adjust ventilation rates to maintain optimal air quality. Implementing indoor humidity control measures help prevent mold growth and maintain a comfortable environment. Acoustic design strategies minimize noise pollution, creating a quieter and more productive indoor environment. Daylighting strategies not only enhance visual comfort but also positively impact occupant health and well-being. Integrating plants and greenery into indoor spaces improves air quality, reduces stress, and enhances overall well-being. The use of ergonomic furniture and equipment supports occupant comfort and reduces the risk of musculoskeletal issues. Implementation of thermal comfort standards ensures that indoor temperatures are within a comfortable range. Flexible workspace designs cater to the diverse needs of occupants, promoting productivity and well-being. Indoor environmental quality certification programs provide a framework for assessing and improving the quality of indoor spaces. Education and awareness programs raise occupant consciousness about the importance of health and well-being, fostering a culture of well-being within the campus community. By incorporating these features, a sustainable smart campus creates indoor environments that are conducive to productivity, health, and overall occupant satisfaction, fostering a positive and thriving atmosphere for students, faculty, and staff.

4.8 Infrastructure Resilience

The features listed for infrastructure resilience in a smart campus contribute to the overall resilience and durability of campus infrastructure. Redundant power and data systems ensure that essential services remain operational even during disruptions. Hazard-resistant infrastructure design and construction help withstand natural and man-made hazards. A robust IT and communication infrastructure supports effective communication and coordination during emergencies. Backup and recovery systems ensure that critical data and systems can be restored promptly. A disaster recovery plan outlines procedures and protocols for responding to infrastructure disruptions. Resilient water supply and treatment systems ensure a reliable water source for the campus community. Energy-efficient buildings and facilities minimize resource consumption and promote sustainability. Smart building automation systems enhance the efficiency and responsiveness of infrastructure operations. Sustainable transportation options reduce dependence on traditional transportation modes. Resilient landscaping and green infrastructure help mitigate the impact of extreme weather events. Resilient waste management systems ensure proper waste disposal and recycling even under challenging conditions. Climate-adaptive infrastructure design anticipates and accommodates the effects of climate change. Regular infrastructure inspections and maintenance identify and address vulnerabilities proactively. Coordination with local utilities and service providers facilitates efficient service restoration and maintenance. By incorporating these features, a resilient smart campus ensures the continuity of essential infrastructure services and enhances the campus's ability to withstand and recover from disruptions.

4.9 Risk Assessment

The listed features of a resilient smart campus contribute to effective risk assessment, enabling the identification, prioritization, and mitigation of key risks and vulnerabilities. Regular risk assessments are conducted to evaluate the campus's exposure to various risks. Key risks and vulnerabilities are identified, allowing the campus to focus resources on the most critical areas. The potential impact and likelihood of risks are quantified, providing a basis for informed decision-making. Continuous monitoring of the risk landscape ensures that emerging risks are promptly identified and addressed. A risk management framework is established to guide risk mitigation efforts and ensure consistency across the campus. Risk assessment tools and techniques are utilized to facilitate comprehensive and accurate assessments. Integration of risk assessment into decision-making processes ensures that risk considerations are factored into strategic and operational planning. Coordination with external partners and stakeholders enhances the campus's ability to address risks collaboratively. Risk communication plans are developed to facilitate effective communication with relevant parties. Regular review and update of risk assessments enable the campus to adapt to evolving risks and changing circumstances. Senior leadership plays a crucial role in risk management, providing oversight and support to the process. Training and education programs are implemented to enhance risk management capabilities across the campus. Risk appetite and tolerance statements help establish clear guidelines for risk-taking and decision-making. Key risk indicators are identified to enable proactive monitoring and early detection of potential risks. By incorporating these features, a resilient smart campus is better equipped to anticipate, mitigate, and respond to risks, enhancing the overall resilience of the campus community.

4.10 Adaptive Design

Adaptive design is a fundamental aspect of a resilient smart campus, enabling it to respond and adapt to changing needs and circumstances. Flexibility in building design and layout allows spaces to be easily reconfigured for different purposes, optimizing their utilization. Multi-purpose spaces and facilities offer versatility and accommodate various activities. The use of modular and adaptable building components allows for quick and efficient modifications or expansions as needed. Incorporating natural light and ventilation enhances occupant comfort and reduces energy consumption. Sustainable and resilient materials ensure durability and minimize environmental impact. Integration of technology infrastructure into building design supports smart systems and connectivity. Accessibility features cater to the needs of individuals with disabilities, promoting inclusivity. Energy-efficient building design and systems minimize energy use and support sustainability goals. Green roofs and living walls enhance building aesthetics, air quality, and environmental benefits. Building orientation and shading strategies optimize energy efficiency. Smart building automation systems enable efficient management and control of building operations. Passive heating and cooling strategies reduce reliance on mechanical systems. Design considerations for future expansion and growth accommodate future needs without significant disruptions. Emphasizing reduced water use and waste generation in design reduces resource consumption and supports sustainability. Resilient landscaping and green infrastructure contribute to the campus's overall resilience and ecological balance. By incorporating these features, a resilient smart campus demonstrates adaptability, sustainability, and an ongoing commitment to meeting evolving needs and challenges.

4.11 Disaster Preparedness

The listed features of a resilient smart campus play a crucial role in ensuring the preparedness and response capabilities of the campus during emergencies and natural disasters. A comprehensive emergency management plan serves as a guiding document that outlines procedures and protocols to be followed during various emergency scenarios. Adequate fuel and water supply ensure the campus can sustain essential operations during extended periods of disruption. Redundant power and data systems provide backup options to maintain critical services and communication channels. Early warning systems enable the campus to receive timely alerts and notifications about impending natural disasters. Effective communication protocols and systems facilitate clear and timely dissemination of information to the campus community. On-campus emergency generators offer an additional power source in the event of a power outage. A robust IT infrastructure supports emergency response efforts by ensuring uninterrupted connectivity and access to vital systems. Hazard-resistant building design and construction techniques minimize the potential impact of disasters on campus structures. Regular emergency preparedness drills and exercises help familiarize the campus community with emergency procedures and enhance their response capabilities. Real-time weather monitoring and analysis allow for proactive decision-making based on changing weather conditions. Integration with local emergency management agencies promotes coordination and collaboration during emergencies. Stockpiles of essential supplies ensure the availability of necessary resources during crisis situations. Flood prevention and mitigation measures are implemented to minimize the impact of flooding events. Shelter-in-place facilities provide safe spaces for individuals to seek refuge during emergencies. Well-defined roles and responsibilities for key personnel clarify their duties

and ensure efficient emergency response operations. By incorporating these features, a resilient smart campus is better equipped to protect the safety and well-being of its occupants, maintain essential services, and facilitate a timely and effective response in the face of emergencies and natural disasters.

