BICYCLE TRANSPORT PLANNING AS A PART OF SUSTAINABLE MOBILITY

A THESIS SUBMITTED TO
THE GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES
OF
MIDDLE EAST TECHNICAL UNIVERSITY

BY

DİDEM ANDİÇ

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR
THE DEGREE OF MASTER OF SCIENCE
IN
CITY PLANNING
IN
CITY AND REGIONAL PLANNING

OCTOBER 2019

Approval of the thesis:

BICYCLE TRANSPORT PLANNING AS A PART OF SUSTAINABLE MOBILITY

submitted by **DİDEM ANDİÇ** in partial fulfillment of the requirements for the degree of **Master of Science in City Planning in City and Regional Planning Department, Middle East Technical University** by,

Prof. Dr. Halil Kalıpçılar
Dean, Graduate School of **Natural and Applied Sciences** _____

Prof. Dr. Çağatay Keskinok
Head of Department, **City and Regional Planning** _____

Prof. Dr. Emine Yetişkul Şenbil
Supervisor, **City and Regional Planning Dept., METU** _____

Examining Committee Members:

Prof. Dr. Serap Kayasü
City and Regional Planning Dept., METU _____

Prof. Dr. Emine Yetişkul Şenbil
City and Regional Planning Dept., METU _____

Prof. Dr. Nilgün Görer Tamer
City and Regional Planning Dept., Gazi University _____

Prof. Dr. Ayşe Tekel
City and Regional Planning Dept., Gazi University _____

Assist. Prof. Dr. Burak Büyükcivelek
City and Regional Planning Dept., METU _____

Date: 17.10.2019

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Name, Surname: Didem Andiç

Signature :

ABSTRACT

BICYCLE TRANSPORT PLANNING AS A PART OF SUSTAINABLE MOBILITY

Andiç, Didem
M.S., City Planning, Department of City and Regional Planning
Supervisor: Prof. Dr. Emine Yetişkul Şenbil

October 2019, 182 pages

Cycling as a way of transportation, has been associated with sustainable mobility all over the world. The new studies and the current debate have shown that achieving sustainable mobility in the current century, depends not just on the environmental health but also depends on the health of individuals and society and on the quality of environment on the local scale. Until 21st century, in the debate on sustainable mobility the main concern was about economic growth by providing efficient mobility of humans and goods. But, the new studies and developments have shown that the subjects of environmental and social impacts, health and inequality must be also emphasized. The concerns about the health of public and the pollution from motorized transport have increased the support on healthy and low-carbon form of mobility: cycling. Hence, countries all over the world, have been implementing policies which support cycling as an urban transport mode to improve sustainable mobility in their cities.

This thesis focuses on the investigation into the necessary measures to achieve a successful sustainable mobility by using cycling as an urban transport mode. The

study has analyzed bicycle transport within sustainable mobility measures among case study cities. The study is aimed to be a guide for bicycle transport planning. The scientific literature review and analysis of case study cities reveal the main findings to encourage cycling as an urban transport mode in terms of improving sustainable mobility. In this content, bicycle transportation in selected sample cities in Turkey has been investigated. The study is concluded with the inferences regarding case studies in terms of improving sustainable mobility to promote cycling.

Keywords: Bicycle, sustainable mobility, bicycle transport, bicycle transport planning

ÖZ

SÜRDÜRÜLEBİLİR HAREKETLİLİĞİN BİR PARÇASI OLARAK BİSİKLET ULAŞIM PLANLAMASI

Andiç, Didem
Yüksek Lisans, Şehir Planlama, Şehir ve Bölge Planlama Bölümü
Tez Yöneticisi: Prof. Dr. Emine Yetişkul Şenbil

Ekim 2019 , 182 sayfa

Bisiklet, bir ulaşım aracı olarak tüm dünyada sürdürülebilir ulaşım ile ilişkilendirilmektedir. Yapılan yeni çalışmalar ve güncel tartışmalar, içinde bulunduğumuz yüzyılda, sürdürülebilir ulaşımın sadece çevre sağlığına değil aynı zamanda bireylerin ve toplumun sağlığına ve yerel ölçekte çevre kalitesine de bağlı olduğunu göstermiştir. Sürdürülebilir ulaşım tartışmaları 21. yüzyıla kadar insanların ve eşyaların etkili bir şekilde taşınmasına bağlı olarak ekonomik büyüme ile birlikte ele alınmaktaydı. Fakat yeni çalışmalar ve gelişmeler çevresel ve sosyal etkilerin, sağlık ve eşitsizlik konularının da vurgulanması gerektiğini göstermiştir. Halk sağlığı ve motorlu ulaşımın yarattığı kirlilik üzerine olan endişeler, sağlıklı ve düşük karbonlu bir hareketlilik şekli olan bisiklete olan desteği artırmıştır. Bunun sonucu olarak, tüm dünya ülkeleri şehirlerindeki sürdürülebilir hareketliliği geliştirmek amacı ile bisikleti kent içinde bir ulaşım aracı olarak destekleyen politikalar uygulamaya başlamışlardır.

Bu tez, kent içi ulaşım aracı olarak bisikleti kullanarak, başarılı şekilde sürdürülebilir hareketliliğe erişebilmek için gerekli ölçütleri incelemeyi amaçlamıştır. Bu çalışma sürdürülebilir hareketlilik ölçütleri kapsamında örnek şehirleri inceleyerek bisikletli

ulaşımı analiz etmiştir. Yapılan çalışmanın bisikletli ulaşım planlaması için bir rehber olması amaçlanmaktadır. Literatür incelemesi ve örnek olarak seçilen kentlerin analizleri, sürdürülebilir hareketliliğin geliştirilmesinde bisikletin kent içi ulaşım aracı olarak teşvik edilmesi için gerekli temel bulguları ortaya koymaktadır. Bu doğrultuda Türkiye'de örnek olarak seçilmiş kentlerdeki bisikletli ulaşım incelenmiştir. Çalışma, sürdürülebilir hareketliliğin geliştirilmesi bağlamında bisikletli ulaşımın teşvik edilmesi için örnek kentlerin analizi ile belirlenen çıkarımlarla sonuçlanmaktadır.

