ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL

ANALYSIS OF E-BIKE CHARGING STATION LOCATIONS: CASE OF KADIKÖY, ISTANBUL

M.Sc. THESIS

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(501181412)

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Thesis Advisor: Prof. Dr. Hilmi Berk ÇELİKOĞLU

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<u>ISTANBUL TEKNİK ÜNİVERSİTESİ ★ LİSANSÜSTÜ EĞİTİM ENSTİTÜSÜ</u>

E-BİSİKLET ŞARJ İSTASYONU KONUMLARININ ANALİZİ: KADIKÖY, İSTANBUL ÖRNEĞİ

YÜKSEK LİSANS TEZİ

Serra GARİPAĞAOĞLU
(501181412)

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Serra Garipağaoğlu, a M.Sc student of ITU Graduate School student ID 501181412, successfully defended the thesis entitled "ANALYSIS OF E-BIKE CHARGING STATION LOCATIONS: CASE OF KADIKÖY, ISTANBUL", which she prepared after fulfilling the requirements specified in the associated legislations, before the jury whose signatures are below.

Thesis Advisor :	**Prof. Dr. Hilmi Berk ÇELİKOĞLU** Istanbul Technical University	....
Jury Members :	**Prof. Dr. Hande DEMİREL** Istanbul Technical University	....
	Prof. Dr. Mustafa KARAŞAHİN Istanbul Gelişim University	....

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To those who dream of a more livable and equitable world,

FOREWORD

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ABBREVIATIONS

AASHTO : American Association of State Highway and Transportation Officials
AHP : Analytic Hierarchy Process
ANP : Analytic Network Process
BAU : Business as Usual
BN : Bayesian Network
BRT : Bus Rapid System
BSS : Bicycle Sharing System
BWM : Best Worst Method
CoM : Compact of Mayors
DB : Deutsche Bahn
DEMATEL : Decision-Making Trial and Evaluation Laboratory
DSS : Decision Support System
E-Bikes : Electric Bicycles
EBCS : Electric Bike Charhing Station
ECF : European Cyclists' Federation
ELECTRE : Elimination Et Choice Translating Reality
EST : Environmentally Sustainable Transport
EU : European Union
EV : Electric Vehicle
EVCS : Electric Vehicle Charging Station
FAHP : Fuzzy Analytical Hierarchy Process
FFBSS : Free-Floating Bicycle Sharing System
GIS : Geographic Information System
HDA : Housing Development Administration
HLAG-ST : High Level Advisory Group on Sustainable Transportation
ICLEI : International Council for Local Environmental Initiatives
IDA : Istanbul Development Agency
IMM : Istanbul Metropolitan Municipality
IPA : Istanbul Planning Agency

IPCC : Intergovermental Panel on Climate Change
IPT : Inductive Power Transfer
ITMP : Istanbul Transportation Master Plan
ITU : Istanbul Technical University
IUDSAP : Integrated Urban Development Strategy and Action Plan
JICA : Japan International Cooperation Agency
JPOI : Johannesburg Plan of Implementation
LGA : Local Govermental Area
MCDA : Multiple Criteria Decision Analysis
MCDM : Multiple Criteria Decision Making
MULTIMOORA: Multi-Objective Optimization by Ratio Analysis Plus Full Multiplicative Form
NEAP : National Environmental Strategy Action Plan
NGO : Non-govermental Organizations
OECD : Organizations for Economic Cooperation and Development
PROMETHEE: Preference Ranking Organization Method for Enrichment Evaluations
SBBSS : Station-Based Bicycle Sharing System
SDGs : Sustainable Development Goals
SPI : Sustainable Planning and Innovations
SPO : State Planning Organization
SUMP : Sustainable Urban Mobility Plan
TCC : Transportation Cordination Center
TOD : Transit Oriented Development
TOPSIS : Technique for Order Performance by Similarity to Ideal Solution
TSI : Turkish Statistical Institute
UCLA : University of California
UCLG-MEWA: United Cities and Local Governments Middle East and West Asian Section
UK : United Kingdom
UN : United Nations
UNEP : United Nations Environment Program
UNFCCC : United Nations Framework Convention on Climate Change
US : United States

USA : United States of America
UVC : Uniform Vehicle Code
VIKOR : Višekriterijumsko Kompromisno Rangiranje
VLR : Voluntary Local Reviews
WHO : World Health Organisation
WPM : Weighted Product Model
WSM : Weighted Sum Model

SYMBOLS

A	: Comparison Matrix
CI	: Consistency Index
CR	: Consistency Ratio
k	: Number of classes / bins
N	: Total frequency
n	: Number of element
R	: Range
RI	: Random Consistency Index
S	: Width of classes
W	: Weight Matrix
w	: Weight
x	: Data
z	: Normalized data
λ_{max}	: Principal Eigenvalue / Largest Eigenvalue

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ANALYSIS OF E-BIKE CHARGING STATION LOCATIONS: CASE OF KADIKÖY, ISTANBUL

SUMMARY

With the Industrial Revolution in the 19th century, the population of cities increased rapidly and their physical areas expanded. In the last quarter of the 19th century, the invention of the automobile and the increase in its affordability with the developing technology led to an increase in automobile ownership in the 20th century. The rapidly increasing use of fossil fuels in production and transportation has created a world far from sustainable globally. In this context, environmental movements that found a common language in the 1960s started and the concept of sustainability was put forward by the Brundtland Commission in 1987. Cities are dominant living spaces. In order to achieve global sustainability goals, cities must be sustainable. For this reason, world cities have started to work toward being sustainable cities by developing policies and action plans since the Brundtland Commission.Today, the most up-to-date and valid sustainability efforts are the C40 union on a local scale and the Paris Agreement on a global scale. C40 cities aim to reach the carbon-zero city target by 2030, while the Paris Agreement aims to keep the global average temperature rise below 2°C compared to the pre-industrial period and to reach the carbon-zero European Continent target by 2050.

According to studies in 2019, 27% of the total carbon emissions in Europe originate from the transportation sector (EEA, 2021a). In addition, 72% of transportation-related emissions originate from road transportation (EEA, 2021b). In this case, it is necessary to create a sustainable transportation system to achieve sustainability goals at the urban and global scale.According to studies in 2017, 16,1% of total carbon emissions in Turkey originate from transportation. Furthermore, 93% of transportation-related emissions originate from road transportation (ÇŞB, 2017). As one of the countries that signed the Paris Agreement, Turkey needs to update its policies and increase its efforts to allocate sustainable transportation. According to studies in 2015, 28% of total carbon emissions in Istanbul originate from transportation. Moreover, 98% of transportation-related emissions originate from road transport (IMM, 2015a). It is essential that Istanbul, one of the C40 cities and the most populous city in Turkey, allocates a sustainable urban transportation system.

Sustainable transportation aims to meet the need for access without harming the human and ecological values of today and the future. One of the basic principles of sustainable transportation is meeting the mobility demand with public transit, pedestrian transportation, and micromobility units by reducing the private car share in transportation. Cycling is also among the sustainable modes of transportation, and it is a unique tool that contributes to the environment, economy, and health and allows social interaction.

The bicycle, invented at the beginning of the 19th century, has been one of the main actors of transportation in the historical process, then lost its popularity with the automobile and became popular again with sustainable transportation targets. Electric

bicycles (e-bikes) were invented at the end of the 19th century, and with the developing battery technology, they have increased their market share in the world, especially in the 21st century. E-bikes are expected to reach 130 million by 2025 and 800 million by 2100 (Morchin and Oman, 2006a; Hung and Lim, 2020). Another factor in the popularization of E-bikes is that it is an individual vehicle that combines the advantages of automobiles and bicycles.

The batteries of e-bikes can be used for up to 5 years when charged with appropriate methods. Charging the battery up to 95% after each trip is recommended to increase battery life. During the journey that will end at home, people will be able to charge their e-bikes at home. However, this situation reveals the need to charge e-bikes during trips that end in public spaces.

Facility location problem is a widely studied subject in private and public sector investments. Facility locations are long-term and strategic decisions, and choosing suitable locations is extremely important. Although e-bike charging stations (EBCS) are implemented in many cities worldwide, it has not yet been discussed as a facility layout problem in the literature.

The number of e-bikes in Istanbul is deficient compared to European cities, and it is not possible to conduct a study by determining the need according to the supply-demand balance. The average range of the produced e-bikes is 35 km (Morchin and Oman, 2006a) and the average trip distance with electric bicycles is 9-10 km (ÇŞB, 2021). In this case, it cannot be said that range is a primary constraint for e-bikes.

For charging stations to be located in public areas, a relationship between electric bicycles and urban functions and infrastructure elements should be established. An analytical method should be adopted by determining the criteria that will affect the location selection.

Since no similar study has been found in the literature for EBCS, the criteria affecting the location selection for electric vehicle charging stations (EVCS), bicycle sharing system (BSS) stations, and bicycle parking structures are examined within the scope of the study. In addition, local laws and regulations are examined and constraints are revealed. Based on these studies, criteria that will affect the determination of the locations of EBCS are determined.

Within the scope of the study, the Analytical Hierarchy Process (AHP), which has the advantage of qualitative and quantitative evaluation, which is one of the Multiple-Criteria Decision Making (MCDM) methods, is used. It is aimed to determine the weights of the criteria by AHP and determine the most suitable locations by Geographic Information Systems (GIS).

A total of 75 experts from Istanbul Metropolitan Municipality (IMM), academia, non-governmental organizations (NGOs), companies, Ministry of Transport and Infrastructure, and Union of Municipalities of Marmara participated in the expert survey prepared to determine the weight of the criteria that affect the determination of EBCS locations at the district scale. The analysis's prominent urban functions and infrastructure elements are rail systems, existing protected bicycle roads, parking lots, bus rapid transit (BRT), parks and green areas, and water transportation.

Kadıköy district is chosen as the study area. The fact that Kadıköy is the district with the highest rate of bicycle use (EMBARQ Turkey, 2015) and that those who first accepted and started riding bicycles in the historical process were those living in Kadıköy (Ceylan, 2020) are among the factors in the selection of Kadıköy as the case area. At the same time, Kadıköy is a district with high mobility due to its location on the Anatolian side and diversity of transportation infrastructure. The presence of many functions such as residential, commercial, business centers, and universities in the district both increases the mobility within the district and causes it to attract a lot of population from outside the district. The district is also a center of attraction with its green areas, cultural functions, and variety of cafes/restaurants. It has the characteristics of a medium-sized European city with its diversity of functions, an area of 25,20 km^2 (Kadıköy Municipality, 2022), and a population of 481 983 people (TÜİK, 2022). A study to be carried out in Kadıköy will also be a guide for medium-sized cities.

According to the criteria determined within the scope of the study, the data of Kadıköy are created with the help of GIS. Kadıköy is examined according to criteria and weights by creating 1x1 km grids. In the analysis, C2 and C1 grids are determined as the priority application area. The common features of these areas are that they contain more than one type of public transportation and attract visitors both from within and outside the district with their functions.

C2 and C1 grids with the highest scores are analyzed in more detail within the scope of the study. Since there is no study in the literature on the walking distance to EBCS, studies on other bicycle infrastructures are examined. In the literature, it has been stated that the maximum walking distance to bicycle parking structures is 100 m, but this distance can be increased if safety is increased and different functions are added. It is also stated that the walking distance for shared bikes is 300 m and a person's walking tolerance is 300 m to access bike. Within the scope of this information, a radius of 100 m as the primary service area, a radius of 200 m as a secondary service area, and a radius of 300 m as a tertiary service area are determined for EBCS. The analysis of C2 and C1 grids aims to include the high-weight criteria in the primary service area. At the same time, proximity to public buildings is taken into account to make easier the connection to the urban electricity infrastructure system. Public property areas are chosen to reduce costs and make implementation easier. In this context, a location that primarily serves the rail system, BRT, green area, parking lot, and bus functions are determined for the C2 grid. At the designated location, the station will benefit from the electrical system of the rail system and BRT, and the land is in public ownership. For the C1 grid, a location primarily serves the rail system, water transportation, green space, parking lot, and bus functions are determined. At the designated location, the station will be able to use the library's electrical system and the land is in public ownership. At the same time, it is important that the determined locations are related to the road and are visible.

The study is carried out to determine the locations of EBCS, which are a bicycle infrastructure element. When the main urban functions and infrastructures are examined, it can be said that supporting these locations with other bicycle infrastructures such as bicycle sharing systems, bicycle parking structures, repair stations, and bicycle roads is essential in increasing the share of bicycle transportation.

Within the scope of the study, it is aimed to determine the locations of EBCS in public spaces. In addition, EBCS should be implemented in residential parking lots, business centers, and shopping centers. Moreover, bicycle transportation should be supported with parking structures.

E-BİSİKLET ŞARJ İSTASYONU KONUMLARININ ANALİZİ: KADIKÖY, İSTANBUL ÖRNEĞİ

ÖZET

19. yüzyılda gerçekleşen Sanayi Devrimi ile kentlerin nüfusu hızla artmış ve fiziksel alanları genişlemiştir. 19. yüzyılın son çeyreğinde otomobilin icadı ve gelişen teknoloji ile ödenebilirliğinin artması 20. Yüzyılda otomobil sahipliğinin artmasına neden olmuştur. Üretimde ve ulaşımda hızla artan fosil yakıt kullanımı global olarak sürdürülebilirlikten uzak bir dünya yaratmıştır. Bu kapsamda 1960'larda ortak dilde yer bulan çevreci hareketler başlamış olup 1987 yılında gerçekleşen Brundtland komisyonu ile sürdürülebilirlik kavramı ortaya konmuştur.

Kentler baskın yaşam alanlarıdır. Global sürdürülebilirlik hedeflerine ulaşmak için öncelikle kentlerin sürdürülebilir olması gerekmektedir. Bu nedenle dünya kentleri Brundtland komisyonundan itibaren politika ve eylem planları geliştirerek sürdürülebilir kentler için çalışmalar yapmaya başlamışlardır.

Günümüzde sürdürülebilirlik çabalarının en güncel ve geçerli olanları yerel ölçekte C40 birliği ve global ölçekte Paris Anlaşmasıdır. C40 kentleri 2030 yılına kadar karbon sıfır kent hedefine erişmeyi, Paris Anlaşması ise küresel ortalama sıcaklık artışının sanayileşme öncesi döneme göre 2°C altında tutulmasını ve 2050 yılına kadar karbon sıfır Avrupa Kıtası hedefine erişmeyi amaçlamaktadır.

Karbon emisyonlarının kaynakları incelendiğinde 2019 yılı verilerine göre Avrupa'da toplam karbon emisyonunun %27'sinin ulaşım sektöründen kaynaklandığı görülmektedir (EEA, 2021a). Ulaşım sektörü kaynaklı emisyonların ise %72'si karayolu ulaşımı kaynaklıdır (EEA, 2021b). Bu durumda kent ölçeğinde ve global ölçekte sürdürülebilirlik hedeflerine erişmek için sürdürülebilir bir ulaşım sistemi yaratmak gerekmektedir.

2017 yılı verilerine göre Türkiye'de toplam karbon emisyonunun %16,1 i ulaşım kaynaklıdır. Ulaşım kaynaklı emisyonların ise %93'ü karayolu ulaşımı kaynaklıdır (ÇŞB, 2017). Paris Anlaşması'nı imzalayan ülkelerden biri olan Türkiye'nin sürdürülebilir bir ulaşım tahsis etmek için politikalarını güncellemesi ve çabalarını artırması gerekmektedir.

2015 verilerine göre İstanbul'da toplam karbon emisyonunun %28'i ulaşım kaynaklıdır. Ulaşım kaynaklı emisyonların %98'i karayolu ulaşımı kaynaklıdır (IMM, 2015a). C40 kentlerinden biri olan ve Türkiye'nin en kalabalık kenti olan İstanbul'un sürdürülebilir bir kent içi ulaşım sistemi tahsis etmesi son derece elzemdir.

Sürdürülebilir ulaşım bugünün ve geleceğin insani ve ekolojik değerlerine zarar vermeden erişim ihtiyacını karşılamayı amaçlar. Kişisel otomobilin ulaşımdaki payını azaltarak toplu ulaşım, yaya ulaşımı ve mikromobilite birimleri ile hareketlilik talebini karşılamak sürdürülebilir ulaşımın temel prensiplerinden biridir. Bisiklet de sürdürülebilir ulaşım modları arasında yer almakta olup çevreye, ekonomiye ve sağlığa katkı sunan, sosyal etkileşime izin veren eşsiz bir araçtır.

19. yüzyılın başında icat edilen bisiklet tarihsel süreçte ulaşımın ana aktörlerinden biri olmuş daha sonrasında otomobilleşme ile popülerliğini kaybedip sürdürülebilir ulaşım hedefleri ile tekrardan hızla popülerleşmiştir. 19. yüzyılın sonunda elektrikli bisikletler icat edilmiş, gelişen batarya teknolojisi ile özellikle 21. yüzyılda dünyada pazar payını yüksek düzeyde artırmıştır. Elektrikli bisiklet sayısının 2025 yılına kadar 130 milyona, 2100 yılına kadar 800 milyona ulaşması beklenmektedir (Morchin ve Oman, 2006a; Hung ve Lim, 2020). Elektrikli bisikletlerin popülerleşmesindeki bir etken de otomobil ve bisikletin avantajlarını bünyesinde toplayan bir bireysel ulaşım aracı olmasıdır.

Elektrikli bisikletlerin bataryaları uygun yöntemlerle şarj edildiğinde 5 yıla kadar kullanılabilmektedir. Batarya ömrünü artırmak için her yolculuk sonrası bataryanın %95 oranına kadar şarj edilmesi önerilmektedir. Evde sonlanacak yolculukta kişi bisikletini evinde şarj edebilecektir. Fakat bu durum bisikletin kamusal alanda sonlanan yolculuklarında da şarj edilmesi ihtiyacını ortaya çıkarmaktadır.

Özel sektör ve kamu sektörü yatırımlarında tesis yerleşim problemi çokça çalışılan bir konudur. Tesis konumları uzun vadeli ve stratejik kararlar olup yerlerinin doğru seçilmesi son derece önemlidir. Elektrikli bisiklet şarj istasyonları bir çok dünya kentinde uygulansa da literatürde henüz bir tesis yerleşim problemi olarak ele alınmamıştır.

İstanbul ölçeğinde elektrikli bisikletlerin sayısı Avrupa kentlerine oranla çok az olup arz talep dengesine göre ihtiyaç belirleyerek bir çalışma yapılması mümkün değildir. Üretilen bisikletlerin ortalama menzilleri 35 km (Morchin ve Oman, 2006a), elektirikli bisiklet ile ortalama erişim mesafesi ise 9-10 km'dir (ÇŞB, 2021). Bu durumda elektirkli bisikletler içim menzilin öncelikli bir kısıt olduğu söylenemez.

Kamusal alanlarda konumlandırılacak şarj istasyonları için elektrikli bisiklet ile kentsel fonkisyonlar ve alt yapı elemanları arasında bir ilişki kurulmalıdır. Lokasyon seçiminde etki edecek ölçütler belirlenerek analitik bir yöntem benimsenmelidir.

Elektrikli bisiklet şarj istasyonları için literatürde benzer bir çalışmaya rastlanmadığından çalışma kapsamında elektrikli taşıtlar için şarj istasyonu yer seçimine, paylaşımlı bisiklet istasyonları yer seçimine, bisiklet park yapıları yer seçimine etki eden ölçütler irdelenmiştir. Ayrıca yerel kanunlar ve yönetmelikler incelenerek kısıtlar ortaya konmuştur. Bu çalışmalardan yola çıkarak elektrikli bisiklet şarj istasyonlarının konumlarının belirlenmesinde etki edecek ölçütler belirlenmiştir.

Çalışma kapsamında Çok Ölçütlü Karar Verme yöntemlerinden biri olan nitel ve nicel değerlendirme avantajına sahip Analitik Hiyerarşi Yöntemi kullanılmıştır. Analitik Hiyerarşi Yöntemi ile ölçütlerin ağırlıklarının belirlenmesi ve Coğrafi Bilgi Sistemlerinden yararlanarak en uygun konumların belirlenmesi amaçlanmıştır.

İlçe ölçeğinde elektrikli bisiklet şarj istasyonu konumlarının belirlenmesinde etki eden ölçütlerin ağırlığını belirlemek için hazırlanan uzman anketine İstanbul Büyükşehir Belediyesi, akademi, sivil toplum kuruluşları, şirketler, Ulaştırma ve Altyapı Bakanlığı ve Marmara Belediyeler Birliği'nden toplam 75 uzman katılmıştır. Yapılan analizlerde öne çıkan kentsel fonksiyonlar ve altyapı elemanları raylı sistemler, mevcut ayrılmış bisiklet yolları, park alanları, metrobüs, park ve yeşil alanlar ve deniz ulaşımı olmuştur.

Çalışma alanı olarak Kadıköy ilçesi seçilmiştir. Kadıköy'ün bisiklet kullanım oranının en fazla olduğu ilçe olması (EMBARQ Turkey, 2015) ve tarihsel süreçte bisikleti ilk kabullenen ve kullanmaya başlayanların Kadıköy'de yaşayanlar olması (Ceylan, 2020) Kadıköy ilçesinin çalışma alanı olarak seçilmesindeki etkenler arasındadır. Aynı zamanda Kadıköy Anadolu yakasındaki konumu ve ulaşım altyapı çeşitliliği nedeniyle hareketliliği fazla olan bir ilçedir. İlçede konut, ticaret, iş merkezi, üniversite gibi bir çok fonksiyon bulunması hem ilçe içinde hareketliliği artırmakta hem de ilçe dışından çok fazla nüfusu kendine çekmesine neden olmaktadır. Sahip olduğu yeşil alanlar, kültürel fonksiyonlar ve kafe/restoran çeşitliliği ile ilçe aynı zamanda bir çekim merkezi özelliğine sahiptir. Sahip olduğu fonksiyonların çeşitliliği, 25,20 km^2 yüz ölçümü (Kadıköy Municipality, 2022) ve 481 983 kişilik nüfusu (TÜİK, 2022) ile orta ölçekli bir Avrupa kenti özelliği taşımaktadır. Kadıköy ilçesinde yapılacak bir çalışma aynı zamanda orta ölçekli kentler için de yön gösterici olabilecek niteliktedir.

Çalışma kapsamında belirlenen ölçütlere göre Kadıköy ilçesinin verileri Coğrafi Bilgi Sistemleri yardımıyla oluşturulmuştur. Kadıköy ilçesi 1x1 km lik ızgaralar oluşturularak ölçütler ve ağırlıklarına göre irdelenmiştir. Yapılan analizlerde C2 ve C1 ızgaraları öncelikli uygulama alanı olarak belirlenmiştir. Bu alanların birden fazla toplu ulaşım türünü bünyesinde barındırması aynı zamanda fonksiyonları ile hem ilçe içinden hem de ilçe dışından ziyaretçi çekmesi ortak özellikleridir.

En yüksek puana sahip olan C2 ve C1 ızgaraları çalışma kapsamında daha detaylı olarak analiz edilmiştir. Elektrikli bisiklet şarj istasyonlarına yürüyerek erişim mesafesi ile ilgili literatürde bir çalışmaya rastlanmadığından diğer bisiklet altyapı elemanları ile ilgili çalışmalar irdelenmiştir. Literatürde bisiklet park yapılarına erişim mesafesinin en çok 100 m olduğu fakat güvenliğinin artırılması ve farklı fonksiyonlar eklenmesi durumunda bu mesafenin artabileceği belirtilmiştir. Aynı zamanda paylaşımlı bisikletler için yürüme mesafesinin 300 m olduğu ve bir kişinin bisiklete erişmek için yürüme toleransının 300 m olduğu belirtilmiştir. Bu bilgiler kapsamında elektrikli bisiklet şarj istasyonları için birincil hizmet alanı olarak 100 m yarıçap, ikincil hizmet alanı olarak 200 m yarıçap, üçüncül hizmet alanı olarak da 300 m yarıçap belirlenmiştir. C2 ve C1 ızgaralarında yapılan analizde birincil hizmet alanında ağırlığı yüksek olan ölçütlerin yer alması hedeflenmiştir. Aynı zamanda maliyeti düşürmek ve uygulamayı kolaylaştırmak için kamu mülkiyetinde alanlar ve kentsel elektrik altyapı sistemine bağlantıyı kolaylaştırmak için kamu yapılarına yakınlık önemsenmiştir. Bu bağlamda C2 ızgarası için öncelikle raylı sistem, metrobüs, yeşil alan, otopark ve otobüs fonksiyonlarına hizmet eden bir konum belirlenmiştir. Belirlenen konumda istasyon raylı sistem ve metrobüsün elektrik sisteminden yararlanabilecektir ve arazi kamu mülkiyetindedir. C1 ızgarası için öncelikle raylı sistem, deniz ulaşımı, yeşil alan, otopark ve otobüs fonksiyonlarına hizmet eden bir konum belirlenmiştir. Belirlenen konumda istasyon kütüphanenin elektrik sisteminden yararlanabilecektir ve arazi kamu mülkiyetindedir. Aynı zamanda belirlenen konumların taşıt yoluyla ilişkisi olması ve görünür olması da önemsenmiştir.

Çalışma bir bisiklet altyapı elemanı olan elektrikli bisiklet şarj istasyonlarının konumlarının belirlenmesi amacıyla yapılmıştır. Öne çıkan kentsel fonksiyonlar ve altyapı elemanları incelendiğinde bu konumların bisiklet paylaşım sistemi, bisiklet park yapıları, tamir istasyonları, bisiklet yolları gibi diğer bisiklet altyapı elemanları ile desteklenmesinin bisikletli ulaşımın payının artmasında önem arz ettiği söylenebilir.

Çalışma kapsamında kamusal alanlarda elektrikli bisiklet şarj istasyonlarının konumlarının belirlenmesi hedeflenmiştir. Ayrıca konut otoparklarında, iş merkezlerinde, alışveriş merkezlerinde elektrikli bisikletler için şarj imkanı yaratılmalı ve güvenli parklanma alanları ile bisikletli ulaşım desteklenmelidir.

1. INTRODUCTION

With the industrial revolution in the 19th century, the population and the physical areas of the cities increased. The invention of the automobile in the last quarter of the 19th century and the decrease in automobile costs with the developing technology in the first quarter of the 20th century increased automobile ownership. Rapid urbanization, increasing population, and the growing area of cities are scaling the transportation problem up in cities. Especially the traffic problems and environmental problems that occur in parallel with the overuse of automobiles make inevitable both the use of public transportation and the integration of transportation modes with public transit. Considering the negative effects of fossil fuels on the world and public health, it is urgent for all cities in the world to support sustainable transportation modes. World cities have been making comprehensive sustainable transportation plans and developing policies in this context. The main purpose of the policies and strategies required for sustainable transportation in the city is to reduce the share of rubber-tired vehicles, especially private cars, in transportation and expand the rail system and non-motorized transportation types. Cycling is an essential component of sustainable transport plans and policies. The widespread use of bicycles contributes to reducing commuting costs, air and noise pollution, traffic accidents, traffic congestion, and climate change. Cycling is an effective vehicle for reducing dependence on non-renewable energy sources and ensuring environmental sustainability. With the development of e-bikes, there has been a revolution in bicycle transportation. E-bikes have made ground as a new means of vehicle between human-powered bicycles and automobiles by overcoming slope, long-distance, condition, and rider's age. If policymakers aim to achieve sustainable transportation, sustainable city, and global sustainability goals, they should support bicycle transportation and make investments for the infrastructure needs of bicycle transportation.

1.1 Motivation of Research

Traffic, noise and air pollution, and fatal accidents are increasing day by day in cities that are developing with a focus on automobiles. Streets have lost their socializing, playing, and living space features and have become areas for cars to move and park. Policymakers make most of their transportation investments for automobiles, and most of the transportation investments consist of intersection and road projects. In 2020, the number of private cars in Istanbul, which has a population of approximately 16 million, is 3 178 321 (TÜİK, 2021b). In this case, it is not a fair approach that most of the transportation investments are made for less than a quarter of Istanbul residents. In order to create a sustainable and equitable transportation system, first of all, public transportation and its integrated transportation modes should be supported. One of these modes of transportation is the bicycle.

One of the vehicle types that rapidly increased its market share in the 21st century is the e-bike. E-bikes provide access to an area of approximately 31,4 km^2 with a radius of 9-10 km in 30 minutes at an average speed of 8-10 km/h. E-bikes emerge as an inclusive mode of transportation. It provides individual travel opportunities, especially for the elderly and the disabled and a fair and environmentally friendly transportation opportunity to many functions in the city, without getting tired and experiencing traffic jams. The operating costs of e-bikes are 4,5 times cheaper than gasoline motorcycles and 9 times cheaper than cars, including energy, purchasing and maintenance costs, compared to these individual transportation modes. E-bikes, which expand the reach of bicycles and remove the slope and fatigue factor from being a restriction, are increasing rapidly in the world's cities. E-bikes are expected to become widespread soon as an intermediate mode of transportation that combines the positive common features of automobiles and bicycles (ÇŞB, 2021).

The batteries of e-bikes can be used for up to 5 years when charged with appropriate methods. If it is not, the battery life is up to 1 year. Charging the battery up to 95% after each trip is recommended to increase battery life. During the journey that will end at home, people will be able to charge their e-bikes at home. However, this situation reveals the need to charge e-bikes during trips that end in public spaces. For charging stations to be located in public areas, a relationship between electric bicycles and urban functions and infrastructure elements should be established. An analytical method should be adopted by determining the criteria that will affect the location selection.

It is essential to make infrastructure investments for bicycle transportation using analytical methods. Studies should be carried out meticulously, especially in cities such as Istanbul, where the place of bicycles in urban memory is less than in European cities. In a large and sloping city like Istanbul, infrastructure investments for e-bikes are important. The increase in the share of e-bikes in transportation means that the streets are used more equitably and safer, and transportation becomes more fair and sustainable.

1.2 Research Objective

Within the study's scope, it aims to present an analytical approach to determining the locations by considering EBCS as a location problem. It aims to reveal the prominent criteria in determining EBCS locations and determine the importance of these criteria. The target of the study is to select the most suitable locations for EBCS by establishing an e-bike relationship with urban functions and infrastructures.

1.3 Scope of Thesis

Within the scope of the study, EBCS is considered as a location problem. An analytical approach is adopted for location determination, and the MCM method, which is AHP, and GIS are used together. Since no similar study has been found in the literature for EBCS, the criteria affecting the location selection for EVCS, BSS stations, and bicycle parking structures are examined within the scope of the study. In addition, walking distances to urban fuctions, local laws and regulations are examined and constraints are revealed. Based on these studies, criteria that will affect the determination of the locations of EBCS are determined. The relationship between urban functions and infrastructures and EBCS is defined. A model is proposed to decide on EBCS locations at the district scale.

1.4 Organization of Thesis

The thesis is organized into five chapters. The motivation, objective, and scope of this study are explained in Chapter 1. Chapter 2 includes a literature review section. In this section, the concepts of Urbanization, Automobilization and their changes in the historical process are discussed on a global, Turkey, and Istanbul scale. The concepts of sustainability, sustainable city, and sustainable transportation are defined. Policies and targets are discussed at the global, Turkey, and Istanbul scales. The development of the bicycle and the place of bicycle transportation in the historical process are examined and its relationship with sustainable transportation policies is revealed. The current situation and targets are discussed on a global, Turkish and local scale. The development and features of the e-bike are determined. The need for a charging station for the e-bike is revealed. Within the scope of location determination, EVCS, BSS, and bicycle parking structures studies are examined in order to determine the criteria that are effective in determining EBCS locations. Constraints in local laws and regulations are investigated. In the 3rd chapter, information about MCDM is given. The application of AHP and its steps are explained. GIS - MCDM relationship has been revealed. The proposed methodology is described in the 4th chapter, and an application is made. The criteria affecting the EBCS locations and the model developed for decision-making are presented. Locations for EBCS are determined in Kadıköy, which is selected as the case area. Chapter 5 includes conclusion.

2. LITERATURE REVIEW

In this section, the concepts of Urbanization, Automobilization and their changes in the historical process are discussed. The concepts of sustainability, sustainable city, and sustainable transportation are defined. Policies and targets are discussed at the global, Turkey, and Istanbul scales. The development of the bicycle and the place of bicycle transportation in the historical process are examined and its relationship with sustainable transportation policies is revealed. The current situation and targets are discussed. The development and features of the e-bike are determined. The need for a charging station for the e-bike is revealed. Within the scope of location determination, EVCS, BSS, and bicycle parking structures studies are examined in order to determine the criteria that are effective in determining EBCS locations. Constraints in local laws and regulations are investigated.

2.1 Urbanization

In this chapter, urbanization will be examined chronologically on the World, Turkey, and Istanbul scale. The formation of cities, the effects and changes of industrialization and migration on urban functions will be discussed.

While defining urbanization, four milestones should be emphasized. The first turning point is the transition to settled life, the second is the city's birth, the third is the formation of the industrial city, and the fourth is metropolization by overcoming the industrial city. Cities in the period when the energy used in agriculture and transportation was based mainly on animal power and the limits of organic energy use could not be exceeded can be defined as pre-industrial cities. The energy limitation in production and logistics prevented the urban population from exceeding 10%. Cities with populations between 25 000 and 100 000 were scarce in the pre-industrial period. The population of the cities was mostly between 5 000 and 10 000. With the industrial revolution in the first half of the 19th century, the first industrial cities ensued in England. The use of advanced technology in agriculture and the development of industry in the urban area started the migration from country to town and the urban population increased rapidly (Tekeli, 2011). Large European cities were beginning to grow beyond the historic city walls. On the other hand, American cities have never had such a border as European cities. Cities that got rid of their borders had lost their healthy structure by spreading rapidly to the surrounding rural areas. In the 19th century, the population of London increased from 900 000 to 4 500 000, the population of Paris increased from 500 000 to 2 500 000, the population of Berlin increased from 190 000 to 2 000 000, the population of New York increased from 60 000 to 3 400 000 (Fishman, 1977). In the second half of the 19th century, the city consisted of factory fumes, undeveloped infrastructure, and widespread neighborhoods of misery where workers lived (Tekeli, 2011). Urban space was first segregated on the basis of class, and then urban centers were abandoned for workers' homes and factories (Fishman, 1977). After the second half of the 19th century, modern urban planning emerged in parallel with political struggles. Unhealthy cities began to be controlled, regulated, and planned. In the second stage of the industrial revolution, with the development of technology and vehicles such as automobiles, trams, railway transportation, and telephone began to be used effectively. Cities were decentralized and spread over 100-150 km in diameter. In the metropolitan area, the urban area began to expand to include the national space (Tekeli, 2011). In the metropolitan city, while industrial establishments were moving out of the center, the center has turned into an area that provides the management, control, and coordination of production. In 1956, nearly 80% of white-collar employees in New York were working in the center. The population moved out of the city. Satellite cities, which were not only dependent on the city center but also specialized in some functions and complemented the central city, were born (dormitory cities, university cities, holiday cities, etc.). The metropolitan economy has not only created core cities and satellite cities that spread over large metropolitan areas but has also grown and expanded to form megacities/urban districts (Kılınçaslan, 2012).

After World War II, Turkey experienced the demographic transition that other countries experienced in the 19th century. Although the Ottoman Empire could not adapt to the industrial revolution in the 19th century, it was among the affected countries. Though industrialization and agricultural technology developments were very limited, the urban population increased from 10% to 25%. The urbanization process in Turkey was very slow until the end of World War II during the republican period. Urbanization was not seen as a fundamental and insurmountable problem (Tekeli, 2011). The Republic of Turkey followed nationalist-liberal and then statist economic policies until World War II. It focused on industrial investments and tried to prioritize reducing the development gap between regions. After World War II, Turkey interacted with the western bloc for political reasons and was included in the Marshall Plan under the Truman Doctrine. The Economic Cooperation Agreement was signed with the United States of America (USA) on July 4, 1948. Between 1948 and 1951, 62 million dollars of grants and 72 million dollars of loan support (with 2.5% interest and to be paid in 35 years) were received from the USA. 22% of this aid is reserved for agricultural goods and machinery. The number of tractors, which was only 961 in 1936, increased to 31 415 in 1952. Agricultural workers who lost their jobs due to mechanization quickly migrated to the cities (Kılınçaslan, 2012). The rate of urbanization increased to around 6% in all cities, changed its characteristics, and started to be perceived as a social problem (Tekeli, 2011). Thus, the share of the urban population in the total population reached 25,1% in 1950 (Kılınçaslan, 2012). The rapid migration from the country to town continued and half of the big cities became slums (Tekeli, 2011). The highest increase was observed between 1980-1990. In 1990, for the first time in Turkey, the rate of urbanization rose above 50%. In 1990, an increase was observed in the urbanization rates of the provinces of Turkey in general. During this period, every province was urbanized, and there was no province with a meager urbanization rate (below 10%) (Garipağaoğlu, 2010). According to Turkish Statistical Institute (TSI) data, the ratio of people living in provincial and district centers to the total population in 2020 is 93%. Istanbul is the most populous city in Turkey, with a population of 15 462 452 (TÜİK, 2021a).