4.12 Emergency Management

The listed features of a resilient smart campus contribute to effective emergency management and response capabilities. Automated emergency response systems provide rapid and automated responses to emergency situations, enhancing the efficiency and speed of response efforts. Centralized monitoring and control systems enable real-time monitoring of campus facilities and systems, allowing for immediate detection and response to potential emergencies. Effective and reliable communication systems facilitate seamless communication among emergency response teams, campus administrators, and the campus community during critical situations. On-site security personnel and emergency responders are trained professionals equipped to handle various emergency scenarios and provide immediate assistance. Access control and surveillance systems help secure the campus and monitor potential threats or unauthorized access. Mass notification systems ensure timely and widespread dissemination of emergency alerts and instructions to the campus community. Incident reporting and tracking systems enable the collection and analysis of data related to emergencies, facilitating post-incident evaluation and improvement of emergency response procedures. An incident command and control center serves as a centralized hub for coordinating emergency response operations and decision-making. Integration with local emergency services promotes collaboration and coordination with external response agencies. A dedicated emergency

operations center provides a central location for managing and coordinating emergency response efforts. Redundant power and data systems ensure continuous operation of critical infrastructure and communication networks during emergencies. Resilient building design and construction techniques enhance the ability of campus structures to withstand and recover from adverse events. Shelter-in-place facilities offer safe spaces for individuals to seek refuge during emergencies. Integrated IT and physical security systems enhance overall security and enable effective incident management. Regular training and drills for emergency response teams prepare them to respond swiftly and efficiently during crisis situations. By incorporating these features, a resilient smart campus is well-prepared to handle emergencies, mitigate risks, and protect the safety and well-being of its campus community.

4.13 Continuity Planning

The listed features of a resilient smart campus contribute to effective continuity planning, ensuring that essential campus functions and operations can continue in the event of a disruption. A business continuity plan outlines strategies and procedures to maintain critical operations and minimize the impact of disruptions. A crisis management team is responsible for coordinating and executing the plan, ensuring a swift and coordinated response. Alternate work locations provide backup facilities where employees can continue their work during a crisis. Data backup and recovery systems safeguard important campus data and enable rapid restoration in case of data loss. Dual power and data feeds provide redundancy, reducing the risk of service disruptions. Cybersecurity measures protect campus systems and data from cyber threats. Emergency funds and resources are allocated to support recovery efforts and ensure essential needs are met. A

supply chain continuity plan ensures the availability of necessary resources during and after a disruption. Scenario planning and simulation exercises help identify potential risks and test response strategies. Communication plans for stakeholders ensure timely and accurate dissemination of information during a crisis. Legal and regulatory compliance measures ensure adherence to applicable laws and regulations. Coordination with external agencies and partners facilitates a collaborative approach to managing disruptions. A recovery and restoration plan outlines steps to restore normal operations and infrastructure. Continual monitoring and improvement processes enable the campus to learn from past experiences and enhance its resilience over time. Executive leadership and support provide guidance and resources to effectively implement continuity planning measures. By incorporating these features, a resilient smart campus is prepared to navigate through disruptions, minimize downtime, and ensure the continuity of essential services for the campus community.

4.14 Community Engagement

Community engagement is a crucial aspect of a resilient smart campus, as it fosters collaboration, inclusivity, and a shared sense of responsibility among campus stakeholders. Regular communication with stakeholders ensures that their perspectives and concerns are heard and addressed. Collaborative decision-making processes involve stakeholders in the planning and implementation of campus initiatives. Feedback mechanisms, such as surveys and polls, enable continuous dialogue and improvement. Public outreach and education programs raise awareness about campus initiatives and sustainability goals. Partnership development with local organizations and businesses promotes mutual support and resource sharing. Volunteer and community service

opportunities allow individuals to contribute to the campus and local community. Participatory planning and design processes empower stakeholders to shape the campus environment. Public meetings and forums provide platforms for open dialogue and engagement. Utilizing social media and digital communication channels enhances accessibility and reach. Campus events and activities that promote engagement create opportunities for connection and dialogue. Cultivating a sense of community and shared responsibility strengthens campus resilience. Supporting diversity and inclusion ensures that all voices are represented and valued. Involving students in campus decision-making empowers them as active participants in shaping their educational experience. The establishment of student-run organizations and initiatives promotes leadership and engagement. By incorporating these features, a resilient smart campus creates a vibrant and inclusive community that collaboratively works towards building a more sustainable and resilient future.

CHAPTER V

SIMULATION

5.1 Creating the topography for Campus area

In order to accurately represent the topography of the campus and its surrounding area, the Autodesk Revit [96] program and the PlaceMaker [97] plugin connected to Revit were employed. The PlaceMaker plugin facilitated the utilization of Cesium-ion [98], a 3D geospatial technology platform, to export the topography with a grid spacing of 10m using GIS connectivity. The selection of the export area was based on the relief map provided by the Istanbul Metropolitan Municipality, taking into account the highest and lowest points of the geography. This area encompassed not only the campus but also the nearby subways, residential areas, and surrounding forests, ensuring a comprehensive representation of the context.

Subsequently, a high-resolution satellite image was generated using Mapbox [99], a cloud-based mapping and location platform for developers. This satellite image was then accurately overlaid onto the exported topography surface, ensuring a realistic representation of the terrain. The integration of the satellite image onto the topography provided valuable visual information and enhanced the overall accuracy of the model.

The resulting terrain model, representing the Özyeğin University Campus and its surroundings, was then transferred to the Rhinoceros 3D program. Rhinoceros 3D powerful simulation capabilities made it the ideal software for further analysis and visualization of the campus terrain. This transfer enabled the utilization of the terrain

model in various simulations, such as analyzing water runoff patterns, assessing solar exposure, and evaluating the impact of the terrain on building placement and design.

Overall, the use of Revit, the PlaceMaker plugin, Cesium-ion, Mapbox, and Rhino facilitated the creation of an accurate and detailed representation of the campus topography. This comprehensive terrain model serves as a valuable tool for conducting simulations, enhancing design decisions, and improving the overall planning and development process of Özyeğin University Campus.