Anahtar Kelimeler: Bisiklet, sürdürülebilir hareketlilik, bisikletli ulaşım, bisiklet ulaşım planlaması

To my father

and

beloved husband

ACKNOWLEDGMENTS

I would like to acknowledge my deepest appreciation to my supervisor Prof. Dr. Emine Yetiskul Senbil, who has enhanced my perspective in my master studies and supported and guided me regardless days and nights. She always encouraged me to be motivated for rewarding studies and made invaluable comments and intellectual guidance kindly. I will appreciate her for valuable support, endless care and I will always be indebted for her efforts.

I would also like to express my gratefulness to my examining committee members Prof. Dr. Serap Kayasü, Prof. Dr. Ayse Tekel, Prof. Dr. Nilgün Görer Tamer and Assist. Prof. Dr. Burak Büyükcivelek for their invaluable comments and supports. I would like to thank to Burak Tümer and Özlem Erten from Metropolitan Municipality of İzmir, Ayşe İçli from Metropolitan Municipality of Konya and Bayram Sarı from Kayseri Ulaşım A.Ş.

I am especially grateful to my parents, Nuray and Erkan Afacan who always support my love of bicycles and to my brother, Mert with whom I enjoyed riding bicycle. I am deeply indebted to them for their endless love and endurance along my entire life and during my study.

I would like to thank Saime and Ömer Andiç for their endless support and patience during my study.

Especially, I would like to express my deepest gratitude to my husband, Halil İbrahim Andiç, who helped me in all my studies and decisions. This study would not have been completed without his affection and confidence.

TABLE OF CONTENTS

ABSTRACT v

ÖZ vii

ACKNOWLEDGMENTS x

TABLE OF CONTENTS xi

LIST OF TABLES xv

LIST OF FIGURES xvi

LIST OF ABBREVIATIONS xxiv

CHAPTERS

1 INTRODUCTION 1

1.1 Definition of the Problem 1

1.2 Research Aim and Research Questions 3

1.3 Outline of the Thesis 3

1.4 The Research Methodology 5

2 CYCLING IN URBAN TRANSPORTATION AND PLANNING 7

2.1 Cycling as a Part of Sustainable Mobility 7

2.1.1 The Measures to Succeed Sustainable Mobility 10

2.1.1.1 The Role of The Governments and Policies 11

2.1.1.2 Consideration of Land Use and Public Transport: Mode Shift 12

2.1.1.3 Supporting Public Acceptability of Mobility 13

2.1.1.4 Remarks of the Considerations 15

2.2 Benefits of Cycling: Cyclists as a Traveler 16

2.3 Bicycle and Public Transport 18

2.3.1 Bicycle Parking on Bus Stops and Rail/Metro Stations 20

2.3.2 Conditions for Taking Bikes on Buses and Trains 23

2.3.3 Bike-Share Systems Near Public Transport Modes 24

2.3.4 Combining Bicycle Routes and Public Transport 24

2.3.5 Remarks of the Measures of Public Transport and Bicycle Integration 25

2.4 Bike Sharing 26

2.4.1 Evaluation of Bike Share Systems 30

2.4.2 Benefits of the Public Bike Share Systems 32

2.4.3 Components of Bike Share Systems 33

2.4.4 Outcomes of the Investigation of Bike Share Systems 35

2.5 Bicycle Network Planning 38

2.5.1 Bicycle Network 38

2.5.1.1 Requirements of Cycle Network 38

2.5.1.2 Functionality of Cycle Network 42

2.5.2 Bicycle Facilities 43

2.5.2.1 Design Requirements of Cycle Routes 43

2.5.2.2 Cycling Specific Facilities 45

2.5.3 Other Bicycle Facilities 49
2.5.4 Intersections and Junctions 51
2.5.5 Bicycle Parking 55
2.6 The Effect of the Natural and Built-up Environment on Bicycle . . . 57
2.7 Bicycle and Socioeconomic Factors 58
3 INVESTIGATION OF BICYCLE TRANSPORT IN SELECTED CITIES . 61
3.1 Introduction 61
3.1.1 Data Gathering and The Features of the Case Study Cities . . . 61
3.2 Copenhagen 63
3.3 Paris 80
3.4 Portland 96
3.5 Conclusion 112
4 INVESTIGATION OF BICYCLE TRANSPORTATION IN TURKEY . . . 117
4.1 Introduction 117
4.2 İzmir 118
4.3 Konya 132
4.4 Kayseri 139
4.5 Conclusion 149
5 CONCLUSION 153
5.1 Summary 153
5.2 Findings 154
5.3 Discussion 162
REFERENCES 165

CURRICULUM VITAE 181

LIST OF TABLES

TABLES

Table 2.1 The evolution of bike share programs 31

Table 2.2 The order of priority of quality requirements for bicycle infrastructure (Adapted from Dufour, 2010 [50]) 42