Istanbul is a city that was established by immigration and continues this characteristic today (Göncüoğlu, 2014). Archaeological excavations show that various colonies settled in Istanbul from the middle of the 7th century BC. Therefore, Istanbul is also an ancient city (Çelik Z. , 1986). Istanbul, which was established as a colony city, was first settled by people coming from Megara in Central Greece and they established Kadıköy (Kalkedon) between 685-680 BC. Between 660 and 657 BC, another group came from Megara and established today's Istanbul at Sarayburnu. Since the first stories, Istanbul was established through migrations and its population consisted of those who came with these migrations (Göncüoğlu, 2014). Istanbul was rebuilt by

Emperor Constantin in the 4th century AD and made the capital. Until Ankara was declared the capital of Turkey, Istanbul was the capital of two great civilizations, the Byzantine Empire and the Ottoman Empire. During the Byzantine period, large mansions were built in Istanbul (Constantinople), and some revenues from the state property were donated to the new population who would come here. The presence of the palace and bureaucracy here and the creation of a new capital increased the population of Istanbul (Çelik Z. , 1986). Constantine I brought the families, administrators, merchants, and artists from Rome to Istanbul, exempted them from taxation, and gave them land and houses (Göncüoğlu, 2014). The population of Istanbul reached between 100 000 and 150 000 in 380. In the centuries that followed, new ports were built on the Marmara coast, and several commercial berths were developed. In the second half of the 5th century, the population of Istanbul was between 200 000 and 300 000. In the inner city, which was bordered by the walls of Istanbul, was encombrement. For this reason, a zoning ban was issued in 450 and it was forbidden for buildings to be higher than 10 floors. Starting from the 10th century, foreigners began to gain privileges in certain areas of the city. Italian colonies, Germans, Arabs, and Jews settled in certain areas of Istanbul (Çelik Z. , 1986). In the 11th century, Turkish soldiers' neighborhoods were established. After the Latin occupation in 1204, the population of Istanbul decreased to around 40 000 - 50 000. In the Ottoman and Byzantine records, in 1402, while the siege of Istanbul was lifted, it was decided to establish a Turkish neighborhood in Istanbul. Thus, 760 households were placed in Istanbul. With the city's capture on May 29, 1453, Istanbul became an Ottoman city. In the census conducted between 1476-1477, the population of Istanbul was close to 100 000. After the conquest of Istanbul, Muslims, Jews, and Emevis from the Black Sea, Rumelia and Anatolia, and the Greek population outside Istanbul were brought to Istanbul. Artisans, craftsmen, merchants, and distinguished families were brought from the newly conquered lands. They were given houses and exempted from taxation. In Istanbul, the policy of creating a quality, workable, scientific, and cosmopolitan society was pursued. At the same time, there was migration to Istanbul from countries outside the borders of the Ottoman Empire (Göncüoğlu, 2014). With the increase in population density, the large squares and wide roads that existed in the Byzantine period gradually disappeared. The empty lands inside the walls were filled, the city spread outside the walls and expanded towards the north and northwest. When the population growth of Istanbul and its suburbs is examined, it is seen that its population was 391 000 in 1844, 430 000 in 1856, 547 437 in 1878, 851 527 in 1886, and 864 576 in 1906. These increases show similarity with the demographic change of European capitals. However, while the reason for the crowding of cities in Europe was the Industrial Revolution, Istanbul did not experience the Industrial Revolution. Istanbul was a privileged city and the reasons for the population increase were different. It was the capital of the empire and the Muslim people who escaped from the turmoil in Europe and the south of Russia migrated to Istanbul (Çelik Z. , 1986). Before World War I, the population of Istanbul reached 1 200 000. With the establishment of the Turkish Republic and the declaration of Ankara as the capital in 1923, the population of Istanbul decreased to 600 000. In the 1930s, planning studies were started for the reconstruction of Istanbul, which was still the largest city in Turkey. In 1936, a 1/5000 scale master plan covering almost all of Istanbul was prepared by the famous urban planner Prost. Even though the Prost Plan could not be fully implemented, it led to some implementation. Neighborhoods with prestigious apartments were established, and the countryside was transformed into places to live all year round. Since Turkey's policy was to develop Anatolian cities in this period, no industrial investment was made in Istanbul. However, as Istanbul was the country's only university city, import center, and weak industrialization center of the private sector, it still showed a certain development. During this period, Istanbul declined from the status of a cosmopolitan world city to the status of being the largest city of a newly established nation-state. After World War II, Turkey's transition to a mixed economy has been a factor in Istanbul's regaining its importance (Tekeli, 2013). Especially in the 1950s, large masses who migrated from the countryside settled in Istanbul. While the population of Istanbul was 983 041 in 1950, it reached 1 466 535 in the 1960s. In 1960, 25% of the population of Istanbul consisted of immigrants who had migrated in the last five years. Squatting in Istanbul also started in this period. The tendency of the country's population to cluster in Istanbul has had more significant effects than the state's policies. Istanbul has created its own economic development with its externalities, internal market, interactive environment, human capital, and geographical advantages. The shaping of the space in the fast-growing city has also taken place in a socio-spatial process. Huge investments had to be made in the field of industry and services to create jobs for the masses that had gathered in Istanbul and in the field of housing and infrastructure for them to settle down. However, Turkey was not capable of making such an investment. Thus, the housing problem was solved not by the administrators but by the newcomers who built slums (IMM, 2009). Those who migrated to Istanbul generally tended to group in the city and settled in neighborhoods with respect to their hometowns. The slum owners have made their houses multi-story and rented them out to their newly arrived hometowns (Tümertekin, 1997). In this period, finding housing became a problem not only for the newcomers but also for the middle class. With the increase in land values in Istanbul, middle-class apartments were built by dividing the land prices. The society also solved the housing problem of the middle class with the build-and-sell housing style (Tekeli, 2013). The rise in urban rent and costs reinforced the tendency of large industries to spread around the city. With its population exceeding 2 000 000, the diversity, prevalence, and wide influence area of urban functions, the shift of industry out of the city, and the existence of more than one center, Istanbul has now reached a scale that can be defined as a metropolis in the 1970s. In the 1970s, the two sides of Istanbul were joined and the number of cars increased, and parts of the city far from the center were opened to settlement with the Bosphorus Bridge built. Another phenomenon that gained momentum in this period was the ownership of secondary residences/cottages, which emerged on the shores of Marmara on both sides of the city. In the 1980s, the urban population reached 3 000 000. The historical peninsula, Karaköy and Beyoğlu on the European side, Üsküdar and Kadıköy on the Anatolian side were located as the main city centers, and more than one sub-center emerged. In the period after 1990, the population in Istanbul has spread outward in the east-west direction. The areas on the city's periphery developed rapidly without infrastructure and plans (IMM, 2009). The population of Istanbul reached 6 779 594 in 1990, 8 467 837 in 1995, and 10 018 735 in 2000 (Bayartan, 2003). Housing Development Administration (HDA), which started to build actively after the 1999 Marmara Earthquake (TOKİ, 2021), built houses for low-income people in the city periphery. In the 2000s, the slums were demolished and the residents were forced to move to high-rise buildings in the city periphery. Istanbul has transformed into a structure in which middle-income people live in the city center and there are poorer neighborhoods around the center, which used to be slums and are now an area for middle- and low-income people to live. Apart from this area, neighborhoods with swimming pools, universities, and hospitals were established on the edge of the area. These areas were used as industrial areas in the past. In these neighborhoods, gated communities were built for the high income, apartments were built for the middle-income, and high-rise buildings were built by HDA for the poor

(Keyder, 2010). Today, the city of Istanbul is a linear metropolis with a population of approximately 16 000 000, with an area of 5313 km2.

2.2 Automobilization

In this chapter, automobilization will be examined chronologically on the World, Turkey, and Istanbul scale. The development of the automobile industry, transportation preferences, decisions, and investments and their effects on urbanization will be discussed.

The first automobile was made in France in 1769 by Nicolas-Joseph Cugnot. This car was a large, heavy, steam-powered tricycle. Light steam cars were produced simultaneously in Germany, France, Denmark, and the USA. Between 1859 and 1860, the storable battery was invented by Gaston Plante in France, and in 1881 the first electric tricycle was made in France by Camille Faure. Although electric vehicles started to be produced in England in 1882 and in the USA in 1890, they were not widespread due to the lack of electric charging infrastructure. The first studies of the gasoline automobile were made in Germany. Gottlieb Daimler and Wilhelm Maybach experimented in the mid-1870s on vaporized petrol to replace gas as a fuel. The first automobile powered by an internal combustion engine was developed by Karl Benz in 1886 (Nübel, 1987). In 1893, the first American-made gasoline automobile was made by Charles and Frank Duryea (Rae, 1987) and presented in Massachusetts. In 1900, there were 8 000 registered vehicles in the USA (Foster, 1983). 4192 automobiles were produced this year, and 28% of these automobiles are powered by electricity (Schiffer, 1994). France, Italy, and smaller European countries also started to produce gasoline automobiles during this period (Britannica, 2011). The first mass-produced automobile was the Model T, produced in the United States in 1908 by Henry Ford. It sold for under $850 in 1908 (average salary of about 18 months), under $300 in 1925 (average salary of about 4 months), and many people owned automobiles. Nearly half of all registered automobiles in the world in the early 1920s were Fords (Britannica, 2020) and electric vehicles have almost disappeared as a commercial product (Schiffer, 1994). More than 15 000 000 Model T automobiles were produced and sold by 1927 (Britannica, 2020). In 1928, while there were 20,24 million automobiles and 2,9 million trucks in the USA, there were 351 000 automobiles and 108 000 trucks in Germany (Blaich, 1987). Between 1913 and 1931, the number of registered motor vehicles in the USA increased 20 times (Rae, 1987). With the abolition of high taxes on vehicle ownership in Germany in 1933 and the development of "People's Car" (Volkswagen) in 1938, private car ownership in Germany increased until World War II. In 1938, the number of cars per 1000 inhabitants reached 19 in Germany, 41 in France, 42 in Great Britain, 8 in Italy (Blaich, 1987) ,and 229,7 in the USA (Davis and Boundy, 2021). Although automobile ownership slowed down during World War II, it gained momentum again after the war (Gössling, 2017b). Especially after World War II, automobiles began to be seen as a prerequisite for continuing and building economic prosperity. The order created by the schedules of trains and tram systems has been disrupted by the automobile. Automobiles provided flexibility and the possibility of traveling at higher speeds (Urry, 2004). Especially in the 1980s and 1990s, social influences such as drive-in cinemas, drive-in restaurants, drive-in stores applications, films, cartoons, and music culture, and associating the automobile with modernism and fashion suggested that the automobile was not an option but a necessity. These applications convinced society and promoted automobile culture (Gössling, 2017a). The number of registered vehicles in the world increased to 122 million in 1960, 812 million in 2022, and 1,3 billion in 2014 (Gössling, 2017b).

Roads that used to belong to pedestrians, bicycles, and vehicles pulled by animals have undergone structural changes with motor vehicles and their importance has increased. In the early 1920s, the highway system in France was categorized into four according to their classes and responsible institutions; these were national highways, regional highways, main local roads, and township roads. England classified its roads into first class and second class with the Ministry of Transport Act in 1919, defined "motorways" as a unique roads with The Special Roads Act in 1949, and established comprehensive road rules with the Highways Act in 1959 (Britannica, 2011). Railroad passenger traffic peaked in the United States in 1920 and then gradually declined except during the World War II era. Before World War II, this reduction in rail transport is directly due to road competition. There was some passenger travel along the coast and to the Great Lakes, but overall volume was negligible and air travel was still in its infancy. The same situation has been experienced in urban public transport systems and light rail systems (Rae, 1987). In the 1950s, with increased social pressure on this issue, massive highways were developed in the USA (Britannica, 2011). In Germany, road construction gained importance with National Socialism. Until 1933, transportation investments were made to improve the railway system and high taxes were imposed on automobiles (Blaich, 1987). In the 1930s, German autobahns (autobahnen) , the world's first national express highway system designed specifically for motor vehicle traffic, were built. These roads have been named “Freeways” by the Federal Highway Administration (Rae, 1987). In 1935, the National Socialists' road investments surpassed railway investments (Blaich, 1987). At the beginning of the 20th century, the use of automobiles and trucks reached high levels in the world. This popularity has accelerated highway construction. This trend has led to increased transportation needs and traffic congestion. Building new highways have increased urban sprawl and the need for new highways has increased (Britannica, 2011).

For the first time, an automobile that runs on gas oil came to the Ottoman Empire in a disassembled form from France at the end of the 19th century. Since the beginning of the 1900s, automobiles have started to be seen on the streets of Istanbul, albeit in small quantities (Çelik M. M., 2019). The public did not like automobiles at first and even feared them because they made a lot of noise and speed (Güneş, 2012). Between 1905 and 1908, the automobile was banned due to the country's political upheaval. With the lifting of the ban, non-Muslims and wealthy local merchants started to own cars. The automobile represented being European. Owning a car was also a luxury in the period when the Republic of Turkey was established after World War I (Çelik M. M., 2019). After World War II, private car ownership in Turkey started to increase in the liberal economy environment (Tekeli, 2009a). With the increase in highway investments within the framework of the Truman Doctrine and Marshall Plan, especially American automobiles and buses were imported (Güneş, 2012). In 1945, the total number of automobiles in Turkey was around 3400. Due to economic reasons, the number of automobiles, which started to increase through imports after the war, remained constant in 1954. With the decrease in imports, motor vehicle assembly began in Turkey in 1954. However, until 1958, there was no development in the assembly industry due to economic reasons (Tekeli, 2009a). The 100% domestic automobile project was started in 1961 with the order of the President. The project name was “Devrim” which means “Revolution” in English and it was completed in 4,5 months. Since the car was peter out on the day it was presented to the public, it became the target of political criticism and the project was canceled (Güneş, 2012). In the first plan period in 1964, vehicles other than private cars were given priority in the assembly industry. Towards the end of 1966, the first serial production of private cars started with “Anadol”. The noticeable increase in private car manufacturing was in the second plan period. Private car ownership has also accelerated with the production of Fiat and Renault. When private cars were imported within the country, the number of automobiles could be kept under control by raising prices through customs duties and imposing import quotas. However, since automobiles are produced in the country, a mechanism has emerged that forces automobile ownership to increase due to reasons such as the existence of the production structure, economic concerns, and pressures from manufacturers, consumers, and sellers (Tekeli, 2009a). After the 1980s, with the ease of import, the increase in production in Turkey, and the effect of the second-hand market, the automobile has become accessible to everyone. Since the 1950s, automobiles have found a place in Turkish cinema as well as in the world. It was often shown as a sign of status and wealth. Similar trends have been observed in real life as well. The Turkish people generally met the automobile late because of economic reasons, and this expensiveness made the automobile to be seen as a status symbol. Although the automobile was getting affordable, the automobile industry's constant setting of new targets has consolidated the automobile's desired object position. Most of the society expressed themselves with their automobiles (Touring the social attraction centers with the automobile, decorating the automobile, writing on the back of the automobile) (Güneş, 2012). In Turkey, where highway investments, automobile industry, and culture are supported, there are 13 099 041 automobiles in 2020 (TÜİK, 2021b).

During the Ottoman Empire, railways were built by foreign entrepreneurs due to economic and technical inadequacies. Various privileges were given to countries such as England, Germany, and France to construct railways in the country. The routes of the railways to be built in the Ottoman Empire were not capable of providing sufficient profit to the investors. For non-economic routes in the world, there was a "mileage reimbursement" application that provided an income guarantee to the investor for each kilometer. The Ottoman Empire agreed to pay mileage reimbursement for the railways to be built by the entrepreneurial countries. Investors, who were not likely to make any losses, started the construction of the railway in the Ottoman Empire. The British in 1856, the French in 1867, and the Germans in 1888 started the construction of railways in the Ottoman lands. However, investors determined their routes according to the economic interests of their own states, not according to the needs of the Ottoman Empire. Thus, the impact areas of the investor countries were formed around the railways. The Hijaz Line, built-in 1910, is the first national railway line in terms of enterprise, capital, labor, and technique. Until the period of the World War I, there was a total of 5411 km of railways in the Ottoman Empire, of which 1997 km belonged to British and French companies, 1923 km belonged to German and Austrian companies, and 1558 km belonged to the Ottoman Empire (Özdemir, 2001). After the proclamation of the Republic in 1923, one of the problems that Turkey had to solve was the transportation problem. Railway construction was given importance in transportation policies. Highways were seen as a complementary element to the railway. The railways were intended to be a network and to achieve this, the individual railways are nationalized and interconnected (Avcı, 2005). In this period, the country had 18 350 km road network. 4 000 km of these roads were in good condition, 13 900 km were stabilized, and 4 450 km were unpaved roads Highways were first dealt with programmatically in 1929 in Turkey. In this period, the Şose ve Köprüler Reisliği (the Department of Macadam and Bridges), which is considered the beginning of the present General Directorate of Highways, was established within the Ministry of Public Works. Again, for the first time this year, asphalt roads have been started to be built on main roads (KGM, 2019). 22 000 km The State Road Network Program, which was prepared by prioritizing some roads that were important for national defense, economy, and tourism, started in 1938 (Şen, 2003). Although the length of the highway reached 40 900 km in 1939, 21 200 km of them were out of repair and unpaved roads. In this period, the share allocated to highways in both the general government budget and public works investments was very low (As, 2013). Although World War II negatively impacted road construction activities, it did not stop it (Şen, 2003). After World War II, Turkey was included in the Marshall Plan in 1948 and grants and loans were received from the USA. In line with the philosophy and principles of Marshall Aids, there has been a great change in Turkey's transportation policies (Kılınçaslan, 2012). The share of investments in highways has increased in transportation investments. While highways were developing rapidly, rail and sea transportation have been neglected. Until 1950, the highways were seen as a system to complement the railway, but after this date, it was accepted as the main transportation system. (Avcı, 2005). In 1950, the share of highways in passenger transport was 47%, and its share in freight transport was 22% (KGM, 2010). One of the biggest factors in supporting highway investments within the framework of the Marshall Plan was American automotive companies and oil monopolies. Between 1950 and 1970 was the golden age of highway construction (Yıldız, 2008). With the establishment of the motor vehicle industry in the 1970s, road policy gained new dimensions. Multi-lane express roads have been started to be built on some main axes with traffic congestion and around cities. During this period, the Bosporus Bridge, the Istanbul Ring Road (Çevre Yolu), and the Golden Horn Bridge were built with a loan from the European Investment Bank (KGM, 2022). After the 1970s, with the increase in the number of commercial vehicles on the road, the efforts to increase the capacity were emphasized. Instead of increasing the existing road network length, the physical and geometric capacity increased (KGM, 2007). In the 1980s, while the capacity increase projects were continuing, the construction of the highway was accelerated with a breakthrough. In the same years, although metro projects were developed in big cities such as Ankara and Istanbul, a planned study could not be carried out. Since urban public transportation remained in the background, the people living in the cities quickly owned automobiles to provide their transportation (Tekeli, 2009a). As of 2003, the main arteries that need to be increased due to traffic density were determined within the framework of the Emergency Action Plan, and divided road constructions were started (KGM, 2022). In 2020, the road network in Turkey reached 68 633 km (KGM, 2021). Turkey's highway priority transport policy has had many negative consequences. With the investments and constructions made, the share of the highway in transportation has increased rapidly. In 2012, the share of highways in domestic passenger transportation was 88,8% and its share in freight transportation was 89.2% (ÇŞB, 2018). The number of motor vehicles has increased rapidly in the country and the cities. In Turkey, this situation led to the emergence of an automotive industry that developed completely dependent on foreign sources and increased the need for oil, a foreign-dependent resource.

Until the second half of the 19th century, urban journeys in Istanbul were mostly made on foot and by boat. The boats were operated by tradespeople and were used for freight and passenger transportation. These boats formed the first public transportation system in Istanbul. Government officials and foreign embassies generally had their own boats. Highway transportation took a longer time than water transportation. Until 1825, only the sultan was allowed to get on the phaeton, but first the officers and then the public was allowed to get on the phaeton. In the 1830s, the number of private phaetons and rental phaetons increased rapidly in the city. Places of Istanbul were shaped for pedestrian movement and very few streets were suitable for vehicle movement. After the big fires that took place frequently in Istanbul, the city was being renewed and the roads were made suitable for vehicles. However, the main determinant in the formation of Istanbul was the establishment of mass transportation systems. In this respect, there were three turning points in the history of Istanbul. The first was the start of regular urban ferry operations in the mid-1850s. The second was the establishment of rail systems such as trams, tunnels, and suburban trains in the 1870s. The third was the start of operation of a large electric tram system in 1914. In the 1927s, Istanbul turned into a developed city on the coast and around the rail system lines. The first automobile came to Istanbul after the 1908 Revolution (Young Turk Revolution). After that, official cars and cars used as taxis were brought. The increase in the number of automobiles occurred after World War I. The number of automobiles in Istanbul, which had a population of 730 334 in 1927, exceeded 1000. The roads built after the years when automobiles started to become widespread in Istanbul were not in the form of the implementation of a comprehensive plan. On the contrary, it was formed as a result of local regulations after the great fires that were very common in Istanbul. Another development in 1927 was bringing buses into the city. The buses, which started operating in 1912, were licensed and started to be operated again. As a result of the agreement made with Ford Company in 1928, an automobile assembly factory was established in Istanbul. Due to the world economic crisis, this initiative could not develop and the increase in the number of automobiles remained limited. In 1935, the total number of private and official vehicles with commercial license plates in Istanbul was 1815. These vehicles carried an average of 47 700 passengers per day. The reason for transporting so many passengers with a small number of vehicles was the minibus system. During the economic crisis, it enabled the emergence of the urban minibus system, which shared the travel costs by using the taxi together. These developments in buses and automobiles have created new demands in both urban and suburban road construction. After World War II, water transportation fleets and bus fleets in the city were developed. The fastest increase in this period was the number of automobiles. In 1950, the total number of private, official, and commercial automobiles in Istanbul reached 5782. With the increase of this number to 10 436 in 1955, significant traffic problems began to be experienced in Istanbul. For this reason, the first signaling projects were started. In 1960, most of the tram lines in Istanbul were removed and replaced by bus lines. Trams were reduced from 56 lines to 16 lines. At the same time, minibusses were included as a new vehicle in the transportation system. In this period, road widening works gained speed and new roads were came on stream for motor vehicles. In 1961, with the abolition of all tram lines on the European side of Istanbul, trolleybuses instead of buses came to the fore. The trolleybus network, which is much larger than the tram network, has been established. With the start of the assembly of Ford brand minibusses in 1961, minibusses started to play an important role in urban transportation by increasing rapidly. In this period, the conflicts between the central and local governments reduced the share of public administrations in urban transportation, and small entrepreneurs became dominant in transportation. This situation has caused urban development to manage transportation supply. In 1966, the tramlines on the Asian side of Istanbul were also removed and replaced by bus lines. No study was carried out on trolleybuses in Istanbul in the following times. In 1966, "Anadol" brand domestic automobile production started in Turkey. Since the amount of production was not high, this situation did not greatly affect automobile ownership. With the decision taken by the city traffic commission in 1966, the number of commercial license plates was stopped. In 1970, there were 55 392 cars in total in Istanbul and their distribution was as follows: 34 930 were private cars, 3716 were official cars, and 16 764 were commercial vehicles. With the came on stream of the Bosphorus Bridge and ring roads in 1973, the Anatolian and European sides of the city were connected with a highway connection, and new trends emerged in the growth and spatial formation of the city. During this period, midibuses with a capacity of 14 passengers were included in the transportation system. The most important development affecting the urban transportation system of this period was the production of Renault and Fiat brand cars in Turkey in 1971. The number of private cars in the city increased rapidly. In 1975, there were 97 703 private cars and 4100 official cars in the city. The number of commercial vehicles did not increase due to license plate restrictions. However, the license plate restriction has led to the emergence of the illegal taxi system in Istanbul. In 1973, approximately 2500 illegal taxis were operating in Istanbul. Bus transportation made significant breakthroughs in 1979. The bus fleet was expanded, bus lanes were created in the city, a transportation card system was brought into play for payment, and a season ticket system was established. In 1980, the population of Istanbul reached 4 643 600. The number of cars in the city was 211 382. 189 379 of them were private cars and 4 461 of them were official cars. Between 1980 and 1985, important road projects that significantly affected the urban form and urban transportation pattern were implemented. In 1985, the population of the Istanbul metropolitan area increased to 5 571 000. The total number of automobiles in the city reached 286 000 (Tekeli, 2009b). In 1988, Fatih Sultan Mehmet Bridge, another bridge connecting the Anatolian side to the European side, came on stream. Thus, the weight of the highway in the city increased even more, and the city's rapid expansion gained momentum. Light rail systems came on stream in 1994 and metro in 2000 (Ayataç, 2016). In 2005, the population of Istanbul reached approximately 12 007 000 and the number of registered vehicles reached 1 522 521 (IMM, 2007a). The Bus Rapid System (BRT) of Istanbul started to be constructed in 2007 and its entire route was completed in 2012 (Buran, 2013). The BRT route is 52 km long and passes through the Bosporus Bridge and the city's congested highway. Marmaray, a rail system project that includes the modernization of the existing suburban train line and its connection with a tubular passage under the Bosporus came on stream partially in 2013 and with all its lines in 2019 (Efe and Cürebal, 2011). The length of the line is 76,3 km. Although large investments were made in the public transportation system during this period, the era of megaprojects began in the city of Istanbul. The Eurasia Tunnel, built for motor vehicles under the Bosporus, came on stream in 2016 (UAB, 2022). The third bridge, Yavuz Sultan Selim Bridge, and Northern Marmara Highway came on stream during this period, and highway transportation and private automobiles were supported again (UAB, 2016; UAB, 2021; UAB, 2022). In 2017, the population of Istanbul reached 15 000 000 and the number of automobiles reached 2,7 million. In 2017, 20% of the journeys were made by private cars, 7% by shuttles, 28% by public transport, and 45% by foot. On the other hand, 72% of public transport journeys were road transport, 2,04% were rail systems, and 0,22% were water transportation (IMM, 2017a). In 2020, the number of private cars in Istanbul, which has a population of more than 15 million, reached 4 388 118 (TÜİK, 2021b).

2.3 Sustainability

In this chapter, sustainability will be examined chronologically on the level of the World and Turkey. The definition of sustainability, sustainability efforts, policies, and international agreements will be summarized.

The modern sustainability movement has been influenced by the ideas of critics, intellectuals, and protesters of the 1960s and 1970s who raised awareness of environmental issues and advocated social justice and rights. While the three E's of sustainability rarely match the trends of the 1960s and 1970s, many of the key concepts that shaped sustainability were articulated before the 1980s. Establishing the "environment" as a conceptual prism through which we can see the world and its place in humanity was perhaps the most important achievement of the environmental movement in the 1960s. Although the word "environment" dates back to the 17th century, its ecologically-based definitions began to be made in 1956 and entered the common language in the 1960s. It has been an innovative act to think of an all-inclusive, interconnected definition of the environment. Because the concept of environment has crossed the conceptual boundaries of "nature". Nature has been the usual way of counting air, water, soil, and animals since ancient times and defining half of life. In the 1960s, large numbers of academics, student groups, activists, and environmental organizations leveraged new and often disruptive scientific research to raise awareness of environmental issues, push for social change, and advocate for government policies that supported the state (Caradonna, 2014). In this section, the efforts that have significant effects on shaping the concept of sustainability and the adoption of sustainability as a policy and their results will be discussed.

The Canadian Wildlife Federation, now Canada's largest non-governmental organization (NGO), was founded in 1962. In Germany, several regional environmental groups emerged and came together to form Bund für Umwelt und Naturschutz Deutschland in 1975. Four of the ten major environmental groups currently operating in the USA were established between 1961 and 1970. These are World Wildlife Fund for Nature, established in 1961, Environmental Defense Fund, established in 1967, the Friends of the Earth, established in 1969, and Natural Resources Defense Council, established in 1970. Satellite offices of these and similar organizations have also been established and have become very active on university campuses. In this way, environmental concerns have now begun to compete with more social and political events in student activism. Newer environmental groups have also emerged in the USA. But they have joined six other groups, which are more entrenched than themselves, to create a strong lobby and a research and advocacy blog that will have a tangible impact on government policy work, environmental awareness, and social practices. The environmental movement of the early 1970s raised public awareness of the world's escalating ecological crisis and resulted in several significant achievements. Although environmentalists could not fulfill all their wishes in this period, they formed a consensus that the world was too dirty, too populated, too wasteful, too consumerist, and too socially unfair. In 1952, London's notorious big smog prompted the United Kingdom (UK) to work on the pioneering Clean Air Act, which came into effect in 1956. In the USA, a rapid series of federal actions, an unprecedented level of environmental regulation and protection, were initiated in the 1960s and several groundbreaking environmental laws were established: the 1963 Clean Air Act (modified in 1970), which regulated air pollution at the national level; the 1964 Wilderness Act, which protects millions of acres of federally owned "wildlife", 1965 Land and Water Conservation Fund Act, 1965 Solid Waste Disposal Act, 1966 Endangered Species Preservation Act, 1968 Wild Scenic Rivers Act, the 1970 National Environmental Policy Act, which requires environmental impact statements for federal projects and actions, and the 1972 Clean Water Act, which regulates toxins and other water pollutants. The culmination of these efforts is the vital US Environmental Protection Agency, founded in 1970 by President Nixon and whose mission is to protect human health and the environment. Similar legislative acts and agencies emerged in other Western countries between the 1970s and 1990s. Environmentalists in many countries have established the Green Party in the political arena. By the mid-1970s, the Greens had operational branches in Belgium, England, and Germany. Perhaps even more important than the emergence of the global Green Party was establishing international institutions and holding conferences dedicated to addressing the world's possible ecological crisis. One of the most notable entities in this field is the United Nations Environment Program (UNEP), which has coordinated international environmental efforts since 1972 and is today one of the leading NGOs promoting sustainability. UNEP emerged from the United Nations (UN) Conference on the Human Environment held in Stockholm in June 1972. The Stockholm conference is the first in a long series of UN-sponsored meetings that developed international environmental law and protection and became the main force and outlet of expression for supporters of the sustainability movement in the late 1980s. This international conference has been a turning point regarding the global dimension and scope of environmental and ecological problems. Since Stockholm, the idea of tackling environmental issues collaboratively has been a cornerstone of international relations and agreements (Caradonna, 2014).

The understanding of sustainability begins with the definition made by the World Commission on Environment and Development in 1987. *"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs"* (World Commission on Environment and Development, 1987). Sustainability is more about supporting the growth of the Earth or a part of it, the human population and the economy, and finding a stable state where human, animal, and plant health will not be endangered due to this growth. The most important difference between traditional environmental protection views and sustainability is that the first focus on environmental remediation and some specific environmental threats, while the second focuses on long-term dynamic processes and creates a proactive and holistic effect. The source of many sustainability ideas that are widely taken for granted today is the work of the UNs' World Commission, commonly referred to as the Brundtland Commission. In 1987, the Brundtland Commission report defined sustainability to consist of three parts, all three of which begin with an e: environment, economy, and equity. Sustainability can only be achieved by simultaneously protecting the environment, ensuring economic growth and development, and promoting equality. The most important feature of this broad concept is that it means that results are required for all three topics and that success in one topic cannot be achieved at the expense of the other. In 1988, the UN Environmental Program created the Intergovernmental Panel on Climate Change (IPCC). This organization aimed to bring scientists together to research climate change and its extent. Many links between carbon emissions and climate change have been evaluated scientifically in the IPCC studies. The reports it published had two main findings. First, global temperatures are rising. Second, this rise can be largely attributed to human activities due to carbon dioxide and other gases emitted into the atmosphere, especially with the use of fossil fuels. The Brundtland Commission report formed the basis for discussions and debates on sustainable development at the Earth

Summit held in Rio de Janeiro in June 1992. At this conference, the importance of international cooperation for the efficient use of resources in the world was emphasized. One outcome of the Earth Summit was the resolutions commonly referred to as *"Agenda 21"*, which contained principles to guide countries in their economic development efforts in the twenty-first century. Agenda 21 has been signed by 178 countries, including the United States. Countries have become the focus of efforts to be more sustainable, especially after the Earth Summit and Agenda 21, perhaps because of the importance the UN attaches to the idea of sustainability. In addition, unlike the previous conferences, a *"multi-voiced and participatory"* approach was developed with the participation of local governments, NGOs, representatives from various sectors, and central institutions (Portney, 2015). In 1996 the second UN Conference on Human Settlements (Habitat II), named *"City and Town Summit"* took place in Istanbul, Turkey. Its objective was to address two major themes concerning all nations: *"adequate housing for all"* and *"viable human settlements in a changing World full urbanization"* (UN, 1996). In 1997 Kyoto Protocol extended the United Nations Framework Convention on Climate Change (UNFCCC) and identified specific targets for reducing greenhouse-gas emissions. In 1997 UN Earth Summit +5 Conference in New York was occurred (Portney, 2015). In the conference held to evaluate the implementations of the decisions taken at the Rio Conference, it was emphasized that concrete initiatives should be taken due to the insufficient implementation. In addition, at this meeting, all countries agreed to create their own National Agenda 21 for sustainable development (Özmehmet, 2008). In 2000, UN Millennium Declaration was occurred. The summit's main theme is to halve poverty in underdeveloped countries by 2015. As a result of the summit, the countries decided to reach the eight targets determined as Millennium Development Goals by 2015 by making global cooperation (UN, 2000). In 2001 European Union Sustainable Development Strategy was created. Thus, it aimed to create European Union (EU) policies to actively support the sustainable development of other countries, especially underdeveloped countries. To meet this ambitious obligation, the EU has committed to assessing the internal and external impacts in all its new policies (Adelle et al, 2006). In 2002 UN World Summit on Sustainable Development (Rio +10 or Johannesburg Summit) was occurred. The most important feature of this summit was that it prioritized providing participants from all segments of the society, taking an active role in the stages of goal setting, strategy development, and decision-making, both during the preparation and meeting process. At the summit, it was decided to make immediate progress is needed to eradicate poverty, diversity the energy supply and increase the global share of renewable energy resources, reduce biodiversity loss, increase corporate social responsibility and accountability, and ensure the effective implementation of intergovernmental agreements and common benchmarks, and the formulation of National Sustainable Development strategies and to start the applications until 2005 (Özmehmet, 2008). In 2005 UN World Summit on the Millennium Goals +5 in New York, in 2009 UN Climate Change Conference in Copenhagen, in 2011 UN Environmental Programme Green Economy Report, and in 2012 UN Conference on Sustainable Development (Rio +20) events were completed. Numerous other international organizations and NGOs have been involved, in various ways, in helping to define the context for sustainability policies; for example, the Organization for Economic Cooperation and Development (OECD) released a Green Growth Strategy and the World Bank created a Sustainable Development Program (Portney, 2015). Adopted by all UN Member States in 2015, the 2030 Agenda for Sustainable Development offered a common plan for peace and prosperity for people and the planet, now and in the future. There were 17 Sustainable Development Goals (SDGs) on the agenda, an urgent call for action by all developed and developing countries in a global partnership. The agenda and objectives aimed to end poverty and other deprivations, tackle climate change, protect the aquatic and terrestrial ecosystem, improve health and education, reduce inequality, and promote economic growth (UN, 2015). Since the agreements that have been made did not have a binding nature of the agenda and targets, they rather set global targets and enabled the signatory countries to set targets (Portney, 2015). The Paris Agreement, adopted at COP'21 held in Paris in 2015, is a legally binding international agreement on climate change. 196 parties have accepted the agreement, which entered into force in 2016. It aimed to limit global warming to well below 2, preferably 1,5 degrees Celsius compared to pre-industrial levels. To achieve this long-term temperature goal, countries aim to reduce their greenhouse gas emissions as soon as possible to achieve a climate-neutral world by the middle of the century (UN, 2021). Countries have done many studies and cooperated to ensure sustainability on a national and global scale. With the involvement of different stakeholders in these studies, the scope of sustainability studies has improved and their effects have increased.

In the 1970s, environment studies began in Turkey, and action plans and policies were tried to be created (Çokgezen, 2007). After the Stockholm Conference, as an indicator of the development of environmental awareness in Turkey, a section on Environmental Problems was included in the Third Five-Year Development Plan covering 1973-1977. It was decided to take some measures to identify environmental problems, monitor international research, make regulations within the framework of principles, and educate society. However, it has also been stated that an application that will deviate Turkey from its development priority by industrializing cannot be accepted. During this period, Turkey's priority was development goals (DPT, 1973). In 1978, with establishing the Prime Ministry Undersecretariat of Environment to deal with national and international activities related to the environment, environmental approaches took their place in state policy (Özmehmet, 2008). In the Fourth Five-Year Development Plan covering 1979-1983, environmental problems came to the fore again. It was stated that the pollution seen in Turkey is the environmental pollution encountered in advanced societies. A solution should be developed to improve the water, sea, air, soil pollution, and bad housing conditions in the slum areas. At the same time, it was stated that voluntary organizations such as foundations, associations, etc. working on environmental problems will be supported, environmental areas for public use will be created in big cities, and developments in the international platform will be followed (DPT, 1979). The Second Environmental Action Program was also accepted and a policy was adopted to prevent pollution and follow scientific developments (Erdem and Yenilmez, 2017). In the 1982 constitution, with the text, *“Everyone has the right to live in a healthy and balanced environment. The state and citizens must develop the environment, protect environmental health and prevent environmental pollution"* (TBMM, 1982) environmental policies took place as binding in a constitutional framework and the concept of environmental protection was included in the constitution for the first time. After the Environmental Law in 1983, various regulations were published (Özmehmet, 2008). In the Fifth Five-Year Development Plan covering 1985-1989, environmental problems in Turkey were expressed as *"environmental pollution as a result of urbanization, erosion and natural disasters, and environmental problems caused by rapid industrialization and modernization in agriculture"*. In this context, the basic approach is not to eliminate the existing pollution but to use, preserve and develop the resources in the best way that future generations can benefit. This plan mentioned that environmental policies should be developed in subjects such as tourism, water quality, and energy sector (DPT, 1985). The Third Environmental Action Program, signed in 1986, included a reduction of dependence on nuclear energy, coal and oil, ensuring energy efficiency, encouraging less-polluting energy sources, and waste management (Erdem and Yenilmez, 2017). The approach aimed at sustainable development, which was heavily discussed at the 1992 Rio Conference, emerged for the first time in the Sixth Five-Year Development Plan. In the Sixth Five-Year Development Plan covering the years 1990-1994, the basic principles of environmental problems were defined as *"To ensure the management of natural resources in a way that will allow continuous economic development by protecting human health and natural balance, and to leave a natural, physical and social environment that is decent for future generations"*. It was stated in the plan that environmental policies should be harmonized in all economic policies, forest, mining, tourism, automotive, and industrial activities (DPT, 1990). While the Community included the concept of *"sustainability"* in its environmental policies in the Maastricht Treaty, which was accepted in 1992 and entered into force in 1993, and in the 5th Environment Action Plan, which came into force in 1993, Turkey has taken a pioneering approach by mentioning this concept in the Sixth Five-Year Development Plan (Erdem and Yenilmez, 2017). Since the Undersecretariat of Environment could not keep up with industrial development, it was closed in 1991 and the Ministry of Environment was established instead (Özmehmet, 2008). Turkey started to prepare the National Environmental Strategy Action Plan (NEAP) in 1995 and completed it in 1998. The preparation process (the coordination of the State Planning Organization (SPO)), the technical support of the Ministry of Environment and the financial support of the World Bank was carried out with the participation of universities, different professional groups, and sectors. In the NEAP, which determines the priority areas of activity in terms of the environment, the sources of pollution that pose a threat to human and environmental health are defined. In addition, a series of initiatives proposed to develop an effective environmental management system for Turkey to achieve its long-term environmental goals. The need to strengthen information and awareness about the environment was emphasized and it was foreseen to take steps to adopt the environmental standards and regulations of the EU (Özmehmet, 2008). In the Seventh Five-Year Development Plan covering 1996-2000, it was stated that although the understanding of sustainable development became widespread, the dangers regarding the environment and the future of the world still prevail, but great progress can be achieved in this field by using the opportunities provided by technology to solve environmental problems. It has been underlined that it has gained its quality and importance has increased in production, employment, and trade (DPT, 1996). It is seen that the Seventh Five-Year Development Plan complies with the Environmental Action Programs in general and the Fifth Environment Action Program and the Amsterdam Treaty in particular. Especially in the perspective of sustainable development, its approach to environmental problems is highly compatible (Erdem and Yenilmez, 2017). NEAP was prepared in the Eighth Five-Year Development Plan covering 2001-2005, and social awareness towards a clean environment increased (DPT, 2001). In the Ninth Five-Year Development Plan covering 2007-2013, environmental problems and policies regarding their solutions were handled together with sustainable development, as in other plans. The preparation of a National Action Plan, in which policies and measures to reduce greenhouse gas emissions will be revealed with the participation of relevant parties within the framework of our country's conditions, and the fulfillment of the obligations regarding the UNFCCC (DPT, 2006), was an indication that the plan has been prepared under the developments in the international arena. In the Tenth Five-Year Development Plan covering 2014-2018, it was stated that Turkey would reduce the pressure on the environment by adopting policies that prioritize the prevention of pollution, the protection of biological diversity and natural resources, and their sustainable use. In this context, it has been observed that in almost all sub-headings such as tourism, infrastructure, energy, logistics and transportation, and industry in the plan, approaches that include environmental protection or prioritize the environment are included. One of the most important dimensions of livable spaces is protecting environmental quality and adopting a development and spatial development approach that will not reduce the welfare and happiness of future generations (KB, 2013). In 2015, Turkey submitted the Intended Nationally Determined Contribution within the scope of the Conference Lima Call for Climate Action. According to Turkey's national contribution statement, it is foreseen that greenhouse gas emissions will be reduced by 21% in 2030 compared to the reference scenario (Business as Usual (BAU)) (ÇŞB, 2016). In 2016, the Paris Agreement entered into force due to meeting the requirement that at least 55 parties ratify the agreement, which accounts for 55% of global greenhouse gas emissions. In 2016, Turkey signed the High-Level Signing Ceremony held in New York together with the representatives of 175 countries. The agreement, which has many goals such as sustainable development and poverty eradication, preventing climate change, and reducing greenhouse gas emissions, envisaged a National Statement of Contribution submission every five years. The Turkish Grand National Assembly ratified the Paris Agreement in 2021 (ÇŞB, 2016). In 2016, Turkey prepared the First Voluntary Local Reviews (VLR) report to evaluate the progress and limitations of the Sustainable Development Goals (UN, 2019). In the Eleventh Five-Year Development Plan covering 2019-2023, it was emphasized that Turkey was defined as a developing country and it was emphasized that the environmental policies to be implemented should not harm the development goals. The terms *"Sustainability"* and *"Sustainable Development Goals"* are included under almost every heading. Current situation determinations were made on the axis of *"livable cities and sustainable environment"* and solutions were suggested for the problems; policy priorities such as building livable cities, improving the quality of life in cities and rural areas, ensuring sustainable environment and natural resource management, and reducing interregional development disparities have been determined. It was aimed to prepare separate Climate Change Action Plans for the seven geographical regions of the country and it was stated that international agreements on this subject would be complied with (SBB, 2019a). Although SDGs are widely included in the Eleventh Five-Year Development Plan, targets and indicators regarding sustainability and the environment are limited. If Turkey's environmental plans are considered in general, priority is given to the purpose of providing development rather than the environment. Despite this difference, almost all of Turkey's environmental policy has been shaped within the framework of EU programs and policies, but it has not shown the same success in practice (Erdem and Yenilmez, 2017).

2.4 Sustainable Cities

In this chapter, the sustainable city approach will be examined chronologically on the level of the World and İstanbul. The definition of sustainable city, sustainable city efforts, policies, and international agreements will be summarized.