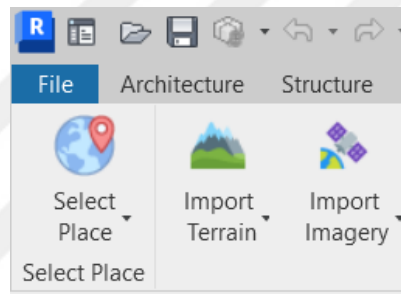


Figure 45: PlaceMaker tools for exporting topography

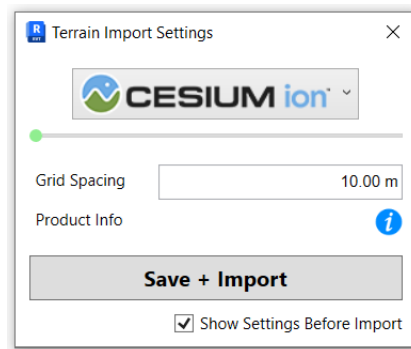


Figure 46: PlaceMaker tools for exporting topography, Cesium-ion

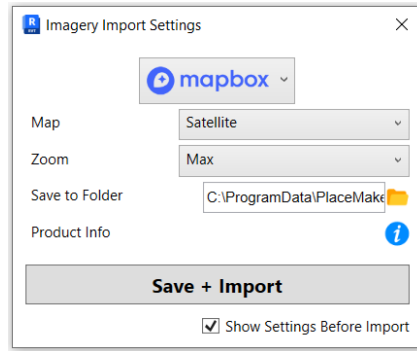


Figure 47: PlaceMaker tools for exporting topography, Mapbox

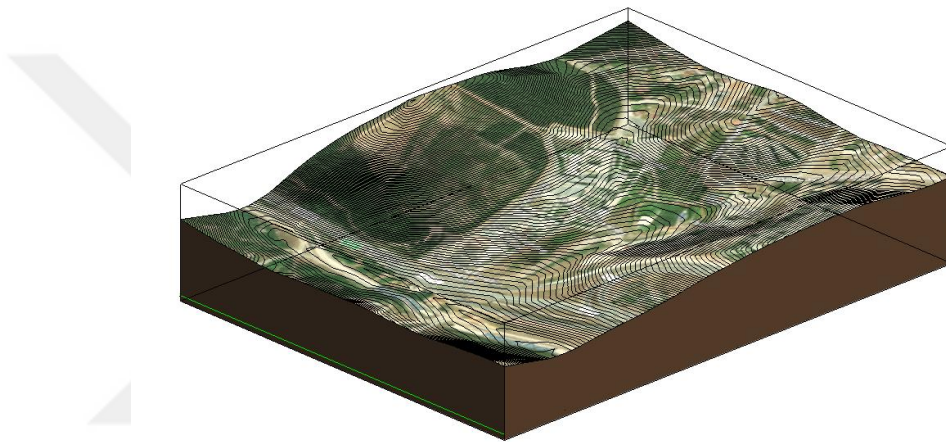


Figure 48: Özyeğin University Campus topography created through Revit and PlaceMaker

5.2 Creating the virtual model of Campus area

The creation of a virtual model of the Özyeğin University campus using the Rhino program involved a meticulous process that incorporated various elements to ensure accuracy for the simulation. The campus master plan provided detailed information on buildings, green areas, and sustainable features, serving as the foundation for the virtual model's development. By comparing the plan with satellite images, the buildings were accurately modeled as polysurfaces and placed on the topography according to their

locations and elevations. Separating the buildings and topography on different layers allowed for detailed rainfall analysis and simulation of water flow. The virtual model serves as a volumetric representation of the campus and a valuable tool for simulations, enabling assessment of sustainability, environmental impact, and resilience. It enhances understanding, planning, and design processes, providing insights for optimizing the campus infrastructure and guiding future development decisions toward a more sustainable and resilient campus environment.



Figure 49: Virtual model of Özyeğin Campus



Figure 50: Virtual model of Özyeğin Campus

5.3 Water flow analysis simulation

The water flow analysis in the context of a valley topography with a stream within the university campus area has a wide range of applications and implications for sustainable and resilient campus development. By examining how water moves across the landscape, assessing flood risks, identifying erosion-prone areas, guiding landscape design and infrastructure planning, and promoting sustainability, the analysis provides valuable insights for effective water management and addressing water-related challenges.

Integrating water flow simulations within the sustainable and resilient campus index allows for the evaluation and enhancement of the campus's ability to manage water resources and adapt to climate change. By analyzing water flow patterns, the simulations

offer insights into the campus's resilience to flooding and erosion, enabling the identification of areas where sustainable water management practices, such as rainwater harvesting systems and green infrastructure, can be implemented. Furthermore, the simulations support the incorporation of natural drainage systems and landscape design elements that promote biodiversity and mitigate the urban heat island effect. By integrating the simulation results into the sustainable and resilient campus index, the campus can effectively evaluate and improve its water management strategies, fostering a more sustainable and resilient environment.

The water flow analysis was conducted in two stages for this study. The first stage focused on determining the path of rainfall water on the terrain alone. In the second simulation, both the terrain and buildings were included, allowing for an investigation of the interaction between the terrain and rainfall response when buildings are present. This comprehensive approach provides a more accurate understanding of water flow dynamics and helps inform decisions related to drainage systems, flood mitigation, and sustainable design practices within the campus environment.

5.4 Algorithm for the water flow analysis on topography

Phase 1: Preparing the Topography

In the first phase of the topography analysis, the mesh surface was transformed into a surface using Grasshopper [10]. This conversion allowed for further manipulation and analysis of the topography. Next, the surface was divided into points using the Divide Surface command. These points were then consolidated into a single list by flattening the point output on the grid. This step was essential for organizing and managing the data for subsequent analysis.

Phase 2: Establishing the Loop

To create a continuous movement pattern for the points on the surface, the Anemone plugin's Loop Start and Loop End components were utilized. These components defined the starting and ending points of the loop. They were interconnected and connected to the Data to Loop component, which facilitated the iteration process. By establishing the loop, the points on the surface would follow a predetermined path instead of solely falling downward. This resulted in the creation of a trail as the points moved through each location.

Phase 3: Running the Simulation

In order to execute the simulation, a Button component was connected to the Loop Start. When triggered, the simulation would commence. The Move component, attached to the Loop Start, controlled the upward movement of the points on the surface. As raindrops naturally descend due to gravity, a negative Z vector was incorporated into the Move component to ensure the downward movement of the points. This adjustment accurately simulated the behavior of raindrops in the analysis.

Phase 4: Analyzing the Point Movement

The Move component was further connected to the Surface Closest Point component, which was responsible for determining the proximity of each point to the surface. Additionally, the surface component, representing the area of interest, was linked to the Surface Closest Point component. This connection allowed for accurate positioning of the points on the surface. To capture the data generated by the simulation, the Record Data option was activated in the Loop End component.

Phase 5: Refining the Data

To remove any duplicate points and streamline the data, the Flip Matrix component was

connected to the Loop End. This step helped to prevent redundant information and optimize the analysis. The resulting data was then passed through the Remove Duplicates component, which eliminated any repeated points. Finally, the List of Polylines was flattened, ensuring a consistent format for further analysis. The Clean Tree component was applied to eliminate null data, enhancing the quality and reliability of the analysis.

The simulation results provide valuable insights into the behavior of water flow within the sloped topography surface. It is evident that the topography plays a crucial role in defining the pathways and accumulation areas of water. These findings are further supported by satellite views, which clearly display the different phases that Köy stream has undergone. The simulation highlights the presence of three main hills located to the east, west, and north of the campus, which significantly influence the movement of rainfall through the valley and contribute to the accumulation of water in Köy stream.

Moreover, the simulation reveals that the D020 highway line in the south of the campus serves as another strategic accumulation point. This finding holds particular importance for the Ömerli Dam, as it underscores the significance of this line in terms of water accumulation, as recognized by İSKİ (Istanbul Water and Sewerage Administration). The simulation results are proportional and consistent with the relief map published by the Istanbul Metropolitan Municipality (İBB), further validating their accuracy.