Table 2.3 Bicycle facility selection based on speed differential [141] 49

Table 2.4 Bicycle parking per land use [141] 56

Table 3.1 The metropolitan area and the city of Paris, [101] 83

Table 3.2 Transportation modes replaced by Vélib' [116] 85

Table 3.3 Subscription of Vélib' system [135] 87

Table 3.4 Charges of New Vélib' Metropole [135] 87

Table 3.5 Bicycle and public transportation relation in case study cities 115

Table 4.1 Existing and proposed Bisim stations 123

Table 4.2 Proposed bicycle network according to 2030 İzmir Transport Master Plan ([30]) 127

Table 4.3 The prices of the nextbike system to rent a bike [111] 135

Table 4.4 Charges of KayBis [90] 143

LIST OF FIGURES

FIGURES

Figure 1.1 Chapters with definitions. 4

Figure 1.2 The structure of the thesis. 5

Figure 2.1 Bicycle share of trips in Europe, North America, and Australia (Data gathered from Buehler and Pucher [18] 8

Figure 2.2 The provision for a successful implementation of sustainable transportation [4]. 16

Figure 2.3 Potential catchment area of Public Transport Station (Adapted from Deffner et al. [48]). 18

Figure 2.4 Public transport bicycle integration (Adapted from Deffner et al. [48]). 19

Figure 2.5 Bike racks in Paddington Station, London [143]. 20

Figure 2.6 Bicycle parking in Deft train station [96]. 21

Figure 2.7 Sheltered bicycle parking at public transit stop, Portland [112]. . 22

Figure 2.8 Bicycle station in Amsterdam's Central Station [117]. 23

Figure 2.9 Estimated number of bike-sharing systems in operation around the world (*as of May) [56] 28

Figure 2.10 Number of bike-sharing trips (July 2018) (Adapted from Woetzel, J. and Kuzneysova, E. [153]). 29

Figure 2.11 Number of public use bicycles worldwide [56]. 29

Figure 2.12 The role of bike share systems in urban mobility (Quay Communications Inc., 2008, cited in Midgley, [107]). 30

Figure 2.13 Vélib' bike share system docking spaces and bicycles in Paris, France [151]. 34

Figure 2.14 Vélib' bike share system station in Paris, France [100]. 34

Figure 2.15 Mesh width. 40

Figure 2.16 The hierarchy of cycle networks ([50]). 42

Figure 2.17 Cycle routes in London, United Kingdom [73]. 44

Figure 2.18 Typical bike path (left) and cycle track (right) configuration [141]. 46

Figure 2.19 Major road and cycle track [21]. 46

Figure 2.20 Typical bike lane (left) and narrow lane (right) configuration [141]. 48

Figure 2.21 Wramborg's model for fatality probability vs. vehicle collision speeds [42]. 49

Figure 2.22 Typical bike boulevard organization [141]. 50

Figure 2.23 Separation of non-motorized and motorized vehicles at intersection [141]. 52

Figure 2.24 Cycle track organization through a junction [141]. 53

Figure 2.25 Cycle track through a miner junction [141]. 53

Figure 2.26 Crosswalk and cycle track junction [141]. 54

Figure 2.27 Cycle track route and bus stop configuration [141]. 54

Figure 2.28 The influence of atmospheric conditions on cycling [49]. 57

Figure 3.1 The PLUSnet cycle network Development Strategy Map ([27]). . 66

Figure 3.2 Sketch from the first Finger Plan created by the Regional Planning Office in 1947 [45]. 67

Figure 3.3 Central bicycle facility at the Lyngby Station in Copenhagen [124]. 69

Figure 3.4 Bycyklen station at Vesterport S-train station, Copenhagen (google maps). 70

Figure 3.5 The network of the Inner Route [79]. 70

Figure 3.6 The Inner Route in Copenhagen [79]. 71

Figure 3.7 “Cycle Serpent” bike path in Copenhagen [25]. 72

Figure 3.8 Differences between cycle track configuration and bike lane configuration in Copenhagen, Denmark [58]. 72

Figure 3.9 Cycle tracks in Copenhagen, Denmark [59]. 73

Figure 3.10 Bike lane between sidewalk and motorized traffic [1] 73

Figure 3.11 Bike lane between on-street parking and sidewalk [1] 73

Figure 3.12 Bus/bike lane in Copenhagen [87]. 74

Figure 3.13 Advanced stop lane in Copenhagen [50]. 74

Figure 3.14 Gyldenløvesgade intersection with waiting space for cyclists, Copenhagen [24]. 74

Figure 3.15 The change of cycle track to bike lane through the intersection, Copenhagen [106]. 75

Figure 3.16 Enhanced bicycle crossing at a large intersections, Copenhagen [97]. 75

Figure 3.17 Car shaped bike parking, bike racks, Copenhagen [125]. 76

Figure 3.18 On-street bicycle parking on the corner of the pedestrian street, Copenhagen ([24]). 76

Figure 3.19 Bicycle parking facilities at bus stops, Copenhagen [131]. 76

Figure 3.20 Nørreport Station, Copenhagen (map style with google; google earth). 77

Figure 3.21 Visual analysis at Norreport Station, Copenhagen. 78

Figure 3.22 The visual analysis of the Nørreport Station, Copenhagen. 79

Figure 3.23 The area of Paris to the Greater Paris. 80

Figure 3.24 A cyclists at Paris Metro [93]. 82

Figure 3.25 Paris Region transit sheds and population density [101]. 84

Figure 3.26 Mode shares in Paris (2010) [109]. 84

Figure 3.27 The Station Map of Vélib' [115]. 85

Figure 3.28 Vandalised Vélib' bike [53]. 86

Figure 3.29 The new Vélib' Metropole [100]. 86

Figure 3.30 Off-the-beaten-track, Paris [159]. 88

Figure 3.31 Off-the-beaten-track Paris [63]. 88

Figure 3.32 Bicycle path at Cours Albert 1er, Paris (google maps). 89

Figure 3.33 Bike path in Allée des Fortifications, Paris [77]. 89

Figure 3.34 Paris, Boulevard de Sebastopol [44] 89

Figure 3.35 Curb-protected two-way cycle track (left) [105] and curb protected one-way cycle track [47]. 90