The concept of sustainable city can be defined simply as *"an ecologically sustainable, socially equitable and economically practicable"* (Blanco and Mazmanian, 2014). The goals of sustainable cities can be expressed merely as reducing the use of natural resources and waste production, simultaneously increasing livability and being in harmony with local, regional, and global ecosystems (Newman and Kenworthy, 1999). Cities are the dominant human habitat. Cities' sustainability initiatives are a critical step towards global sustainability. If the planet's sustainability is concerned, then the focus needs to be on the sustainability of cities. Throughout human history, cities are places where global challenges converge, ideas are tested, and creativity and solutions emerge. Cities have a shared concern about the challenges of urbanization and they came together by realizing that the answer can be found by charting a new route and becoming more sustainable socially, economically, and environmentally (Blanco and Mazmanian, 2014).

The Brundtland Commission (United Nations' World Commission), established in 1987 and is the source of many sustainability ideas widely accepted today, has also been a pioneer in sustainable cities. The Brundtland Commission advocated paying special attention to urban sustainability, saying that cities in industrialized countries have a significant share in resource use, energy consumption, and environmental pollution. The pursuit of city-based sustainability has received support in many western countries. The Brundtland Commission report formed the basis for discussions and debates on sustainable development at the Earth Summit held in Rio de Janeiro in June 1992. One outcome of the Earth Summit was the resolutions, commonly referred to as *"Agenda 21"*, which contain principles to guide countries in their economic development efforts in the twenty-first century. The International Council for Local Environmental Initiatives (ICLEI) was established in 1990 by 200 local governments from 43 countries at the World Congress of Local Governments for a Sustainable Future held at the UN headquarters in New York. Chapter 28 of Agenda 21, titled *"Local Authorities Initiatives in Support of Agenda 21"*, has been the foundation of ICLEI. Their first international program is Local Agenda 21, an initiative promoting participatory governance and local planning in sustainable development, and the Cities for Climate Protection initiative. ICLEI administrative council assumed more comprehensive duties and powers in 2003 and changed its name to ICLEI- Local Governments for Sustainability. The organization's primary mission is to provide broad advice and technical assistance to cities seeking to understand *"best practices"* (Portney, 2015). The Clinton Foundation was founded in 2001 by former US President Bill Clinton. This foundation has undertaken the mission of working with cities to mitigate climate change. In 2005, the foundation established C20 with 18 megacity representatives to "*reduce climate pollution and creating*". In 2006, the C40 committee was established with the participation of 22 more presidents (C40, 2020). The foundation's C40 initiative works on different business and program areas to improve the quality of life in the world's megacities. The Foundation's activities primarily focus on providing technical and financial support to help cities strengthen their biophysical environment cost-effectively. A climate protection program has been established by the Foundation, in which member and volunteer cities will work together and reduce carbon emissions. The United States Conference of Mayors' Climate Protection Program, created by mayors who came together in 2005 under the influence of the Kyoto Protocol, invites mayors to register and make a commitment to reduce their carbon emissions. The US Environmental Protection Agency also implements a similar climate program. Other NGOs working with cities for sustainability-associated programs include the World Bank's Sustainable Cities Initiative, the International Institute for Sustainable Development, the International Monetary Fund, the World Water Council, and the Urban Water Sustainability Council. The National League of Cities' Sustainable Cities Institute and the International City Management Association's Center for Sustainable Communities are the supporting organizations in the USA (Portney, 2015). Support for sustainable cities has gained momentum day by day. The OECD, the European Community, and even Word Bank have a sustainable cities program (Newman and Kenworthy, 1999).

Istanbul, which has a unique geographical location, a magnificent historical past, and great cultural and economic potential, is one of the most important cities of our country and the world. These values of Istanbul, which has such privileged geography, historical and cultural accumulation, and unique natural beauties, are gradually disappearing due to the development pressure and unplanned development it is exposed to. Along with this awareness, Istanbul Metropolitan Municipality (IMM), like other local governments in the world, has worked for Istanbul to be a sustainable city, prepared plans, made commitments, and became member of various unions. This section will discuss the primary efforts made to make Istanbul a sustainable city.

Istanbul Environmental Plan was made in 2009. This plan aimed to "*preserve Istanbul's universal cultural and natural values, and to give Istanbul a strengthened city status on a world scale with its nature, quality of life, accessibility and young, dynamic population*". In the plan, two elements stood out in the spatial planning of

Istanbul. The first of these was *"size"* and the second was *"management and manageability of growth"*. By presenting the reason for the reorganization of its spatial structure, it was aimed to prevent the destruction of these two problems, or in other words, the living resources and values of Istanbul. In this context, it was aimed that every land use decision in Istanbul contributes to the sustainability of the natural and ecological structure of the city. This Plan included important tools and decision support systems that aim to make economic and ecological decisions in a way that does not conflict with each other, that these decisions overlap with the strategic approaches on land use, and that address sustainable development with all its dimensions by shaping the social structure, administrative decisions and space. With the plan, the main principles of the development of Istanbul were determined; A road map was drawn to guide the sub-scale plans to ensure environmental, economic, social, and spatial integration and increase the quality of life to prevent negative consequences. This process made it necessary for Istanbul to seek sustainability in general and environmental sustainability in particular (IMM, 2009). The 2007-2011 Strategic Plan was created in 2007 with the vision of *"being the pioneer and leading municipality that makes Istanbul, Turkey's visible face and window to the world, a sustainable world city with a high quality of life by protecting its unique heritage"* (IMM, 2007b). With this plan, current situation analyzes were made and strategic goals and targets were determined. The 2014-2023 Istanbul Regional Plan was prepared under the coordination of Istanbul Development Agency (IDA) in 2014. This plan determined the relationship between the plans, policies, and strategies formed at the national level and the activities carried out at the local level and the development axes. Priority areas, strategies, targets, and measures determined in line with the needs of Istanbul have been put forward. It was a high-scale plan that included all stakeholders and aimed to be implemented through participatory methods. The 2023 Istanbul Vision had three main components; Having the right to comment on the global economy, producing high added value, innovative and creative economy (i), fair sharing, inclusive and learning society (ii), pleasant, authentic urban spaces and sustainable environment (iii). Within the plan's scope, it has been revealed that spatial development in Istanbul is not a sustainable development dynamic. Strategies and policies were produced by analyzing the current situation (İKA, 2014). By voluntarily signing the Global Climate Agreement of Mayors (Compact of Mayors (CoM)) in 2015, it was committed to reducing Istanbul's greenhouse gas emissions and preparing a greenhouse gas inventory and climate change action plan. CoM is a global coalition of mayors and city officials who voluntarily commit to reducing local greenhouse gas emissions, building climate-resilient cities, and monitoring developments transparently (IMM, 2017b). IMM will play a key role in mobilizing local parties and citizens together to create a low-carbon and climate-resilient city, strive for a renewable energy-based, low-emission and resilient development, support coordination and cooperation between actors, and adopt practices for local adaptation and mitigation. IMM has committed to allocate a budget with the Malatya Consensus Istanbul Declaration made by UCLG-MEWA. In addition, IMM declared that it would develop its institutional capacity for the fight against climate change, creating new and innovative funding sources in this direction, supporting urban agriculture, strengthening training, raising awareness and making resource efficiency studies on waste management, encouraging renewable energy and energy efficiency investments, ensuring sustainability in products and services in supply processes (IMM, 2018). United Cities and Local Governments Middle East and West Asia Section (UCLG-MEWA), established in 2014, is an important network that works to establish cooperation between local governments in the region and localize the global agenda (IMM, 2017b). The Istanbul Climate Change Action Plan, completed in 2018, has been integrated with the international city networks of which IMM is a member and the Malatya Consensus Istanbul Declaration on climate change.This action plan has been prepared as an important and ambitious first step to strengthen national and local cooperation and guide other cities (IMM, 2018). In 2006, the city of Istanbul became a member of C40 Cities. The C40 Climate Leadership Group, of which more than 90 megacities are members, with a population of 600 million worldwide and representing 25% of the global economy, offers the opportunity to share information and experience effectively on climate change among its members. Its difference from other programs is that it is focused on big cities and has a global scale. C40 evaluates the work of cities on climate change in 7 main areas, which are: adaptation and management of water resources (i), energy (ii), finance and economic development (iii), measurement and planning (iv), solid waste management (v), transport (vi), and regional planning and development (vii) (Mavi Sürdürülebilir Kalkınma, 2017). There also have various networks created by C40 to support the plans and implementations of member cities. Istanbul is a member of five of these networks: Walking & Cycling Network (i), Food Systems Network (ii), Waste to Resources Network (iii), Water Security Network (iv), and Air Quality Network (v) (C40 Cities, 2019). With Deadline 2020, members of C40 are committed to achieving their city's carbon-neutral target by 2050 through a *"fair share"*. As a C40 member, IMM signed the Deadline 2020 Commitment in October 2019 and accepted the goal of Istanbul to be a carbon-neutral and climate change resilient city by 2050 (IMM, 2021a). Istanbul Planning Agency (IPA) was established in 2020 with the aim of *"planning a fair, green, creative and happy Istanbul with scientific coordination"* (İPA, 2020). Vision 2050 Office was established as one of the sub-components of IPA. It has focused on issues that touch every aspect of life, such as the climate crisis, transportation, infrastructure, culture, employment, agriculture, and food policies. It evaluates the current situation on these issues and creates a future vision within a two-year work program framework. It aims to prepare action plans that will be put into practice. It is aimed to follow a participatory policy in the planning process. Universities, public and private sectors, NGOs, and 16 million Istanbul residents are defined as stakeholders (Vizyon 2050 Ofisi, 2020). As a result of the meetings it held with IMM's internal and external stakeholders in 2020, the Local Equality Action Plan was formed. Main headings were created according to the problem areas the narratives and reports pointed out. In the plan participation (i); gender-based/violence against women and discrimination (ii); health (iii); poverty (iv); housing (v); economic empowerment and employment (vi); care services (vii); urban planning, design, accessibility and the safe city (viii); social support (ix); mobility and transport (x); culture, arts, recreation, sports and green space (xi); public relations information promotion (xii); livable city (xiii); education and lifelong learning (xiv), disaster/crisis (xv) were determined as headings. Analyzes were made for each of these titles, and targets, actions, and indicators were determined (IMM, 2020a). In line with the goal of Istanbul to be a carbon-neutral and climate change-resistant city by 2050, the Istanbul Climate Change Action Plan was prepared in 2021. This plan is directly associated with transportation-oriented plans such as the Istanbul Sustainable Urban Mobility Plan and the Istanbul Bicycle Master Plan (IMM, 2021a).

2.5 Sustainable Transportation

In this chapter, sustainable transportation will be examined chronologically on the level of the World, Turkey, and İstanbul. The definition of sustainable transportation, sustainable transportation efforts, policies, and relevant international agreements will be summarized.

Everybody in the world travels to shop or work; all kinds of raw materials must be transferred from the land to production or use, and all products must reach the market from the production site and from the personnel to the consumer. Transport, the term covering these activities, plays a crucial role in the fabric of today's urbanized nation. The way people live or work has changed as a result of developments in lifestyles and transportation facilities; therefore, what can be said for the future is that these developments and changes will continue to occur (O'Flaherty, 1997). Thus, the critical question is how this continuous process in transportation will take place and what kind of strategies will be needed to have a more sustainable and livable future in urban areas, both socially, economically, and environmentally.

Based on the sustainable development definition of the Brundtland Report published in 1987, sustainable transportation can be defined as *"the current transport and mobility needs without compromising the ability of future generations to meet these needs"* (Black W. R., 1996). In 1998 the Centre for SustainableTransportation in Canada viewed a sustainable transport system as one that:

> *allows the basic needs of individuals and societies to be met safely and in a manner consistent with human and ecosystem health, with equity within and between generations (i); is affordable, operates efficiently, offers choice of transport mode, and supports a vibrant economy (ii); limits emissions and waste within the planet's ability to absorb them, minimizes consumption of non-renewable resources, reuses and recycles its components, and minimizes the use of land and production of noise (iii).*

European countries generally use *"sustainable mobility"* instead of *"sustainable transportation"*. In the Mobility 2001 report by MIT and Charles River Associates, sustainable mobility has defined as *"the ability to meet the needs of society to move freely, gain access, communicate, trade and establish relationships without sacrificing other essential human or ecological values today or in the future"* (Black W. R., 2010).

Many countries have carried out sustainable transportation studies, prepared plans, and made commitments as members of various associations. In the mid-1990s, many OECD countries realized that their current policies could not lead society towards a more sustainable transport system. The main reason for this was the lack of a definition of sustainable transport and clear goals to achieve it. Acknowledging all these problems, the OECD Environmental Policy Committee's Task Force on Transport initiated the Environmentally Sustainable Transport (EST) project. With the EST Project, different from traditional approaches to developing transportation policy, an environmentally sustainable transportation vision for 2030 has been adopted and EST criteria have begun to be established. It was aimed to define what EST means, to develop a vision with clear goals and criteria, and then to identify ways and means to re-realize them (Wiederkehr et al, 2004). Another important effort in Sustainable Transport studies is the European Common Transport Policy and White Papers. The European Common Transport Policy had its origins in the Treaty of Rome in 1957. It was created to allow the free movement of goods, services, capital, and labor and primarily to oversee the requirements for intra-Community transport (Attard and Shiftan, 2015). The next major development in the European Transport Policy was the White Paper titled *"The Future Development of the Common Transport Policy"* published in 1992 (the European Communities, 1992). This White Paper has expanded the objectives of the Common Transport Policy to include sustainability and social cohesion. During the 1990s, the European Commission published Green Papers and White Papers for seeking to play a coordinating role in funding research and disseminating best practice experience in various sectors, including urban transport (Schmidt and Giorgi, 2001). In 2001, the White Paper *"European Transport Policy for 2010: Time to Decide"* was published. This study was more comprehensive than the previous ones. For the first time, problems were diagnosed, their relationships were clearly outlined, and solutions were also proposed. Thus, the European Commission has defined sustainable mobility in its strategy for the urban environment (Attard and Shiftan, 2015). Moreover, at the World Summit on Sustainable Development held in 2002, the role of transportation was once again discussed in the outcome document - Johannesburg Plan of Implementation (JPOI). JPOI has provided multiple areas for infrastructure, public transport systems, goods delivery networks, affordability, efficiency and convenience of transportation, improving urban air quality and health, and reducing greenhouse gas emissions (UN, 2020). In 2006, *"Keep Europe Moving: a transport policy for sustainable mobility"* was published. With this study, future transport policies for the union were determined and additional tools were proposed to achieve sustainable mobility. The White Paper *"Road map to a Single European*

Transport Area: Towards a Competitive and Resource Efficient Transport System" was published in 2011. It strengthened the principles of sustainable mobility and advocated a mode change in freight and passenger transport. In parallel with these studies, the European Commission published an *"Action plan on Urban Mobility"* in 2009 recommending the adoption of Sustainable Urban Mobility Plans (SUMP) (Attard and Shiftan, 2015). This plan support sustainable urban mobility under six themes: promoting integrated policies (i); focussing on citizens (ii); greening urban transport (iii); strengthening funding (iv); sharing experience and knowledge (v); and optimizing urban mobility (vi) (EC, 2009). In 2010, the Council of Europe supported this initiative, suggesting in its 2011 White Paper that such plans could be made mandatory for cities of certain sizes and made subject to the submission and supervision of the allocation of regional development and cohesion funds (Attard and Shiftan, 2015). The global interest in transportation has continued in recent years. World leaders unanimously agreed that transport and mobility are at the heart of sustainable development at the 2012 UN Conference on Sustainable Development (Rio +20). Subsequently, the UN Secretary-General identified transport as an essential component of sustainable development and the Five-Year Action Agenda. To this end, the Secretary-General established the High-Level Advisory Group on Sustainable Transport (HLAG-ST) in August 2014, representing all transport modes, including road, rail, aviation, maritime, ferry, and urban public transport providers. The Advisory Group's policy recommendations were *"Mobilizing Sustainable Transport for Development"*, published at the first Global Sustainable Transport Conference in November 2016. Sustainable transportation efforts have gained momentum today, thanks to sustainable transportation policies included in the studies of sustainability and sustainable city approach and specific studies directly on this subject. In the 2030 Agenda for Sustainable Development, sustainable transport was among several SDGs and objectives, particularly those related to food security, health, energy, economic growth, infrastructure, cities, and human settlements. The importance of transport for climate action is increasingly recognized in the UNFCCC. The transport sector will play a significant role in achieving the Paris Agreement because close to a quarter of global energy-related greenhouse gas emissions are from transport. These emissions will increase significantly in the coming years (UN, 2020).

In 2019, 27% of total greenhouse gas emissions in the EU originated from the transport sector. (23% excluding international aviation and marine emissions) (EEA, 2021a). 72% of the total greenhouse gas emissions originating from transportation originate from road transportation (EEA, 2021b). Road transport also causes local environmental problems such as noise and particulate pollution (Xenias and Whitmarsh, 2013). In developing countries, the effect of transportation on air pollution is 80% (Samaras and Ilias, 2013) and 0,5 million people die each year from transport-related air emissions. Deaths from traffic accidents have a similar rate. Therefore, it is very important to develop sustainable transportation systems, especially in urban areas (Kennedy et al, 2005).

The relationship between urban form and sustainable transportation is seen in Figure 2.1. Urban form can be used as a tool to provide sustainable transportation. But first, it should be understood how the urban form affects travel patterns. Urban-style solutions often include mixed-use design, greater work-housing balance, pedestrian and bicycle friendly design, and street layout improvements at the local scale. At the regional level, the scale of analysis can be divided into the macro-level (local government area (LGA)) and the micro-level (railway corridor). The local or neighborhood level characteristics influence travel patterns at the LGA level. Local/neighborhood-level travel patterns are influenced by individual behavior (Black et al, 2002).

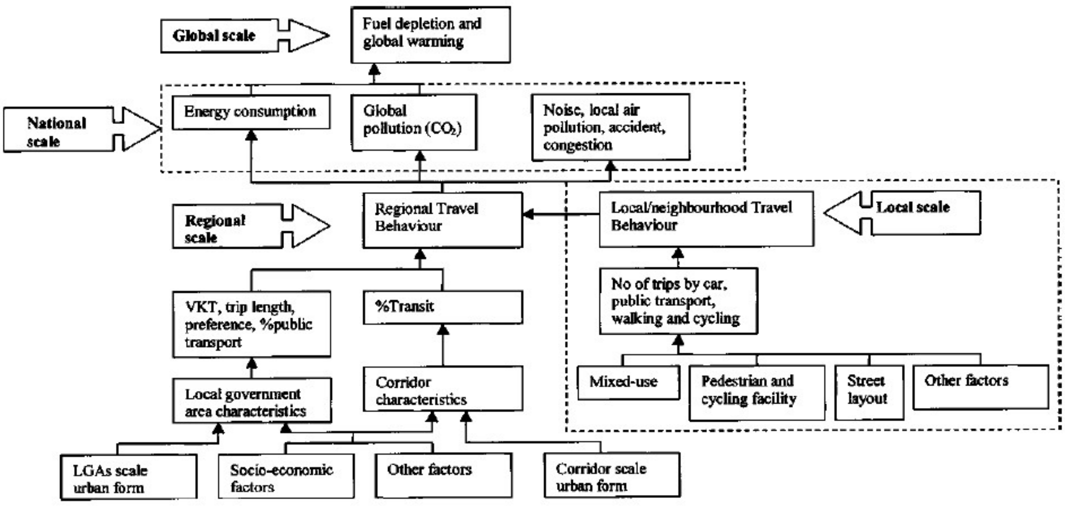


Figure 2.1 : Urban form and sustainable transportation (Black et al, 2002).

It was widely recognized that there is a need to shift to more environmentally sustainable transportation to reduce carbon footprints and environmental impacts (Hull, 2008). Three main approaches can be identified that will lead to more environmentally sustainable transportation: increasing efficiency and reducing the effects of motor vehicles on the climate and environment through technological advances and low-emission fuels (i); adopting measures that restrict automobile use (for example, by imposing tolls and parking fees and reducing parking opportunities) and encouraging walking, cycling, public transport and car-sharing (ii); and urban planning, mobility management and use of Information and Communication Technologies, etc. to reduce the need for travel (iii) (Bardal et al, 2020).

Of all the worldwide initiatives to promote urban and transport sustainability, the Transit-Oriented Development (TOD), which emerged in the late 1980s, was undoubtedly one of the most successful. Basically, TOD can be defined as land use and transportation planning that makes sustainable modes of transportation feasible and desirable and maximizes the efficiency of transportation services by concentrating urban development around public transportation stations. Its main objectives are to reduce motorized transport, especially single-person transportation, reduce motorized transportation times, and increase non-motorized transportation such as pedestrians and bicycles (Ibraeva et al, 2020). Pedestrian transportation, bicycle transportation, and public transportation modes increase accessibility while reducing the environmental impacts and traffic problems of transportation (Rastogi, 2011). Understanding these benefits, support for public transportation, pedestrian, and bicycle modes has increased worldwide, especially in metropolitan areas (Moreland-Russell et al, 2013).

In 2019, the dominance of CO2 was seen in Turkey's emission profile, with a rate of 78.9%. 20% of total CO2 emissions in Turkey originated from the transportation sector (TÜİK, 2021c). In 2017, the share of transportation in total greenhouse gas emissions in Turkey was 16.1%. 93% of CO2 emissions originating from transportation originate from road transport (ÇŞB, 2017). Today's road transport not only threatens human health due to its environmental impact but also causes deaths due to traffic accidents. In 2019, more than 1 million road traffic accidents occurred in Turkey and 174 896 of these accidents were traffic accidents with death and injury (TÜİK, 2020). Turkey needs to develop sustainable transportation systems for these reasons.

In Turkey, there was no detailed policy proposal regarding urban transportation in the Development Plans until the end of the 70s. In the 1980s, the importance of public transit in urban transport was emphasized. It was noted that zoning plans and transportation plans should be evaluated together. In the Sixth Five-Year Development Plan covering 1990-1994, it was mentioned that transportation and land use issues should be handled together and an institutional structure should be established in urban transportation. In addition, the first examples of sustainability policy began to be seen in this period. It was reported that legal measures should be taken by drawing attention to the effects of toxic gases emitted from vehicles on the environment and human health (DPT, 1990). The Seventh Five-Year Development Plan and the Eighth Five-Year Development Plan made various determinations regarding urban transportation. The Eighth Five-Year Development Plan covering 2001-2005 included policy recommendations on increasing traffic safety, improving the quality of public transit, improving pedestrian and bicycle transportation, parking lot management, taxi management, and maritime transportation (DPT, 2001). On the other hand, the Ninth Development Plan covering 2007–2013 stated that public transport was not developed enough and there are transportation problems such as excessive fuel use and environmental pollution. This plan recommended policies emphasizing participatory, sustainable, environmentalist, pedestrian, and bicycle transportation (DPT, 2006). According to the Tenth Development Plan covering 2014 – 2018 pedestrian and bicycle road applications, public transportation system integration and intelligent transportation systems will be cared (KB, 2013). The Eleventh Development Plan covering 2019-2023 emphasized that demand-side policies should be implemented instead of supply-side policies in order to reduce traffic congestion, accidents, and air pollution in cities. It was emphasized that public transportation and non-motorized transportation units (pedestrian, bicycle, etc.) should be encouraged instead of private cars and smart transportation systems should be widespread (SBB, 2019b). The Integrated Urban Development Strategy and Action Plan (IUDSAP) was prepared in 2007-2010 according to the 2023 target year for sustainable urban development. One of the ten commissions established within the scope of this study. Urban Technical Infrastructure and Transportation Commission was one of them. The report prepared by the commission emphasized that the connection between urban planning and transportation planning should be established. It was stated that public transportation, pedestrian and bicycle journeys should be effective in the city, the tendency of development related to cars should be prevented, and restrictions should be imposed on the use of cars. It is aimed to make infrastructure and business investments in a way that will support these modes. All these studies emphasized that technology should be used effectively and public participation should be ensured (ÇŞB, 2010). Another work in line with the 2023 target year was the Turkey Transportation and Communication Strategy, prepared in 2011 by the Ministry of Transport. The strategic purpose of urban transportation in the strategy document is

> *to establish a system that is safe, easiest to access and use, weighted on public transportation, fast, comfortable, has the highest contribution to economic and social development, will positively affect urban development, environmentally friendly, and will contribute to modern urban life with the least cost to the user.*

In addition, the goals and recommendations of this strategy are similar to IUDSAP (UAB, 2011). With the approval of the Paris Agreement signed in 2016, which aims to limit the global temperature increase to 1,5 degrees at the end of this century, by the Turkish Grand National Assembly in 2021 (ÇŞB, 2016), Turkey has accelerated its work on sustainable transportation. Transport and Logistics Master Plan, National Intelligent Transport Systems Strategy and Action Plan, and Sustainable, Smart Mobility Strategy studies have been started by the Ministry of Transport to determine high-level strategy and green development targets for sustainable and smart transport, green port, development of railway transport, reduction of fuel consumption and emissions, and dissemination of micro-mobility vehicles. In order to encourage sustainable and environmentally friendly modes of transportation by reducing transportation-oriented carbon emissions, studies are continuing. These studies aim to establish a transportation network in cities where short and medium-distance journeys can be made by walking, scooter, bicycle, and public transportation and long-distance journeys can be made with shared electric vehicles and rail systems (Karaismailoğlu, 2021). The transportation sector will play a critical role in the success of the Paris Agreement for Turkey, as in all countries of the world.

As stated in the previous sections, Istanbul is the largest city in Turkey in terms of population, number of vehicles and other transportation statistics, as well as its economic and social size. Today, one of the biggest problems in Istanbul is traffic congestion and the resulting environmental problems, loss of time, excessive fuel consumption, and traffic accidents. Although many studies have been done and carried on to make Istanbul a more accessible city, Istanbul is still far from a sustainable urban transportation structure. In 2015, the contribution of transportation to the total carbon footprint in Istanbul was 28%. 98% of the total carbon footprint originating from transportation originates from road transportation (IMM, 2015a). Road transportation is one of the most important causes of air pollution and noise pollution in Istanbul (TMMOB, 2019). The current road transport system is also far from being a safe transport system. Istanbul is the city with the highest number of road traffic accidents in Turkey. According to 2019 data, 26% of total traffic accidents in Turkey occurred in Istanbul. In 2019, 306 452 road traffic accidents took place in Istanbul, and 16 737 of these accidents were traffic accidents with death and injury (TÜİK, 2020). For this reason, it is very important to develop sustainable transportation systems, especially in Istanbul.

Policies and principles focusing on public transportation were adopted for safe, fast, comfortable, and economical urban transportation in the 1997 Istanbul Transportation Master Plan (ITMP), which was prepared by Istanbul Technical University (ITU) for IMM and entered into force after being accepted by Transportation Coordination Center (TCC). This plan did not include the 3rd Bridge and ring roads under discussion. Emphasizing that for a sustainable city and transportation system in Istanbul, the public transportation system, especially rail and sea transportation, should be developed, and targeting the year 2010, this plan foresees the construction of a rail system network of 250 km in Istanbul. This plan aimed to ensure the integration of the rail system, which will form the main axes of the city's public transportation system, with rubber-tired public transportation lines and sea transportation lines (Gerçek, 2005). The ITMP targeting the year 2010 was partially implemented. In order to adapt to the dynamic structure of the city, there was a need for an integrated master plan study in line with the long-term metropolitan land use plan, which includes effective policies and investment planning for the transportation sector in Istanbul. For this reason, IMM started to work on the Integrated Urban Transport Master Plan for the Istanbul Metropolitan Area with the target of 2023 in 2006, and technical cooperation was achieved with the Japan International Cooperation Agency (JICA). JICA is advancing its activities around the pillars of a field-oriented approach, human safety, and effectiveness, efficiency, and speed. As a result of the workshops, seminars, meetings, and evaluations, various reports were created, and the ITMP was prepared at the end. Due to the revision of the 1/100 000 scale Istanbul Environmental Plan in 2009, the need to revise the 2023 targeted ITMP arose before publication (IMM, 2011).

Due to Turkey's long-term development strategy targets included in the Eighth Five-Year Development Plan covering 2001-2023, the 1/100 000 scale Environmental Plan for Istanbul was renewed in 2009. This plan stated that the priority in transportation is people, not private cars, by targeting the establishment of a public transportation-based transportation system in which transportation types are integrated (IMM, 2009). With the ITMP, which was revised in 2009 and published in 2011, depending on the land use and population structure of 2023 for Istanbul, it is economically low-cost and contributes to the planned development of the city; which minimizes the damage to the environment from an ecological point of view it is aimed to meet the transportation demands of the people living in the city by establishing a sustainable transportation system that is socially bound to the principle of social equality, compatible with the historical and cultural identity of the city. It includes qualities such as accessibility, comfort, security, and reliability. The plan aimed to create a more livable urban environment as a result of reducing motor vehicle traffic in the future, improving public transportation infrastructure and increasing mobility and accessibility in the city by encouraging traffic demand from private vehicles to public transportation (IMM, 2011). The Strategic Plan covering 2015-2019 aims to develop accessible new transportation policies where citizens can benefit from urban transportation in a fast, economical, safe, and comfortable way, has been preserved. Within the scope of ITMP studies, it was aimed to increase public transportation services, reduce private car dependency, improve road network, use traffic management policies effectively and increase traffic safety (IMM, 2015b). In the Strategic Plan covering 2020-2024, the target of *"Accessible Istanbul"* was determined, and it was aimed to increase the integration, quality, and accessibility of public transportation and to develop the technological infrastructure to develop urban transportation within the scope of sustainable mobility (IMM, 2020a). Sustainable transportation policies have also gained momentum with Istanbul's membership in the C40 network. One of the topics that C40 deals with within the scope of Climate Action is transportation. By adopting policies that prioritize people-friendly streets over cars, the C40 has adopted a vision for cities where people travel mostly on foot, bike, or shared transportation, with the remaining vehicle journeys using zero-emission vehicles (C40 Cities, 2021). In 2019, IMM started Turkey's first SUMP. The main purpose of SUMP was to help improve accessibility throughout the city. It aimed to create a safe, economic, and environmentally friendly transportation system, increase the quality of service for everyone, and ensure that the transportation system is used more efficiently. The plan has been prepared for a sustainable future in line with Istanbul's unique geography and historical values. This plan aimed to create a transportation system that promotes inclusive, innovative, environmentally friendly, and integrated mobility and accessibility solutions for all citizens in Istanbul. Unlike traditional transportation plans, SUMP has adopted a people-oriented, inclusive and participatory approach. It has created long-term visions and strategies for Istanbul and its surrounding provinces for developing a plan that brings together different sectors. While Istanbul SUMP aimed to make Istanbul's transportation more resilient against climate change and social and economic fragility, it aimed to increase accessibility to every city point and improve the quality of life. All studies, strategies and projects carried out within the scope of Istanbul SUMP were developed with the participation of all relevant and active stakeholders (NGOs, professional chambers, universities, experts, other public and private sector representatives related to transportation, transportation system operators, and citizens) (Global Future Cities, 2021). The Istanbul Climate Action Plan, published in 2021, has developed strategies for electrifying logistics vehicles and public transportation to reduce emissions by 2050. It aimed to increase the public transportation and bicycle in modal share and set targets for 2030, 2040, and 2050 (IMM, 2021a).

2.6 Bicycle Transportation

In this chapter, bicycle transportation will be examined chronologically on the level of the World and İstanbul. The development of the bicycle industry, transportation preferences, decisions and investments, bicycle transportation efforts, policies, and relevant international agreements will be summarized.

At the beginning of the 19th century, the wooden mechanism called *"velocipede"*, *"hobby-horse"*, *"draisine"* or *"running machine"* was invented by Karl von Daris in 1817. This mechanism moved by pushing the machine with the foot and offered a different driving experience. The velocipede, which made its name quickly, was made and sold in many countries such as England, France, and the USA with different designs of the same mechanism. In 1866, the first two-wheeled pedal-powered velocipede with a pedal located on the front wheel was produced at the same time by the French Pierre Lallenent and Pierre Michaux. These velocipede bicycles, which had meager ride comfort due to their iron skeleton structure and caused severe injuries, were known as *"boneshakers"* among the people. In 1869, the high-wheeled bicycle emerged, created by the French Eugene Meyer and put into mass production by the British James Starley. The downside of this bike was that it was more challenging to ride downhill and uphill. Over the next 10 years, Starley's improvements to bicycles and tricycles earned him the title of *"Father of the Cycle Trade"*. Inventors such as Eugène Meyer and James Starley later made new models with an oversized front wheel for stability. These bikes were called *“penny-farthings”* or *“ordinaries”* and they provided more comfortable movement on roads without asphalt pavement as today. During the 1870s and 1980s, the ordinaries led to the emergence of competitive racing by cycling clubs and were even used as a long-distance bikes. Although developments in bicycle design were happening rapidly, *“ordinaries”* did not provide a safe and comfortable ride. Getting on and off required extra skill due to the high wheels. The fact that the driver was almost sitting on the front wheel required balance ability, and the mixed braking mechanism, which was operated by reverse pedaling or lever, was also an obstacle to safe driving. *“Ordinaries”* were also expensive vehicles, and for all these reasons, their drivers were usually athletic young men from the upper and middle classes. During this period, different designs of the velocipede with two, three, and four wheels were made around the world. Sylver Roper from Massachusetts invented the *"steam velocipede"* in 1863. It was said that this four-wheeled and steam-powered velocipede could reach a speed of 64 km/h. In 1878, the Englishman William Grout invented the *"folding bike"*. But these bikes did not become popular in everyday use until the 1960s. In 1885, James Starley's nephew, Englishman John Kemp Starley, invented the *"safety bicycle"* with equal-sized wheels and a chain drive. Shortly after that, new developments in brakes and tires provided the basic template for the modern bicycle. Early safety bicycles had solid rubber tires. In 1888 the pneumatic tire was invented by Scottish John Boyd Dunlop. Thus, both safety and comfort characteristics of the bicycle have increased and the bicycle has rapidly expanded its popularity. Millions of safety bicycles were produced in the UK and Europe within a decade. Bicycles emerged from the hegemony of upper and middle-class athletic and young men and even became a symbol of the women's movement. Numerous improvements were made to materials, design, and components after 1900, but the basic structure of the bike remained almost static. The most important technical development in this period was *"multiple-speed gearing"*, which William Reilly patented in 1896 and developed rapidly in the following years. In 1963, *"high-rise bicycles"* were invented by Schwinn with fast maneuverability and high acceleration. Although this bike with small wheels and long handlebars was especially popular with young people, the *"10-speeds bike"* became more popular within a few years. With the oil embargo in 1974, bicycle sales accelerated and bicycle popularity increased during this period. In the 1970s, mountain bikes called *"clunkers"* were invented and became the standard bike in the World (Hadland and Lessing, 2014; Smethurst, 2015; Do, 2018; Andrews, 2021; Berto, 2021). On the other hand, the electric bicycle was invented by Odgen Balton in 1890 and continues to evolve with changes in bicycle design and battery technology and is rapidly increasing in popularity. Today, different types of bicycles are produced that appeal to many different purposes and user groups, such as children's bicycles, bicycles for the elderly, bicycles for the disabled, tandem bicycles, and cargo bikes.