It is essential to emphasize that these observations are based solely on the topography and its impact on water flow. Other factors, such as land use, vegetation, and infrastructure, may also influence the overall water dynamics in the area. Thus, future analyses that consider these additional factors could provide a more comprehensive understanding of the water system and its behavior within the campus and its surroundings.

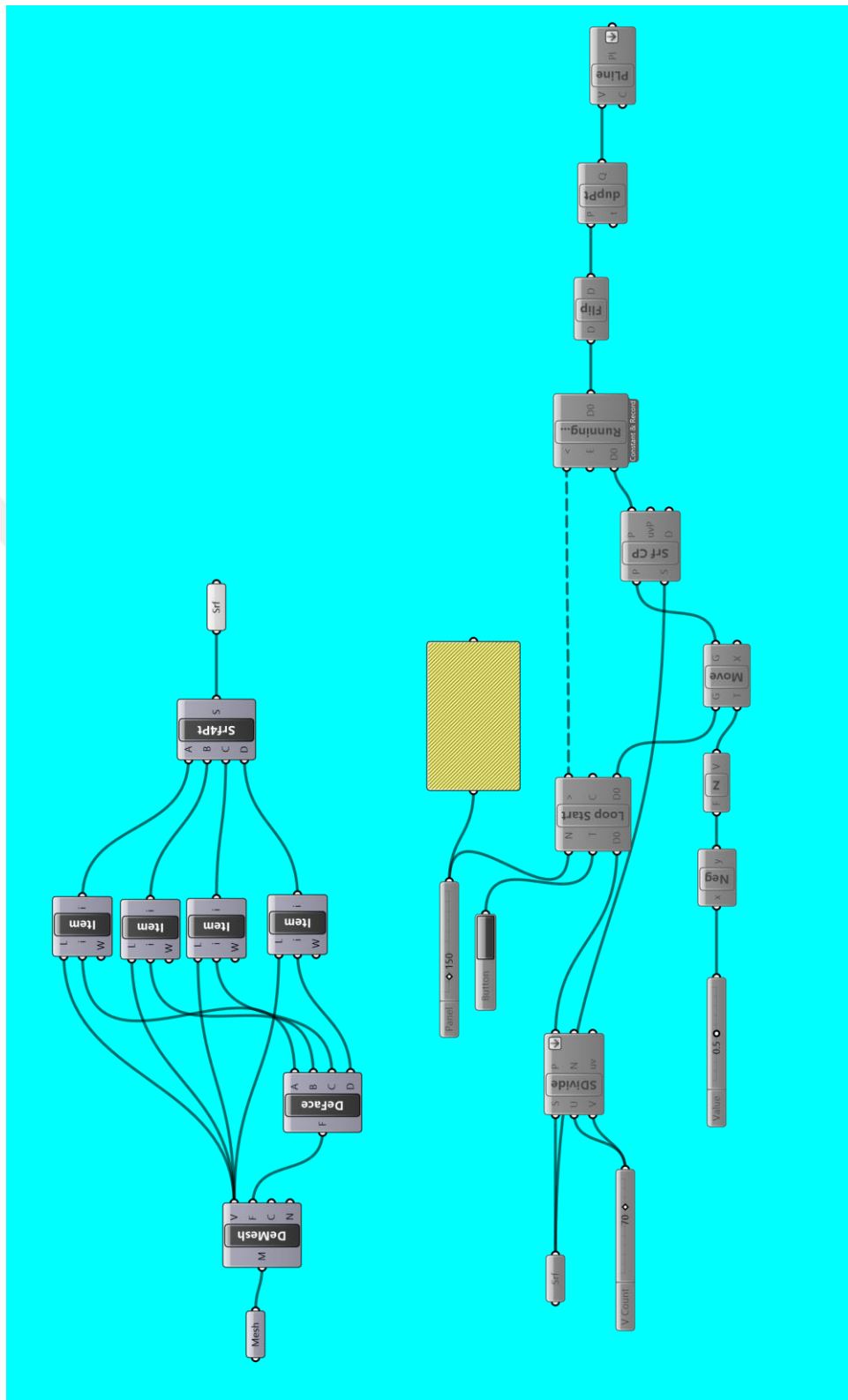


Figure 51: Topography Rainflow Analysis Generative Algorithm

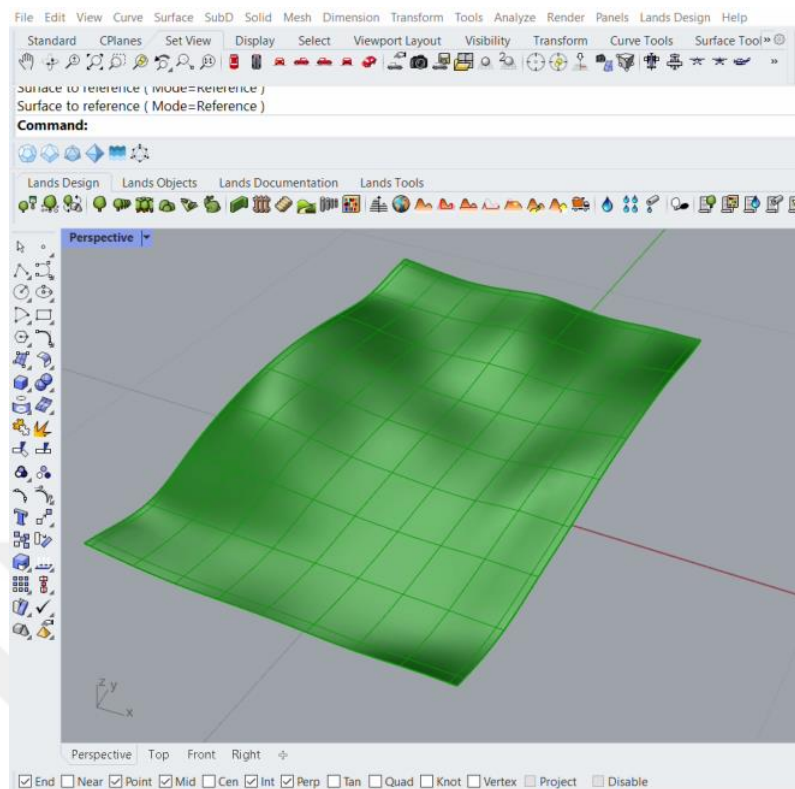


Figure 52: Simulation view 1

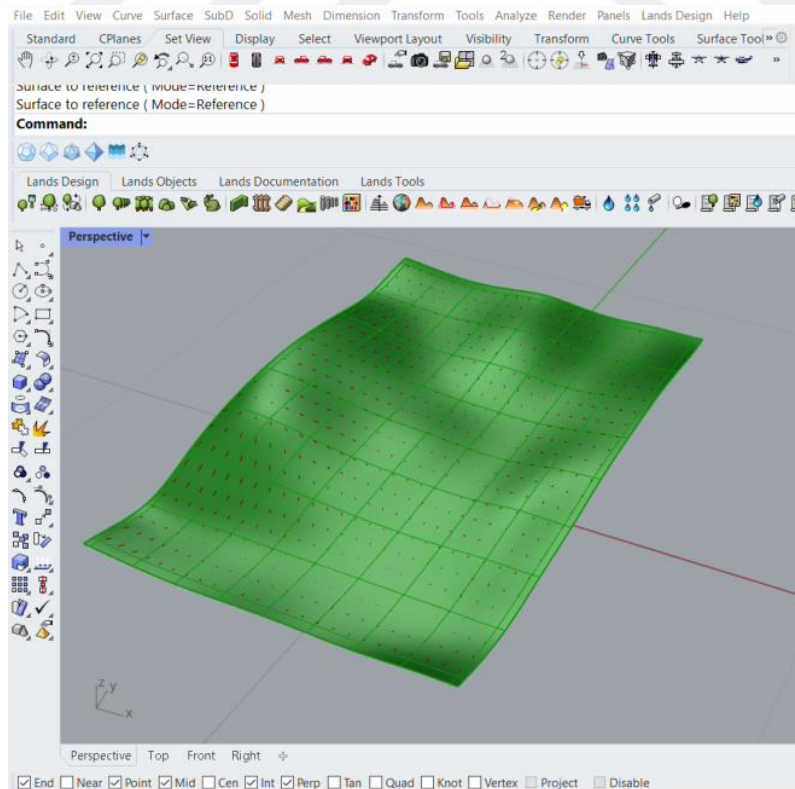


Figure 53: Simulation view 2

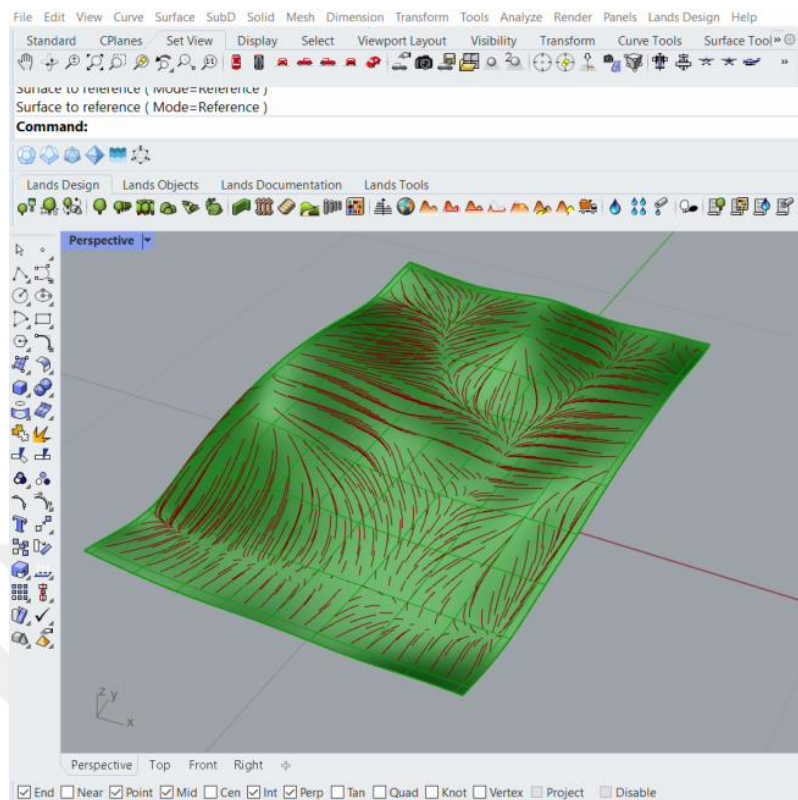


Figure 54: Simulation view 3

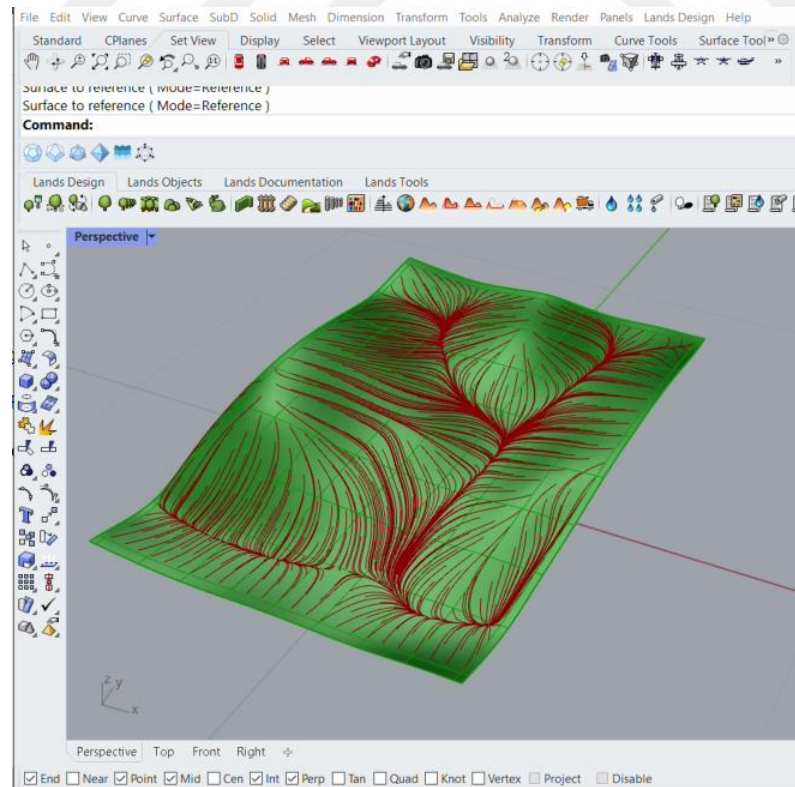


Figure 55: Simulation view 4



Figure 56: Comparison views for topography rainflow analysis

5.5 Algorithm for the water flow analysis including buildings

Phase 1: Creating the Boundary and Defining the Rain Area

In this phase, a boundary was established around the terrain to prevent water particles from overflowing. The rain area was defined as a box in Grasshopper, representing the region where rain would occur. Separate breps were created for the buildings and the terrain surface. The surface was given thickness in the Z direction using the extrusion component, and all surfaces were converted into meshes for simulation compatibility. These mesh masses were then connected to the Solid Point Collide component, which would handle the interaction of the raindrops with the surfaces. Additionally, two Boolean Toggles were added as start buttons for initiating the simulation.

Phase 2: Determining the Number of Raindrops

To determine the quantity of raindrops, the rain area brep previously created in Rhino [9] was imported into Grasshopper [10]. The Populate Geometry component was introduced, allowing the specification of the desired number of raindrops within the defined rain area. The Populate Geometry component was then connected to the Solid Point Collide component, enabling the raindrops to interact with the surfaces.