Figure 3.36 Parking-protected two-way cycle track (left) and Off-street two-way cycle track past Vélib' station (right) in Paris, France [105]. 90

Figure 3.37 Contra-flow bike lane, Paris [10], [15] 91

Figure 3.38 Contra-flow bike lane along left side of the car park (left) and bike lane on the left side of the street and parked cars [105]. 91

Figure 3.39 Bike/ bus lane with space to overtake bicycles, Paris [48] 91

Figure 3.40 Bike lanes continue through complex intersection (left) and Raised curbs, clear markings for bike lanes through an intersection (right) [105] 92

Figure 3.41 White painted bike lane stencils across intersection (left) and Pavement markings for off-street cycle track next to crosswalk markings (right) [105] 92

Figure 3.42 Véligo bicycle park, Paris [98]. 92

Figure 3.43 Bike racks in car park, Paris [98]. 93

Figure 3.44 Saint-Lazare Station, Paris (map style with google; google earth). 93

Figure 3.45 Pictures from the intersection at the Saint-Lazare Station (google earth, street view). 94

Figure 3.46 The implication of the visual analyses at Saint-Lazare Station, Paris. 95

Figure 3.47 The urban design framework ([39]). 98

Figure 3.48 Bikeway network comparison ([37]). 99

Figure 3.49 Bicycles on TriMet Bus and on the Portland Aerial Tram [104]. . 100

Figure 3.50 A top local route in Portland [78]. 102

Figure 3.51 Different points from bike path tour route in Portland (google maps street view). 102

Figure 3.52 I-205 path, Portland [104]. 103

Figure 3.53 Cycle track configuration in Portland, [40], [33] 103

Figure 3.54 One way cycle track in SW Broadway near Portland State University, Portland, (bikeprotland.org). 104

Figure 3.55 Two way cycle track in Portland, [108]. 104

Figure 3.56 Buffered bike lane Portland, Oregon ([34]). 104

Figure 3.57 Buffered bike lane in Portland, Oregon [108]. 105

Figure 3.58 Bus/bike lane with space to overtake, Portland (source: [41]). . . 105

Figure 3.59 Advanced stop lane, Portland ([36]). 105

Figure 3.60 Bicycle box at intersection, Portland [11]. 106

Figure 3.61 Green stripes for bicycle crossings, Portland [38]. 106

Figure 3.62 Bike racks placed in car park space, Portland [99]. 107

Figure 3.63 On street parking, Portland [110]. 107

Figure 3.64 The Rose Quarter TC MAX Station (map style with google; google earth). 108

Figure 3.65 Pictures of the visual analysis at the Rose Quarter TC MAX Station (google earth, street view). 109

Figure 3.66 The visual analysis of the Rose Quarter TC MAX Station. 110

Figure 4.1 The attitude of İzmir Transport Master Plan (Adapted from [30]). 119

Figure 4.2 Classification of the public transportation network ([30]). 121

Figure 4.3 Proposed and current main transport points ([30]). 122

Figure 4.4 Existing and proposed Bike Share System bicycle network, Bisim, stations ([30]). 123

Figure 4.5 Modal share of public transport modes [85]. 124

Figure 4.6 Mode shares of transportation by 2017 ([30]). 124

Figure 4.7 ESHOT bike racks on buses [13] 125

Figure 4.8 Bikes on board, İzmir Metro [30]. 126

Figure 4.9 Bicycle stations of Bisim 126

Figure 4.10 Cycle path along the cost line and bicycle counter, İzmir 127

Figure 4.11 Proposed secure bike parking, İzmir [30] 128

Figure 4.12 Bike racks outside of the Bornova metro station, İzmir [30] . . . 128

Figure 4.13 Bicycle parking consists of racks, İzmir 128

Figure 4.14 Konak Metro Station, İzmir (map style with google; google earth). 129

Figure 4.15 Pictures of the visual analysis at the Konak Main Transit Node (google earth, street view). 130

Figure 4.16 The visual analysis of the Konak Main Transit Node. 130

Figure 4.17 Locations of Nextbike stations in nextbike website [111]. 134

Figure 4.18 Bike lane at Şefikcan Street occupied by parked cars 136

Figure 4.19 Konya bicycle network [74] 136

Figure 4.20 Bicycle repair stations in Konya [20]. 137

Figure 4.21 Aydınlık Evler Tram Station, Konya (map style with google; google earth). 138

Figure 4.22 Pictures of the visual analysis at the Aydınlık Evler Tram station (google earth, street view). 138

Figure 4.23 The visual analysis of the Aydınlık Evler Tram station, Konya. . 138

Figure 4.24 Kayseri Transportation Master Plan [19]. 141

Figure 4.25 Transfer points in Kayseri [19]. 142

Figure 4.26 Kaybis station, docks and bikes 143

Figure 4.27 KayBis stations [91]. 144

Figure 4.28 Park and ride by Kaybis bike share system at Humat parking garage (left) and bike racks at Forum Kayseri (right) 145

Figure 4.29 Proposed bicycle network to link the transit stations and stops [19] 145

Figure 4.30 Kayseri Büyükşehir Belediyesi Tram Station (map style with google; google earth). 147

Figure 4.31 Pictures of the visual analysis at the Büyükşehir Belediyesi Tram station 147