In the middle of the 19th century, local policymakers started to reorganize the streets to increase the efficiency of the city and manage the rapidly increasing number of people and vehicles. City councils and traffic departments tried to regulate the transportation of new cities shaped by the industrial revolution by widening streets, building new roads, demolishing buildings, and regulating traffic speed (Oldenziel and Albert de la Bruheze, 2011). After World War I, studies promoting urban planning, traffic policies, and motor vehicles gained momentum in nation-states (Möser, 2009; Zezina, 2009). During this period, civil-society organizations lost their influence on urban transportation policies globally, and professional groups (civil engineers, traffic engineers, etc.) worked on this issue. These professionals thought that cycling was a problem. They defined the bicycle as dangerous, an obstacle to modern mobility, and a cause of traffic jams and traffic accidents (Oosterhuis, 2019). Around the same time, working-class organizations opposed anti-cycling regulations and demanded more space for cyclists. In 1935, this situation came to the fore in the British parliament. It was emphasized that 9,5 million cyclists should consider as many as 2,25 million motor vehicle users (Oldenziel and Albert de la Bruheze, 2011). However, during this period, traffic experts and policymakers in almost all of Europe thought that modern motorized traffic was inevitable in the future and that motorized transportation would replace the old-fashioned bicycle, and they carried out their studies according to these ideas (Mom, 2005). For example, almost all policies to reduce accidents between cyclists and automobiles have focused on regulating bicycle transport. The work was dominated by educating, disciplining, and even discouraging cyclists (Epperson, 2014). In this period, the cities of Germany and Belgium separated the bicycle traffic flows in the cities and made the roads belong to motor vehicles. In 1937, the mayor of the Belgian working-class city of Antwerp proposed banning cyclists from riding together. In addition, Antwerp authorities have closed many roads for cyclists and forced cyclists to use bike lanes in other regions. The same happened in Hannover, Germany. In the manufacturing port city Manchester, the worker-dominated city council has prioritized forming an extensive public transport system over investing in bike lanes for working-class voters (Oldenziel and Albert de la Bruheze, 2011). Policymakers in the UK have had similar attitudes. Cyclists, who have had the right to use highways since the 1890s, did not want to lose their rights. NGOs opposed the construction of segregated bicycle lanes in the 1930s and stated that this situation threatened cyclists and that the bicycle was a stakeholder in traffic. They stated that segregated bike lanes would cause car users to ignore cyclists (Epperson, 2014). The reactions of workers, cycling NGOs, and cyclists were perceived as threats by policymakers and this led to new anti-cyclist policies. Between World War I and World War II, there was an incredible increase in the number of cyclists in Germany. For this reason, traffic engineers and urban planners decided to systematize the bicycle road design. However, in the designs, the aim was not to create ride comfort for cyclists but to remove cyclists from the roads they set aside for motor vehicles. They defined bike lanes as a safe solution to avoid traffic chaos and congestion. Creating separate traffic flows was a common idea among traffic engineers and urban planners during this period, not only in Germany but also in almost all of Europe. In short, the most remarkable thing about the interwar period was that policymakers, traffic engineers, and urban planners all believed that cars will inevitably become the dominant mode of transport in the future, despite the boom in cycling in most cities (Oldenziel and Albert de la Bruheze, 2011). The 1944 Uniform Vehicle Code (UCV) allowed cyclists in the US to ride only near the curb or in a bike lane if available. It prohibits cyclists from using the road. This is known as the "*mandatory sidepath law / mandatory bike lane law*" and includes the *"ride to the right rule"* (Schultheiss et al, 2018). During the 1950s, after World War II, the heavily damaged European cities were rebuilt. After World War II, the number of bicycles in cities increased faster than before, especially due to the economic effects. However, post-war reconstruction efforts and the increase in pro-auto attitude accelerated the structuring of cities with a non-bike-friendly policy (de la Bruheze, 2000). Urban planners, influenced by the USA's city and transportation models, one of the leaders of automobile culture, defined automobiles as modern and progressive and bicycles as outdated and unsafe (Epperson, 2014). This vision also prevails in urban planning and traffic engineering, which was established in the USA to plan and modernize the traffic of post-war Europe and especially Germany. Academics, professionals, and consultants in this new discipline played an important role in shaping Europe's post-war transport by collaborating with politicians. Cycling NGOs in England during the post-war reconstruction period adopted sectioned-off cycle lanes, but the government resisted having segregated cycle lanes. Thus, bicycles were pushed out of the way in England as in Germany and Belgium (Oldenziel and Albert de la Bruheze, 2011). Cycling has been neglected or subject to hostility (Epperson, 2014). In this period, automobile-oriented mentality dominated policymakers, including the Netherlands and Denmark. NGOs have lobbied heavily to build and maintain cycling infrastructure. However, Dutch and Danish local policymakers defined cyclists as careless, unpredictable, undisciplined, and unskilled traffic participants who hinder motor and public transport (de la Bruheze, 2000). The transportation professionals of the period covering 1950-1975 in Europe saw the bicycle as a dangerous, irresponsible object that would not suit modernity and progress, while the city councils completely ignored the bicycle and prioritized public transportation *"for those who do not have cars"*. For instance, the Stockholm traffic commission believed that public transport should serve the car-free proletariat in this period. In Belgium, Germany, and Switzerland, the authorities took more drastic measures during this period. Policymakers have suspended the construction of bike lanes and even removed existing bike lanes to create space for cars. Cycling was prohibited in most of the city streets in Hannover, and on non-prohibited roads, cyclists were forced to share car-dominated and focused roads. In Switzerland, parking areas for cars were created by removing bicycle lanes, and, in Basel, cars were allowed to park on pavements. This attitude soon spread to Europe. Cycle lanes, which were first used to separate and discipline bicycles from other modes of transport, were later used as an opportunity to increase space for automobiles (Oldenziel and Albert de la Bruheze, 2011). Thus, bicycles and bicycle infrastructure were removed from the policy agenda in almost all of Europe. In the late 1960s, from Copenhagen to New York and Toronto, grassroots organizations challenged the technocratic views of transportation professionals. In 1967, anarchist cycling activist Provo appealed to

Amsterdammers to say *“no more to the asphalt terror of the motorized bourgeoisie”*. Provo was against capitalism, communism, fascism, bureaucracy, militarism, professionalism, dogmatism, and authoritarianism. With the White Bicycle Action Plan, Provo aimed to ban cars and create a free bike program against motor terrorism in Amsterdam. He painted fifty bicycles white and left them for public use in the city. He laid the foundation of the shared bicycle system by saying that white bicycles belong to everyone and do not belong to anyone. Activists, fed up with dangerous, congested, polluted, auto-focused cities, promoted a better quality of life. They described the link between cycling and slowing urban speed and improving city life, health, and environment. Grassroots organizations demanded the transition from a city ruled by cars to cities focused on public transport, bicycles, and pedestrians. They have made efforts to revive and reinvigorate cycling NGOs. Participants in the movement formed a broader cultural resistance to the technocratic and consumer welfare states of the 1960s and successfully incorporated the bicycle into integrated traffic plans as the normal mode of transport for urban mobility. Thus, bicycle lanes have turned into symbols of health and sustainability. The Human Environment Conference was held in Stockholm in 1972 by the UN. Cycling activists took the stage at this conference to protest the passive environmental attitudes of the UN and called for cycling against pollution (Furness, 2010). Policymakers in many cities in Europe formed partnerships with grassroots initiatives of the 1970s or adopted their rhetoric. Environmental awareness, the awareness that cities run by cars cause more problems than they solve, the energy crises of 1974-1976, and the economic recession of the 1980s forced policymakers to engage in bicycle-friendly studies and develop attitudes. Creating integrated bike lanes and a bike network has become the new policy tool. Cycling has been revived in the cities of Switzerland, Belgium, England, and Germany (Epperson, 2014). Policymakers and the auto lobby in Basel, Switzerland, thought that the re-popularization of the bicycle would be short-lived. They did not want to go back from the anti-bike decisions and claimed that there would be no turning back once a concession was made. The wait-and-see attitude of policymakers has led to street protests by cyclists and NGOs. These protests have forced the city council to reconsider its long-term anti-cycling policies. In Swiss cities, streets had to be made accessible, bicycle traffic lights had to be implemented, cyclists had to be given traffic and parking rights, and infrastructure had to be built. Throughout the 1990s, Swiss policymakers focused on building bike lanes through temporary ties they formed with grassroots initiatives. However, daily use of bicycles remained below the old levels compared to the automobile-oriented pre-urban period. A similar situation was observed in Belgium and England. In Antwerp, which lacks adequate urban bicycle infrastructure, mostly automobiles and public transport were preferred for transportation. In Manchester, NGOs have campaigned for cycling infrastructure. In this way, policymakers in England developed bicycle lanes (Oldenziel and Albert de la Bruheze, 2011). Bicycle-related plans were also included in the Transport White Paper published in 1977. However, the policies in this period were not focused on promoting cycling for transportation purposes in urban areas until the 1980s but on recreational cycling. According to the surveys conducted in England, potential cyclists were afraid to share the streets with cars during this period. British experiences of the once-popular cycling culture have been completely erased from the collective memory. In the 1990s, the central government initiated the Cycle Challenge Project. In addition, the *"Bikeability"* project was initiated by NGOs in 2006 to encourage young people to use bicycles and provide bicycle training at national standards. In 2008, the same program for adults was launched (Oldenziel and Albert de la Bruheze, 2011; Epperson, 2014). Policymakers in Germany have also been exposed to pressure from NGOs to develop bicycle transportation. Although there were bicycle lanes during the automobile-oriented urbanization period in Germany, they were not integrated into traffic planning and city development. Most cities have invested in public transport rather than cycling. German policymakers heard demands from the working class to support bicycle transport before. They began to design and build bicycle lanes under pressure from NGOs to reinvigorate cycling culture. In this era of accelerating cycling policy, new cycling experts and local policymakers have identified bike lanes as the safe and only viable way to promote cycling. Although infrastructure works gained momentum in Germany during this period, efforts to recreate urban cycling traditions were insufficient (Oldenziel and Albert de la Bruheze, 2011). In 2015, to increase bicycle modal share from 10% to 15%, bicycle lanes were built and to make streets bicycle-friendly, traffic calming projects were carried out in residential areas in Berlin. Until the 2000s, bicycle infrastructure studies were carried out with road construction, while a special budget of 1,5 million euros was allocated for bicycle infrastructure works in 2000. This budget has been increased periodically and exceeded 30 million euros in 2020. The budget includes the elimination of the gaps in the existing bicycle lanes, the construction of new bicycle lanes, the integration of public transport, the construction of bicycle parking areas, trainings, etc., spent in the fields. In addition to building bicycle lanes, parking management in Berlin is very strict. Restricted parking areas are only permitted to residents or paid, and limited-time parking is permitted. In addition, traffic calming methods were applied. Streets with a speed limit of 30 km/h and even *"Spielstrassen"* with a speed limit of 7 km/h were created. 72% of Berlin's streets are traffic-calmed. The city administration in Berlin established Berlin's first Bicycle Council (FahrRat) in 2003 to become a stakeholder in determining cycling strategies. This group consists of cycling experts, cycling industry representatives, cycling NGOs, and transit providers working at research centers. In addition, the Call-A-Bike Program was started by German Railways (DB) in 2002 and 3000 shared bicycles were located at the train stations in 2006. With Berlin becoming a stakeholder in Sustainable Planning and Innovations for Bicycles (SPI-Cycles), an EU funding program, efforts to increase the share of bicycles in daily use have also gained momentum. The use of bicycles in Danish and Dutch cities has also decreased with the widespread use of automobiles, but this decrease has not been as much as in other European cities (Pucher and Buehler, 2007; City of Berlin, 2020). The bicycle has not completely disappeared from the agenda due to the financing problems of Denmark and the Netherlands and unstable policies in project development. This created space for NGOs supporting cycling to negotiate with policymakers (Epperson, 2014). High automobile taxes in Denmark and the Danish Heart Foundation's definition of healthy cycling in the late 1960s increased the power of cycling in Copenhagen (Oldenziel and Albert de la Bruheze, 2011). Copenhagen's cycling policy and objectives are laid out in the Cycling Policy Plan covering 2002-2012. With this plan, targets such as increasing the share of bicycles in business trips to 50%, reducing cyclist injuries by 50%, and increasing the safety feeling of cyclists from 57% to 80% were set. In 2007, this plan was revised and the target of *"the best city in the World for cycling"* was set. This plan included two innovative policies to support cycling: free bike rental and annual cyclist surveys. Cycling facilities and programs account for one-third of Copenhagen's road transport budget, with its extensive bicycle lanes network and bicycle infrastructure services (Pucher and Buehler, 2007). Danish policymakers quickly integrated grassroots activism into their traffic plans. Since the 1990s, they have been pioneers in promoting cycling as part of environmental and energy policies. As in Denmark, the rate of cycling in the Netherlands declined sharply in the early 1950s but remained relatively high in the

1970s compared to other European cities. In line with the economic problems of the Netherlands, the textile town of Enschede was built as a compact city focused on pedestrians and bicycles. In addition to the traditional *"laissez-faire"* and mixed traffic policies, bicycle lanes have started to be built in Amsterdam. Eindhoven's high-tech and automobile-focused town connected regional bicycle networks throughout the 1980s and 1990s. However, in the working-class mining town of Heerlen, a pressure group has not formed on the issue of bicycle transportation. Bicycle commuting did not occur again in Heerlen, which did not have a bicycle policy vision (Oldenziel and Albert de la Bruheze, 2011). On a larger scale, a positive reassessment of slow traffic such as pedestrian and bicycle transport has led to the replanning of suburban areas. Traffic calming residential areas have emerged, where pedestrians and cyclists have more traffic rights than cars. In the early 1990s, the Dutch government included the bicycle in the national Transport Structure Plan. It has also published a special master plan to guide comprehensive safe cycling infrastructures and urban and regional traffic policies for cyclists. In 1992, the city voted to continue the restriction of car parking in the city center and supported this practice, which has existed since the 1970s. In 2006, the city of Amsterdam made efforts on issues such as bicycle parking facilities, bicycle thefts, traffic safety, improving the bicycle lanes network, and encouraging young people to ride bicycles, with the policy plan named Choosing for Cyclist: 2007-2010. Between 2007 and 2010, 40 million euros were spent on these projects from the city budget. Combined with the budget allocated from other departments of the state, 70 million euros were spent within the scope of this 4-year plan within the scope of Amsterdam's bicycle transportation policies. These initiatives can be described as a gradual but steady policy change from motor vehicle transport to bicycle transport. Cycling-friendly NGOs, city planning preferences, late car mobility, and government policies have a greater impact on the Netherlands' success in cycling than Dutch culture and the country's flat geography (Oldenziel and Albert de la Bruheze, 2011; Pucher and Buehler, 2007). Similar processes were experienced in the USA as in Europe. Although there were advocacy groups related to cycling until the mid-1960s, the demands and efforts were focused on recreation rather than transportation purposes (Epperson, 2014). Although there have been bicycle lanes in the USA since the early 1900s, the city of Davis in California started planning for the bicycle infrastructure in 1966. Studies initiated to make the streets the safest for cycling in the most feasible and economical way created the University of California (UCLA) Guidelines, published in 1972 (Schultheiss et al, 2018). John Forester, a local engineer and amateur racing cyclist, opposed the *"mandatory bike lane law"*. Defending that the bicycle should be one of the other vehicles on the road, Forester has prepared an Effective Cycling Course publication and created a program. Involved in the California Statewide Bicycle Committee, he has worked to change bicycle lane standards and laws around cycling. But in this period, the most important development about cycling in the USA occurred with Richard Rogers's efforts. He expressed that the biggest reason for the *"mandatory bike lane law"* is the language because the UVC does not define the bicycle as a *"vehicle".* It only gave certain rights and responsibilities to the bike. Rogers formally expressed this problem in a petition to the California Attorney General in 1974. As a result of these efforts, the bicycle was defined as a *"vehicle"* in the same year (Epperson, 2014). Another development in 1974 was the Bicycle Guide published by the American Association of State Highway and Transportation Officials (AASHTO) (Schultheiss et al, 2018). In 1975, the *"ride to right"* rule was abolished in California and studies on bicycles began to take place on the agenda of the US at the national level (Epperson, 2014). In the 1990s, with the Critical Mass event (the collective rides of cyclists at peak hours on the last Friday of every month), which started in San Francisco has spread around the world with the slogan *"we are not blocking traffic; we are traffic!"* (Furness, 2010).

Cycling, which started with grassroots organizations and turned into local and national plans and projects and then included in sustainability efforts, has an important position today. Global and UN-level policies such as the Paris Agreement, the SDGs, and the New Urban Agenda form the basis of their arguments for promoting cycling in the EU and across continental borders. Cities around the world are developing more sustainable mobility systems and, therefore, cycling policies and infrastructure for more sustainable cities. The momentum of these efforts has increased with the Covid-19 period. Studies show that air pollution, including exhaust fumes, poses a significant risk in the Covid-19 outbreak. Potential solutions are creating lower speed limits on roads where pedestrians are stuck on narrow sidewalks and motor vehicles have wide cross-sections, preventing motor vehicle drivers from using side streets in residential areas to avoid congested main roads, building pop-up bicycle lanes, and widening pedestrian paths (Laker, 2020). The World Health Organization (WHO) stated that many people are moving for going to work or meet their basic needs in the city during the Covid-19 period. It stated that this mobility should be provided by bicycle or on foot as much as possible. These modes of transport help meet the need for access while providing physical distance (WHO, 2020). During this period, pop-up bike lanes were built at 42nd and 34th Streets in Manhattan in New York City, USA, along Smith Street in Brooklyn, and connections with existing bike lanes were provided. At the same time, the effect of red lights on the bicycle was tried to be reduced by regulating the signal duration in Manhattan and Brooklyn (New York Municipality, 2020). Bicycle maintenance and repair shops have been identified as essential businesses that will continue to operate during Covid-19 (Kirker, 2020). As a pilot project, in Oakland, USA, 42nd Street, East 16th Street, West Street, Arthur Street, and Plymouth Street were closed to motor vehicle traffic and opened to bicycle and pedestrian access. In the event that the pilot project was successful, it has been announced that the 120 km road, which constitutes 10% of the city, will be closed to motor vehicles (Thomas, 2020). To reduce congestion, prevent vehicle access and parking in Vancouver, Canada, Stanley Park and Beach Street have been closed to motor vehicle traffic, making them accessible to bicycles and pedestrians (Laker, 2020). 72 km of pop-up bike lanes were created in Bogotá, Colombia (BYCS, 2020). 650 km of bicycle lanes were created in Paris, France (Sandor, 2020). The priority in the project has been determined as the routes with public transportation lanes with heavy passenger capacity to serve the post-Covid-19 period. The city invested 300 million euros in building this entire network (Mavrokefalidis, 2020). 50 euros support was provided to the citizens for bicycle repair. The investment included cycling training (BBC News, 2020). Pop-up bike lanes have been created in Berlin, Germany because cyclists need more space to maintain social distance. Authorities stated that they used removable tape and mobile signs to mark the extended lanes and that the system could be removed once existing movement restrictions were lifted (Oltermann, 2020). Both new routes have been determined to create pop-up lanes, and existing bicycle lanes have been expanded to accommodate social distancing (Mobycon, 2020). The speed limit of urban roads in Spain has been regulated as 30 km/h, making the roads safer for pedestrians and cyclists (Linan, 2021). Pop-up bike lanes have led to significant increases in cycling (Kraus and Koch, 2021). 2020 can be defined as a new *"bicycle boom"* in the world's cities (Bernhard, 2020). According to 2020 data, more than 530 thousand daily bicycle trips were made in New York (New York City DOT, 2020). In Bogata, cycling modal share has reached 7% (Jaramillo, 2020). In 2020, the cycling modal share was 17% in Tokyo and 16% in Shanghai (Deloitte, 2021). The cycling modal share in Budapest has doubled compared to 2018 and reached 4% (Bucsky, 2020). In London, cycling modal share, which has almost doubled compared to 2019, has been 5,3% in 2020 (Macmichael, 2021). A similar trend was observed in Viana and cycling modal share increased by nearly 3% to 9% (Cycle Competence Austria, 2021). The cycling modal share was 5% in Paris (Imbert, 2019), 49% in Copenhagen (Handshake, 2021), %25 in Bremen (CI, 2019), 30% in Amsterdam, 23% in Rotterdam, 25%, 13% in Berlin, 7% in Dublin, 7% in Stockholm, 5% in Manchester, 2% in Barcelona, 2% in Rome (Deloitte, 2021). New bicycle infrastructure actions have increased bicycle traffic by between 11% and 48% in European cities (Haubold, 2021). In addition, one of the goals of the EU Cycling Strategy, prepared within the scope of Horizon 2030, was to increase the cycling modal share in Europe by 5% to 12% by 2030 (EUCS Expert Group, 2017). The European Cyclists' Federation (ECF) has defined the relationship of cycling with the Global Goals for Sustainable Development. ECF stated that the bicycle is one of the important tools in achieving the sustainable development goals of the UN organization, which reveals the steps to be taken on climate change, which is causing more serious problems on global, national, and urban scales, and stated that bicycles directly contribute to eleven of the seventeen SDGs (ECF, 2016). All these developments and efforts show that the bicycle, both a sustainable transportation unit and an active transportation unit, will find more place on the agenda as a policy in the coming days.

Thomas Stevens is the first person to complete a world tour using *“penny-farthing”* on two wheels. In 1884, he started his tour in San Francisco and ended in Tehran, and published his memories of his tour named *"Around the World On A Bicycle"*. In his book, he also wrote about people in many countries who saw him riding a bike and their attitudes towards bicycle (Ceylan, 2020). The first arrival of the bicycle in the Ottoman Empire was announced in the newspaper Tarik, dated 31 August 1885. According to this news, an American named Monsieur Tomas Stefanis (Thomas Stevens) first came to Istanbul with his bicycle, then arrived in Ankara after a five-day journey via Izmit, and then went to Sivas via Yozgat (Süme and Özsoy, 2010). Thomas’ tour attracted the Ottoman Empire, and sometimes the people insisted on riding his bike (Stevens, 1939). During this period, bicycle tours were very popular globally and Istanbul and Anatolia were attractive routes for these tours (Ceylan, 2020). Cyclists who attracted people's attention in the Ottoman Empire were Thomas Gaskell Allan and William Lewis Sachtleben. Two young people who set out from America in 1890 with the *"Safety Bicycle"* attracted attention in Istanbul and Anatolia, both with their bicycles and cameras. In the streets they passed, they encountered large audiences from both state officials and the public (Çaykent, 2016). The bicycle, which was the subject of many articles and cartoons in the press and was called the *"devil's car"*, continued to be called *"velospit"* or *"velespit"* until the 1950s. The people of Istanbul, who first learned about the bicycle from the press, recognized this new invention with the name *"velospid"*, which is the wrong pronunciation of the French word *"Vélocipéde"*. The first bicycles were imported to Istanbul in the 1880s. Seeing a cyclist passing through the streets of Istanbul between the years 1890-1895, when the number of bicycles coming to Istanbul began to increase, became a curious sight for Istanbulites. In these years, people who used bicycles were ridiculed as *"modern"* types, and the first riders were accused of snobbery from time to time (Süme and Özsoy, 2010). In fact, local people described being seen by bicycle as lightness, shame, and sin. Still, a few brave youngsters have increased the courage of others by cycling in the Prince Islands and Kadıköy (Ceylan, 2020). Bicycles began to use Izmir in 1885 through Christian families dealing with trade. During this period, the number of non-Muslim bicycle enthusiasts exceeded 200. Shoemaker Ali Efendi was the first Turk to successfully cycle in Izmir (Süme and Özsoy, 2010). The bicycle, which the American feminist Susan B. Anthony called the *"freedom machine"*, has come to symbolize the *"new woman",* especially in England and the USA at the end of the 19th century. In Turkey, women met for the first time by bicycle in Izmir, towards the end of the 19th century, at the same time as other countries in the world. Although women were using bicycles in Izmir in 1895, the habit of women riding bicycles in the Ottoman Empire was formed in the first quarter of the 20th century (Ceylan, 2020). Another cyclist activity seen at the same time in Europe and America was bicycle races. With the spread of bicycle races in the world, bicycle races in the Ottoman Empire began to be held regularly. The first regular bicycle race was held at Thessaloniki Racecourse in 1897. Although the first bicycle race in Istanbul occurred in 1895, the Turks did not participate in the competition. Cycling races in Istanbul were organized with the initiatives of bicycle importers. They aimed to encourage the public to cycle and increase bicycle sales by building race tracks in Istanbul. Cycling races in Istanbul were reorganized after the proclamation of the Constitutional Monarchy II, and sports clubs in the Ottoman Empire started to give place to cycling sports activities. In 1895, with the increase in the number of bicycles in the Beyoğlu district of Istanbul, the municipality wanted to ban cycling except on the Taksim-Şişli road and applied to the Interior Ministry of the period. The Interior Ministry rejected this request. In 1907, the bicycles used in Istanbul started to be registered by the municipality and the name of the driver was recorded by giving a number to each bicycle. In 1894, a European newspaper article about bicycles in armies was presented to Sultan Abdülhamit. Abdülhamit started to research about bicycles that were used in the USA army. After the Constitutional Monarchy II, bicycles were bought for municipal police, police, postal service, army, and officers of some ministries, and they were allowed to use them as vehicles. In the 1900s, various societies began to be established in order to organize bicycle races in the Ottoman Empire. In Turkey, on the other hand, in the first years of the republic, bicycles began to find more place in daily life, and at the same time, their use in sports increased. With these developments, the Turkish Cycling Federation was established in 1923 (Süme and Özsoy, 2010). After World War II, Turkey was included in the Marshall Plan in 1948 and grants and loans were received from the US. In line with the philosophy and principles of Marshall Aids, there has been a great change in Turkey's transportation policies (Kılınçaslan, 2012). The share of investments in highways has increased in transportation (Avcı, 2005). Turkey's transportation policies have focused on road transportation and automobiles like other world countries. Although the economic conditions in Turkey prevent rapid automobileization, as in European countries and the USA, a transportation system based on individual management, such as taxis and minibusses, defined as para-transit, has developed. Bicycles still existed in the country as a means of transportation until the number of automobiles in the country increased with the domestic production of automobiles that started in the 1970s. Bicycles have been widely used as a means of transportation in cities and rural areas for business and other purposes. Especially in the settlements of Aegean, Mediterranean, Southern, and Central Anatolia, where the topography is suitable, the citizens used bicycles to access the municipality, district governorship, workplace, field, and garden. During the times when shuttle vehicles were not invented yet for factories, bicycles were the most common transportation modes used by workers in factories in industrial cities such as Adapazarı, İzmir, Adana, İzmit, and Eskişehir. During this period, public officials used their bicycles with official license plates and postal deliverers, and police performed their duties with this official *"non-motorized vehicle"*. With the widespread use of the automobile in the 1970s, the streets began to lose their functions such as playing, socializing, walking and cycling and were handed over to motor vehicles that were moving and waiting in a jam or parking. Bicycle infrastructure has not been considered in the zoning plans made until today, and bicycle transportation has been ignored in transportation studies and master plans. Although transportation studies and transportation master plans were made in more than 20 cities in our country, data about bicycles were collected in very few of these studies (surveys and censuses), bicycle journeys were not shown in demand-forecast models in any of these studies, and the recommendations generally remained at the level of policies and strategies. Despite these recommendations, practices continued to give priority to motor vehicles (Öncü, 2020; ÇŞB, 2021). In addition, although a bicycle was defined as a *"vehicle"* in the Highway Traffic Law (EGM, 2020), which covers traffic-related rules, conditions, rights and obligations, their implementation and supervision, relevant institutions and their duties, authorities, and responsibilities, working procedures and other provisions the rights and responsibilities of the bicycle are given little attention and the existing rights and responsibilities are ignored by both inspectors and motor vehicle users. Bicycle users have also changed their transportation preferences with motor vehicle-oriented plans and practices in the urban transportation system.

In the middle of the 19th century in the world, bicycle lanes began to be built in cities. In Turkey, the first bicycle lane was constructed in Seydişehir, which looks like a big town connected to Konya. The Russians, who built the Etibank Aluminum Facilities, contributed to the modern urbanization of Seydişehir and provided access between the factory and the city center with wide sidewalks, bicycle lanes, and a double lane road. This bicycle lane was 1,64 km and was the first bicycle lane in Turkey (İHA, 2021). Cycling's entry into national policies was for the first time with the Eighth Five-Year Development Plan covering 2001-2005. It aimed to improve the services to pedestrians and cyclists in urban transportation policies (DPT, 2001). Ninth Five-Year Development Plan covering 2007-2013, was stated that pedestrian and bicycle transportation and public transportation would be given priority in order to create a sustainable urban transportation system in the process of harmonization with the EU, and the use of these modes would be encouraged (DPT, 2006). With the inclusion of bicycles in the development plans, bicycle transportation started to take place in the strategies of the Ministry of Transport in 2011. In the strategy document containing 2023 targets prepared by the Ministry of Transportation, the approach

> If the present structure of the city is not interfered with, the choice of automobile-oriented transportation will remain as one of the most critical factors that irreparably degrade the physical environment. In transportation, especially in public transport, expansion of renewable and clean energy options, prioritization and dissemination of public transport for people to deliver, bringing restrictions to automobile use in cities, giving priority to policies in pedestrian and bike transportation, to creating a high-balanced and accessibility of transportation systems based on the automobile with demand and traffic management approaches and the creation of a high transport system, the implementation of development models that support bicycle and pedestrian transportation by public transportation, not a car addiction in the city planning

accepted to support bicycle transportation (UAB, 2011). In 2012, design standards for active transportation types, including bicycles, were defined by the Turkish Standards Institute (WRI, 2022). In 2013, they published the design rules of bicycle roads (TSE, 2013a ; TSE, 2013b ; TSE, 2013c) and bicycle parking structures (TSE, 2013d). In the Tenth Five-Year Development Plan covering 2014-2018, the bicycle concept was included in more than one area compared to previous years. It was stated that the applications to promote cycling started. It aimed to make applications to encourage cycling, establish bicycle sharing systems in the cities, and develop bicycle tracks for sports purposes. (KB, 2013). In 2015, the Ministry of Environment and Urbanism published Turkey's first bicycle-oriented regulation named *"Regulation on Designing and Building of Bike Routes, Bike Stations and Bicycle Parking on Urban Roads"*. It aimed to ensure that bikes are used for transportation purposes and to organize the procedure and principles of designing, constructing, and operating bike lanes, bicycle stations, and bicycle parking (ÇŞB, 2015). In 2019, this regulation was developed and revised and was named *"Bicycle Routes Regulation"*. By expanding its purpose and scope, this regulation aimed to determine the procedures and principles regarding the planning, design, and construction of bicycle lanes and bicycle parking stations to ensure that bicycles can be used for purposes such as transportation, sightseeing, and sports (ÇŞB, 2019). The bicycle concept was included in the Presidential Annual Program for the first time in 2018 during the Tenth Development Plan period.

However, no target was set in the program. Only 330 000 bicycles were given away in the country in 2017 within the scope of the *"Project for Increasing Physical Activities"* (KB, 2018). The Eleventh Development Plan covering 2019-2023 included more concrete incentive mechanisms and metric values in bicycle transportation than other plans. It aimed to establish legal and financial support mechanisms to encourage bicycle use. Bicycle lane master plan and implementation plan were prepared, and it was planned to construct bicycle lanes and implement bicycle-sharing systems. By revealing that there was 1048 km of bicycle lanes in Turkey at the end of 2018, it has aimed to have 4048 km of bicycle lanes by the end of 2023 (SBB, 2019b). In the 2019 Presidential Annual Program published during the Eleventh Development Plan period, it was stated that the *"Project for Increasing Physical Activities"* continued and that 330 000 bicycles were given away in 2018. In this program, the Ministry of Environment and Urbanization, Ministry of Transport, Ministry of Strategy and Budget, and Municipalities were determined as responsible and cooperating institutions and it was stated that within the scope of the development of non-motorized transportation modes, they would support the construction of bicycle lanes in cities (SBB, 2019a). Another national development in 2019 was the Regulation on the Procedures and Principles for Increasing Energy Efficiency in Transportation, dated 2 May 2019, published by the Ministry of Transport. It set out the rules for creating low emission areas in this regulation. First, it aimed to reduce and prevent transit vehicle traffic passing through these areas, then to make it unattractive to come to these areas by car with parking restrictions and pricing, and finally ban it completely. On the other hand, it aimed to keep the central areas alive with effective and high-quality public transportation services and make access attractive with bicycle infrastructure and services (UAB, 2019). In the Presidential Annual Program for 2020, policies and measures related to cycling have been further developed. The Ministry of Environment and Urbanization and local governments have been determined as responsible and cooperating organizations. It aimed to revise the Bicycle Routes Regulation, prepare a Bicycle Route Master Plan and Implementation Plan, and establish a bicycle sharing system to promote bicycle transportation (SBB, 2020). In the Presidential Annual Program for 2021, the 2019 targets were included in the program again, and besides, policies and measures related to cycling were discussed more concretely. An important development in this program was the objective of providing financial support to the 282 km urban bicycle lanes to be built within the framework of the Bicycle Routes Regulation. In addition, the concept of sustainable tourism was included in the program in 2020 with the driving force of the negative impact of the Covid-19 pandemic on the tourism sector. In this context, the *"Bike Friendly Accommodation Facility Certificate"* system was implemented in order to encourage bicycle tourism (SBB, 2021). The Presidential Annual Program for 2022 included the 2020 targets again. Financing support for urban bicycle lanes has been increased to the target of 1000 km. In addition, it has been stated that the *"Bike Friendly Accommodation Facility Certificate"* has been given to 10 facilities since 2020 (SBB, 2022). Another feature of 2019, 2020, and 2021 Presidential Annual Programs was that they reveal performance indicators related to the length of the bicycle lane. In order to reach the bicycle lane km target in the Eleventh Development Plan, an annual average of 600 km of bicycle lanes should be built in case of equal annual distribution. However, when these performance indicators are examined, as seen in Table 2.1, 100 km of bicycle lanes were built between 2018-2019, 118 km or 366 km between 2019-2020, and 586 km between 2020-2021. When the indicators are examined, it is seen that the current situation analysis cannot be done properly. The main reasons for this situation are that bicycle infrastructure has not been taken into account in the zoning plans made until today, bicycle transportation was ignored in transportation studies and transportation master plans, and the lack of regular records of bicycle lanes in cities due to deficiencies in policy and strategy at the national level. In addition, some infrastructure projects were implemented without any plan, study, or project, some were removed after they were built, some were not inspected and their function changed due to illegal paring, vandalism, etc. are also factors in this situation. These factors make it difficult to set targets for cycling infrastructure on a national scale. Increasing financial support for the construction of bicycle lanes in the Presidential Annual Program in 2019 and 2020 positively affected Table 2.1. One of the beneficial studies in terms of bicycle policies by the Ministry of Environment and Urbanization in 2021 was the Turkey Cycle Lane Master Plan publication. Within the scope of the study, while focusing on the use of bicycles between settlements for tourism purposes and developing infrastructure proposals for these journeys, strategies have been developed for both urban and urban bicycle use (ÇŞB, 2021).

Table 2.1 : Performance indicators for targets in national plans - Cycle lane length (Cumulative).

Plans	2018 (km)	2019 (km)	2020 (km)	2021 (km)	2022 (km)	2023 (km)
Eleventh Development Plan 2019-2023 (SBB, 2019a)	1048 (existing)					4048 (target)
Annual even distribution to reach the target	1048	1648	2248	2848	3448	4048
Presidential Annual Program for 2020 (SBB, 2020)	1048 (existing)	1148 (estimated)	1248 (target)			
Presidential Annual Program for 2021 (SBB, 2021)		1148 (existing)	1266 (estimated)	1548 (target)		
Presidential Annual Program for 2022 (SBB, 2022)			1514 (existing)	2100 (estimated)	3100 (target)	

According to research by World Resources Institute (WRI), it has been determined that 16 of 30 metropolitan cities have bike lanes longer than 25 km and 13 metropolitan cities have bike-sharing systems. As seen in Figure 2.2, Turkey's most extended bicycle road infrastructure is located in Konya with 550 km. Following Konya, Bursa (368 km), Istanbul (314 km), and Sakarya (169 km) follow respectively. 36% of metropolitan cities have bicycle roads between 26-100 km, and 46% have bicycle roads between 1-25 km (WRI, 2022)

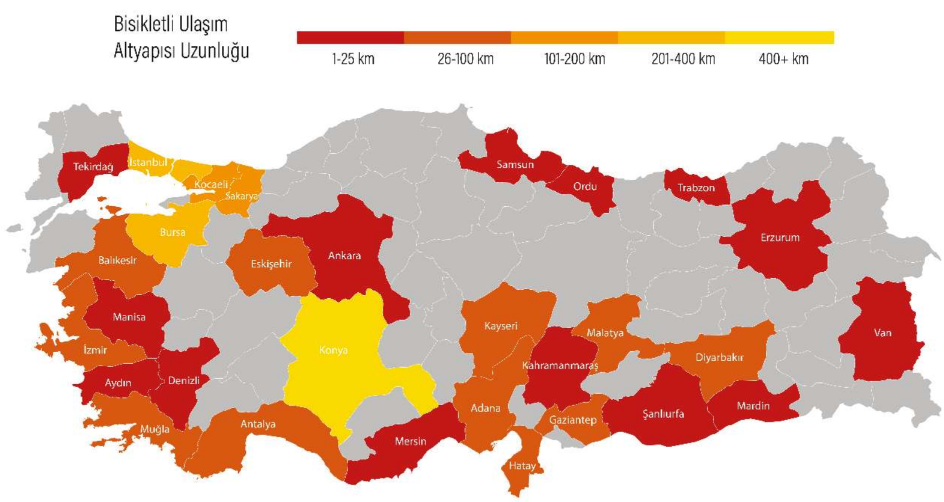


Figure 2.2 : Lengths of bicycle roads in Turkey (WRI, 2022).

As seen in Figure 2.3, 43% of metropolitan cities in Turkey have a bicycle sharing system. When the capacities of the sharing systems are examined, Istanbul is the metropolitan city with the most comprehensive bike-sharing system, with 262 stations and 2600 bicycles in terms of the number of stations and rental bikes. Following Istanbul, the cities with an extensive bike-sharing system are Kocaeli, Konya, İzmir, and Kayseri. In these cities, the number of stations varies between 55 and 87, and the number of bicycles varies between 520 and 890. In the other 7 metropolitan cities, the number of stations varies between 1 and 15, and the number of bikes varies between 20 and 120. These data show that the bike-sharing system is still developing in 23% of metropolitan cities (WRI, 2022).

Figure 2.3 : Bicycle sharing system in Turkey (WRI, 2022).

Compared to the bicycle transportation policies in the world, the development of these policies in Turkey coincides with a much later period. Most EU countries have prepared their national cycling strategies and plans since the 19th century, put their action plans into practice, and updated these strategies and plans in line with the new needs that emerged over time. Although it is pleasing that the bicycle transportation efforts in Turkey are on the national agenda, a strategically holistic study does not stand out compared to European countries and even the USA. Many areas such as bicycle transportation infrastructure (parking areas, maintenance stations, charging stations, etc.), data collection (use rate, frequency, distance, demographics, purpose, counts, etc.) and analysis, communication campaigns, deterrence and incentive mechanisms, trainings are ignored. To reach the final target of the Paris Agreement, signed by the central government in 2016 and approved by the Turkish Grand National Assembly in 2021, a significant reduction in global emissions is required. Considering that 93% of the CO2 emissions originating from transportation in Turkey originates from road transportation (ÇŞB, 2017) and that the bicycle is one of the main actors of sustainable transport (ÇŞB, 2021), Turkey's policies and production on bicycle transportation should accelerate in the coming days.

In the middle of the 19th century in the world, bicycle lanes began to be built in cities. On the other hand, although it is unknown when the first bicycle road was built in Istanbul, its entry into the policy agenda is very new. Cycling was first on the agenda of IMM in 2005 within the scope of *"Survey, Planning, Design of Bicycle Roads and Pedestrian Roads and Making Regional Transportation and Traffic Studies Project in Istanbul"*, and this project was the first planning study that considered bicycle routes in Istanbul. Within the scope of the study, 630 km of bicycle lanes throughout Istanbul were proposed and projected. However, a proper project was not made according to today's conditions since the determining issues and standards for bicycle lanes were insufficient within the legislative structure at the time of the study (IMM, 2020b). Bicycle was also included in the Environmental Plan published in 2006. In order to manage the road transportation infrastructure in line with the principles of sustainable transportation, it was emphasized that the urban transportation problem could not be solved by dealing with the supply side alone and demand management studies should be done. It was mentioned that this situation is inefficient transportation despite automobiles occupying approximately 69% of the roads. It was reported that this situation is unfair to cyclists and pedestrians, which was never considered. However, this has remained as a determination and no strategy has been developed for bicycle transportation (IMM, 2006). When IMM's Strategic Plan covering 2007-2011 is examined, it is seen that there was no target or policy regarding bicycle transportation in this document. Sustainable urbanization and sustainable transportation targets were mentioned in the plan and public transportation was determined as a solution to achieve these goals. In addition, it has been stated that the rapid increase in the rate of automobile ownership in Istanbul has strained the existing highway systems in terms of capacity, but as a solution proposal, *"focusing on highway intersection and tunnel construction"* has been given, which are opposite to sustainable urbanization and sustainable transportation. This plan also reported the modal share for Istanbul's urban transportation, but pedestrian or bicycle transportation was neglected in the modal share (IMM, 2007b). Although it was not a metric target, in the Environmental Report published in 2009, limiting the vehicle traffic in the city's central areas and supporting pedestrian and bicycle transportation took place as transportation policies (IMM, 2009). ITMP, published by IMM in 2011, stated that bicycle transportation is one of the most effective systems that can significantly reduce automobile traffic in short-distance journeys. It was mentioned that creating bicycle road network, making bicycle parks, providing bike-sharing services, awareness-raising activities and trainings needs to be done (IMM, 2011). In the Household Survey published in 2012, there wasn't any question specific to *"cycling"* (IMM, 2012). When IMM's Strategic Plan covering 2015-2019 is examined, it is seen that there was no policy regarding bicycle transportation in this document. The only target for bicycle transportation has been determined as projecting bicycle roads and it was aimed to project 60 km bicycle roads every year. Neither the implementation of the projects and other infrastructure projects nor communication strategies were mentioned. In the plan, it was determined that one of the biggest problems of Istanbul at present is the providing urban transportation services, and a healthy transportation structure was targeted. However, to provide speed, comfort, and safety in pedestrian and vehicle traffic, it aimed to prepare road, intersection, and parking lot projects with an approach far from sustainable transportation policy (IMM, 2015b). The Climate Change Action Plan, published in 2018, was the first study to evaluate the current situation properly and metrically and set targets regarding bicycle transportation. Targets such as making 800 km of streets suitable for urban bicycle transportation by the end of 2023, constructing bicycle lanes on university campuses and establishing bike-sharing system, having 1053 km of bicycle lanes and 5000 shared bicycles in 2023, having free carrying of bicycles in public transport, installing bicycle carriers on buses, increasing the number of bike parks to 300 and the bike capacity to 2000 by 2020, establishing electric bicycle charging stations in central bicycle parking areas by the end of 2019, creating infrastructure and incentives for IMM personnel to come to work by bicycle were determined (IMM, 2018). In 2020, the Bicycle Master Plan was published with the vision of *"Istanbul, the city where the culture of cycling is developed, the use of bicycles is widespread in transportation, and pedaling for a healthy society and a clean environment"*, and Istanbul's bicycle transportation policies and targets have been determined. At the same time, it was aimed to design and build bicycle roads and bicycle parking spaces within the framework determined by the bicycle master plan. By 2023, it was aimed to ensure the active use of 1050 km of bicycle lanes (IMM, 2020b). When IMM's Strategic Plan covering the years 2020-2024 is examined, it is seen that bicycle transportation was widely included in this document. In addition to objectives such as implementing legal and financial support mechanisms to encourage bicycle use, preparing a bicycle road master plan and implementation plan, constructing new bicycle roads in this context, improving and promoting bicycle transportation, a target of 1050 km bicycle roads has been set until the end of 2024 (IMM, 2020c). The IMM signed the *"Deadline 2020"* Commitment at the *"C40 Mayors Summit"* held in Copenhagen in October 2019. With this commitment, the target of being a *"carbon neutral"* and *"resilient city"* for 2050 has been accepted (IMM, 2019a). As a result of all these sustainability efforts, IMM started Turkey's first SUMP study in 2019. Among the main objectives and principles of SUMP, promoting bicycle transportation was also included, and studies in this direction were carried out through participatory processes (IMM, 2020d). Simultaneously, two new organizations were established in December 2019 under the Transportation Planning Directorate, under the Department of Transportation. These are the Bicycle Chief and the Pedestrian Access Chief. Bicycle Chief's Office prepares bicycle lane projects, carries out planning and reporting studies, designs bicycle sharing system stations and bicycle parking spaces, carries out national and international projects, organizes workshops, conducts communication and awareness studies to make the bicycle a visible component of the urban transportation system throughout Istanbul. In addition, Eurovelo coordinatorship was established within the IMM in 2021 to be included in the European cycling routes network *"EuroVelo"*, which is supported by the European Union (EU) and defined as the *"Sustainable Tourism"* project (IMM, 2021b). In 2021, one of the useful works by IMM in terms of bicycle policies was the ISBIKE Cycling School project. This training aimed to gain basic cycling skills and culture, and 6702 Istanbul residents were trained during the summer (IMM and ISBIKE, 2021). IMM and IPA prepared *"Istanbul Climate Vision"* within the scope of Istanbul's *"Deadline 2020"* Commitment at the C40 Mayors Summit, which was established in 2020 with the aim of *"planning a fair, green, creative and happy Istanbul with scientific coordination"*. By 2050, it was aimed that 50% of daily trips will be made by foot and bicycle in *"Istanbul Climate Vision"*. At the same time, this vision document aimed to increase the bicycle roads in Istanbul to 650 km by 2050 (IMM and IPA, 2021).