Phase 3: Adjusting the Simulation Time

In this phase, the simulation time was adjusted. A numerical value was input and connected to the Z vector, controlling the speed and direction of movement for the raindrops. To ensure the raindrops moved in a downward direction, the Reverse component was employed. The Load component was added to combine the number and rate of raindrops, setting the stage for the simulation.

Phase 4: Configuring the Raindrop Properties

To configure the raindrop properties, the Sphere Collide component was connected to the Populate Geometry component. The size of the raindrops was specified using numerical values, determining their visual representation in the simulation. The Floor Component, along with additional numerical data, was introduced to provide a reference plane for the raindrops and facilitate their interaction with the surfaces.

Phase 5: Merging and Activating the Components

In this phase, the Floor, Sphere Collide, Solid Point Collide, and Load Components were merged using the Merge component. By combining these components, the interactions between the raindrops and surfaces were integrated into the simulation. The Bouncy

Solver from the Kangaroo plug-in was employed to activate the movement of the raindrops, ensuring realistic behavior. To control the simulation, a reset button and an additional Boolean Toggle were added to the Bouncy Solver.

Phase 6: Enhancing the Visual Representation of the Simulation

The final phase involved enhancing the visual representation of the simulation. The output of the Bouncy Solver, representing the raindrops' movement, was connected to the mesh sphere, mesh color, and color swatch components. This configuration enabled the raindrops to be visualized as small blue spheres within the simulation. The radius of the Mesh Sphere was combined with the droplet size, completing the setup for the simulation and providing a visually appealing representation of the raindrop movement.

The two simulations, one considering only topography and the other incorporating both topography and campus buildings, provide valuable insights into water flow dynamics. The results of the two simulations using different algorithms demonstrate compatibility in terms of the impact of topography on water flow and the influence of buildings as barriers.

In the second simulation, the manipulation of water flow by buildings becomes evident, as they act as obstacles for the movement of water. The main accumulation points for Köy stream remain consistent between the two simulations, except for a specific area in the northern part of the campus where shuttle parking is located, which exhibits a newly identified significant accumulation area. Another notable area is the slope of the valley on the east side, where the dormitory buildings (1-2-3 and 4) are situated.

These simulations serve as a foundation for further developments in the model and algorithm, enabling the inclusion of other significant parameters for water

management and climate adaptation strategies. By incorporating features such as walls surrounding the campus area, vegetation and trees, different roof types with varying water permeability, diverse soil types, GIS climate data, and regional rainfall data, the model can be improved for more accurate and comprehensive results.

Expanding the simulation to incorporate these additional factors will enhance the understanding of water dynamics and enable the assessment of various scenarios and interventions for effective water management and climate adaptation strategies in the university campus. It will contribute to the development of sustainable and resilient approaches to address the challenges posed by climate change and promote responsible water resource management.

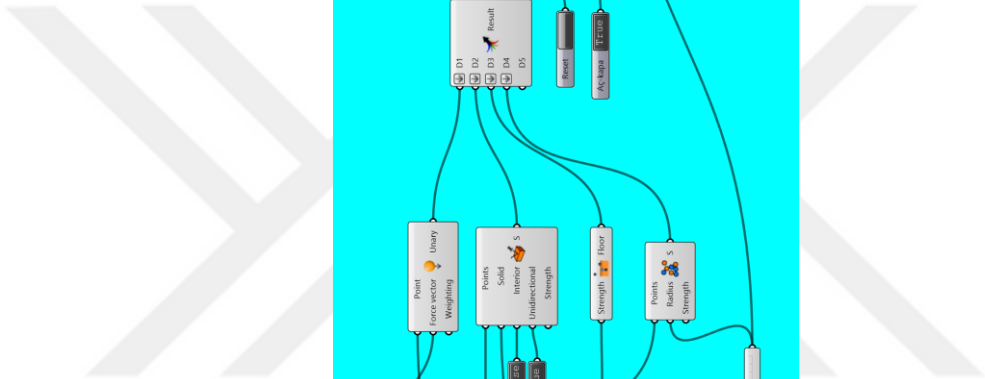


Figure 57: Topography and Buildings Rainflow Analysis Generative Algorithm

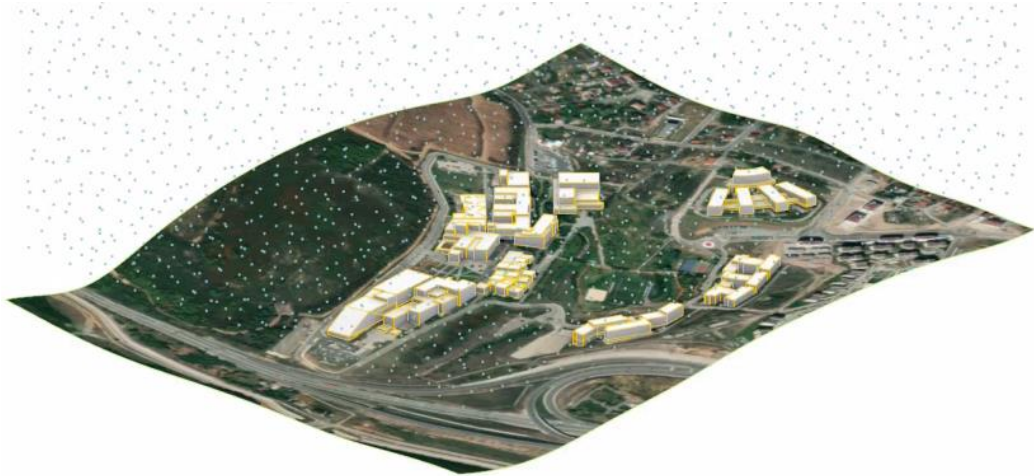


Figure 58: Simulation view 2.1



Figure 59: Simulation view 2.2



Figure 60: Simulation view 2.3



Figure 61: Simulation view 2.4



Figure 62: Simulation view 2.5



Figure 63: Simulation view 2.6



Figure 64: Key map for photography



Figure 65: 1-View of Student Center



Figure 66 : 2-View of Student Center and Dorm 4



Figure 67: 3-View of Dorm 4 and Stream bed



Figure 68: 4-View Stream bed



Figure 69: 5-View of Sport Center



Figure 70: 6-View of AB3



Figure 71: 7-View of Dorms 1,2,3



Figure 72: 8-View of OZU X



Figure 73: 9-View of OZU X and AB3



Figure 74: 10-View of AB1



Figure 75: 11-View of SCOLA



Figure 76: 12-View of Architecture Building



Figure 77: 13-View of AB2 and Student Center



Figure 78: 14-View of Stream



Figure 79: 15-View of OZU X



Figure 80: 16-View of OZU X, AB2 and AB3

CHAPTER VI

DISCUSSION

In the literature review, it was found that research on the preparedness of university campuses for disasters related to climate change has focused less on the principle of resilience compared to the principle of sustainability. Reports supported by findings suggest an expected increase in the frequency and intensity of natural disasters caused by climate change in the next 10 years [5], [16]. Sustainability is considered the norm for stability & balance [23], making it an effective principle in efforts to prevent climate change. On the other hand, resilience acknowledges non-linear & unpredictable change & chaos as the norm [23]. Therefore, considering the visible effects of global warming and the preparation process for natural disasters, it is important to consider the principle of resilience. While there are certification practices analyzing the sustainability of buildings, there is limited research focusing on resilience analysis. University campuses can be thought of as small cities [37]. In this sense, studies on the sustainability and resilience of university campuses can contribute to both the universities themselves and larger cities in a broader context.