Figure 4.32 The visual analysis of the Büyükşehir Belediyesi Tram station. . 148

Figure 5.1 A proposed system for cycling. 161

LIST OF ABBREVIATIONS

AICV	Animation, Insertion et Culture Velo
CO2	Carbon dioxide
CO2e	Carbon dioxide emission
CVC	Club des Villes Cyclables
EST	Environmentally Sustainable Transportation
FUB	The Federation Francaise des Usagers de la Bicyclette
GHG	Green Hose Gases
GPS	Global Positioning System
ITS	Intelligent Transportation Systems
MAX	Metropolitan Area Express
MDB	Movument de Defense de la Bicyclette
NACTO	National Association of CityTransportation Officials
OECD	Organisation for Economic Co-operation and Development
PBOT	The Bureau of Transportation
RAPT	Autonomous Parisian Transportation Administration
RER	Regional Express Rail Passenger Trains
TDM	Transportation Demand Management
TODs	Transit - Oriented Developments
U.S.	United States
UK	The United Kingdom
UNhabitat	United Nations Human Settlements Programme
USA	The United States of America

CHAPTER 1

INTRODUCTION

1.1 Definition of the Problem

Globally, there has been a remarkable increase in urban population in 2007. Thus, for the first time, world's urban population was more than world's rural population in 2007. In 1990, %43 of the population of the world was urban, and in 2014, %54 of the world's population was living in urban areas. According to the United Nations %66 of the world's population has been expected to live in urban regions by 2050 [145]. In Turkey, in 1985 urban population had become more than rural population, %53 of the Turkey's population was urban.

According to "unhabitat.org", approximately 7.5 billion trips were made in world-wide cities in each day by 2005. In 2050, it is expected to be nearly four times as many passenger-kilometers travelled as in 2000. In the world, rapid urbanization on a global scale creates challenges for urban mobility.

Traditional response to mobility problems such as traffic congestion is to build new roads, highways, fly-overs and tunnels, or to add new lines to existing roadways, or highways, but unfortunately this leads to increase in number of vehicles on roads. For short term, this ensures relief in traffic but for long term increasing the number of vehicles adds new users on roads and over again traffic congestion occurs. Building new roads, tunnels and fly-overs are short term solutions, environmental conditions, existing built-up areas or geographical barriers will not allow for the construction of new roads as well. Insufficient public transportation systems encourage private car ownership. In recent years there has been an increase in the traffic congestion due to the increase in the car ownership.

In the world, there are noticeable water, air and soil pollutions. Globally, %24 of the CO_2 emission has emerged from transportation sector [62]. Dependence on motorized mobility causes a stunning air pollution which affects the quality of life and the biodiversity negatively. Day by day air quality gets worse and this fact causes serious health problems in the urban life. Although the OECD countries have aimed to decrease air pollution, that alone is not enough to decrease air pollution around the world. Developed countries have the highest impacts on environment such as air pollution or global warming but these impacts are perceived also all over the world. It can be said that the environmental impacts of transportation sector is effective worldwide [64]. On the contrary, an ongoing increase in air pollution is expected globally.

The form of transportation and land use related to the automobile dependence shows some problems for environmental, economic and social sustainability of cities. Automobile dependent cities produce greenhouse gases and emission such as carbon monoxide.

There are economic problems such as loss of the productive rural land and urban land to sprawl. As a consequence of the automobile dependence, traffic congestion has economic costs such as waiting in the junctions, increase of the travel times and increase of the transport related CO_2 emissions. Looking for parking, the time spent for fueling and maintaining a vehicle are problems of car dependence too. Social problems could be less obvious than economic and environmental problems, but there are harmful effects of automobile dependence on the nature of human and public realm.

In the continuingly developing world, developing technologies and studies about sustainable mobility have affected the understanding and remarks of the sustainable mobility notion. These developments showed that the problems are not only related to transportation but also related to land-use, urban forms, locations of residences, culture, technology, easy and fast access to internet, smart phones, social media apps and changed the expectations of society that also impacts the mobility patterns. The new debate showed that achieving sustainable mobility not just only depends on environmental health but also depends on health of individuals, society and quality of the environment. The health of public and the pollution from motorized transport

concerns increased the support on healthy and low-carbon form of mobility: cycling.

1.2 Research Aim and Research Questions

Globally, cycling has become complementary as a part of the sustainable mobility in the plans with the increased transport problems. All around the world, cities want to be cities of bicycles as an essential part of sustainable mobility. The main aim of the study is to evaluate the elements of bicycle transport planning to improve the sustainable mobility. This aim leads to following central research question: "To what extent the bicycle transport planning is affected by public transport, natural and built-up environment, bike share systems, network planning and sustainable mobility measures?" The main research question is divided into five sub-questions. These questions are:

1. Which factors of bicycle transport planning are stated in the scientific literature?
2. Which sustainable mobility measures affect bicycle transport planning?
3. To what extent does natural and built-up environment affect bicycle transport planning?
4. To what extent socioeconomic factors affect bicycle transport planning?
5. What are the essentials in bicycle network planning?

In order to answer to these questions, Copenhagen, Paris and Portland have been selected and analyzed as case study cities.