Table 2.2 shows IMM's bike lanes targets and the targets are inconsistent according to plans. When the indicators are concerned, it is seen that the current situation analysis cannot be done correctly. Among the reasons for this situation are the ignorance of bicycle transportation in transportation plans and policies until recently and the lack of regular records of bicycle lanes in cities due to deficiencies in policy and strategy at the national level. In addition, some infrastructure projects were implemented without any plan, study, or project, some were removed after they were built, and some of them changed their function due to illegal parking and vandalism because they were not inspected. This makes it difficult to set targets for bicycle infrastructure at the urban scale. Increasing financial support for the construction of bicycle paths in the Bicycle awareness in 2019 and 2020 had a positive impact in Istanbul as well as in Turkey.

Table 2.2 : Performance indicators for targets in IMM plans - Cycle lane length (Cumulative).

Plan	2018 (km)	2019 (km)	2020 (km)	2021 (km)	2022 (km)	2023 (km)	2024 (km)	2050 (km)
Climate Change Action Plan (IMM, 2018)	114 (existing)	302 (target)				1053 (target)		
Istanbul Bicycle Master Plan (IMM, 2021a)		187,8 (existing)				1050 (target)		
IMM Strategic Plan 2020-2024 (IMM, 2020a)		266,2 (existing)	350 (target)	500 (target)	650 (target)	850 (target)	1050 (target)	
IMM - Directorate of Transportation Planning December Information Note (2022)	310,4 (existing)	318,2 (existing)	359,7 (existing)	374,1 (existing)				
Istanbul Climate Vision (IMM and IPA, 2021)				350 (existing)				650 (target)

The current situation and targets of the IMM regarding the cycling modal share are shown in Table 2.3. It is seen that the cycling modal share was 0.5% in 2006 and 0.07% in 2012 (IMM, 2012). One of the goals of the Istanbul Climate Change Action Plan, published in 2018, is to increase the cycling modal share in transportation to 2% in 2019 (IMM, 2018). However, the cycling modal share reached only 1% in 2020 (Deloitte, 2021). If cities are grouped according to the cycling modal share, cities with less than 10% are defined as "insufficient", cities with 10%-20% "moderate", and cities with more than 30% "good" cycling conditions (ÇŞB, 2021). Apart from the target of 50% of daily trips to be made by foot and bicycle by 2050 (IMM and IPA, 2021) within the scope of the *"Istanbul Climate Vision"*, Istanbul has maintained its status as a city with *"inadequate cycling conditions"* in its current situation and targets.

Table 2.3 : Performance indicators for targets in IMM plans – Modal share.

Plan	2006 (%)	2012 (%)	2019 (%)	2030 (%)	2040 (%)	2050 (%)
Istanbul Masterplan Household Surveys share (IMM, 2012)	0,05 (existing)	0,07 (existing)				
Climate Change Action Plan (IMM, 2018)			2 (target)			
Deloitte (2021)			1 (existing)			
Istanbul Climate Vision (IMM and IPA, 2021)						50 (target) (bicycle & pedestrian)
Climate Change Action Plan (2021a)				1 (target)	5 (target)	
SUMP (2022)					5-10 (target)	

Today, one of the biggest problems in Istanbul is traffic congestion and the resulting environmental problems, loss of time, excessive fuel consumption, and traffic accidents. Although many studies have been made and are underway to make Istanbul a more accessible city, Istanbul is still far from a sustainable urban transportation structure and needs intense efforts in this regard. Compared to the transportation policies of world cities, the preparation of bicycle transportation policies in Istanbul coincides with a much later period. Although it is pleasing that Istanbul's bicycle transportation efforts are included in local strategic plans, a strategically holistic study does not stand out compared to European countries and even the USA. Efforts in many areas such as bicycle transportation infrastructure (parking areas, maintenance stations, charging stations, etc.), data collection (use rate, frequency, distance, demographics, purpose, counts, etc.) and analysis, communication campaigns, deterrence and incentive mechanisms, trainings exist, but a systematic frame is ignored. For the *"Deadline 2020"* Commitment signed by IMM at the *"C40 Mayors Summit"* in 2019 to reach its target of being a *"carbon neutral"* and *"resilient city"* for 2050, a significant reduction in urban emissions is required. Considering that 98% of the total carbon footprint from transportation in Istanbul originates from road transportation (IMM, 2015a) and that the bicycle is one of the main actors of sustainable transport (ÇŞB, 2021), Istanbul's policies and studies on bicycle transportation should gain momentum in the coming days.

2.7 Electric Bicycles

The first battery-powered bicycle was invented in 1895 by Ogden Bolton, Jr., powered by a gearless hub motor in the rear wheel and has a 10 V battery. In 1896, Charles Thery invented a wheel with an electric motor hub that could be applied to vehicles and specifically bicycles, to increase efficiency. Hosea W. Libbey invented the *"crank-axle hub-motor powered e-bike"* in 1897. This bicycle had crank rods that couple the twin rear wheels to the motor. In 1898, Mathew John Schnepf invented the *"wheel periphery belt drive e-bike"*. The outer surface of the driving belt delivers propulsion power at the road surface. In the same year, Gordon John Scott invented an e-bike that used a generator instead of a battery, but this invention was considered to have an inefficient design. John Schnepf invented friction roller-wheel drive e-bike in 1899. With this design, Schnepf also thought that the battery could be charged while going downhill, but he stated that this would not be enough for a full charge and that the battery would need to be recharged after the trip. Invented by Albert Hänsel in 1900, the electric motor of the e-bike was operated by pedaling to charge the battery. The electric motor was powered to assist power when pedaling while climbing a slope by switching off the electric motor and battery circuit. In 1939, Thomas M. McDonald invented the first e-bike to use an electric hub motor mounted on the front wheel. In 1946 Stefanos Argyris invented an e-bike with the engine running in line with the chain to assist the rider while pedaling. In 1969, G. A. Wood, Jr. invented the e-bike using multiple subfractional horsepower motors. From the 1990s to the end of the twentieth century, many significant improvements were made to e-bikes over previous versions. The first commercial versions of e-bikes were also available in the 1990s. Since the beginning of the 21st century, e-bikes have been further developed with advanced technologies to increase their performance. Taiwanese Lin and Kaohsiung invented the e-bike that can be folded and rotated by hand, with two additional wheels to assist when moving in folded, and had smaller wheels to take up less space. Mark R. Huber invented the e-bike that pedaled to charge the battery or partially powered a hub motor mounted on the front wheel. While the studies and development of e-bikes were increasing rapidly, the e-bike market was also developing fast. Many automobile brands such as Ford, Mercedes, Opel, Honda, BMW, Hyundai, Peugeot, and Volkswagen have started to work on e-bikes. E-bike sales were expected to reach 130 million in 2025 and 800 million in 2100. Although the regions where the e-bike market is most developed in the world are China and Western Europe, the market is growing rapidly in the USA, Latin America, and the Middle East (Morchin and Oman, 2006a; Hung and Lim, 2020).

In cities around the world, people use e-bikes for many purposes such as commuting to work, police and army applications, delivery of goods and services, recreation, and establishing access to periphery villages (Morchin and Oman, 2006a). E-bikes have expanded the bicycle's area of influence in space. While human-powered bicycles (conventional/pedal only bikes) provide access to an area of approximately 78,5 km^2 with a radius of 4-5 km in 30 minutes at an average speed of 8-10 km/h, e-bikes have increased this area of influence by approximately 4 times in the same time. Compared to pedestrian transportation, the access distance for a pedestrian at an average speed of 4-5 km/h corresponds to an area of approximately 12,5 km^2 with a radius of 2 km in 30 minutes. With e-bikes, people can access an area 25 times larger than the pedestrian access area at the same time. Research reveals that most of the urban trips are below this distance. In other words, the trips in the cities are mostly within the service area of bicycles and e-bikes. In addition, since the e-bike reduces fatigue during driving, the driver can easily travel more than 30 minutes. Studies prove that e-bikes increase travel distances for all age groups, even for users over 75 years old. E-bikes have also ruled out one of the most critical constraints of riding bicycle by making cycling easier in cities with high slopes. In addition to all these advantages, e-bikes emerge as an inclusive mode of transportation. It provides individual travel opportunities, especially for the elderly and the disabled. It provides a fair and environmentally friendly transportation opportunity to many functions in the city, such as education, culture, art, office, and industrial facilities, without getting tired and without experiencing traffic jams. The operating costs of e-bikes are 4,5 times cheaper than gasoline motorcycles and 9 times cheaper than cars, including energy, purchasing and maintenance costs, compared to these individual transportation modes. E-bikes, which expand the reach of bicycles and remove the slope and fatigue factor from being a restriction, are increasing rapidly in the world's cities. E-bikes are expected to become widespread in the near future as an intermediate mode of transportation that combines the positive common features of automobiles and bicycles (ÇŞB, 2021). It will be an effective form of transport, especially for commuting to downtown workplaces, home-to-station travel, and station-to-workplace travel (Morchin and Oman, 2006a).

With the use and popularity of e-bikes in cities, countries have made various laws and regulations. These regulations, seen in Table 2.4, have also shaped the bicycles' features, such as speed limits and engine power.

Table 2.4 : E-bike regulations in countries worldwide (Morchin and Oman, 2006a; Hung and Lim, 2020).

Location	Speed limit (km/h)	Motor power limit (W)	Weight limit (kg)	Other Limitations
EU	25	250	None	Pedal-assist motor power must be zero when bike reach 25 km/h speed.
UK	25	200	40	The limit is 250 W and 60 kg for tricycles. Must have pedals and on/off switch
USA	32	750	None	Must have pedals and less than 4 wheels.
Canada	32	500	None	Must have pedals and less than 4 wheels and on/off switch
China	30	240	20	Must have pedals
Hong Kong				Operation of e-bike in any public area is totally banned
Japan	24	None	None	Pedal-assist motor power must be zero when bike reach 24 km/h speed.
Australia	25	250	None	The speed limit can be exceeded by 10%.
New Zealand	None	300	None	
Israel	25	250	30	
Taiwan	30	No	40	Power only engages during pedaling

E-bikes can be broadly classified into three main categories: pure e-bikes (i), power-assisted bicycles (pedelecs) (ii), and e-bikes that combine pure and power-assisted modes (iii). Pure e-bikes are e-bikes where the rider controls the electric power with the handlebar without pedaling. Power-assisted bicycles are human-electric hybrid bicycles, and the electric power provides power support to the rider while pedaling. Combining e-bikes can be used, either way, depending on the rider's preference (Hung and Lim, 2020). E-bikes could also be classified by kit type, motor assembly, motor type, motor placement, throttle type, and battery type. E-bikes are also classified by purpose, for instance, city bicycle, hill bicycle, distance bicycle, speed bicycle, etc (Muetze and Tan, 2007). Many features of e-bikes, such as battery types, engine types, purposes of use, and the countries' regulations, as mentioned before, are effective in the performance of the produced e-bicycle. E-bikes produced in 2004 have a range of 19-60 km with a charged battery and the average range is 35 km (Morchin and Oman, 2006b).

Keeping the battery charged for a long time after it is close to or exceeds 100% shortens the battery life. At the same time, 0% charge of the battery shortens the battery life. Before the battery energy drops to 0%, charging it every few rides, depending on the length and duration of the ride, will increase the battery life. If the battery is well maintained, its lifespan can reach 5 years, but if it is not used well, it will need to be replaced in less than 1 year (Pedego, 2015). Suitable charging methods will contribute to its efficient use as well as further promote the use of e-bikes. E-bike charging methods can be classified as wireless charging and plug-in charging. The wireless charging method uses Inductive Power Transfer (IPT) technology to charge the battery without physical contact. On the other hand, plug-in charging provides charging of the battery by transferring electricity from the charging station to the battery with the help of a cable. In addition, these charging stations can be solar powered as well as obtain energy from the urban electricity infrastructure (Beh, et al, 2013; Beh et al, 2015; Biya and Sindhu, 2019; Hung and Lim, 2020). For charging a battery, there are three regimes of time: rapid (i), quick (ii), and slow (iii). Full of battery charging time, which takes 1 hour or less for rapid, around 3 hours for quick, and more than 10 hours for slow charging, depends on battery type and battery capacity of e-bikes (Morchin and Oman, 2006b).

2.8 Location Determination

In this section, general information about location problems was discussed. Since there is no study in the literature on e-bike charging station location determination, the methods and criteria used in the location selection of electric vehicle charging stations (EVCS) and bicycle infrastructure systems were examined. In addition, walking distances to urban facilities and local laws and regulations were also be included in this section.

Facility location problems are usually cost minimization functions. It aims to locate a series of facilities according to some requests from those who will use the facility (Hale and Moberg, 2003). For private and public sectors, the decisions made on facility location problems are critical in strategic planning. The branches of locating facilities are broad-based and long-lived. This process influences many operational and logistical decisions. Due to the high costs of property acquisition and facility construction, facility location/relocation decisions are long-term and strategic investments (Owen and Daskin, 1998).

Location theory studies were first conducted by Alfred Weber in 1909 to minimize the distance between the warehouse and the customer. Although there were several location theory studies, later on, other researchers were also interested in this topic with the switching centers in a communications network and police stations in a highway system location studies conducted by Hakimi in 1964 (Hakimi, 1964; Hekmatfar and SteadieSeifi , 2009)

Location problems consist of four elements: existing demand points or routes in which demanders are located (i), some new facilities which will be located (ii), a feasible solution space in which new facilities and the demand points are spread (iii), and a measurement criterion (distances, time, cost, etc.) between facilities and demander (iv) (ReVelle and Eiselt, 2005).

There is also a wide range of applications for facility location problems and each application needs its specific decision variables or objective functions. Location problems models can be examined in three categories: classical models such as single facility location problem, multiple facility location problem, median problem, center problem and covering problem, contemporary models such as hierarchical facility location problem, hub location problem, and competitive location problem and advanced models such as location in supply chain (Hekmatfar and SteadieSeifi , 2009).

Location studies can be categorized into location problems, allocation problems, and location-allocation problems (Hekmatfar and SteadieSeifi , 2009).

What the service is and who provides it are also important when deciding on the facility location. The goal of the private sector is to minimize costs and maximize profits. There are three types of facilities for public sector: ordinary facilities such as libraries, hygienic clinics (i), emergency facilities such as fire stations, police stations (ii), and undesirable facilities, such as waste areas (iii). For ordinary facilities, the aim is usually to maximize service for more people. For emergency facilities, the objective is generally consisted of maximizing the minimal covering. For undesirable facilities, the purpose is to minimize the effect of this area on the residents near it (Hekmatfar and SteadieSeifi , 2009).

Location selection among a set of alternatives along with several conflicting criteria is a Multiple Criteria Decision Making (MCDM) problem. Satisfying all requirements simultaneously in selecting from a finite number of other options is not possible when measures conflict and in such cases, MCDM methods provide a compromise solution to the problem (Sennaroglu and Varlik Celebi, 2018).

Electric vehicles (EVs) are the popular technologies worldwide to prevent environmental pollution and provide solution to fossil fuel energy resource crisis. As the initial work of EVCS construction, site selection plays a significant role in its whole life cycle, which, however, is a complicated MCDM problem involving many conflicting criteria (Liu et al, 2019).

Table 2.5 : Studies on EVCS site selection.

References	Methodology	Criteria
Kaya et al. (2020)	GIS and MCDM (AHP, PROMETHEE and VIKOR methods.)	Attractive centers (shopping mall, stadium, university, public buildings, etc.), parking lots, slope, distance
Hosseini and Sarder (2019)	Bayesian Network (BN) model	Technical, economic, environmental, and social criteria
Liu et al. (2019)	MCDM (DEMATEL and UL-MULTIMOORA)	Environmental, economic, society
Guo and Zhao (2015)	MCDM (Fuzzy TOPSIS)	Environmental, economic, society
Karaşan et al. (2020)	MCDM (DEMATEL, AHP, and TOPSIS)	Cost (land cost, transportation cost, etc), geography & infrastructure (accessibility, road network, land use, etc.), reliability & safety, and society
Chen et al. (2013)	Mixed-integer programming model	Minimized the cost of access Parking demand, local jobs, population density, and travel characteristics
Jordán et al. (2019)	Genetic algorithm, multi-agent systems	Point of Interest (PoI), population, traffic, social networks, popularity.
Phonrattanasak (2012)	Ant colony optimization (ACO)	Create grids Minimize annual cost of power line loss, travelling cost of EVs in recharging, investment cost and variable cost of operation of FCS while maintaining system security
Wu et al. (2016)	MCDM (PROMETHEE ANP)	Economic, engineering feasibility, service availability, social, environmental, and land
Güler and Yomralıoğlu (2018)	MCDM (Fuzzy AHP) and GIS	Distance to green areas, roads, petrol stations, shopping malls, park areas, and transportation stations. Slope, income rates, land values, and population density

Studies on EVCS location problems with different solution methodologies are summarized in Table 2.5. According to studies, it could be said that MCDM is widely used in EVCS location determination problems.

The Bicycle Sharing System (BSS) provides people with the opportunity to experience a healthy, pleasant, and environmentally friendly journey on short and medium-distance journeys. At the same time, it has the advantage of being integrated with public transportation in the first and last mile journeys. BSS can be categorized according to the type of operation. These are; the Station-Based BSS (SBBSS) and the Free-Floating BSS (FFBSS) (Caggiani et al, 2018). SBBSS ends when the people pick up the bike from the station and use it for the journey, then leave them at another station and pay for the time they use the bike (Alvarez-Valdes, et al., 2016). On the other hand, FFBSS does not include any bike stations. The users unlock the bikes with their phones, and when they complete their journies, they park the bikes in suitable places without a station and lock them with their phones (Pal and Zhang, 2017). In SBBSS, the distance between stations and the user's access problem is a significant problem (Liu et al, 2012). Improving the user's use of the Shared Bicycle System can be achieved with a three-phase design and operation. First, the number, location, and size of stations must be decided at the strategic level. In the second stage, the number of bicycles in the system should be decided at the tactical level. In the third stage, the repositioning system of bicycles should be determined at the operational level. According to demand, bicycles should be transported between stations (rebalanced) and bicycles should be transported to workshops for maintenance and repair needs (Alvarez-Valdes, et al., 2016). The strategic level can be defined as a design improvement problem. In this context, studies have identified how to optimally select the location, capacity, and number of stations of BSSs and consider the concerns of users and operators when planning the systems. Techniques related to BSS locations that were used in the literature are categorized as “Mathematical Algorithms”, “MCDM”, and “Geographic İnformation System (GIS)-based modeling” (Bahadori et al, 2021). Studies on BSS location problems with different solution methodologies are summarized in Table 2.6. According to studies, it could be said that MCDM is widely used in BSS location determination problems.

Table 2.6 : Studies on BSS site selection.

References	Methodology	Criteria
Croci and Rossi (2014)	Linear panel-data models	Close to restricted traffic areas, rail system stations, and PoI (cinemas, museums, universities, etc.)
Fazio et al. (2021)	GIS and MCDM	socio-economic information, public transit accessibility, attractiveness, POIs
García-Palomares et al. (2012)	GIS	Population, activities, and the public transit network
Park and Sohn (2017)	Minimum impedance (p-median) model	Metro stations, shopping centers, parks, and residences.
Krykewycz et al. (2010)	GIS and Travel Demand Model	Retail jobs, population, bicycle lanes, bicycle friendly streets, locations of tourist attractors (cultural, entertainment, sports, and restaurants), parks and recreation areas, bus stop etc.
Eren and Katanalp (2022)	Fuzzy Logic based GIS, MCDM (AHP, VIKOR, Psychometric VIKOR)	Transportation network (railway stations, ferry piers, highways, bicycle paths, planned bicycle paths, minibus routes, bus stops and routes), build environment (population density, business centers, university campus, hospital, municipalities, city halls, parks, scenic rods, museums, cultural places, entertainment centers, sport center), natural environment (slope).
Wuerzer and Manson (2016)	GIS, Retail Gravitation Law model, Huff model	Demographics and employment, and traffic analysis zones, trip attractors (retail businesses, services such as ATMs, restaurants, hospitals, public agencies, and entertainment such as museums, parks, and movie theatres)
Conrow et al. (2018)	GIS-based coverage optimization	Access distances (0,5 miles to the bike path, 0,25 miles to the bus stop, 0,5 miles to population density) The low-middle income region, 0.5 miles to the population density.
Jahanshahi et al. (2019)	Fuzzy, GIS, MCDM (AHP, VIKOR) and JENKS	Subway station, bike station, important intersections, population centers, educational, recreational and commercial centers, slope level, and bike lanes
Ghandehari et al. (2013)	MCDM (AHP)	Bicycle lanes, public transport and road networks (parking lot, public transport, etc.), demand (administrative area, trade area, residential area), and use type (school, historical and attractive location, parks and leisure area)
Wuerzer et al. (2012)	GIS	Population density, employment density, higher education, bus stops, bike lanes, parking garages, trade facilities, ATMs, and parks
Institute for Transportation and Development Policy (ITDP) (2018)	Map creation with 1x1 km grids Field work	Public transit stops and stations, bike lanes, and any other important demand generators or facilities. Distance between stations should be approximately 300 m.
National Association of City Transportation Officials (NACTO) (2016)	Description	Being close to bicycle lanes, public transit stops and stations, pedestrianized areas

Parking and complementary infrastructure for bicycles are defined as *"Bicycle end of trip facilities"* Bicycle parking infrastructure includes: stands or racks that support bikes; and shelters or enclosures that protect parked bicycles (Transport Canada, 2010). Bicycle parks can be categorized into three topics according to their purpose of use, parking period, and safety levels. These are bicycle rails or rocks which provide low security to users (shoppers, visitors, and employees are their primary users) for short to medium term parking (i), lockable enclosure facilities and shelters which provide medium security to users (employees, students, bike-and-ride commuters are their main users) for the all-day parking (ii), and fully enclosed individual lockers which provide high security to users (bike-and-ride commuters at railway and bus stations) for the all-day and night parking (Austroads, 2017). The presence of a bicycle parking structure is a factor that will increase commuting by bike (Yang et al, 2015).

The number of academic studies on bicycle transportation is relatively high and it is increasing day by day. However, the majority of studies focus on bike lanes, cycling levels, BSSS, etc. The studies on bicycle parking facilities have key gaps in research methods, data availability, and measurement to study bicycle parking (Heinen and Buehler, 2019). For this reason, while examining the studies on bicycle parking facilities, it was investigated which criteria came to the fore in locating these structures. Studies on bicycle parking facility location problems and the criteria affecting them are summarized in Table 2.7. According to studies land use, public transportation stations and stops, bicycle infrastructure, distance and visibility are the outstanding criteria.

Table 2.7 : Studies on bike parking facility site selection.

References	Criteria
Yan and Zheng (1994)	Significant relationship between parking demand and land use, and public transport integration. Walking tolerance of cyclists after parking their bicycles is 300 m.
The Danish Cyclists Federation (DCF) (2008)	Roads used by cyclists, urban functions and public transport units, and visibility Walking distance of 0-15 m for short-term parking facilities and up to 100 m for long-term parking facilities. Longer walking distances could be acceptable as the level of security increases, and the possibility of more extended parking is provided.
Transport Canada (2010)	Land use, designated bike routes, road environment, topography, distance
Ascobike and ITDP (2011)	Bicycle network
Association of Pedestrian and Bicycle Professionals (APBP) (2015)	Long-term parking should be designed to the needs of employees, residents, public transit users, and others with similar needs.

Table 2.7 (continued) : Studies on bike parking facility site selection.

References	Criteria
Transport for London (TfL) (2016)	Distance
Austroads (2016a; 2016b; 2017)	Distance to the destination point, pedestrianized areas, visibility.
Van Kampen et al. (2021)	Socioeconomic, journey, and neighborhood characteristics, distance
Turkish Standart Institute (2013d)	Demand generator facilities (public transportation, cinema, theatre, cafe, business center, shopping area, industrial facility, hospital, school, sports facility, beach), visibility

Walking distances in urban area vary according to the function to be accessed. The walkability distances were examined as walking distance to social facilities, public transportation, BSS, and bicycle parking facilities. Studies walking distances to urban facilities are shown in Table 2.8.

Table 2.8 : Studies on walking distances to urban facilities

References	Criteria
Ministry of Environment, Urbanisation and Climate Change (2014)	Educational facilities: kindergarten and primary school up to 500 m, secondary school up to 1000 m, high school up to 2500 m Health facility: primary care clinic up to 500 m, hospital up to 1000 m Social and cultural facility: up to 1000 m Religious facility: mosque, church, and synagogue up to 400 m, masjid and chapel up to 150 m Green area: Playground and sport ground up to 500 m
Rhonda and Mulley (2013)	400 meters, or multiples such as 800 meters, as key distances in network and service planning
NSW Ministry of Transport (2006)	90% of households in each of the 15 metropolitan bus contract regions should be within 400 m of a bus route and/or rail system during the day (commuter peaks, inter-peak and weekend daytime) and within 800 m of a bus route and/or rail system at night time. This is measured as the straight-line distance, not road or walking distance.
Greater Vancouver Transportation Authority (2004)	accessibility distance to public transportation units is specified as 400 m for Vancouver
HKL (2008)	accessibility distance to public transportation units is specified as 300 m for Helsinki
Australia Public Transport Authority (2003)	accessibility distance to public transportation units is specified as 500 m for Perth
Global Designing Cities Initiative (GDCI) and NACTO (2016)	Public transportation stop: up to 400 m Bicycle: up to 300 m, or a 5-minute walk
Yan and Zheng (1994)	Walking tolerance of cyclists after parking their bicycles is 300 m
The Danish Cyclists Federation (DCF) (2008)	Short-term parking facilities: 0-15 m Long-term parking facilities: up to 100 m Longer walking distances could be acceptable as the level of security increases, and the possibility of more extended parking is provided.

While locating bicycle infrastructure elements, these points must be accessible by bicycle. For this reason, local laws should be examined and it should be investigated in which areas the use of bicycles is allowed. 2918 - Highway Traffic Law covers traffic-related rules, conditions, rights and obligations, their implementation and supervision, relevant institutions and their duties, authorities and responsibilities, working procedures, and other provisions in Turkey. Bicycle is defined as a *"non-motorized vehicle"* in the Highway Traffic Law. Highway Traffic Law states that bicycles are non-motorized vehicles that move by turning the wheel with the pedal or hand with the muscle power of the person on it. Electric bicycles whose maximum continuous rated power does not exceed 0,25 KW, whose power decreases as they accelerate, and whose power is completely cut off after reaching a maximum speed of 25 km/h or immediately after the pedaling is interrupted are also included in this class. Highway Traffic Law states that the maximum speed of a moped is 45 kilometers per hour. The cylinder volume will not exceed 50 cubic centimeters if it is an internal combustion engine. The maximum continuous nominal power output will not exceed 4 kilowatts if it is an electric engine. There are four-wheeled motor vehicles with the same characteristics as two- or three-wheeled vehicles whose net weight does not exceed 350 kilograms. Battery weights will not be considered when calculating the net weights of those working with electricity. Due to its definition and features, moped is considered different from bicycle and e-bike.

According to Highway Traffic Law, bicycles should be ridden on bicycle roads if a bicycle road exists. If there is no bicycle road, bicycles should be ridden on roads with a speed limit of up to 50 km/h. It is also prohibited to ride bicycles on sidewalks and pedestrianized areas. (EGM, 2020).

Bicycle Routes Regulation aimed to determine the procedures and principles regarding the planning, design, and construction of bicycle lanes and bicycle parking stations to ensure that bicycles can be used for purposes such as transportation, sightseeing, and sports. In this regulation, the maximum slope of the routes on which bicycle roads will be implemented is 4%. It is recommended to build a bicycle road up to 240 m with a 5-6% slope, up to 120 m with a 7% slope, up to 90 m with an 8% slope, up to 60 m with a 9% slope, and up to 30 m with a 10% slope (ÇŞB, 2019). The relationship between cycling and slope is related to the rider's condition for human-powered bikes and battery power for e-bikes. However, these limit values can be considered when determining the slope-related criteria.

2.9 Discussion

The bicycle, which was invented at the beginning of the 19th century, has made a ground all over the world not only as a means of vehicle, but also as a sport and recreational vehicle and even culture. The industrial revolution that started at the end of the 18th century has created significant changes in urban functions. In the second half of the 19th century, the city became unhealthy due to factory fumes, its infrastructure was not developed, and a city structure in which the slums where the workers lived were widespread. With the industrial revolution, not only the functions of the cities have changed, but also the cities have been exposed to great pressure of immigration. In the same period, with the increase in automobilization, both cities were exposed to urban sprawl and transportation investments and urban designs began to be focused on automobiles. In the mid-19th century, local politicians started to reorganize the streets to increase the efficiency of the city and manage the rapidly growing number of automobiles. With the automobile-focused preparation of transportation plans, the streets have lost their functions of socialization, play area, and access area with transportation units at different speeds. They have completely become the movement and parking area of motor vehicles. During this period, while the modal share of bicycles in the world decreased rapidly, the modal share of automobiles quickly increased.

With the definition of the concept of sustainability towards the end of the 20th century, sustainability efforts all over the world started to gain momentum. The goal of achieving global sustainability started from the cities, the dominant living spaces, and the concept of sustainable city was developed. Various targets have been set in order to reach sustainable cities. One of them is emission limitations. It is necessary to create a sustainable transportation system in order to achieve sustainable cities and, therefore global sustainability since more than 70% of the emissions from transportation in the world are caused by road transportation. For this reason, agreements, commitments, and efforts focused on sustainability and sustainable city have also included sustainable transportation targets. The concept of sustainable transportation, which prioritizes pedestrian, bicycle, and public transportation, has proposed bicycle transportation for the agenda worldwide. With the acceleration of the infrastructure works and communication campaigns required for bicycle transportation, the modal share of bicycles has started to increase. With the development of e-bikes, there has been another revolution in bicycle transportation. E-bicycle has made a ground as a new means of vehicle between human-powered bicycle and automobile by overcoming obstacles such as slope, long-distance, condition and rider's age.

E-bikes, which is an environmentally friendly, low-occupancy, inclusive, economical, social transportation unit of the 21st century, need a bicycle charging station in addition to traditional bicycle infrastructure investments. The e-bikes, which have a range of 19-60 km with a charged battery, have an average range of 35 km and riders could easily travel over the average trip distance of 10 km. However, the energy falling to 0% reduces the battery life of the e-bikes. E-bikes providers recommend charging the e-bikes every time or every 2-3 uses. This situation makes it inevitable for local governments to invest in bicycle charging stations in public areas.

Rapid urbanization, increasing population, and automobilization have put pressure on Turkey in parallel with the world. Global sustainability, sustainable city, and sustainable transportation were also on Turkey's agenda and made it a party to international agreements and commitments. In this context, the national and local governments that support bicycle transportation have also followed the developments in e-bikes globally, made national definitions, and included them in regulations and plans. If e-bike efforts were examined on the scale of Istanbul, bicycle charging stations, one of the necessary infrastructure investments for e-bikes, were added to the agenda for the first time in the Istanbul Climate Change Action Plan Final Report published in 2018. With the Park and Go project, creating sheltered, free, and secure bicycle parking areas with a total capacity of 700 bicycles, especially at public transport connection points such as cityline ferry ports, BRT, tram, and metro stations, has been aimed. In addition, the target of increasing the capacity of existing bicycle parking spaces from 982 to 2000 has been set. Moreover, as a pilot project, it was aimed to install charging sockets for electric bicycles in central bicycle parking areas by the end of 2019. However, this target of e-bike charging stations was not included in the strategic plans nor the Istanbul Bicycle Masterplan. Bicycle parking areas mentioned in the Istanbul Climate Change Action Plan and whose capacity was to be increased were bicycle racks. These units serve for short-term parking as a function for reasons such as security, weather conditions, etc. There is no regular and complete data on its distribution throughout the city, and the site selection criteria are unknown. The target of placing e-bike charging stations is in the same report as the bike racks target. In other words, it is understood that an evaluation will be made between the places of these parking racks while choosing the location for the charging stations. Considering that the charging time of e-bikes ranges from 1 to 10 hours, riders should leave their bikes for charging in places that are physically and visually safe, sheltered from weather conditions, and close to their destination or transfer points. The concept of "central bicycle parking areas" mentioned in the report as a location selection criterion is insufficient and subjective. Inevitably, almost all location selections made without specific parameters will not in use as the bicycle parking racks in Istanbul. While determining the charging station location for e-bikes, the concept of "centers" for bicycle transportation should be examined. In order to determine the parameters for the decision of these centers, the parameters and importance levels should be determined by asking questions such as which urban functions are attractive to access with bicycles, which urban functions do we want to make attractive to access with a bike as a policy, which public transport units have a strong relationship with cycling, as a policy, which public transport units do we want to strengthen their relationship with bicycles, what are the attractive factors and constraints for accessing by bike. An intuitive decision-making model is not valid for public investments and optimal budget use should be the target for public investments. Analytical approaches should be adopted instead of an intuitive decision-making model to achieve goals. Analytical decision-making enables an easy understanding of every step to reach the goal and group work and cumulative project development. If policymakers aim to achieve sustainable transportation, sustainable city, and global sustainability goals, they should set measurable targets instead of subjective targets and conduct analytical studies.

3. METHODOLOGY: MULTIPLE-CRITERIA DECISION MAKING

Decision-making is the action of choosing one of the available alternatives to achieve goals and objectives (Can, 2015).

Decision-making takes place in two ways, intuitive and analytical. While intuitive decisions are not supported by data or documents, the decision-maker evaluates a large amount of information based on his/her own intuition and makes decisions quickly. Decisions made based on intuition are difficult to accept by others. Because the decision-maker may have difficulty in explaining his/her logic chain to others and sometimes cannot express it. Uncertainties may arise about where other participants will add their information. The decision-maker may be in a difficult situation when synthesizing the experiences of himself/herself or other relevant people. It won't be easy to re-examine such a decision in the future. With poor decisions being made, no one around the manager (decision maker) knows how the decision should proceed and whether it is good or bad. There is no learning and creation process through group participation in such decisions. On the other hand, analytical decision-making is based on the principle of more efficient resolution of problems by dividing them into smaller meaningful subsections in a hierarchical manner. The analytical approach allows for the sharing of values and ideas. In this type of approach, decisions are transformed into a strategic cluster, and the criteria that are problematic at all levels in the decision-making process are repeatedly explained and put forward. Analytical decisions provide effective and consistent answers to complex and difficult-to-solve problems. These problems require a great deal of organization, math, and numbers (Saaty, Fundamentals of Decision Making And Priority Theory with the Analytic Hierarchy Process, 2000).

A coherent framework needs to be found to determine which particular options should be chosen. Therefore, some steps should be followed in the decision-making process: identification and investigation of the problem (i), elimination of unsuitable options (ii), model creation (iii), synthesis (iv), testing and realization of the decision (v), decision reporting (vi) (Saaty and Vargas, 2006).

Multiple-criteria decision-making (MCDM) or multiple-criteria decision analysis (MCDA) deals with structuring and solving decision and planning problems involving multiple criteria. The aim is to support decision-makers who face such problems. Typically, there is no uniquely optimal solution for such problems and it is necessary to use the decision maker's preferences to distinguish between solutions (Majumder, 2015).

Multiple-criteria decision-making problems can be examined under three main headings; choice (i), sorting (ii), and ranking (iii) problems. In choice problems, the aim is to determine the best alternative or make a good choice among many options that are difficult to compare with each other or have equal weights. In sorting problems, alternatives are classified according to specific criteria or preferences. The aim here is to reassemble options that show similar characteristics and behaviors. In ranking problems, alternatives are ranked from good to bad in a measurable or definable way. This sorting process can be multi-part in various ways (Turan, 2015).

The weighted sum model (WSM), the analytic hierarchy process (AHP), the revised AHP, the weighted product model (WPM), the elimination et choice translating reality (ELECTRE), and the technique for order performance by similarity to ideal solution (TOPSIS) method are the ones which are the most widely used MCDM (Triantaphyllou, 2000)

3.1 Analytic Hierarchy Process (AHP)

Analytical Hierarchy Process (AHP) is a method developed by Thomas L. Saaty in 1977, in which human judgments are also used in decision-making processes. AHP is a method that finds the best option in multiple-criteria decision problems with a finite number of possibilities. (Ho, 2008) AHP technique provides quantitative and qualitative decision variables (Vargas, 1990). A single result can be achieved by combining the decisions of stakeholders with different experiences, knowledge, and education (Saaty, 2008a). In the AHP technique, a hierarchical structure is created that shows the purpose of the problem to be solved, criteria, sub-criteria, and decision alternatives (Saaty, 2008b). Although logic plays an essential role in decision-making, it is insufficient in establishing relationships in complex problems. For example, according to logic, if A is stronger than B and if B is stronger than C, then A will be stronger than C. But inconsistencies can be seen in real life. For example, in a sporting event, team A beats team B, team B beats team C, but team C could beat team A. AHP is also an application that allows inconsistencies between preferences and options like this (Saaty, 1988).

To summarize, the AHP process has eight major uses. It allows the decision-makers to: design a form that represents a complex problem (i), measure priorities and choose among alternatives (ii), measure consistency (iii), predict (iv), formulate a cost/benefit analysis (v), design forward/backward planning (vi), analyze conflict resolution (vii), develop resource allocation from the cost/benefit analysis (viii) (Saaty, 1988).

While using the AHP technique, experts compare criteria and alternatives in pairs. Saaty's scale, whose interval is from 1 to 9, is often used in this comparison (Anderson et al, 2001).

3.1.1 Strengths and weaknesses of AHP

The strengths of AHP can be listed as follows (Bhutta and Huq, 2000; Kuruüzüm and Atsan, 2001; Tahriri et al, 2008; Timor, 2011; Ishizaka and Nemery, 2013).

It provides an easy-to-implement decision-making methodology that allows the decision-maker to accurately determine their preferences for the goal.

It has a structure/process that simplifies complex problems.

It increases decision-maker’s understanding of the definition and elements of the decision problem.

It allows both qualitative and quantitative information to be included in the decision process, with objective and subjective considerations regarding a decision problem.

The decision-maker can analyze the flexibility of the final decision by performing a sensitivity analysis. It allows the decision-maker to measure the degree of consistency of their judgments.

It is suitable for use in group decisions.

The weakness of AHP can be listed as follows (Bhutta and Huq, 2000; Kuruüzüm and Atsan, 2001; Timor, 2011; Shahroodi et al, 2012; Ishizaka and Nemery, 2013).

The rank reversal phenomenon is an issue that should be considered in the implementation of AHP, and when any decision alternative is added to or removed from the problem, the order of decision alternatives changes. Discussions in the literature about the validity of the rank reversal situation continue.

The subjective nature of the modeling process is seen as a limitation of AHP. This means that the methodology cannot guarantee *"absolutely correct"* decisions.

As the number of levels in a decision hierarchy increases, the number of pairwise comparisons also increases. This requires more time and effort to establish the AHP model.

3.1.2 Steps of AHP

In this section, the steps followed from the initial step of the AHP to the decision-making step, which is shown in Figure 3.1. are summarized.