This thesis aimed to propose a resilient smart campus design index that integrated smart city indicators together with resilient planning and design strategies. The objectives of the study were to identify the relationship between smart city indicators and resilient planning and design strategies for university campuses, investigate the challenges and opportunities of integrating digital twin and smart city technologies in designing climate adaptive university buildings, and provide recommendations for addressing these challenges. This index was created based on the certification systems and indicators identified in the literature review. Since sustainability primarily aims to prevent climate

change and reduce carbon footprint, the indicators defining sustainability features in the table were selected accordingly. Among these indicators, water management took the first place as it plays a crucial role in mitigating the adverse effects of climate change related to rainfall and drought. This involves implementing various strategies and practices, such as rainwater harvesting systems, permeable paving, and green infrastructure for effective stormwater management. Additionally, using low-flow showerheads and toilets, greywater recycling systems, and efficient plumbing fixtures and fittings help minimize water consumption. Water-efficient landscaping, irrigation systems, and regular water audits contribute to responsible water usage. The use of water-efficient appliances and equipment, leak detection and repair programs, and education and awareness initiatives further promote water conservation. Incorporating water-efficient dishwashing and laundry systems, drought-resistant plants, and cooling tower water treatment and management enhance sustainable water practices. Water metering and monitoring systems, as well as utilizing reclaimed water for non-potable uses, support comprehensive water management on university campuses.

Implementing sustainable land use practices is crucial for achieving sustainability on university campuses, especially regarding water management. Green infrastructure, such as permeable surfaces and green roofs, effectively handle stormwater, reducing runoff and improving water quality. Integrating green spaces into campus design creates natural habitats and promotes water conservation through sustainable landscaping. Additionally, preserving natural areas safeguards water sources and supports biodiversity. To minimize water pollution, sustainable agriculture and food production practices should be implemented, along with effective waste management to properly dispose of

hazardous materials. Using native plants and sustainable building materials can further reduce water usage and environmental impact. Furthermore, implementing green procurement policies prioritizes water-efficient fixtures, while preserving historic buildings maintains cultural heritage while minimizing water-intensive construction. It's important to note that energy-efficient street lighting indirectly conserves water resources by reducing energy consumption. By implementing these practices, campuses can actively manage water resources and advance their overall sustainability goals.

The implementation of green buildings is crucial for enhancing the sustainability and water efficiency of university campuses. To achieve this, recommendations include incorporating water-efficient plumbing fixtures and fittings, such as low-flow toilets and faucets, using green roofs and living walls to capture and purify rainwater, and utilizing low-toxicity building materials and non-toxic cleaning products. Energy-efficient HVAC systems and net-zero energy building design contribute to reduced energy consumption and indirectly conserve water resources. Smart building automation systems optimize heating and cooling, maximizing natural light and ventilation. Additionally, energy-efficient windows, insulation, solar shading, and daylighting strategies further enhance energy and water efficiency. By utilizing sustainable and locally-sourced building materials, campuses can minimize their environmental impact. Smart power outlets and power strips enable efficient use of electrical devices, while indoor air quality monitoring and control systems promote water conservation. Integrating these practices enables university campuses to significantly improve their sustainability and water efficiency, creating a healthier environment for the campus community and making a positive impact on the environment.

The implementation of renewable and efficient energy strategies is vital for enhancing the sustainability and water efficiency of university campuses. Smart building automation systems optimize energy usage and reduce water consumption through efficient HVAC systems. Net-zero energy buildings further reduce reliance on traditional energy sources and minimize water usage. Campuses can support clean energy generation through the purchase of renewable energy credits and carbon offsets. Energy management systems enable real-time monitoring and control of energy usage. Power-saving measures in computer labs and data centers conserve energy and indirectly reduce water usage. Implementing geothermal systems can utilize natural thermal energy to reduce energy consumption and water usage. Energy audits and assessments identify conservation opportunities. Demand response systems adjust energy consumption during peak periods. The use of solar panels and other renewable energy sources generates clean energy and reduces reliance on water-intensive energy sources. Battery storage systems ensure a continuous power supply. Energy-efficient lighting, appliances, windows, and insulation further minimize energy consumption and indirectly reduce water usage. Microgrids enhance resilience and reduce dependence on external energy sources. Campus-wide conservation programs promote sustainable practices. By implementing these strategies, university campuses can reduce their carbon footprint, conserve water resources, and contribute to a more sustainable and water-efficient future.

Implementing Access to Transportation strategies is essential for enhancing the sustainability and water efficiency of university campuses. Education programs and awareness initiatives should promote sustainable transportation options, such as biking and public transit. Bike-sharing programs and storage facilities encourage cycling as a water-efficient alternative to cars. Campus shuttles, car-sharing programs, and vanpools

reduce single-occupancy vehicles, thereby minimizing traffic congestion and water-intensive parking needs. Electric vehicle charging stations support clean transportation and reduce greenhouse gas emissions. Promoting walking, biking, and public transit also reduces reliance on water-intensive private vehicles. To further encourage sustainable travel choices, university campuses should provide sustainable transportation options for field trips, adopt a pedestrian-friendly campus design, and implement traffic calming measures. Offering public transportation passes and integrating them with campus technology platforms can facilitate access to information and promote sustainable travel. Moreover, providing secure bike parking facilities and fostering collaboration with local transportation providers strengthen sustainability efforts.

By implementing these strategies, university campuses can effectively reduce their environmental impact, conserve water resources, and foster a more sustainable and water-efficient transportation ecosystem.

In addition to addressing transportation, focusing on Indoor Environmental Quality is crucial for enhancing sustainability and water efficiency on university campuses. By implementing Indoor Environmental Quality strategies, campuses can create a healthier indoor environment while minimizing water pollution. To achieve this, it is essential to use low-toxicity building materials and non-toxic cleaning products that contribute to improved air quality. Maximizing natural light and ventilation through well-designed spaces, along with implementing air filtration and monitoring systems, promotes a healthier indoor environment while conserving water. Incorporating acoustic design, daylighting techniques, and greenery further enhances occupant well-being and reduces energy consumption. Additionally, measures such as indoor humidity control, ergonomic furniture, and thermal comfort standards contribute to occupant comfort while conserving

energy and water. By prioritizing occupant health and implementing these strategies, university campuses can create a sustainable and water-efficient environment, fostering a culture of well-being and sustainability.

When unpredictable and chaotic situations are considered as the norm for resilience, recommendations were made regarding the identification, prevention, and management of potential extraordinary situations related to climate change. These recommendations were listed as Infrastructure Resilience, Risk Assessment, Adaptive Design, Disaster Preparedness, Emergency Management, Continuity Planning, and Community Engagement.