1.3 Outline of the Thesis

The main aim of the study is to evaluate the elements of bicycle transport planning to improve the sustainable mobility. In this context, this study is divided into five chapters. Chapter 2 provides an overview of the scientific literature on bicycle transport planning and of the other relevant bicycle planning literature. In this chapter, cycling

as a part of sustainable mobility, benefits of cycling, bicycle and public transportation, bike share systems, bicycle network planning, and socioeconomic factors have been investigated. Chapter 3 focuses on the case study cities chosen from Europe and United States. The case study cities are investigated in the content of the sustainable mobility measures. This investigation has aimed to endure the existing cycling conditions and to be a guide for bicycle transport planning. Chapter 4 investigates the bicycle transport in selected cities in Turkey as a part of sustainable mobility. Chapter 5 presents the conclusion part of the thesis. This chapter includes the findings from the literature review and case study analysis.

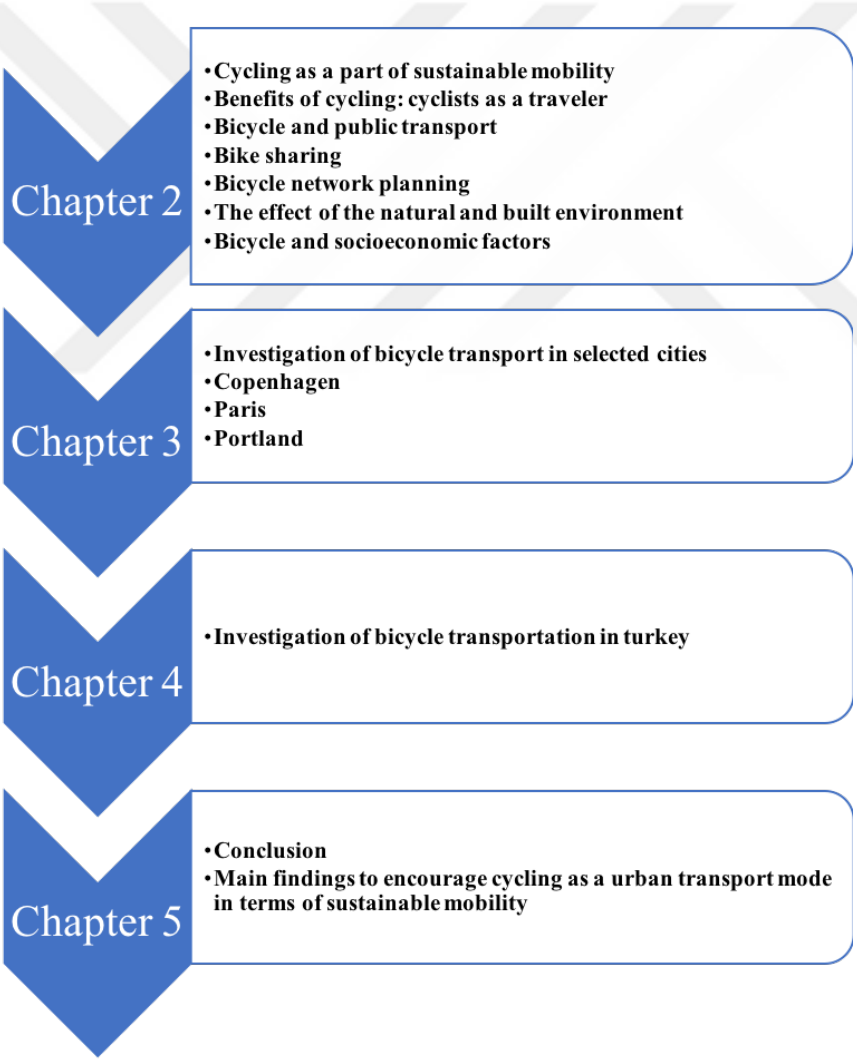


Figure 1.1: Chapters with definitions.

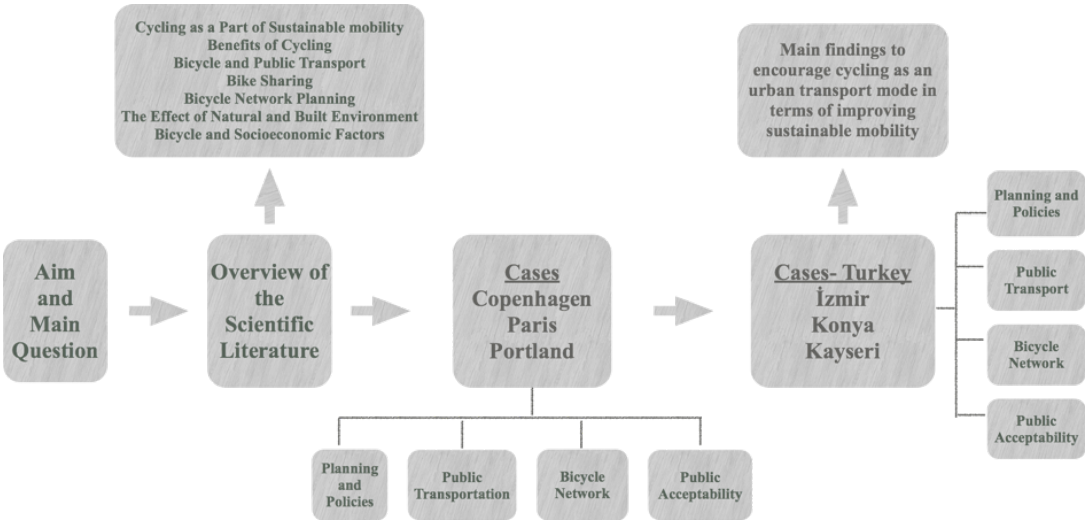


Figure 1.2: The structure of the thesis.