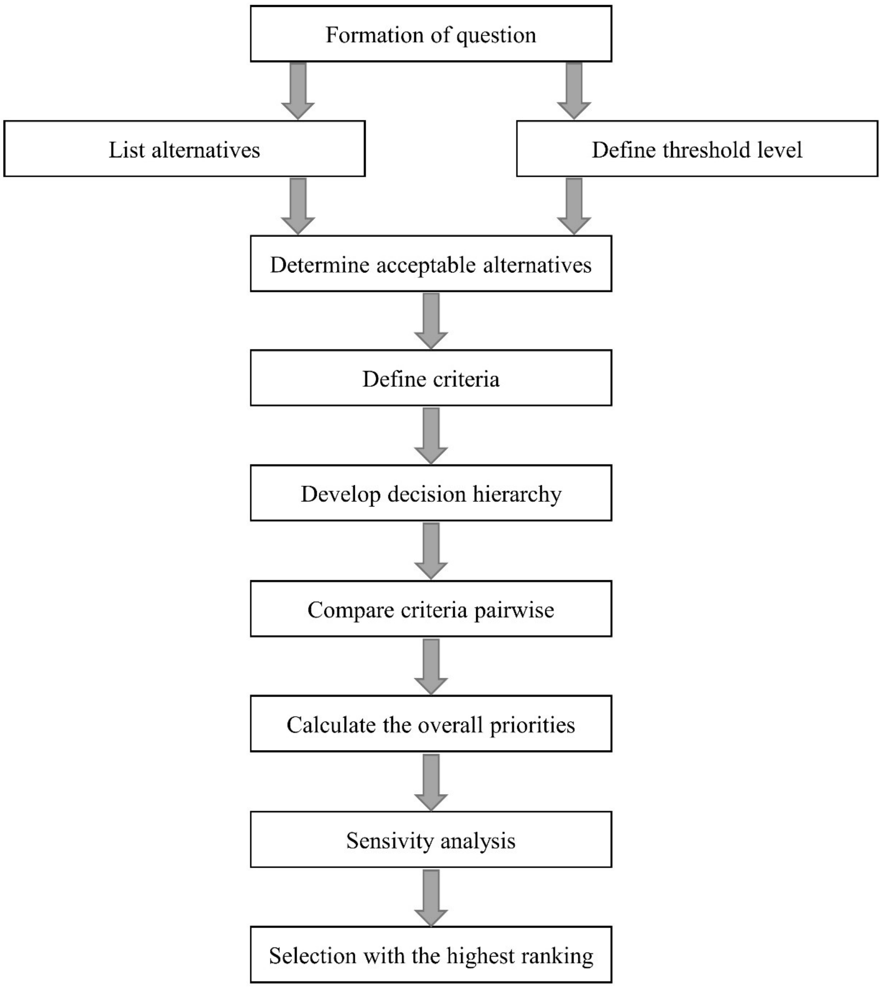


Figure 3.1 : Nine phases of AHP.

AHP first divides a determined problem into small parts and then brings together the solutions of all sub-problems containing the results obtained. Organizing emotions, thoughts, decisions, and perceptions in a structure that affects the decision facilitates decision making. Judgments are also organized from the more general and less controllable to the more specific and controllable (Saaty, 1994; Bohanec, 2004).

3.1.2.1 Defining decision problem and determining purpose

A person's dissatisfaction with his/her situation or inability to reach a goal or a negative stimulus he/she feels creates an obstacle that he/she needs to escape from or wants to change. In other words, a problem can be defined as the difference between a person's current situation and the situation he/she wishes to be in.

In every method where there is a decision-making problem, the first and most crucial step is to define the problem. With the definition of the problem, the target that the decision-makers want to reach with AHP is determined (Saaty, 2008b).

3.1.2.2 Listing decision criteria and identifying possible decision alternatives

This step, which includes determining the decision points and the factors affecting the decision points, can be considered the process of decomposing a decision-making problem into sub-problems in a hierarchical order that will make it easier to understand and evaluate. AHP allows decision-makers to model complex problems in a hierarchical structure that shows the relationship between the problem's main objective, criteria, sub-criteria, and options (Saaty, 1980). More than one criterion can be determined related to the subject, as well as the sub-criteria of these criteria. The criteria set should be clear and concise.

3.1.2.3 Establishing hierarchical structure

Hierarchy is a tree-like representation of the division of reality into levels and sublevels. (Hacımenni, 1998). In the AHP technique, a hierarchical structure is created that shows the purpose, criteria, sub-criteria, and decision alternatives of the problem. (Tzeng and Huang, 2011). This structure of AHP is shown in Figure 3.2.

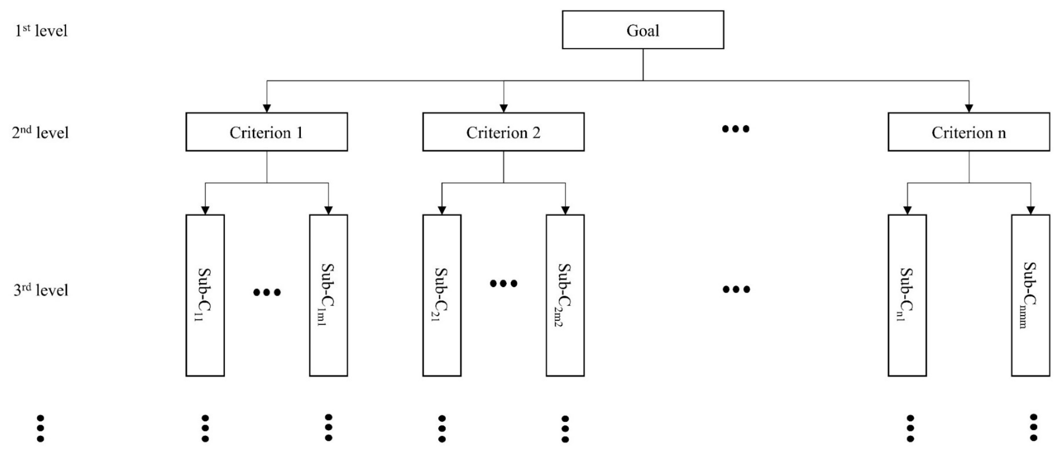


Figure 3.2 : Hierarchical structure in the AHP method (Tzeng and Huang, 2011).

The formation of the decision hierarchy depends on the number of levels, the complexity of the problem, and the degree of detail the analyst needs to solve the problem. (Zahedi, 1986)

Elements of the next level control elements of each level of the hierarchy. The target is of the greatest importance and takes the value 1. This value is divided among the elements of the second level, and the value of each of these elements is also divided among the elements of the third level. This continues up to the level of the options at the bottom. (Hacımenni, 1998).

In order to determine the best option, first of all, the degree of importance of the criteria according to the purpose is determined. The criteria are compared with each other in terms of target. Then, for each criterion, the degree of influence of the sub-criteria on that criterion is found. Finally, the degree to which the options meet the sub-criteria is found by comparing the options against each sub-criterion. (Webber et al, 1997)

3.1.2.4 Pairwise comparison of criteria

At this step, the relative importance scale, which consists of numbers expressing the importance levels of the criteria, is determined to create the comparison matrix.

In the evaluation, the AHP Fundamental Scale, which consists of 5 main and 4 intermediate values, suggested by Saaty, and includes values from 1 to 9, is used (Saaty, 2001). The decision makers' concerned make unnecessary comparisons with this scale, which can be seen in Table 3.1. For example, if this value is 7, it is understood that the i^{th} criterion is very important compared to the j^{th} criterion. In this case, similarly, the j^{th} criterion is important at the level of 1/7 compared to the i^{th} criterion. In comparison, intermediate values express the phenomenon between two main values.

The reasons for accepting the upper limit as 9 points in the AHP Fundamental Scale are as follows (Çol Yılmaz and Gercek, 2014):

- The method developed by Saaty gives the best results for n<10 point scale, especially for 7 point scale. In other words, when solving multiple-criteria decision-making problems with AHP, significant inconsistencies may occur if the scale is greater than 9 points.
- If the matrix elements are very large numbers, this can create more significant inconsistencies.

Table 3.1 : The fundamental scale of absolute numbers (Saaty and Vargas, 2006).

Rating Scale	Definition	Explanation
1	Equal importance	Two elements contribute equally to the objective
2	Weak	Between equal and moderate
3	Moderate importance	Experience and judgment slightly favor one element over another
4	Moderate plus	Between moderate and strong
5	Strong importance	Experience and judgment strongly favor one element over another
6	Strong plus	Between strong and very strong
7	Very strong importance	An element is favored very strongly over another; its dominance demonstrated in practice
8	Very, very strong importance	Between very strong and extreme
9	Extreme importance	The evidence favoring one element over another is one of the highest possible order or affirmation

3.1.2.5 Calculating weight and comparison matrices

During the AHP application, the degree of importance of the criteria preferred by the individuals within the scope of the relevant subject is determined in accordance with the scale in Table 3.1 through a questionnaire or interview. Here, pairwise comparisons are made between the criteria and, if any, sub-criteria. The weights of the criteria (w) are obtained as a result of pairwise comparisons. Since the decision to be taken with the AHP is completely dependent on the comparisons of the people, the people whose opinions are sought should have expert or sufficient knowledge about the subject to be decided for the results to be consistent. Based on these judgments, a comparison matrix is created in AHP. This matrix is created by converting judgments into numerical values (Saaty, 2000).

The comparison matrix between criteria is a square matrix of size nxn. The diagonal elements of this matrix are always 1 and we only need to fill up the upper triangular matrix. In a decision process with n criteria, $\frac{n(n-1)}{2}$ comparisons are made (Saaty, 1988).

Sometimes, absolute scales, which are expressed in values obtained by measurements such as distance and weight, are also used when creating a comparison matrix. In cases where absolute scales are used, the comparison matrix is created directly with the measurement values. Significance ratings (preferences) based on information obtained by relative or absolute measurements are converted into a matrix. When the importance level of the i^th^ criterion and the j^th^ criterion is indicated by a_{ij}, the comparison matrix is generally written as follows (Vargas, 1990):

$$A = \begin{bmatrix} a_{11} & \cdots & a_{1j} & \cdots & a_{1n} \\ \vdots & & \vdots & & \vdots \\ a_{i1} & \cdots & a_{ij} & \cdots & a_{in} \\ \vdots & & \vdots & & \vdots \\ a_{n1} & \cdots & a_{nj} & \cdots & a_{nn} \end{bmatrix} \tag{3.1}$$

A matrix is created by making pairwise comparisons of different criteria. The $a_{ij} = \frac{w_i}{w_j}$ term in the matrix expresses how important criterion i is to criterion j to achieve the goal.

The general form of the weight matrix is given below:

$$W = \begin{bmatrix} w_1/w_1 & \cdots & w_1/w_j & \cdots & w_1/w_n \\ \vdots & & \vdots & & \vdots \\ w_i/w_1 & \cdots & w_i/w_j & \cdots & w_i/w_n \\ \vdots & & \vdots & & \vdots \\ w_n/w_1 & \cdots & w_n/w_j & \cdots & w_n/w_n \end{bmatrix} \tag{3.2}$$

If a_{ij} expresses the importance of the i^{th} feature relative to the j^{th} feature, a_{ji} also expresses the importance of the j^{th} feature relative to the i^{th} feature. This value is calculated by equation (3.3) if the a_{ij} value is obtained, and this equality is called positive reciprocal.

$$a_{ji} = \frac{1}{a_{ij}} \qquad a_{ij} \neq 0 \quad i, j = 1,2, \dots, n \tag{3.3}$$

Since the fundamental scale (1-9 points) is used when making pairwise comparisons in AHP, comparisons matrix elements are always positive and square matrix.

$$a_{ij} > 0 \qquad i, j = 1,2, \dots, n \tag{3.4}$$

The diagonal elements of the comparison matrix are 1. Since the criteria are compared with themselves on the diagonal of the matrix, their relative values (priorities) become 1.

$$a_{ii} = \frac{w_i}{w_i} = 1 \tag{3.5}$$

3.1.2.6 Syntheses

Each column of the comparison matrix is summed. The normalized matrix is calculated by dividing the elements of each column in the comparison matrix by the sum of their column.

$$a'_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}} \qquad i, j = 1,2, \dots, n \tag{3.6}$$

The priority vector (normalized principal Eigenvector) is calculated by averaging each row of the normalized matrix.

$$w_i = \left(\frac{1}{n}\right) \sum_{i=1}^{ni} a'_{ij} \qquad i, j = 1,2, \dots, n \tag{3.7}$$

A priority matrix is formed by multiplying the priority vector with the comparison matrix.

A new matrix is obtained by dividing each element of the priority matrix into the priority vector elements. The elements of this matrix are averaged and the Principal Eigenvalue (largest Eigenvalue) (λ_{max}) is calculated.

The following formula is used to calculate the consistency index (CI)

$$CI = \frac{(\lambda_{\max} - n)}{(n-1)} \quad (3.8)$$

The following formula is used to calculate the consistency ratio (CR).

$$CR = \frac{CI}{RI} \quad (3.9)$$

RI represents the random consistency index and is used in transactions by selecting the appropriate value from the values given in Table 3.2.

Table 3.2 : Average random consistency index (RI) (Tzeng and Huang, 2011).

Number of elements	3	4	5	6	7	8	9	10	11	12	13
RI	0,52	0,89	1,11	1,25	1,35	1,40	1,45	1,49	1,51	1,54	1,56

- Generally, the matrix is considered consistent if the CR is 10% or less (Wind and Saaty, 1980).
- It is also said that the comparison matrix is consistent if λ_{max} = n (Shrestha et al, 2004).

In case this acceptance is not realized, inconsistencies regarding the judgments or decisions made should be minimized. Pairwise comparisons are checked before making any structural changes to the established hierarchical sequence. Thus, the inconsistency index of the problem can be reduced without changing the model by reviewing the priorities and making readjustments (Akad and Gedizoğlu, 2007)

3.1.3 Group decision making with AHP

In the AHP technique, instead of resorting to the judgment of a single person, the judgment of a group of experts on a subject is generally applied. Information about each participant's judgment is obtained and combined mathematically. The mathematical combination of personal judgments is accomplished by calculating the geometric mean of the elements of comparison matrices (Forman and Kirti, 1998).

The CR of the created group matrix is expected to be below 10%. In addition, each participant's individual survey evaluations should be consistent. In other words, the CR should be calculated separately as a result of each expert's evaluation. Inconsistent questionnaires should be made by the expert who answered the questionnaire or removed from the analysis, or the most inconsistent answers should be corrected and the CR should be reduced below 10% (Forman and Kirti, 1998).

In the AHP, if the expertise levels or types of the participants are different, the judgments they make can be weighted and then the geometric mean can be calculated (Saaty, 2008a). For example, the academy can be weighted as 0,4, public sector as 0,3, private sector as 0,2, NGOs as 0,1 depending on the type of problem in a decision.

3.2 GIS and Multiple-Criteria Decision Making

In the early 1980s, the software system called Geographic Information System (GIS) was developed commercially. GIS, a new information processing technology, has provided many advantages, such as automating, managing, and analyzing spatial data (Jankowski, 1995). The two aspects of GIS definitions that focus the most are technology and problem-solving. According to the technological approach, GIS is defined as *"a set of tools for the input, storage and retrieval, manipulation and analysis, and output of spatial data"* (Marble, 1984). GIS plays an important role in a comprehensive decision-making process according to the problem-solving approach. The functionality of GIS could be clarified with its three features: the feature of storing and accessing data and information like a special purpose digital database (i), the feature of integrating geographical technologies and decision-making techniques (ii), and the feature of providing support for making decisions (iii). GIS should be viewed as a software, analysis, and decision-making system (Malczewski, 1999).

Spatial multiple-criteria decision problem includes geographically defined alternatives and evaluation criteria (Jankowski, 1995). In GIS terminology, alternatives consist of points, lines, areas, and criterion values. Conventional MCDM techniques assume that the entire area is spatially homogeneous, but in some analyses, the decision depends on the area's functions. In spatial MCDM, analysis is done by combining geographical data and decision makers' preferences. Using GIS and MCDM techniques together while solving spatial decision problems will not only provide efficiency to the decision-maker but also support each step of decision-making (Malczewski, 1999).

Structured and unstructured decision problem (Simon, 1960) forms the basis of a decision support system (DSS). In a structured decision problem, the decision-maker has all the elements of the subject to be decided. Structured decision problems could even be solved with the help of a computer, without the need for a decision-maker, since all such elements exist. In the unstructured decision problem, the decision-maker does not have the elements of the subject to be decided. There is a structure that changes and cannot be defined in each repetition. In this case, the solution of the problem depends on the decision-maker's experiences. Most of the time in real life, spatial decision problems are found somewhere between these two extreme examples and are defined as semistructured. These three decision problem structures are shown in Figure 3.3. The semi-structured frame of spatial decision problems is one of the areas where the DSS concept is applied the most. These problems are solved by the decision-maker with computer support. In addition, spatial DSS can be multicriteria. In this case, multicriteria DSS is created by utilizing the integration of GIS capabilities and MCDM techniques (Malczewski, 1999).

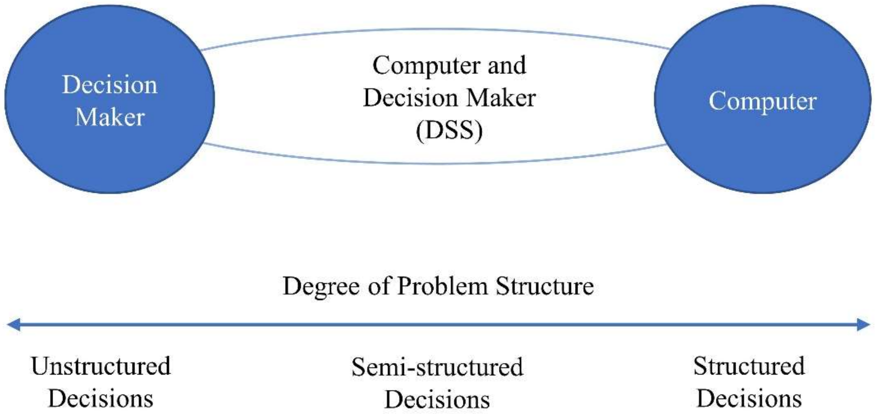


Figure 3.3 : Degree of decision problem structure (Malczewski, 1999).

4. ANALYSIS FRAMEWORK

In this section, information will be given about Kadıköy, which is selected as the case area. For charging stations to be located in public areas, a relationship between electric bicycles and urban functions and infrastructure elements is established. An analytical method is adopted by determining the criteria that will affect the location selection. Within the scope of the study, the AHP, which has the advantage of qualitative and quantitative evaluation, which is one of the MCDM methods, is used. It is aimed to determine the weights of the criteria by AHP and determine the most suitable locations by GIS.

4.1 General Overview to Case Area

As seen in Figure 4.1, Kadıköy, located on the Anatolian side of Istanbul, is east of the area where the Bosphorus opens to Marmara. It is surrounded by the district of Maltepe in the east, the Bosphorus and the Marmara Sea in the west, Üsküdar and Ataşehir districts in the north, and the Marmara Sea in the south. Kadıköy, which has an area of 25,20 km^2 (Kadıköy Municipality, 2022), has a population of 481 983 (TÜİK, 2022).

As seen in Figure 4.2, Kadıköy district consists of 21 neighborhoods. These are Caferağa, Osmanağa, Rasimpaşa, Koşuyolu, Acıbadem, Hasanpaşa, Bostancı, Caddebostan, Dumlupınar, Eğitim, Erenköy, Fenerbahçe, Feneryolu, Fikirtepe Göztepe, Kozyatağı, Merdivenköy, Sahrayıcedit, Suadiye, Zühtüpaşa ve Ondokuzmayıs neighborhoods.

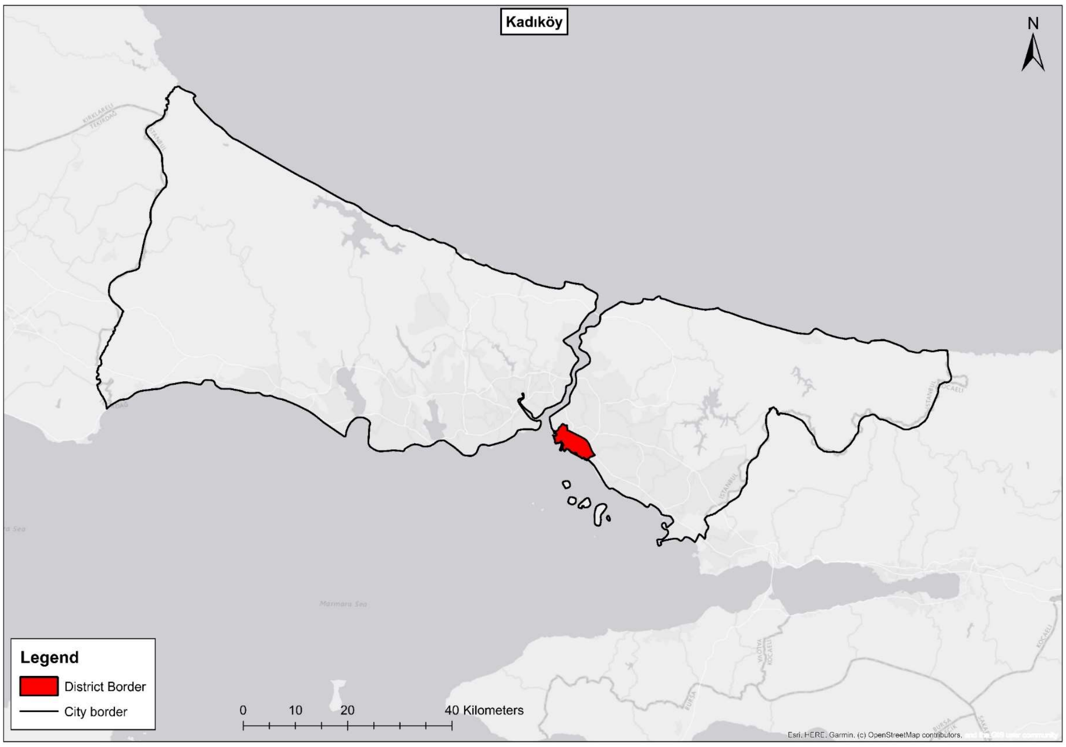


Figure 4.1 : Location of Kadıköy in Istanbul.

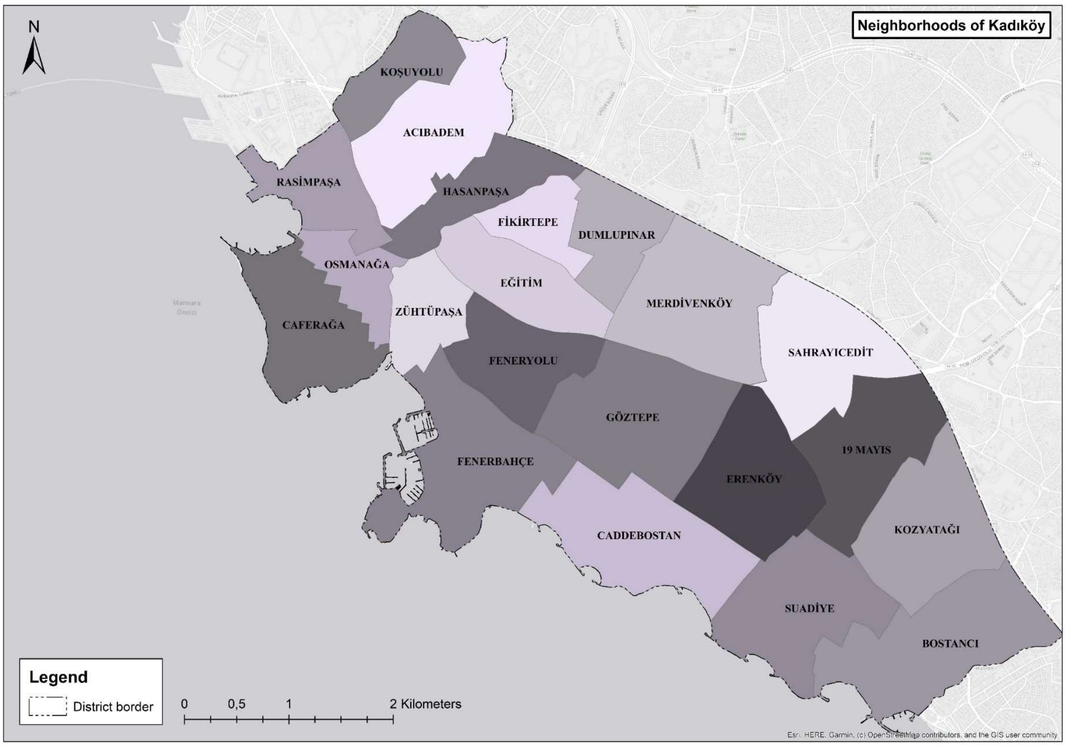


Figure 4.2 : Neighborhoods of Kadıköy.

Kadıköy was estabilished on six hills. These hills are Göztepe, Fikirtepe, Acıbadem, Altıyol, Cevizlik (Küçük Moda), Koşuyolu from east to west (Kadıköy Municipality, 2022). While the east-west axis throughout the district has a generally flat topography, the slope direction in Kadıköy, which can be considered as flat compared to other districts, is generally on the north-south axis, as seen in Figure 4.3.

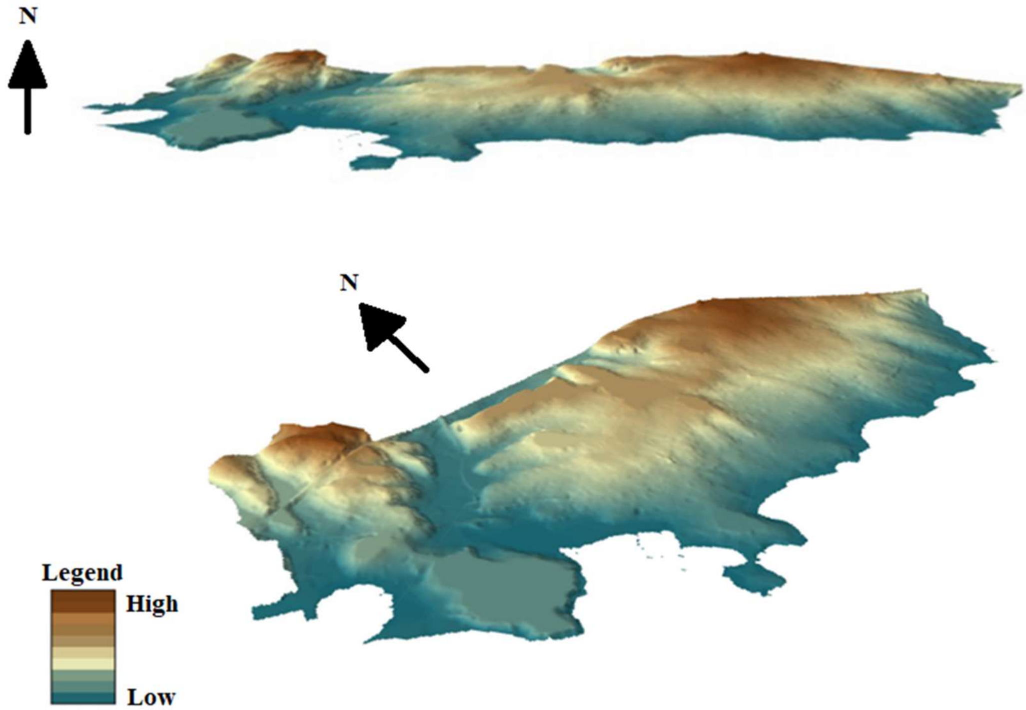


Figure 4.3 : Topographic map of Kadıköy (Kadıköy Municipality, 2019).

Kadıköy District, which is the gate of the Bosphorus on the Anatolian Side, has an important position in country and urban transportation. It is a transfer center connecting the Anatolian Side to the European Side with its closeness to the Bosphorus Bridge, the presence of rail systems and especially its efficiency in sea transportation. As seen in Figure 4.4, transportation within the district is provided by highway, railway, and seaway.

The main transportation arteries connecting the important centers on the Anatolian Side to the city and the districts in the town are located in Kadıköy. The district's most important road transport links are Beach Road, Bağdat Street, Minibus Road, and D-100 Highway. The most important of these is the D-100 Highway, also known as E-5. This highway intersects with the O-2 Highway to Fatih Sultan Mehmet Bridge in

Kozyatağı District and the O-1 Highway to the Bosphorus Bridge at Uzunçayır. The important roads in the district are shown in Figure 4.4.

One of the stations of the railway line connecting various centers of Anatolia to Istanbul is Söğütlüçeşme Station, located in Kadıköy District. Located in the south of Kadıköy, this line (Marmaray) is also important in terms of suburban transportation from Gebze on the Anatolian side and Halkalı on the European side of the city. Kadıköy-Kaynarca Metro (M4 line) passes along the D-100 Highway from the north of the district. Kadıköy-Moda, Kadıköy-Fenerbahçe and Kadıköy-Bostancı tram lines served between 1934-1966. In 2003, Kadıköy-Moda line started to serve again under the name of nostalgic tram. In addition, with the opening of Göztepe-Ümraniye Metro (M12 line), Bostancı Dudullu Metro (M8 line), which are under construction, the rail system connection of the district in the north-south direction will be strengthened. The rail system routes and stations in the district are shown in Figure 4.4.

One of the important public transportation units of Istanbul, which connects the Anatolian Side and the European Side, is the BRT, which has a route length of 52 km. The first stop of BRT on the Anatolian side is located in Kadıköy District, which is shown in Figure 4.4. At the same time, the central stops of rubber-tired public transport modes such as buses and minibusses are also located in Kadıköy. For this reason, it is possible to reach almost every part of the Anatolian Side from the district with rubber-tired public transportation modes. The bus routes and stops in the district are shown in Figure 4.5.

When it comes to transportation in Kadıköy, the first thing that comes to mind is sea transportation. Ferry ports in Kadıköy are in Caferağa and Bostancı neighborhoods. It is possible to access many urban and extra-urban destinations from these ports. In addition, there are regular trips to various coastal districts of Istanbul from the sea bus ports in Kadıköy and Bostancı. Kalamış Bay also has a large marina (Kadıköy Municipality, 2019). The ports in the district are shown in Figure 4.4.

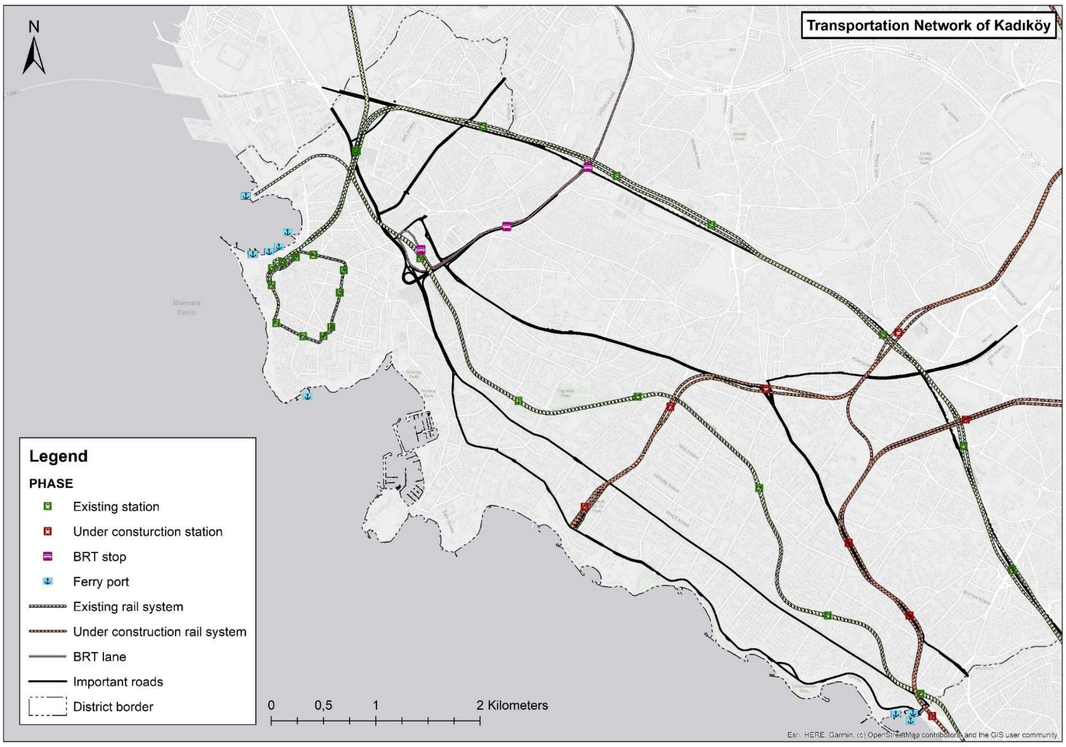


Figure 4.4 : Transportation network of Kadıköy.

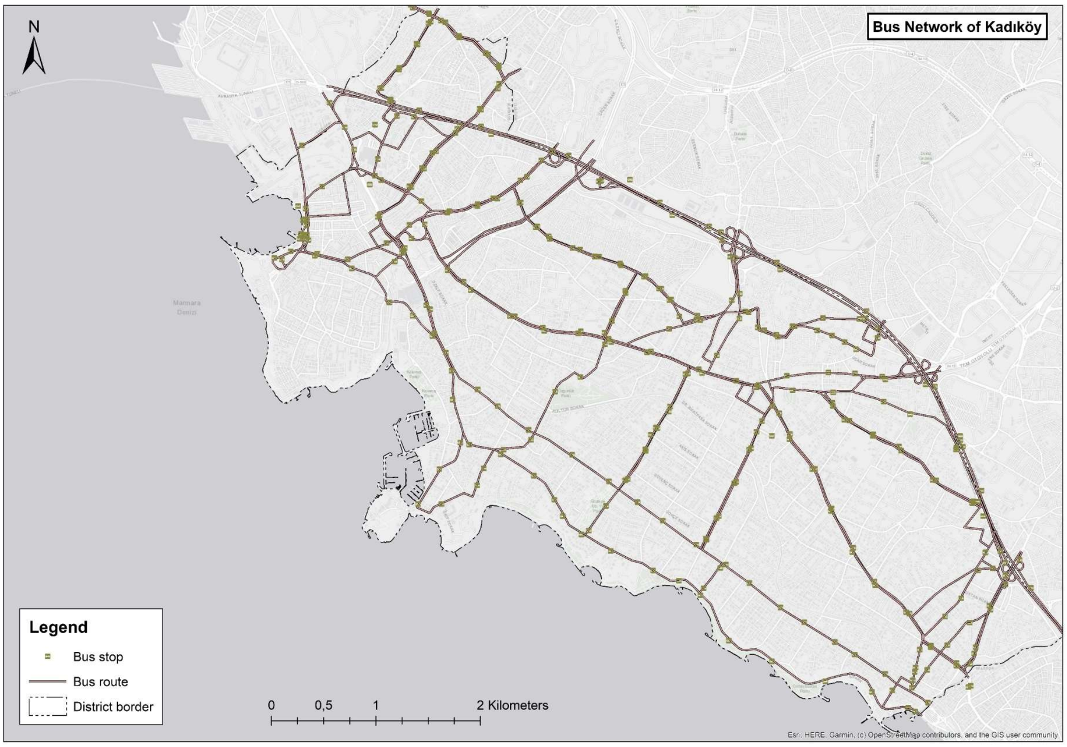


Figure 4.5 : Bus network of Kadıköy.

When the bicycle usage values are examined on the basis of districts of Istanbul, it has been revealed that Kadıköy is the most frequently used route (EMBARQ Turkey, 2015). Kadıköy is the 6th district with the longest bicycle road and the 3rd district with the longest protected bicycle road. It is the 4th district according to the bicycle road/highway ratio and the 2nd district according to the protected bicycle road/ highway ratio. When the bicycle transportation infrastructure of Kadıköy is examined, it is seen that all of the existing bicycle roads are protected. As seen in Figure 4.6, 23,11 km of it is existing protected bicycle road and 8,80 km of it is bicycle road in project phase. Bicycle roads are mostly located on the coastline and provide access to the inner parts of the district in a few sections. Although its relationship with other sustainable transportation modes such as the rail system and sea transportation is not very strong, this relationship is relatively higher compared to other districts.

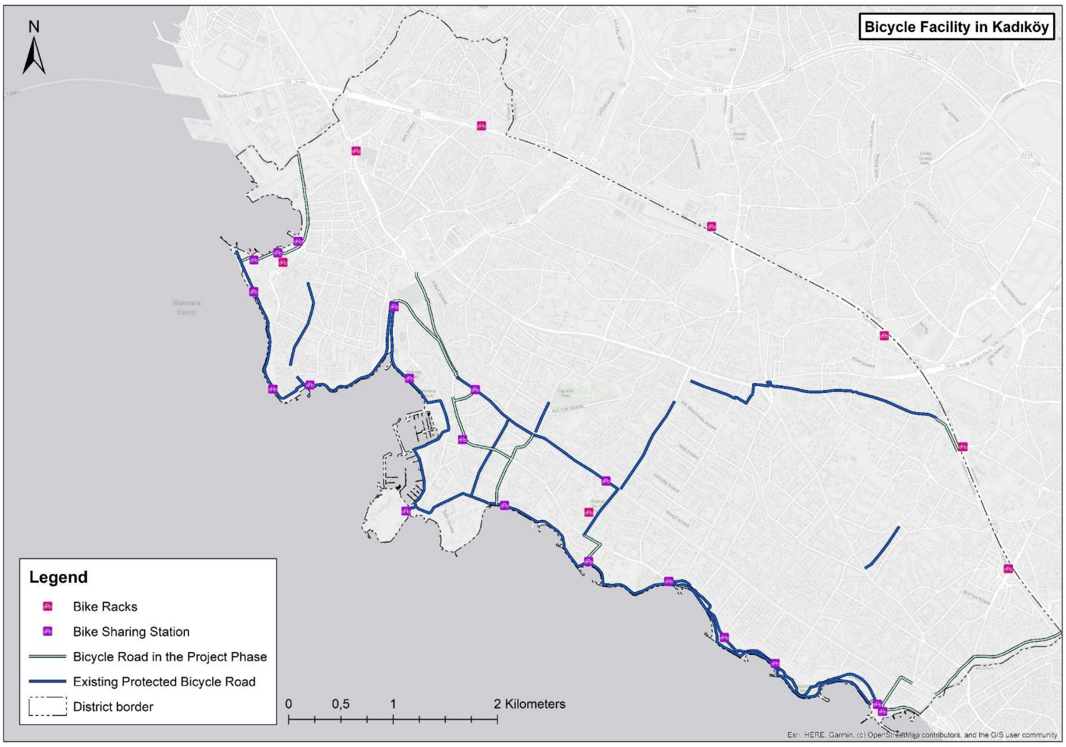
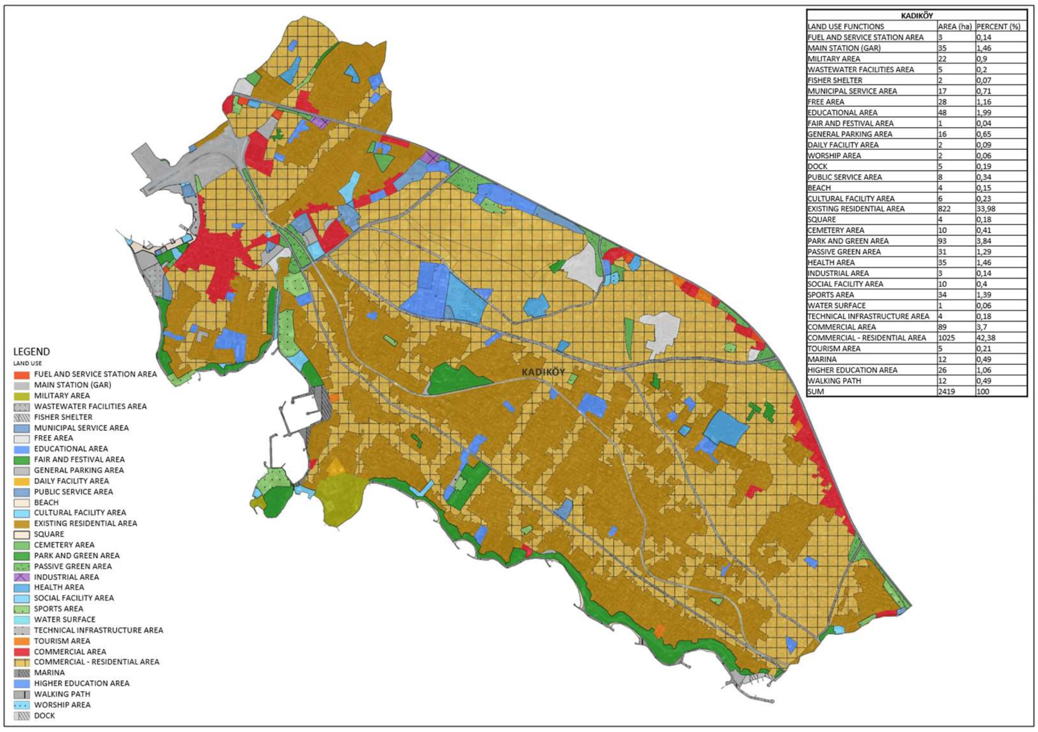


Figure 4.6 : Bicycle facility in Kadıköy.