Water plays a crucial role in the context of university campus natural disasters, and its consideration is vital across various aspects of campus resilience. Infrastructure resilience, for instance, encompasses characteristics that enable water systems to withstand and recover from disruptive events. This includes resilient water supply and treatment systems, as well as the implementation of green infrastructure practices that promote sustainable water management. By incorporating these characteristics, universities can ensure continuous access to safe water, even during and after natural disasters.

Risk assessment, another essential aspect of campus preparedness, involves identifying and evaluating potential risks and vulnerabilities related to water and climate change. This includes specific consideration for water-related challenges caused by climate change, such as water scarcity and flooding. By conducting regular assessments and prioritizing strategies for mitigation, universities can proactively address these water-related risks and vulnerabilities.

Adaptive design, with a particular focus on water and climate change, is crucial

for universities aiming to build resilience. This approach involves incorporating strategies such as green roofs, resilient landscaping, and design elements that reduce water usage and waste generation. By optimizing building orientation, shading, and utilizing sustainable materials, universities can minimize their water and energy footprint while adapting to changing climate conditions.

Disaster preparedness, specifically concerning water-related challenges and the impacts of climate change, is of utmost importance. Universities should prioritize measures to ensure an adequate supply of fuel and water, as well as implement flood prevention and mitigation strategies. Effective monitoring of real-time weather conditions, hazard-resistant building design and construction, and early warning systems contribute to campus readiness. Communication protocols, emergency generators, and robust IT infrastructure support emergency response efforts and enhance the university's ability to manage water-related disasters.

Continuity planning is crucial for universities to maintain operational resilience in the face of water-related challenges and the influence of climate change. It involves developing comprehensive plans and strategies to ensure the continuous availability of water and other critical resources. This includes backup systems, redundant power and data infrastructure, and scenario planning to address potential disruptions. By considering water-related challenges in continuity planning, universities can safeguard their essential services and minimize the impact of disruptions on campus operations.

Lastly, community engagement plays a pivotal role in addressing water-related challenges and building resilience. By involving students, stakeholders, and the wider community, universities can foster collaboration and shared responsibility in water management. Public outreach, education programs, partnerships with local organizations,

and participatory planning processes create a sense of community involvement. By incorporating diverse perspectives, universities can better address water-related challenges and implement effective solutions.

The features of the resilient smart campus design index outlined in different areas collectively contribute to creating a sustainable and resilient campus environment. By implementing these features, a resilient smart campus fosters a culture of sustainability, resilience, and well-being for its campus community while effectively addressing the challenges posed by climate change and promoting responsible stewardship of resources.

Additionally, the study aimed to analyze the sustainability and resilience of a university campus through simulation technology, specifically focusing on the risks associated with climate change. The simulations conducted in this study were centered around water-related aspects to assess the campus's preparedness and adaptability to climate change impacts. The findings from these simulations contributed to the development of the proposed resilient smart campus design index and provided valuable insights for climate change adaptation and sustainable planning and design in university settings.

To experience water-related natural events in a physical environment, a simulation was created on a virtual campus model to test the sustainability and resilience features identified in this study under the impact of precipitation. This simulation was conducted using a terrain slope model and buildings on a sloping terrain model. As a result, the orientation of rainwater was determined based on the slope of the terrain and the positions of the buildings.

The results of the simulation were compared to satellite images published by IBB from 1970 to 2022 [68]. It was observed that water movement on the campus site occurred

in connection with the slope of the terrain. It was also found that the streams located in the middle of the valley-shaped terrain have strategic importance as water collection areas. This simulation is designed to explore the relationship between climate change and water movement analysis. It provides an opportunity for further development and testing of various features within the index table.



CHAPTER VII

CONCLUSION

In conclusion, the research conducted in this study has provided valuable insights into the sustainability and resilience of university campuses in the face of climate change. The literature review highlighted the importance of considering both sustainability and resilience principles in preparing campuses for climate-related disasters. While sustainability focuses on preventing climate change and achieving stability, resilience acknowledges the non-linear and unpredictable nature of change and chaos.

The proposed resilient smart campus design index integrates smart city indicators with resilient planning and design strategies. It addresses various aspects of campus sustainability and resilience, including water management, sustainable land use, green building practices, renewable energy strategies, transportation access, and indoor environmental quality. These aspects contribute to creating a campus environment that is both sustainable and resilient, benefiting the campus community and the larger city context.

Water management emerged as a crucial factor in the index, considering its role in mitigating the adverse effects of climate change. Strategies such as rainwater harvesting, green infrastructure, water-efficient fixtures, and responsible water usage practices were identified as key components of water management on university campuses. Sustainable land use practices, including green infrastructure and preservation of natural areas, were found to support water conservation and improve water quality.

Green building practices, such as the use of water-efficient plumbing fixtures, green roofs, and energy-efficient systems, were identified as vital for enhancing the sustainability and water efficiency of university campuses. The integration of renewable and efficient energy strategies, along with the implementation of smart building automation systems, contributes to reduced energy consumption and indirectly conserves water resources.

Addressing transportation access on campuses through sustainable options like biking, public transit, and car-sharing programs helps reduce reliance on water-intensive private vehicles. Indoor environmental quality strategies, such as the use of low-toxicity materials, natural light, and ventilation, contribute to a healthier indoor environment while minimizing water pollution.

Additionally, recommendations were made regarding the identification, prevention, and management of potential extraordinary situations related to climate change. Infrastructure resilience, risk assessment, adaptive design, disaster preparedness, emergency management, continuity planning, and community engagement were highlighted as key areas of focus for campus resilience.

The simulations conducted as part of the research assessed the campus's preparedness and adaptability to climate change impacts, particularly in relation to water-related aspects. The results of the simulation demonstrated the connection between the terrain slope and water movement on the campus site. The streams located in the valley-shaped terrain were identified as strategic water collection areas. The simulation provides a foundation for further development and testing of features within the resilient smart campus design index.

In conclusion, the integration of smart technologies, including City Information Modeling, Building Information Modeling, IoT, and digital twins, presents a powerful and comprehensive toolkit for university campuses to effectively tackle climate change effects. By embracing these technologies and their interconnected nature, campuses can enhance their capacity for sustainable planning, resource optimization, and proactive adaptation. Furthermore, their efforts can serve as a catalyst for broader urban transformations, promoting the adoption of smart solutions in mitigating and adapting to climate change on a larger scale. Through these endeavors, university campuses can play a pivotal role in shaping a more resilient and sustainable future.



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VITA

Doğa Bitik received her BSc degree in Architecture from Politecnico di Milano in 2019. She worked as a BIM Technician at, Studio Archemi. She completed her internship at MTA Associati in Milano. She has attended workshops like MinD Mad in Design and Atmosphere. She studied at Liceo Scientifico Galileo Galilei in Istanbul. Her research focuses on intelligent systems and new applications for architecture and urban design.