1.4 The Research Methodology

The case study cities have been chosen from Europe and United States. First group have a high level of cycling mode share as an urban transport mode and have increased the already high level, the second group have increased the level of cycling mode share without any cycling history in the city. Copenhagen from Denmark, have a historical cycling culture and increased the already high level of cycling mode share in the city. Data has been gathered for the case study city analysis from (1) state, local government, and municipality statistics and reports; (2) transportation plans, bicycle plans, official documents, and transportation sections of each city's municipalities official websites, transportation; (3) national level cycling organizations and research centers.

In Turkey the elements of bicycle transport planning as a part of sustainable mobility are examined in case study cities. The case study cities chosen from the municipalities that have promoted cycling as an urban transport mode in their city. These cities are İzmir, Konya and Kayseri. In Konya cycling is popular since 1920. Although Kayseri and İzmir have no history of cycling, they have gained great success on promoting cycling as a transport mode. Data has been gathered for the case study city analysis from (1) local government statistics and reports; (2) transport plan, bicycle plans, and

transportation sections of each city's municipalities official websites; (3) interviews with city's municipalities.

CHAPTER 2

CYCLING IN URBAN TRANSPORTATION AND PLANNING

2.1 Cycling as a Part of Sustainable Mobility

Cycling as a way of transportation, is associated with sustainable mobility in the world. In the European Commission [55], by the new urban mobility culture, development of bicycle infrastructure should be regarded essential for sustainable mobility vision. Growing number of cities' municipalities are willing to become cities of bicycles, as an essential part of sustainable mobility. As cities become increasingly to be more sustainable, cycling has become complementary in the plans. Also, the concerns about present transport problems and results of these problems on the earth and on the health of the human, lead the modern society to pay more attention to sustainable mobility.

In a manner of planning, accessibility to low-cost, space efficient infrastructure generally refers to the definition of "bicycle". Bicycle is an ideal short and medium distance transportation mode and has the capability of connecting different land uses. It is also affordable, nonpolluting and energy efficient that makes bicycle an ideal short and medium distance transportation mode to move people to transportation terminals, schools, businesses, parks and social facilities. Also land requirements and installation cost per space for bicycle is smaller and cheaper than for cars (other urban transport modes). Development of bicycle transportation and integration of bicycle and public transportation makes contribution to reducing CO_2 emissions.

When the sustainable mobility first occurred in 1992, the term was generally connected with traveling for employment, movement of productions, impacts on environment, efficiency of transportation modes, and traffic demand, until the year 2000.

After decades, studies and discussions about sustainable mobility has lead to a new perspective. By 2000s, the viewpoint about the term has changed a lot with the consideration of travel for leisure time activities, impact on economy, accessibility, and congestion reduction. Especially after 2010, in the light of the technological developments, the studies about sustainable mobility has become concerned about innovation, transition over sustainable mobility, a multilevel attitude, big data, carbon emission and impacts on health. These developments and concerns have started the cycling renaissance in industrialized world.

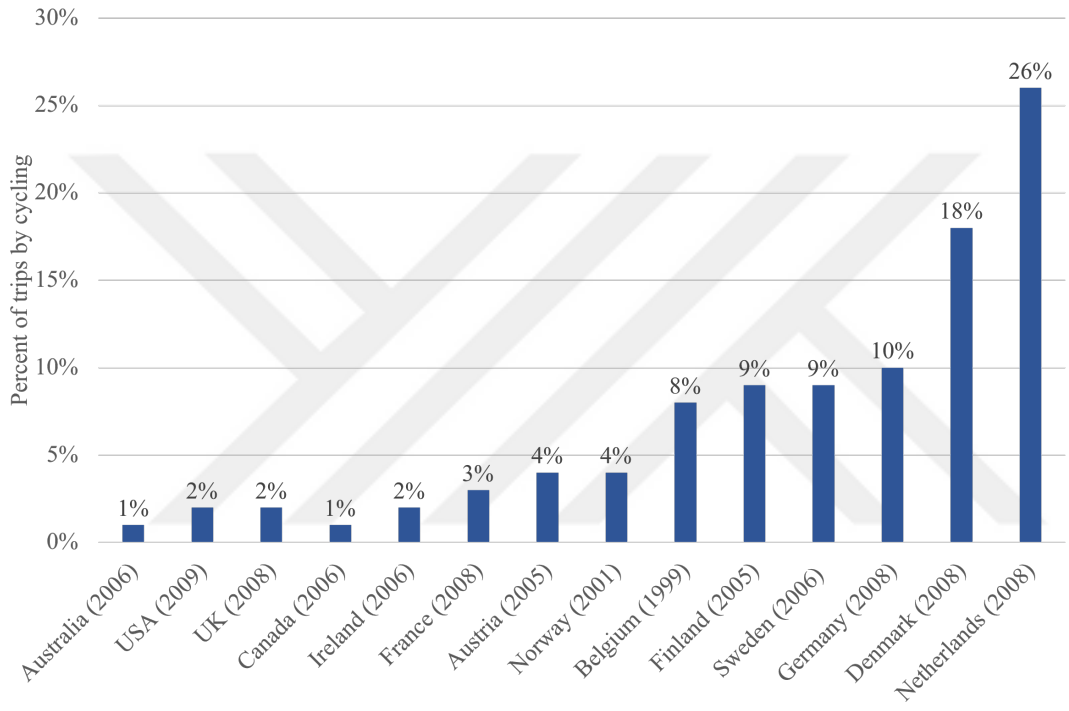


Figure 2.1: Bicycle share of trips in Europe, North America, and Australia (Data gathered from Buehler and Pucher [18]

Countries in Europe, North America, and Australia, have been implementing policies about cycling as an urban transport mode to improve sustainable mobility in their cities. These cities in different continents have differences in cycling levels, and policies. In the United States, Australia, and Canada, the mode share of cycling is about 1 percent. In Ireland and the United Kingdom it is about 2 percent. In Netherlands the mode share of cycling is 26 percent and in Denmark 18 percent (see Fig 2.1). The cycling levels in European countries are higher than in North America

and Australia. This difference is originated from that European countries are bike-friendly countries and on the contrary other countries are car oriented countries [18].