When the BSS in Kadıköy is examined, it is seen that there are bicycle stations with a total capacity of 300 bicycles in 19 locations. The stations belonging to the BSS are located in the coastal area serving recreational purposes and their relations with the public transportation units are pretty weak. 8 bicycle racks, each of which has a capacity of 5 bicycles, are mostly located in the metro stations. In addition, there are bicycle racks in the district that do not have location records made by different public institutions. These bicycle racks are idle due to lack of maintenance, problems in site selection, unsuitable designs, security concerns, etc.

The land use map of Kadıköy district is shown in Figure 4.7. When the land use is examined, 42.38% of it has mixed-use function as a commercial-residential area, and 33.98% of its existing residential area. Although commercial functions are centered in Rasimpaşa, Caferağa and Osmanağa neighborhoods, commercial functions are seen in the northeast and northwest areas of the district. Compared to other districts, it is the district with the highest number of educational facilities with its primary and secondary schools, university campuses, and education centers. When other social facilities are compared, it is the 2nd district with the highest number of health institutions and the 6th district with the highest number of cultural facilities (IMM, 2019b). Fenerbahçe Park, Göztepe Park, Özgürlük Park, and the green areas along the coast are the most important active green areas of Kadıköy. It has a long coastline of approximately 21 km from Haydarpaşa to Bostancı in the northwest-southeast direction (Kadıköy Municipality, 2022). The social facilities and green areas of Kadıköy have also made the district a social attraction center.



KADIKÖY		
LAND USE FUNCTIONS	AREA (ha)	PERCENT (%)
FUEL AND SERVICE STATION AREA	3	0,14
MAIN STATION (GAR)	35	1,46
MILITARY AREA	22	0,9
WASTEWATER FACILITIES AREA	5	0,2
FISHER SHELTER	2	0,07
MUNICIPAL SERVICE AREA	17	0,71
FREE AREA	28	1,16
EDUCATIONAL AREA	48	1,99
FAIR AND FESTIVAL AREA	1	0,04
GENERAL PARKING AREA	16	0,65
DAILY FACILITY AREA	2	0,09
WORSHIP AREA	2	0,06
DOCK	5	0,19
PUBLIC SERVICE AREA	8	0,34
BEACH	4	0,15
CULTURAL FACILITY AREA	6	0,23
EXISTING RESIDENTIAL AREA	822	33,98
SQUARE	4	0,18
CEMETERY AREA	10	0,41
PARK AND GREEN AREA	93	3,84
PASSIVE GREEN AREA	31	1,29
HEALTH AREA	35	1,46
INDUSTRIAL AREA	3	0,14
SOCIAL FACILITY AREA	10	0,4
SPORTS AREA	34	1,39
WATER SURFACE	1	0,06
TECHNICAL INFRASTRUCTURE AREA	4	0,18
COMMERCIAL AREA	89	3,7
COMMERCIAL - RESIDENTIAL AREA	1025	42,38
TOURISM AREA	5	0,21
MARINA	12	0,49
HIGHER EDUCATION AREA	26	1,06
WALKING PATH	12	0,49
SUM	2419	100

Figure 4.7 : Land use map of Kadıköy (IMM, 2019b).

4.2 Analysis Set-up

The criteria affecting the EBCS locations and the model developed for decision-making are presented in this chapter. Locations for EBCS are determined in Kadıköy, which is selected as the case area.

4.2.1 Methodology

Within the scope of the study, it is aimed to provide a model that can be used in the location selection of e-bike charging stations (EBCS) and to develop a method for determining the location selection points. In this context, a six-stage process was followed.

In the first stage, the condition of the EBCS in bicycle transportation policies and action plans, the relationship between e-bikes-charging and range, the relationship between e-bikes-charging and time, determination of EVCS location studies, determination of BSS station location studies, determination of bicycle parking facilities location studies, walking distances to urban functions, and local regulations are examined. The results of the literature research enabled the determination of the criteria affecting the EBCS location selection.

In the second stage, considering the literature studies, the criteria and sub-criteria that are effective in the location of EBCS, which is a bicycle infrastructure, were determined and a hierarchical structure was established.

In the third stage, the importance of the criteria and sub-criteria was determined with an expert questionnaire and priority matrix was created. The weights of the criteria were determined by AHP, a MCDM method. The model to be used in the EBCS location selection was created.

In the fourth stage, the data of the criteria were converted to a standard scale with linear normalization in order to perform arithmetic operations.

In the fifth stage, Kadıköy District is divided into 1x1 km grids. The scores of the grids were calculated with the formula created for the EBCS location selection. For locating EBCS, the priority order of the grids has been determined and a priority map has been created with GIS.

In the sixth stage, the 1x1 km gird with the highest score from the grids was chosen as the micro-scale study area. The public spaces on the grid were identified and mapped. For EBCS, locations that will serve the most priority functions in these areas have been examined. The service distance is determined as 100 m. The most suitable location for EBCS has been determined.

4.2.2 Determining the criteria and sub-criteria and establishing the hierarchical structure

The condition of the EBCS in bicycle transportation policies and action plans, the relationship between e-bikes-charging and range, the relationship between e-bikes-charging and time, determination of EVCS location studies, determination of BSS station location studies, determination of bicycle parking facilities location studies, walking distances to urban functions, and local regulations are examined. In these studies, mostly PoIs such as commercial facilities, sports facilities, educational facilities, public facilities, health facilities, parks, etc., public transportation integration, parking lots, bicycle facilities, pedestrianized areas, slope, demographics, land cost, distance criteria were used.

Urban functions at the location of the EBCS gain importance, as it is expected that the driver will prefer to charge his/her bike at the destination point or attractive stop due to the long charging time. In addition, the number of e-bikes is not many in Istanbul in the current situation. The charging station to be implemented means the policy of making the urban function an attractive point for e-bike access in the future. For this reason, within the study's scope, it aims to establish a relationship between the charging station and urban facilities.

The priorities were determined according to the literature as follows.

- According to their characteristics, PoIs are the criteria that create a potential demand for bicycle transportation.
- Integration with other modes of transport should be one of the criteria when carrying out bicycle infrastructure work.
- Bicycle roads and bikeable streets are essential criteria in bicycle infrastructure works.

The main criteria and sub-criteria were formed by examining the relations of criteria with each other as a result of literature research. Demography is not included in the hierarchy, since demography is not a type of infrastructure. Land cost and distance were used as criteria on a micro-scale and were not included in the hierarchy. Since the average trip distance with e-bike is less than average range of fully charged e-bike, the distance is defined as the access distance to the urban functions.

As seen in Figure 4.8, a 5-level hierarchy is established in this study. EBCS location selection is determined as the ultimate goal in the 1st level. In the 2nd level, 3 main criteria are determined and these are PoI, transportation integration, and bikeability. 11 sub-criteria in the 3rd level, 23 sub-criteria in the 4th level, and 17 sub-criteria in the 5th level are determined.

4.2.3 Generating and mapping data

The data sets of the criteria and sub-criteria shown in Figure 4.8 are obtained from the currently available data in Google Earth Pro and Open Street Map, which are virtual GIS systems, from IMM, and the field studies carried out on site. Definition and sources of each critertia are indicated in the Table 4.8.

The pandemic started in Turkey on March 11, 2020, and various related measures (curfew, restrictions for specific age groups, interruption of education, etc.) were taken. For this reason, the data belonging to March 2019 before the restriction are preferred for the public transport boarding data sets.

Before the analysis, the data of the criteria are converted to a standard scale with linear normalization to perform arithmetic operations. Linear normalization is simply calculated with the following formula:

$$z_i = \frac{x_i - \min(x)}{\max(x) - \min(x)} \tag{4.10}$$

where $x=(x_1,...,x_n)$ and z_i is now your ith normalized data.

While setting up the model, Kadıköy is divided into 1x1 km grids, data are processed in the Geographical Information System (GIS) environment and mapping are created with Esri ArcGIS as seen in Figirue 4.9.

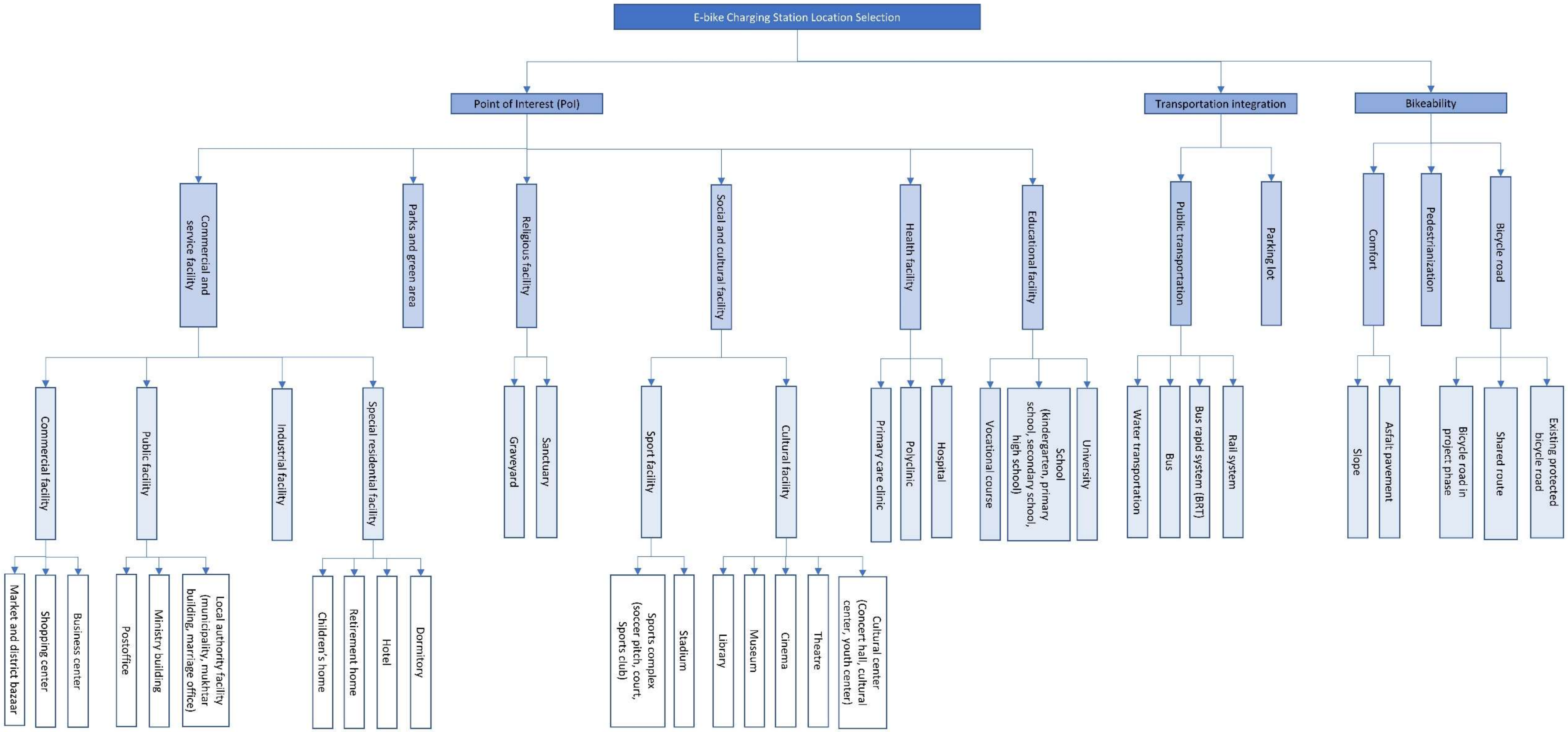


Figure 4.8 : Hierarchy tree.

Table 4.1 : Defimition of each criteria

Main criteria	Sub-criteria	Sub-criteria	Sub-criteria	Data format	Data source
Point of interest (PoI)	Educational facility	University		Amount	Open Street Map, Google Earth Pro, Field Study
		School		Amount	Open Street Map, Google Earth Pro, Field Study
		Vocational course		Amount	Open Street Map, Google Earth Pro, Field Study
	Health facility	Hospital		Amount	Open Street Map, Google Earth Pro, Field Study
		Polyclinic		Amount	Open Street Map, Google Earth Pro, Field Study
		Primary care clinic		Amount	Open Street Map, Google Earth Pro, Field Study
	Social and cultural facility	Cultural facility	Cultural center	Amount	Open Street Map, Google Earth Pro, Field Study
			Theatre	Amount	Open Street Map, Google Earth Pro, Field Study
			Cinema	Amount	Open Street Map, Google Earth Pro, Field Study
			Museum	Amount	Open Street Map, Google Earth Pro, Field Study
			Library	Amount	Open Street Map, Google Earth Pro, Field Study
		Sport facility	Stadium	Amount	Open Street Map, Google Earth Pro, Field Study
			Sport complex	Amount	Open Street Map, Google Earth Pro, Field Study
	Religious facility	Sanctuary		Amount	Open Street Map, Google Earth Pro, Field Study
		Graveyard		Amount	Open Street Map, Google Earth Pro, Field Study
	Parks and green area			Area	Open Street Map, Google Earth Pro, Field Study

Table 4.1 (continued) : Definition of each criteria.

Main criteria	Sub-criteria	Sub-criteria	Sub-criteria	Data format	Data source
Point of interest (PoI)	Commercial and service facility	Special residential facility	Children's home	Amount	Open Street Map, Google Earth Pro, Field Study
			Dormitory	Amount	Open Street Map, Google Earth Pro, Field Study
			Hotel	Amount	Open Street Map, Google Earth Pro, Field Study
			Retirement home	Amount	Open Street Map, Google Earth Pro, Field Study
		Industrial facility		Amount	Open Street Map, Google Earth Pro, Field Study
		Public facility	Local authority building	Amount	Open Street Map, Google Earth Pro, Field Study
			Ministry building	Amount	Open Street Map, Google Earth Pro, Field Study
			Post office	Amount	Open Street Map, Google Earth Pro, Field Study
		Commercial facility	Business center	Amount	Open Street Map, Google Earth Pro, Field Study
			Shopping center	Amount	Open Street Map, Google Earth Pro, Field Study
			Market and district bazaar	Amount	Open Street Map, Google Earth Pro, Field Study
Transportation integration	Parking lot			Capacity	Istanbul Metropolitan Municipality
	Public transportation	Rail system		Number of boarding	Istanbul Metropolitan Municipality
		BRT		Number of boarding	Istanbul Metropolitan Municipality
		Bus		Number of boarding	Istanbul Metropolitan Municipality
		Water transportation		Number of boarding	Istanbul Metropolitan Municipality
Bikeability	Bicycle road	Existing protected bicycle road		Length	Istanbul Metropolitan Municipality
		Shared route		Length	Istanbul Metropolitan Municipality
		Bicycle road in project phase		Length	Istanbul Metropolitan Municipality
	Pedestrianization			Length	Istanbul Metropolitan Municipality
	Comfort	Asphalt pavement		Length	Istanbul Metropolitan Municipality
		Slope		Length (up to 10%)	Istanbul Metropolitan Municipality

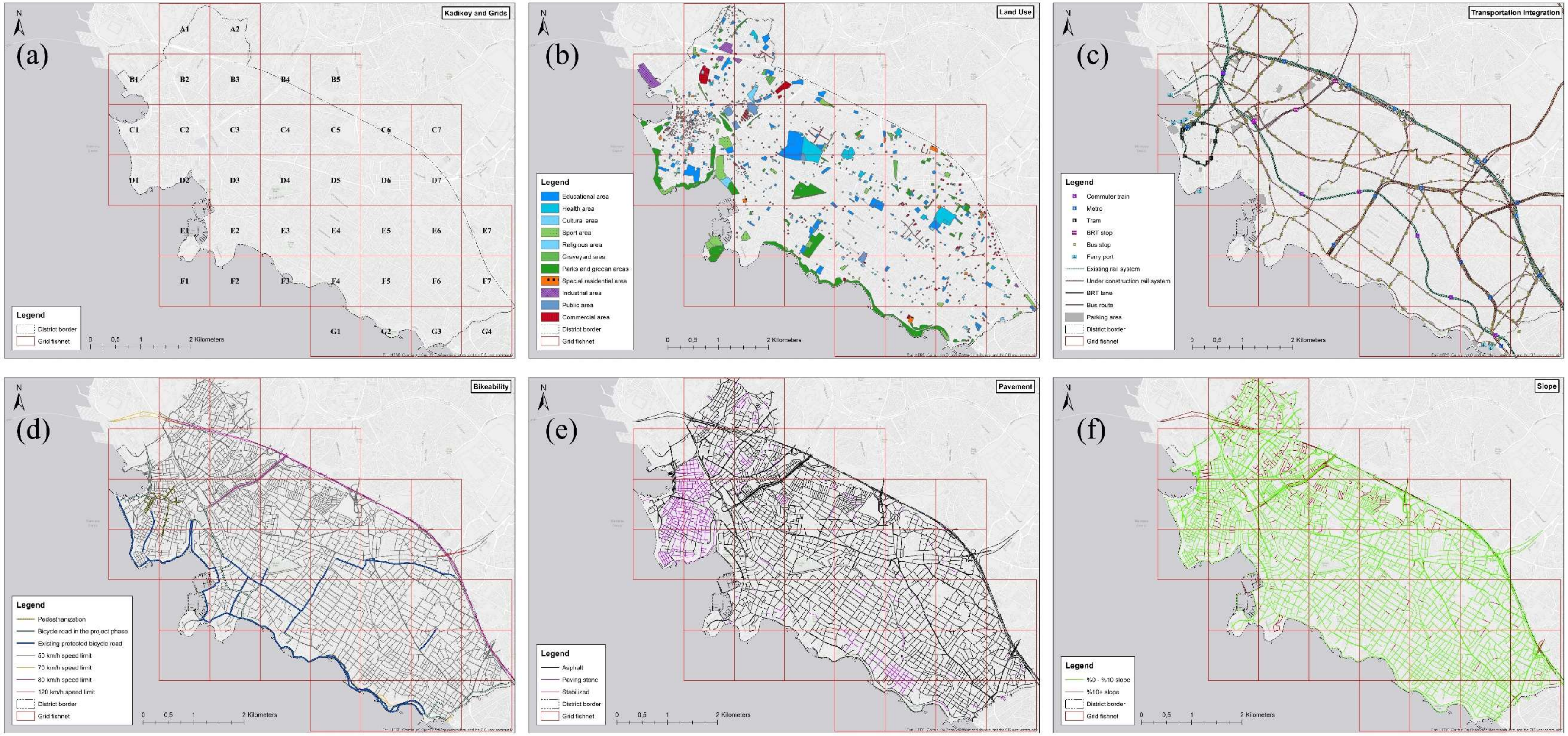


Figure 4.9 : (a) Grids in Kadıköy. (b) Land use of Kadıköy according to the determined criteria. (c) Parking lots, public transport routes, stops and stations in Kadıköy according to the determined criteria. (d) Bicycle lanes and pedestrianization roads of Kadıköy according to bikeability criterion. (e) Road pavement of Kadıköy according to bikeability criterion. (f) Road slope of Kadıköy according to bikeability criterion.

4.2.4 Survey application

Online and face-to-face surveys are conducted with experts in IMM, academicians in universities, members of bicycle NGOs, experts in companies, Ministry of Transport and Infrastructure, and Union of Municipalities of Marmara. 75 experts evaluate the main criteria and sub-criteria for the location selection of the EBCS through online and face-to-face surveys. Criteria and sub-criteria are compared in pairs. Saaty's scale, shown in Table 3.1 is used in this comparison. As the institutional distribution of the survey participants is seen in the Figure 4.10 (a), IMM has the highest ratio with 57,33%. The distribution of IMM participants according to their departments is seen in Figure 4.10 (b)

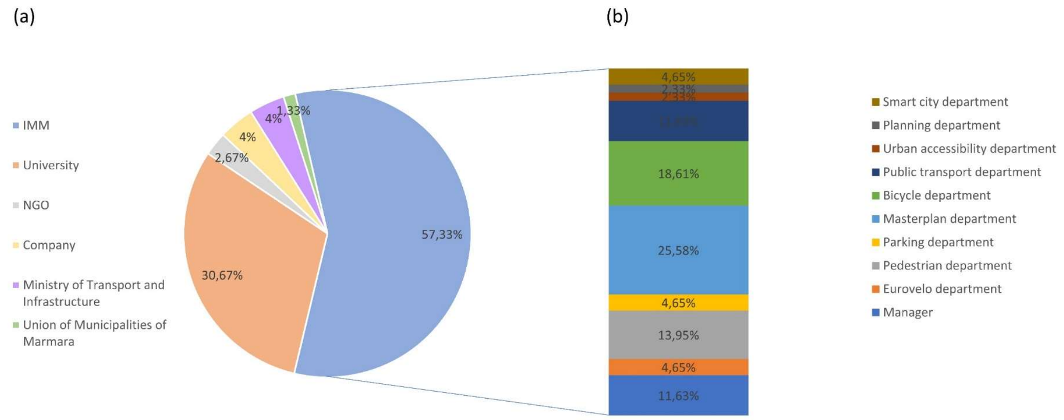


Figure 4.10 : (a) Distributions of experts who participated in the survey. (b) Distributions of experts who are working in IMM.

4.2.5 Calculations with AHP

By combining the individual judgments and priorities with the AHP, pairwise comparison matrices for the group are created and the weights of the criteria are calculated. As a result of the evaluation, the final weights are obtained by taking the geometric means of the weights in the pairwise comparision matricies created by 75 decision makers using the Saaty scale.

The CR values of the pairwise comparison matrix calculated according to the answers of both each expert and group decision. CR values of each matrix are less than 10%.

Table 4.2 : Weights of each criteria.

Main criteria	Local weight	Sub-criteria	Local weight	Sub-criteria	Local weight	Sub-criteria	Local weight	Global weight
Point of interest (PoI)	0,278	Educational facility	0,308	University	0,595			0,051
				School	0,290			0,025
				Vocational course	0,114			0,010
		Health facility	0,078	Hospital	0,384			0,008
				Polyclinic	0,276			0,006
				Primary care clinic	0,340			0,007
		Social and cultural facility	0,183	Cultural facility	0,425	Cultural center	0,26	0,006
						Theatre	0,17	0,004
						Cinema	0,17	0,004
						Museum	0,15	0,003
						Library	0,25	0,005
				Sport facility	0,575	Stadium	0,33	0,010
						Sport complex	0,67	0,020
		Religious facility	0,044	Sanctuary	0,737			0,009
				Graveyard	0,263			0,003
		Parks and green area	0,218					0,060
		Commercial and service facility	0,169	Special residential facility	0,208	Children's home	0,22	0,002
						Dormitory	0,51	0,005
						Hotel	0,18	0,002
						Retirement home	0,09	0,001
				Industrial facility	0,147			0,007
				Public facility	0,300	Local authority building	0,51	0,007
						Ministry building	0,23	0,003
						Post office	0,25	0,004
				Commercial facility	0,345	Business center	0,30	0,005
						Shopping center	0,38	0,006
						Market and district bazaar	0,32	0,005
Transpor-tation integration	0,422	Parking lot	0,254					0,107
		Public transportation	0,746	Rail system	0,497			0,157
				BRT	0,207			0,065
				Bus	0,121			0,038
				Water transportation	0,175			0,055
Bikeability	0,300	Bicycle road	0,644	Existing protected bicycle road	0,687			0,133
				Shared route	0,137			0,027
				Bicycle road in project phase	0,176			0,034
		Pedestrianization	0,157					0,047
		Comfort	0,199	Asphalt pavement	0,380			0,023
				Slope	0,620			0,037

Table 4.2 shows the local and global weights calculated for the criteria and sub-criteria. According to the results of AHP, the transportation integration criterion has the highest weight, with a weight of 0,422. This criterion is followed by the bikeability criterion with a weight of 0,300 and the criterion of PoI with a weight of 0,278. When the global weights are examined, the rail system sub-criterion has the highest weight with 0,157. This sub-criterion is followed by existing protected bicycle road with 0,133 weight, parking lot with 0,107 weight, BRT with 0,065 weight, parks and green area with 0,060 weight, water transportation with 0,055 weight, and university with 0,051 weight.

Table 4.3 : Identification of scores of each grids.

Name	Score	Name	Score
C2	0,504	C4	0,136
C1	0,467	E6	0,127
B2	0,318	F6	0,124
B3	0,290	F3	0,117
D3	0,279	E5	0,114
D1	0,274	E1	0,113
B4	0,268	A1	0,099
D2	0,253	F5	0,091
E2	0,248	E4	0,090
E3	0,244	A2	0,089
G3	0,219	E7	0,088
G2	0,214	G4	0,055
D4	0,193	B1	0,053
F4	0,182	G1	0,053
C3	0,177	C6	0,053
D7	0,165	C7	0,017
D6	0,158	F1	0,010
D5	0,157	B5	0,006
F7	0,148	F2	0,000
C5	0,142		

In Table 4.3, the score results of the grids are shown. C2 and C1 grids take place in the first two rows, and these grids are expected to be considered priority and other options in the order will follow them. EBCS to be implemented throughout the district will be able to be located systematically according to the scores calculated based on these criteria and sub-criteria.

A histogram is created to determine the frequency of grids' scores.

The Sturges rule for determining the number of classes (bins) (k) in a frequency distribution with total frequency N is

$$k = 1 + 3{,}22 * \log N \tag{4.11}$$

The data's total range (R) is calculated as follows by subtracting the smallest value n_{min} from the largest value n_{max}.

$$R = n_{max} - n_{min} \tag{4.3}$$

The width of classes (S) is calculated as follows

$$S = \frac{R}{k} \tag{4.4}$$

The histogram is created as a result of the operations as in Figure 4.11.

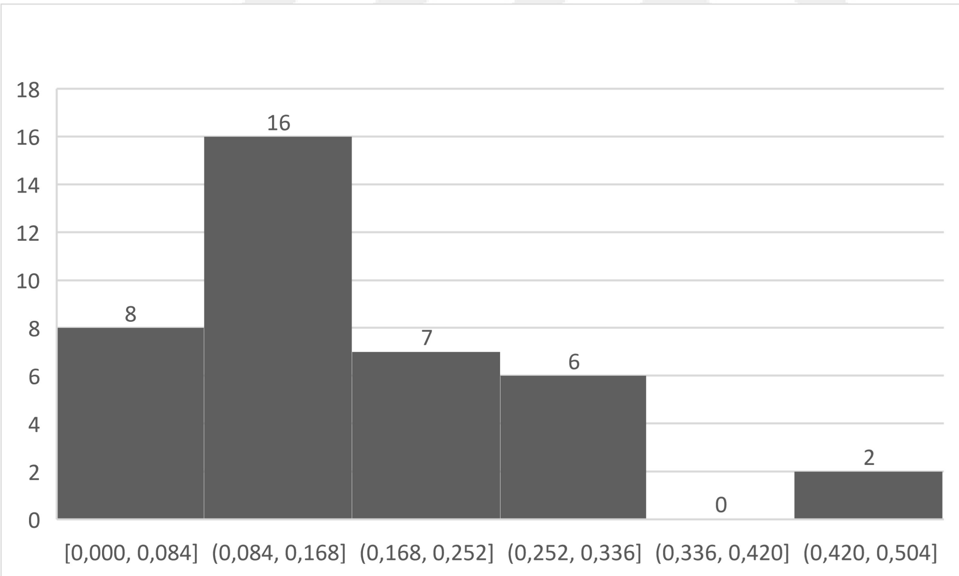


Figure 4.11 : Frequency of grids' scores.

The map in Figure 4.12 is created according to the created histogram.

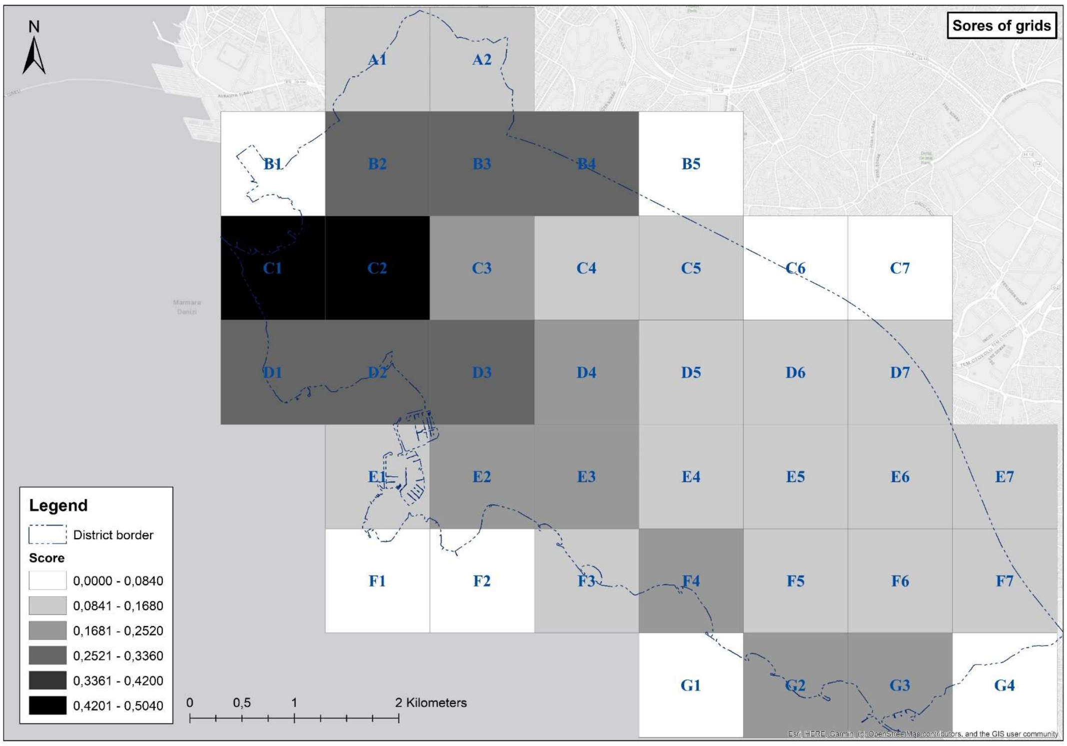


Figure 4.12 : Scores of grids.

4.3 Creation of Compliance Map

C2 grid with a score of 0,504 and C1 grid with a score of 0,467, which have the two highest scores, are analyzed and the most suitable locations in these grids are found for EBCS.

The C2 and C1 grids with the highest score are analyzed and mapped according to the criteria and sub-criteria in Figure 4.8, as seen in Figure 4.13, Figure 4.14, Figure 4.15, Figure 4.16, Figure 4.17, and Figure 4.18. C2 and C1 grids include all the functions in land use criteria except the industrial area. C2 grid does not include water transportation and C1 grid does not include BRT from the transportation integration. C2 grid does not have existing protected bicycle road from the bikeability.

In addition, while locating EBCS, public property lands within the grids are also included in the map to minimize the land cost and make implementation easier.

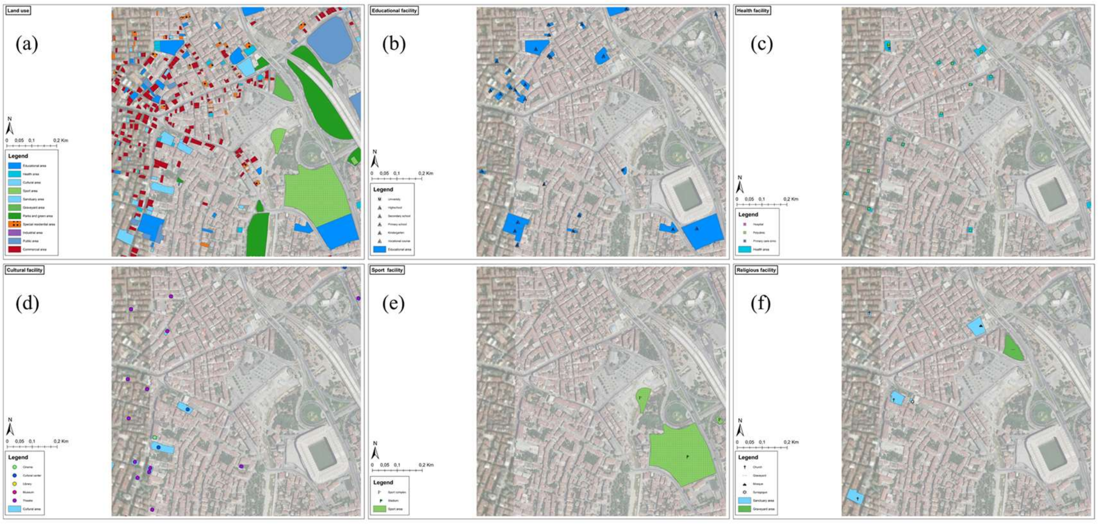


Figure 4.13 : (a) Land use of C2 grid. (b) Educational facility in C2 grid. (c) Health facility in C2 grid. (d) Cultural facility in C2 grid. (e) Sport facility in C2 grid. (f) Religious facility in C2 grid.

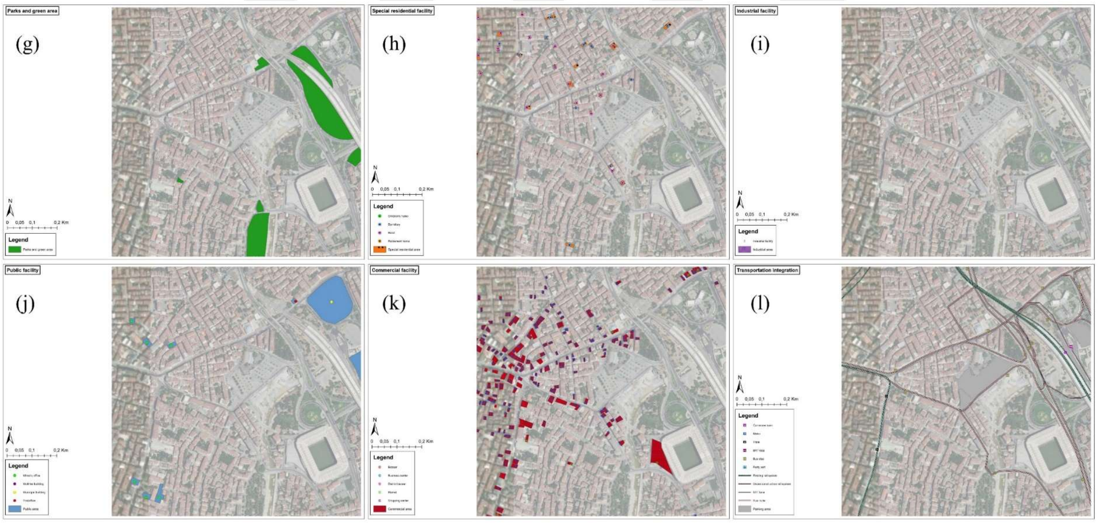


Figure 4.14 : (g) Parks and green areas in C2 grid. (h) Special residential facility in C2 grid. (i) Industrial facility in C2 grid. (j) Public facility in C2 grid. (k) Commercial facility in C2 grid. (l) Parking lots, public transport routes, stops and stations in C2 grid.

Figure 4.15 : (d) Bicycle roads and pedestrianization roads of C2 grid. (e) Road pavement of C2 grid. (f) Road slope of C2 grid.

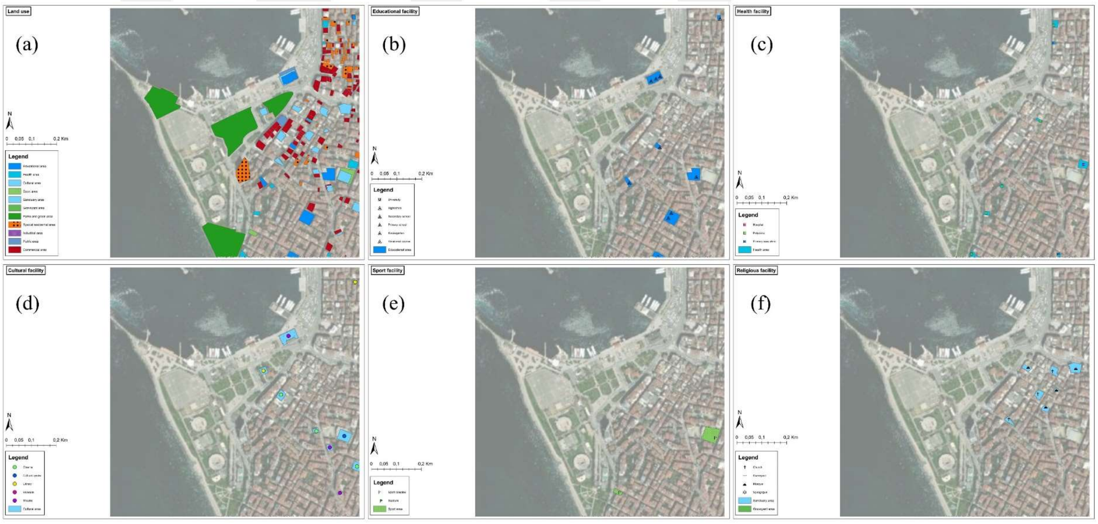


Figure 4.16 : (a) Land use of C1 grid. (b) Educational facility in C1 grid. (c) Health facility in C1 grid. (d) Cultural facility in C1 grid. (e) Sport facility in C1 grid. (f) Religious facility in C1 grid.

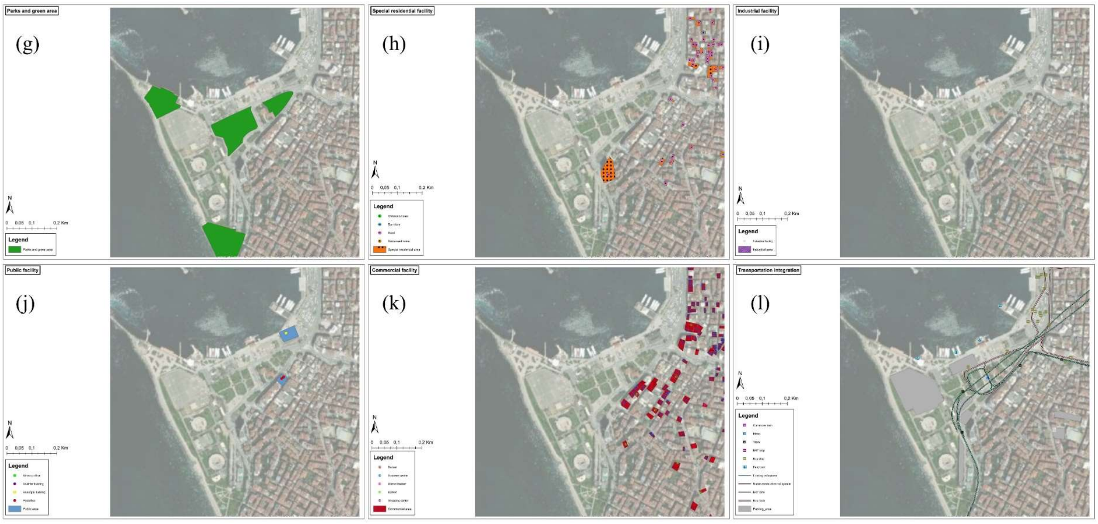


Figure 4.17 : (g) Parks and green areas in C1 grid. (h) Special residential facility in C1 grid. (i) Industrial facility in C1 grid. (j) Public facility in C1 grid. (k) Commercial facility in C1 grid. (l) Parking lots, public transport routes, stops and stations in C1 grid.

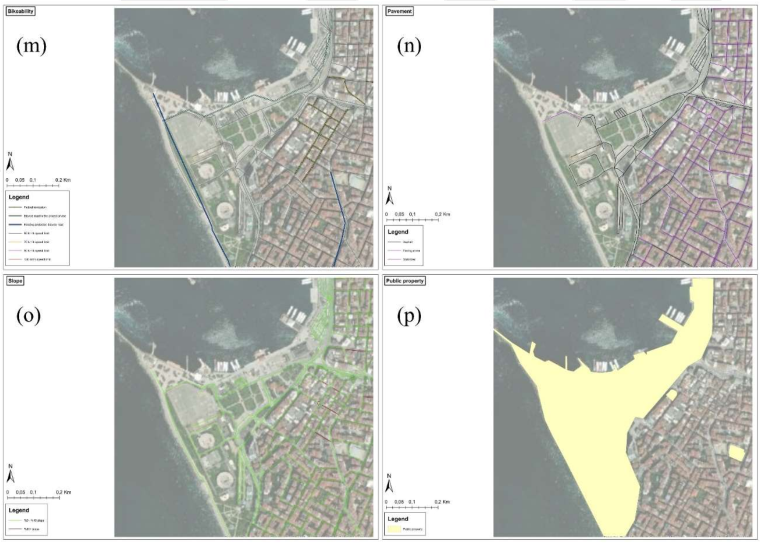


Figure 4.18 : (d) Bicycle roads and pedestrianization roads of C1 grid. (e) Road pavement of C1 grid. (f) Road slope of C1 grid.

4.4 Findings and Discussion

For the bicycle parking structures, the maximum walking distance was determined as 100 m in accordance with the literature. It has been specified that this distance may increase slightly as the functions and safety provided by the bicycle parking structure increase. It has also been stated that the maximum walking tolerance of a person to a bicycle is 300 m. The literature has not found a walking distance tolerance related to EBCS. Therefore, based on this information, the priority service area of EBCS is determined as the area within a 100 m radius like bicycle parking structures. In addition, EBCS is considered an attractive function for cyclists, and functions within 100-200 m are considered within the secondary service area, and functions within 200-300 m are considered within the tertiary service area. The upper limit is preserved as 300 m in accordance with the literature.

Among the main criteria, the transportation integration criterion has the highest weight. The criteria with the highest weights among the functions in the C2 grid are the rail system, parking lot, BRT, and parks and green area, respectively. For this reason, priority is given to the place where these functions are clustered in the C2 grid. The EBCS is located to primarily serve these functions within 100 m, as in Figure 4.19. The primary service area of the selected location also includes municipality and bus stops. In addition, the EBCS is located in the public property area. The proximity of the location to the rail system and BRT will also facilitate its connection to the electrical infrastructure.

The criteria with the highest weights among the functions in the C1 grid are the rail system, existing protected bicycle road, parking lot, parks and green area, and water transportation, respectively. For this reason, priority is given to the place where these functions are clustered in the C1 grid. The EBCS is located to primarily serve these functions within 100 m, as in Figure 4.20. The primary service area of the selected location also includes library and bus stops. In addition, the EBCS is located in the public property area. The proximity of the location to the library will also facilitate its connection to the electrical infrastructure.

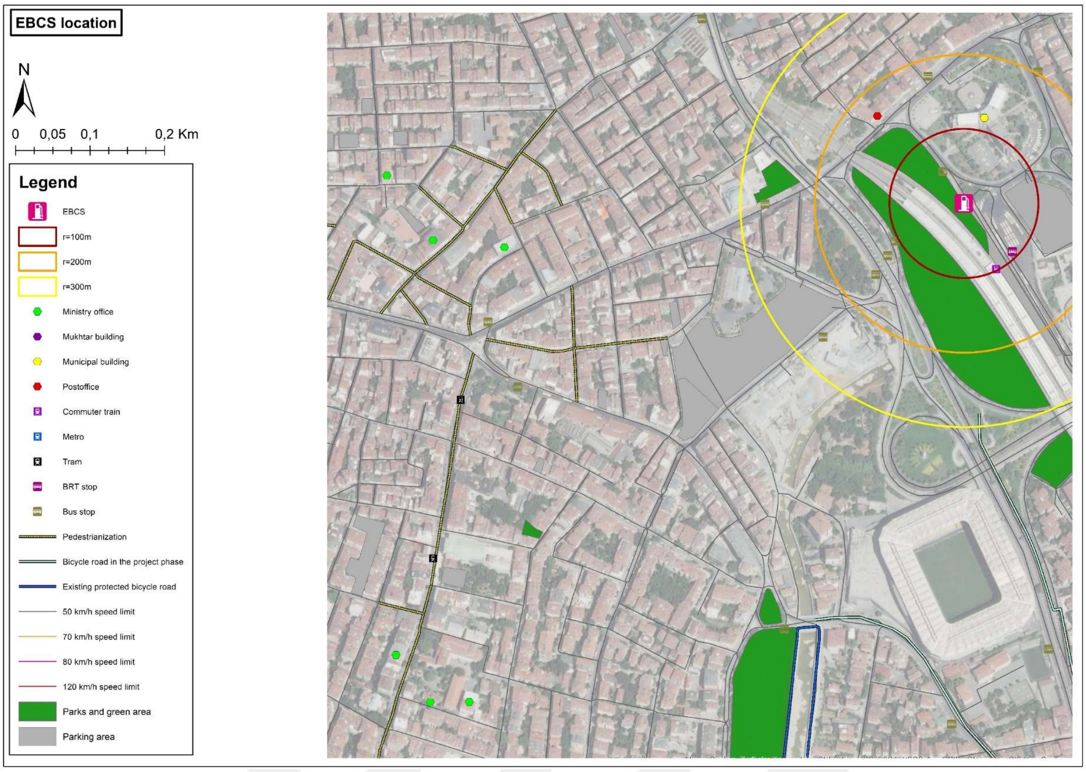


Figure 4.19 : Determination of EBCS location in C2 gird.

Figure 4.20 : Determination of EBCS location in C1 gird.

Within the scope of the study, the primary service area for EVCS was determined as the area within a 100 m radius. However, when the pedestrian access distances to urban facilities are examined, the distances vary according to their functions. For example, pedestrian access distances to educational facilities are determined as up to 500 m for kindergarten and primary school, up to 1000 m for secondary school, and up to 2500 m for high school. Walking distances to health facilities are determined as up to 500 m for primary care clinics and up to 1000 m for hospitals. Walking distances to social and cultural facilities are determined as up to 1000 m. Walking distances to religious facilities are determined as up to 400 m for mosques, churches, and synagogues and up to 150 m for masjids and chapels. Walking distances to green areas are defined as up to 500 m.(ÇŞB, 2014). The determined service distance remained below these limit values. Limit values that vary according to functions are valid for journeys that start and end on foot. Cycling is also door-to-door transportation, so drivers' walking tolerance will lower after leaving their bikes at the charging station. For this reason, it is thought that the type of bicycle parking facility in the area where the EBCS is located is more important than the urban function to be accessed in expanding the service area. For example, while the walking distance for parking racks serving short-term bicycle parking with a low-security level is 0-15 m, the walking distance for fully enclosed individual lockers serving long-term bicycle parking with a high-security level is 100 meters. Moreover, longer walking distances could be acceptable as the level of security increases and the possibility of more extended parking is provided (DCF, 2008; Austroads, 2017). In other words, designing EBCS and bicycle parking facilities together will increase the primary service area of both. However, since the tolerance for walking distance to a bicycle is determined as 300 m (NACTO, 2016; ITDP, 2018), it is not considered appropriate for EBCS to exceed the upper limit of this value. The e-bike/e-scooter charging stations within bicycle hubs and hangars project carried out in the UK (Falco, 2002) proves that a similar trend is embraced by the private sector and supported by the public sector.

While determining the criteria within the scope of the study, the residential area is not included in the criteria. EBCS investment is primarily aimed to be made in public areas. In this way, it aims to serve more people and encourage access to public spaces with e-bikes. The fact that mobility centers, docking stations, and charging infrastructure are designed to be used universally by more than one operator instead of proprietary solutions (ARUP, 2021) is also included in the literature, supporting this decision. However, allocating space for EBCS in the parking lots of residences and including EBCS in the parking regulations will provide the charging need for e-bikes and support the system to be more visible.

In order to reduce the investment cost within the scope of the study, it is prioritized to make the application primarily on public property areas. When examined on the scale of Turkey, the authority and responsibilities of roads are shared between the ministry of transport and infrastructure, the district municipality, and the city municipality. The authority and responsibility for urban roads mainly belong to the district and city municipalities. For this reason, the method followed in the parklet application, which is public seating platforms that convert curbside parking spaces into vibrant community spaces (NACTO, 2013) can also be applied for EBCS. The land cost can be avoided by reserving 1-2 vehicles from roadside parking lots for EBCS. Installing the system in roadside parking lots will constrain access to the electricity supply. Charging stations can be solar-powered or obtain energy from the urban electricity infrastructure (Beh et al, 2013; Beh et al, 2015; Biya and Sindhu, 2019; Hung and Lim, 2020). In this case, it is necessary to analyze the urban electricity infrastructure and decide on the type of charging station optimally.

In the AHP analysis, the second highest weight is the existing protected bicycle road. However, when the location determinations at the micro scale are examined, it is seen that the EBCS cannot be directly related to the bicycle roads in the C1 and C2 grids. Nevertheless, it is possible to establish a relationship with the rail system and parking lots with the highest weight. As a result of the analysis, it has emerged that EBCS, a bicycle infrastructure, should support these functions. However, the fact that bicycle roads do not have connections with these functions appears to lack application. When determining a location for bicycle parking structures, it is aimed that cyclists can reach the parking area with their bicycles. Road connection is provided with bicycle parking structures (DCF, 2008). With a similar approach, although EBCS cannot be associated with bicycle roads in C1 and C2 grids, its relation with vehicle roads is ensured. In addition, visibility is determined as an important criterion for ensuring the safety of bicycle parking facilities (DCF, 2008; TSE, 2013d; Austroads, 2016a; Austroads, 2016b; Austroads, 2017). EBCSs in C1 and C2 grids are located in visible areas due to the road connection and the density of pedestrian circulation.

5. CONCLUSION

In this study, the changes that urbanization and automobilization have undergone in the historical process are examined, and the emergence, definitions, and policies of sustainability, sustainable city, and sustainable transportation targets are examined on a global, local and urban scale. Bicycle transportation, one of the sustainable transportation modes, has been discussed in terms of policy and planning, and the features and needs of e-bikes are revealed. In the examinations, it is determined that one of these needs is EBCS, which must be located in public spaces.

Kadıköy is determined as the case area where the number of cyclists is higher than in other districts and one of the first districts to accept bicycles in the historical process. EBCS is discussed as a location determination problem. AHP, a decision support system, is used to determine EBCS locations in Kadıköy. AHP is one of the commonly used methods among MCDM methods.

First of all, the criteria that will affect the locating of the EBCS are determined by using the criteria that affect the locating of other bicycle infrastructures and EVCS. BSS and bicycle parking structures, among the bicycle infrastructures, are examined. At the same time, studies on walking distances to urban functions are also examined. Restrictions in national legislation are also a guide in the study. With AHP, the hierarchical structure of the problem is created, criteria and sub-criteria are determined. Since the average travel distance of e-bikes is smaller than the range of their batteries, range was not taken as a criterion within the scope of the study.

As a result of the analysis, it is seen that the criteria of the rail system, existing protected bicycle road, and parking lot are more important than the others.

As seen in Figure 4.12, within the scope of the model, when EBCS implementation is prioritized, it should be implemented in other grids according to their scores, starting from C2 and C1 grids.

When the ranking is examined, it is seen that the common feature of the C2 and C1 grids are the areas where the integration between transportation modes is easy and the number of trips is high, so there are many visitors from within and outside the district. Grids, which are at the bottom of the prioritization, are the areas where residential areas are denser.

C2 and C1 grids are re-evaluated according to the functions with high weights, and suitable locations for EBCS are proposed so that these functions will stay on the impact area. Common features of the proposed locations are that they are close to multiple public transport modes, parking lots, parks and green area. They are located on public property land and close to publicly operated structures to ease access to electrical systems.

Therefore, the priority service area of EBCS is determined as the area within a 100 m radius like bicycle parking structures. In addition, EBCS is considered an attractive function for cyclists, and functions within 100-200 m are considered within the secondary service area, and functions within 200-300 m are considered within the tertiary service area. The upper limit is preserved as 300 m in accordance with the BSS and bicycle parking structures studies.

The feature that distinguishes this study from the studies in the literature on bicycle infrastructure is that the issue of determining the charging station location for e-bikes has not been studied before. The study also revealed that the current perspective on bicycle transportation should be developed and urban and transportation policies should be updated.

Despite the large number of sub-criteria within the scope of AHP, the participation of a sufficient number of experts in the survey can be considered one of the successful aspects of the study.

EBCS was added to the agenda for the first time in the Istanbul Climate Change Action Plan Final Report published in 2018. With the Park and Go project, creating sheltered, free, and secure bicycle parking areas with a total capacity of 700 bicycles, especially at public transport connection points such as cityline ferry ports, BRT, tram, and metro stations, has been aimed. In addition, the target of increasing the capacity of existing bicycle parking spaces from 982 to 2000 has been set. Moreover, as a pilot project, it was aimed to install charging sockets for electric bicycles in central bicycle parking areas by the end of 2019. However, this target of EBCS was not included in the strategic plans nor the Istanbul Bicycle Masterplan. Bicycle parking areas mentioned in the Istanbul Climate Change Action Plan and whose capacity was to be increased were bicycle racks. These units serve for short-term parking as a function for reasons such as security, weather conditions, etc. There is no regular and complete data on its distribution throughout the city, and the site selection criteria are unknown. The target of placing e-bike charging stations is in the same report as the bike racks target. In other words, it is understood that an evaluation will be made between the places of these parking racks while choosing the location for the charging stations. Considering that the charging time of e-bikes ranges from 1 to 10 hours, riders should leave their bikes for charging in places that are physically and visually safe, sheltered from weather conditions, and close to their destination or transfer points. The concept of "central bicycle parking areas" mentioned in the report as a location selection criterion is insufficient and subjective. Inevitably, almost all location selections made without specific parameters will not be in use as the bicycle parking racks in Istanbul. This study primarily presents an analytical approach to determining EBCS locations, one of the Istanbul Climate Action Plan targets. In addition, findings from this study provide insight to local authorities and planning and transportation experts on locating EBCS.

The application has flexibility within the framework of AHP and can be repeated in case of changing the inputs or adding new options. Criteria that are attractive or intended to be attractive to cyclists on a local scale can be determined and added to the model, and the study can be easily used for cities with different transportation cultures.

In order to provide predictions, it is necessary to increase the up-to-dateness of the data used in the analysis and to restructure the transportation data in parallel with the urbanization and population growth of the city.

To achieve global sustainability goals, it is necessary to create a sustainable city and sustainable transportation system. In order to achieve sustainable transportation targets and an equitable transportation system, automobile-oriented transportation investments should be abandoned, and investments and studies should be carried out to support multi-modal transportation focusing on public transit and micromobility. Bicycles should be included in urban transport plans and models.

In addition to infrastructure investments, a holistic policy should be established, especially bicycle transportation should be supported by awareness studies and trainings.

Various reward and incentive mechanisms should be developed to strengthen the link between public transport and cycling. Bicycle parking structures, EBCS, bicycle roads, bicycle repair stations, etc., should be located at these points to make cycling access to public transport attractive.

Possible future extensions to our study involve decision-making optimization on location of cost-effective charging stations for e-bikes through constraints of infrastructure related costs, energy consumption, etc.

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APPENDICES

APPENDIX A: Questionnaire

APPENDIX A

This questionnaire was prepared to provide data for a postgraduate study on a decision support model on the **determination of the locations of electric bicycle charging stations at the district scale.** For the reliability of the study, it is important that you answer all the questions completely. Thank you for your interest in the study, your time and valuable contributions.

Writer:
Serra GARİPAĞAOĞLU
Istanbul Technical University
Department of Civil Engineering
Transport Engineering Programme

e-mail: serragaripagaoglu@gmail.com

Thesis Advisor:
Prof. Dr. Hilmi Berk ÇELİKOĞLU
Istanbul Technical University
Department of Civil Engineering

Expert who solving questionnaire form

Name, surname:

Profession:

Institution:

Figure A.1 : Questionnaire.

Evaluation method

On the following pages, you are asked to evaluate the effects of the criteria that may affect the **"E-Bike Charging Station Location Selection"**. During the evaluation, the criteria will be compared in pairs and their importance will be indicated on the given scale according to the concept they affect.

Evaluation examples

Example first assessment question

Please rank the effect of the following main criteria on **"E-Bike Charging Station Location Selection"** in order of importance as **"most important = 1"**. (You can give the same sequence number to those of equal importance)

Sample initial assessment

If you think that the effect of **"POIs"** on **"E-Bike Charging Station Location"** is the **"most important"**, the effect of **"transport integration"** and **"bikeability" "equal"** and **"less important"** than the effect of **"POIs"**, you will need to fill in the chart as follows.

Criterion	Importance
PoI	1
Transportation integration	2
Bikeability	2

Example evaluation question

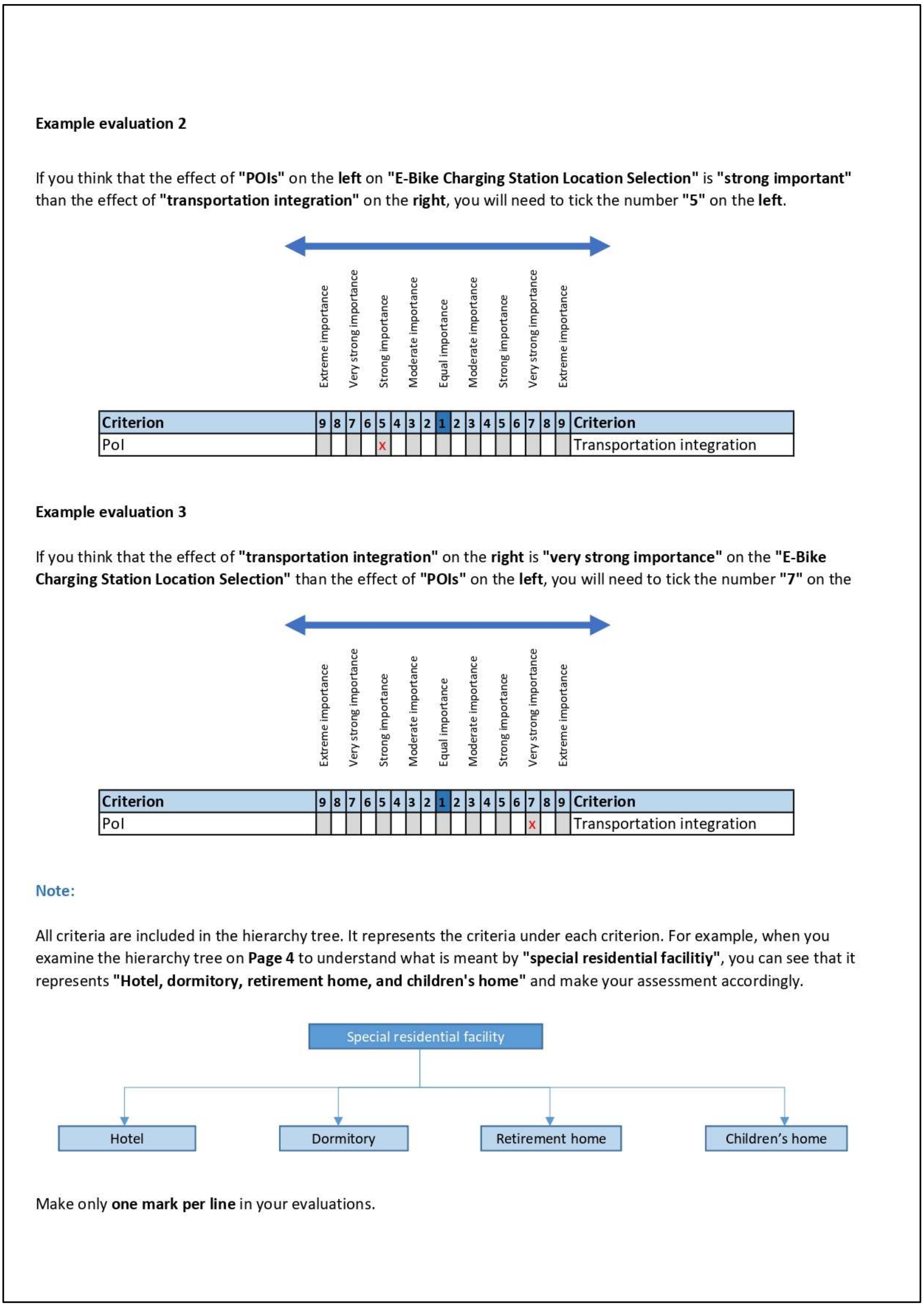
Compare the effects of the following main criteria on the **"E-Bike Charging Station Location Selection"**, taking into account the order you have determined above.

Example evaluation 1

If you think that the effect of **"POIs"** and **"transport integration"** on **"E-Bike Charging Station Location Selection"** is equal, you will need to tick the middle number **"1"**.

	Extreme importance	Very strong importance	Strong importance	Moderate importance	Equal importance	Moderate importance	Strong importance	Very strong importance	Extreme importance									
Criterion	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Criterion
PoI									x									Transportation integration

Figure A.1 : Questionnaire.



Example evaluation 2

If you think that the effect of **"POIs"** on the **left** on **"E-Bike Charging Station Location Selection"** is **"strong important"** than the effect of **"transportation integration"** on the **right**, you will need to tick the number **"5"** on the **left**.

Extreme importance | Very strong importance | Strong importance | Moderate importance | Equal importance | Moderate importance | Strong importance | Very strong importance | Extreme importance

Criterion	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Criterion
PoI					x													Transportation integration

Example evaluation 3

If you think that the effect of **"transportation integration"** on the **right** is **"very strong importance"** on the **"E-Bike Charging Station Location Selection"** than the effect of **"POIs"** on the **left**, you will need to tick the number **"7"** on the

Extreme importance | Very strong importance | Strong importance | Moderate importance | Equal importance | Moderate importance | Strong importance | Very strong importance | Extreme importance

Criterion	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Criterion
PoI															x			Transportation integration

Note:

All criteria are included in the hierarchy tree. It represents the criteria under each criterion. For example, when you examine the hierarchy tree on **Page 4** to understand what is meant by **"special residential facilitiy"**, you can see that it represents **"Hotel, dormitory, retirement home, and children's home"** and make your assessment accordingly.

Make only **one mark per line** in your evaluations.

Figure A.1 : Questionnaire.

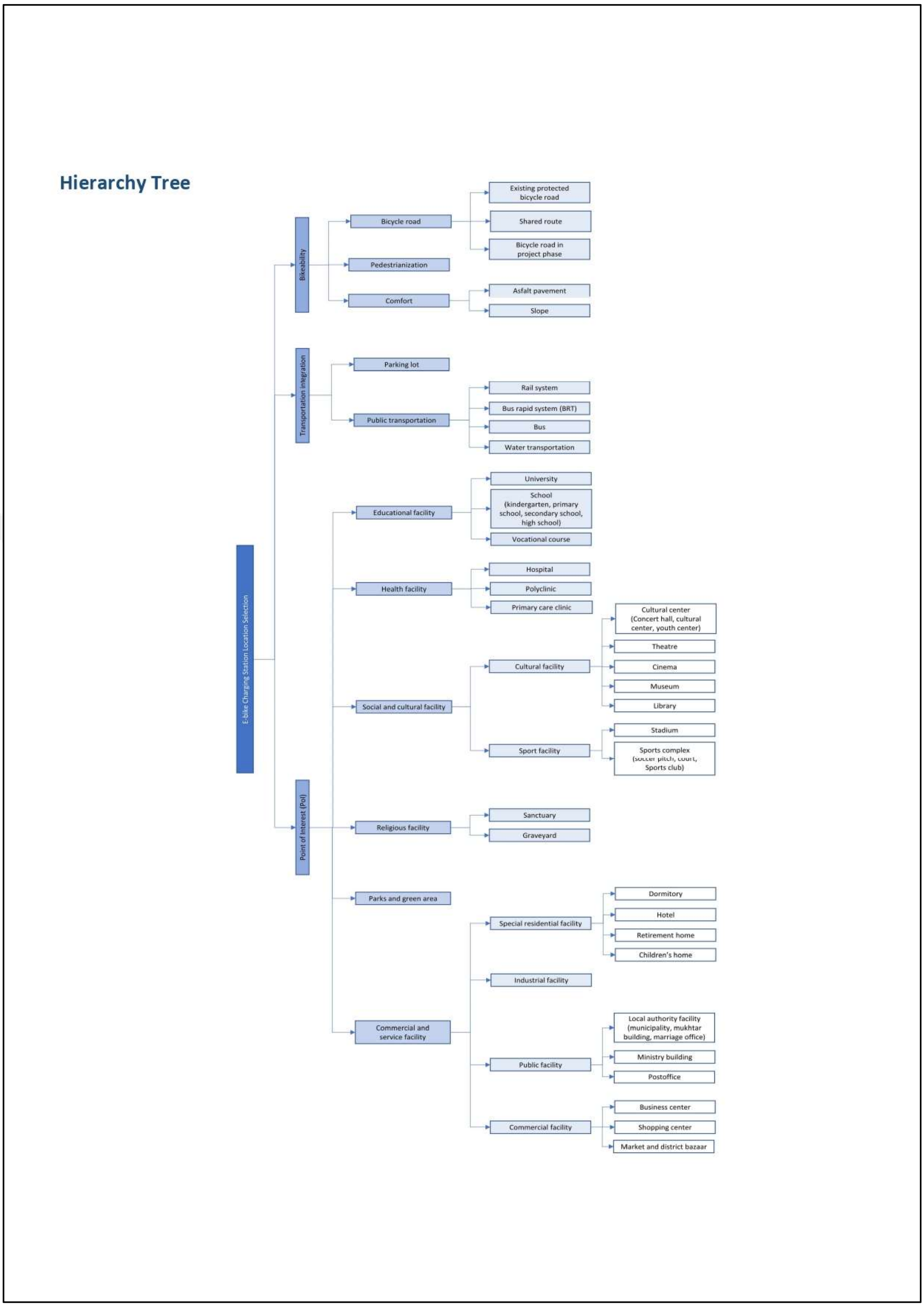
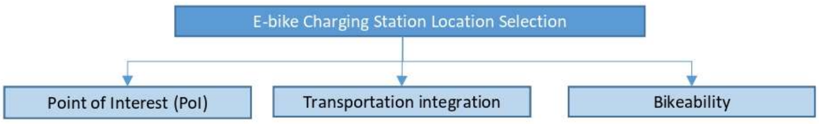


Figure A.1 : Questionnaire.

The previous pages are for information purposes and you can start the evaluation from this page.



1) Please rank the effect of the following main criteria on the **"E-Bike Charging Station Location Selection"**, in order of importance, with the **"most important = 1"**. (You can give the same sequence number to those of equal importance)

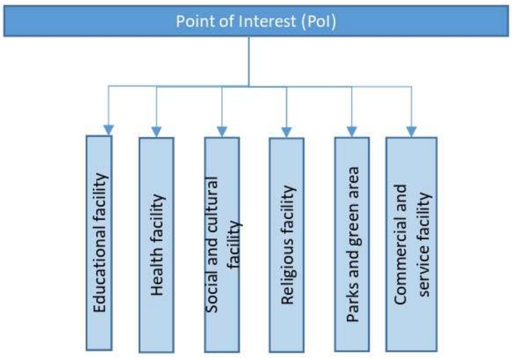
Criterion	Importance
PoI	
Transportation integration	
Bikeability	

2) Compare the effects of the following main criteria on the **"E-Bike Charging Station Location Selection"**, taking into account the order you have determined above.

Extreme importance | Very strong importance | Strong importance | Moderate importance | Equal importance | Moderate importance | Strong importance | Very strong importance | Extreme importance

Criterion	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Criterion
PoI																		Transportation integration
PoI																		Bikeability
Transportation integration																		Bikeability

Figure A.1 : Questionnaire.



3) Rank the effect of the following criteria on **"POIs"** in order of importance, with the **"most important = 1"**. (You can give the same sequence number to those of equal importance)

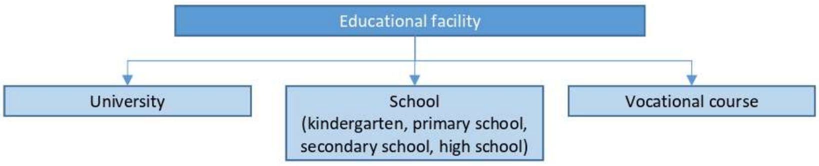
Criterion	Importance
Educational facility	
Health facility	
Social and cultural facility	
Religious facility	
Parks and green area	
Commercial and service facility	

Figure A.1 : Questionnaire.

4) Compare the effects of the following criteria on **"PoIs"**, taking into account the order you determined on the previous page.

	Extreme importance		Very strong importance		Strong importance		Moderate importance		Equal importance		Moderate importance		Strong importance		Very strong importance		Extreme importance	
Criterion	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Criterion**
Educational facility																		Health facility
Educational facility																		Social and cultural facility
Educational facility																		Religious facility
Educational facility																		Parks and green area
Educational facility																		Commercial and service facility
Health facility																		Social and cultural facility
Health facility																		Religious facility
Health facility																		Parks and green area
Health facility																		Commercial and service facility
Social and cultural facility																		Religious facility
Social and cultural facility																		Parks and green area
Social and cultural facility																		Commercial and service facility
Religious facility																		Parks and green area
Religious facility																		Commercial and service facility
Parks and green area																		Commercial and service facility

Figure A.1 : Questionnaire.



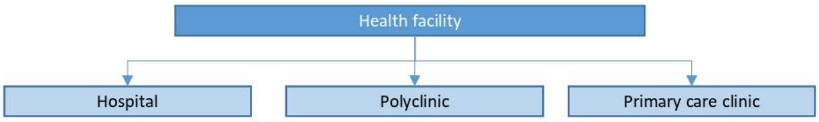
5) Rank the effect of the following criteria on "**Educational Facility**" in order of importance, with the **"most important = 1"**. (You can give the same sequence number to those of equal importance)

Criterion	**Importance**
University	
School	
Vocational course	

6) Compare the effects of the following criteria on **"Educational Facilitiy"**, taking into account the order you have determined above.

Criterion	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Criterion**
University																		School
University																		Vocational course
School																		Vocational course

Figure A.1 : Questionnaire.



7) Rank the effect of the following criteria on **"Health Facility"** in order of importance, with the **"most important = 1"**. (You can give the same sequence number to those of equal importance)

Criterion	Importance
Hospital	
Polyclinic	
Primary care clinic	

8) Compare the effects of the following criteria on **"Health Facilitiy"**, taking into account the order you have determined above.

Criterion	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Criterion
Hospital																		Polyclinic
Hospital																		Primary care clinic
Polyclinic																		Primary care clinic

Figure A.1 : Questionnaire.

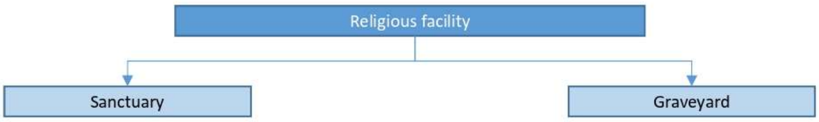
9) Rank the effect of the following criteria on **"Social and Cultural Facility"** in order of importance, with the **"most important = 1"**. (You can give the same sequence number to those of equal importance)

Criterion	Importance
Cultural facility	
Sport facility	

10) Compare the effects of the following criteria on **"Social and Cultural Facilitiy"**, taking into account the order you have determined above.

Criterion	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Criterion
Cultural facility																		Sport facility

Figure A.1 : Questionnaire.



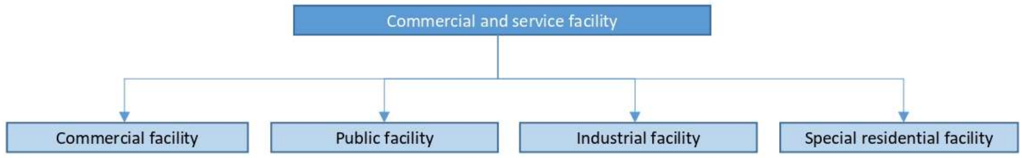
11) Rank the effect of the following criteria on **"Religious Facility"** in order of importance, with the **"most important = 1"**. (You can give the same sequence number to those of equal importance)

Criterion	Importance
Sanctuary	
Graveyard	

12) Compare the effects of the following criteria on **"Religious Facilitiy"**, taking into account the order you have determined above.

Criterion	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Criterion
Sanctuary																		Graveyard

Figure A.1 : Questionnaire.



13) Rank the effect of the following criteria on **"Commercial and Service Facility"** in order of importance, with the **"most important = 1"**. (You can give the same sequence number to those of equal importance)

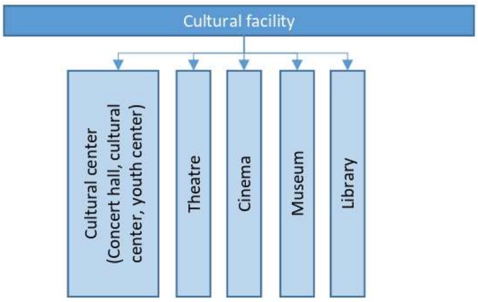
Criterion	Importance
Commercial facility	
Public facility	
Industrial facility	
Special residential facility	

14) Compare the effects of the following criteria on **"Commercial and Service Facilitiy"**, taking into account the order you have determined above.

Extreme importance
Very strong importance
Strong importance
Moderate importance
Equal importance
Moderate importance
Strong importance
Very strong importance
Extreme importance

Criterion	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Criterion
Commercial facility																		Public facility
Commercial facility																		Industrial facility
Commercial facility																		Special residential facility
Public facility																		Industrial facility
Public facility																		Special residential facility
Industrial facility																		Special residential facility

Figure A.1 : Questionnaire.



15) Rank the effect of the following criteria on **"Cultural Facility"** in order of importance, with the **"most important = 1"**. (You can give the same sequence number to those of equal importance)

Criterion	Importance
Cultural center	
Theatre	
Cinema	
Museum	
Library	

16) Compare the effects of the following criteria on **"Cultural Facilitiy"**, taking into account the order you have determined above.

Criterion	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Criterion
Cultural center																		Theatre
Cultural center																		Cinema
Cultural center																		Museum
Cultural center																		Library
Theatre																		Cinema
Theatre																		Museum
Theatre																		Library
Cinema																		Museum
Cinema																		Library
Museum																		Library

Figure A.1 : Questionnaire.

17) Rank the effect of the following criteria on **"Sport Facility"** in order of importance, with the **"most important = 1"**. (You can give the same sequence number to those of equal importance)

Criterion	Importance
Stadium	
Sports complex	

18) Compare the effects of the following criteria on **"Sport Facilitiy"**, taking into account the order you have determined above.

Extreme importance, Very strong importance, Strong importance, Moderate importance, Equal importance, Moderate importance, Strong importance, Very strong importance, Extreme importance

Criterion	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Criterion
Stadium																		Sports complex

Figure A.1 : Questionnaire.

19) Rank the effect of the following criteria on **"Commercial Facility"** in order of importance, with the **"most important = 1"**. (You can give the same sequence number to those of equal importance)

Criterion	Importance
Business center	
Shopping center	
Market and district bazaar	

20) Compare the effects of the following criteria on **"Commercial Facilitiy"**, taking into account the order you have determined above.

	Extreme importance	Very strong importance	Strong importance	Moderate importance	Equal importance	Moderate importance	Strong importance	Very strong importance	Extreme importance	

Criterion	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Criterion
Business centeri																		Shopping center
Business centeri																		Market and district bazaar
Shopping center																		Market and district bazaar

Figure A.1 : Questionnaire.

21) Rank the effect of the following criteria on **"Public Facility"** in order of importance, with the **"most important = 1"**. (You can give the same sequence number to those of equal importance)

Criterion	Importance
Local authority facility	
Ministry building	
Postoffice	

22) Compare the effects of the following criteria on **"Public Facilitiy"**, taking into account the order you have determined above.

Criterion	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Criterion
Local authority facility																		Ministry building
Local authority facility																		Postoffice
Ministry building																		Postoffice

Figure A.1 : Questionnaire.

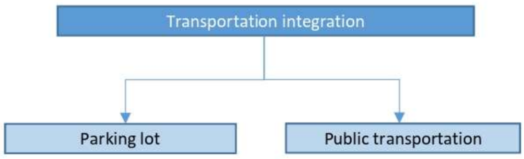
23) Rank the effect of the following criteria on **"Special Residential Facility"** in order of importance, with the **"most important = 1"**. (You can give the same sequence number to those of equal importance)

Criterion	Importance
Hotel	
Dormitory	
Retirement home	
Children’s home	

24) Compare the effects of the following criteria on **"Special Residential Facility"**, taking into account the order you have determined above.

Criterion	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Criterion
Hotel																		Dormitory
Hotel																		Retirement home
Hotel																		Children’s home
Dormitory																		Retirement home
Dormitory																		Children’s home
Retirement home																		Children’s home

Figure A.1 : Questionnaire.



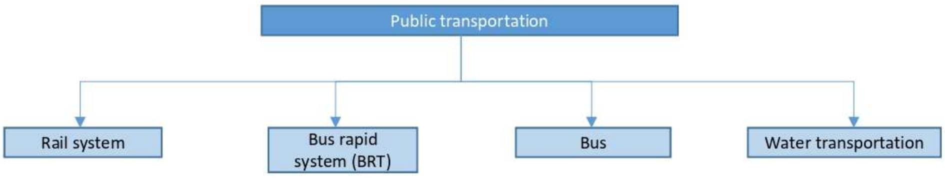
25) Rank the effect of the following criteria on **"Transportation Integration"** in order of importance, with the **"most important = 1"**. (You can give the same sequence number to those of equal importance)

Criterion	Importance
Parking lot	
Public transportation	

26) Compare the effects of the following criteria on **"Transportation Integration"**, taking into account the order you have determined above.

Criterion	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Criterion
Parking lot																		Public transportation

Figure A.1 : Questionnaire.



27) Rank the effect of the following criteria on **"Public Transportation"** in order of importance, with the **"most important = 1"**. (You can give the same sequence number to those of equal importance)

Criterion	Importance
Rail system	
BRT	
Bus	
Water transportation	

28) Compare the effects of the following criteria on **"Public Transportation"**, taking into account the order you have determined above.

Criterion	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Criterion
Rail system																		BRT
Rail system																		Bus
Rail system																		Water transportation
BRT																		Bus
BRT																		Water transportation
Bus																		Water transportation

Figure A.1 : Questionnaire.

29) Rank the effect of the following criteria on **"Bikeability"** in order of importance, with the **"most important = 1"**. (You can give the same sequence number to those of equal importance)

Criterion	Importance
Bicycle road	
Pedestrianization	
Comfort	

30) Compare the effects of the following criteria on **"Bikeability"**, taking into account the order you have determined above.

Criterion	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Criterion
Bicycle road																		Pedestrianization
Bicycle road																		Comfort
Pedestrianization																		Comfort

Figure A.1 : Questionnaire.

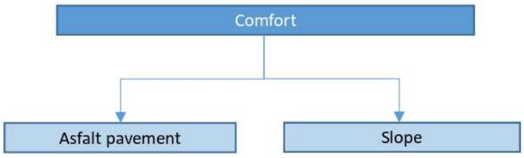
31) Rank the effect of the following criteria on **"Bicycle Road"** in order of importance, with the **"most important = 1"**. (You can give the same sequence number to those of equal importance)

Criterion	Importance
Existing protected	
Shared route	
Project phase	

32) Compare the effects of the following criteria on **"Bicycle Road"**, taking into account the order you have determined above.

Criterion	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Criterion
Existing protected																		Shared route
Existing protected																		Project phase
Shared route																		Project phase

Figure A.1 : Questionnaire.



33) Rank the effect of the following criteria on **"Comfort"** in order of importance, with the **"most important = 1"**. (You can give the same sequence number to those of equal importance)

Criterion	Importance
Asfalt pavement	
Slope	

34) Compare the effects of the following criteria on **"Comfort"**, taking into account the order you have determined above.

Criterion	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Criterion
Asfalt pavement																		Slope

Figure A.1 : Questionnaire.

CURRICULUM VITAE

Name Surname : Serra Garipağaoğlu

EDUCATION :

- **B.Sc.** : 2018, Istanbul Technical University, Faculty of Civil Engineering, Civil Engineering Department
- **B.Sc. (Minor)** : 2019, Istanbul Technical University, Faculty of Architecture, Department of Urban and Regional Planning

PROFESSIONAL EXPERIENCE AND REWARDS:

- 2020- Currently Istanbul Metropolitan Municipality – Department of Transportation – Civil Engineer
- 2020-2020 Istanbul Metropolitan Municipality – Department of Technical Works – Civil Engineer
- 2019-2019 DESTECH Müşavirlik Mühendislik ve Proje A.Ş. – Department of Transportation – Civil Engineer

OTHER PUBLICATIONS, PRESENTATIONS AND PATENTS:

- **Garipağaoğlu S., Duman B. M., İpek H. N., and Çol Yılmaz, D.** 2022: A Strategical Approach for Promoting Cycling And Raising Public Awareness in City of Istanbul: The Case of Isbike Bicycle School. Velo-City *2022*, June 14-17, 2022 Ljubljana, Slovenia.
- **Garipağaoğlu S., Duman B. M., and Tanrıverdi, S. C.** 2021: Investigation of the Effect of Creating Co-Working Places on Bicycle Transportation. 14th