In the academic literature, the terms “sustainable transportation” and “sustainable mobility” are handled as synonymous. Mostly, in Europe sustainable mobility term is used [72]. In this regard, Berger et al (2014) [9], makes an explanation that mobility is being mobile and along quality consideration and points the capacity of comprising distance in physical space. This kind of viewpoint mentioned the revealed and potential mobility which means being mobile because man or goods can be moved or move between different places. Hence, in this study, sustainable mobility is used.

The continuingly developing world and developing technologies has affected the questions to achieve sustainable mobility vision. These developments have shown that the problems are not only about transportation but also about land-use, urban forms, locations of residences, culture, technology, easy and fast access to internet, smart phones, social media apps, and have changed the expectations of society that also impact the mobility patterns. With the 20th century, the studies have shown that transportation systems were unsustainable [6], [9], [72]. It is understood that mutual effect of transportation and land-use affects must be considered to achieve sustainable mobility [72]. Also, for a solution of the sustainable transportation, the other factors such as businesses, investors, governments and society must be involved. So, an inter-disciplinary approach should be handled. In the current century, according to the new studies, the new debate showed that achieving sustainable mobility depends not just on environmental health but also depend on health of individuals, society and quality of environment locally. In the first period of sustainable mobility, until 20th century, the main concern was about economic growth by providing efficient mobility of humans and goods. But, the new debate showed that environmental and social impacts, health and inequality must be emphasized. The health of public and the pollution from motorized transport concerns increased the support on healthy and low-carbon form of mobility, cycling.

2.1.1 The Measures to Succeed Sustainable Mobility

To succeed sustainable mobility for bicycle planning, briefly, there are four main key subjects to be considered [7]. The first consideration is about using technology for transportation such as promoting hybrid vehicles, clean vehicles, alternative fuels, electro mobility, bike share systems, or intelligent transportation systems (ITS). The use of technology in transportation industry will lead to attain the efficiency purpose. Secondly, pricing is an important input for the efficiency and usage of the transportation modes. Operating implementations such as road pricing, congestion charging could lead to promote the use of more efficient vehicles. Thirdly, public transport and land use decisions should be considered to lower the travel times, and travel distances. This approach ensures the change of model split. Lastly, promotion of information, involvement of public, involvement of the targeted groups, awareness raising with education of children should be taken into account.

To sum up, government policies and planning, public acceptability, participation of the target groups, involvement of public for social engagement, advertisement, clear policies, promotion of alternative fueled vehicles, technology, and innovation systems form the core of the vision of sustainable mobility in modern society. In other words, not only changing the physical assets is enough but changing dependence on fossil fuels, life style of people should be overemphasized. Across the world, it is expected that upto %66 of the population of the world will become urban in 2050. This fact must be taken into consideration while visioning sustainable mobility for our world. Besides this fact, the ever-shifting developments in technological innovations, communication and information technologies lead the mobility being more than going from a to b. Also, the ever-shifting development in technology, lead people to access new knowledge swiftly and to question the quality of life, wellbeing, livability in cities, goal in their life, and social life and to compare the performances of the cities. This could infer the importance of technological systems to achieve sustainable mobility vision.

2.1.1.1 The Role of The Governments and Policies

To build the transition to sustainable mobility, governments have the most important roles that include defining their roles, limits, national goals and opportunities clearly through a widening perspective. The government should be taking into consideration the citizens' problems, and difficulties they live in everyday life with being trustworthy.

The increasing automobile dependence is one of the most important issues that governments should fight against. For instance, in Turkey after 1980s the tendency on economic growth and infrastructure investment have led to urban sprawl. In addition to these, the developments and investment on automobile manufacturing industry, and the steady increase in the household income ended up with rapid increase in automobile ownership [132]. In Japan, the government managed the rapid increase in automobile ownership with forcing General Motors and Ford to leave manufacturing. After all these actions, the government has regulated the policies to promote the infrastructure of rail and subway. On the other side, the policies in USA and Europe have promoted motorized mobility through motor industry, road and infrastructure construction manufacturers, oil and fuel establishments [70]. While dealing with car dependent mobility, the role of government is crucial to determine strong and clear policies to manage motorization while promoting integrated public systems, walking and cycling.

With the debate of new discourse, the effects of the air pollution, water pollution and climate change on human health and reasons of these impacts might be redefined based on the fossil fuel dependent life style. Governments undertake that CO_2 reduction, shifting from non-renewable energy to cleaned fossils and renewal energy. At this point bicycle plays an important role. Government's promotion of bicycle use feeds the low carbon traffic. Copenhagen is a good example for the government promotion of bicycle statewide. Additionally, governments might regulate the enforcements to CO_2 reduction targets with carbon taxes, road pricing, and by increasing fuel prices to attract cycling through society. These enforcements are disincentive on citizens and companies to use environment friendly transport modes and alternative fuels. Also it is important to promote alternative fueled vehicles for public trans-

portation. An alternative promotion might be car sharing as an alternative way for CO_2 reduction with decreasing automobile mobility and also the need for parking spaces in the city.T

The impact of CO_2 emission from fossil fuels on environment and health are not counted in the fuel prices. Global warming, serious health problems, and loss of agricultural lands are some of the results of the increased CO_2 emission. These results are priceless but to battle against decrease on CO_2 emission, these impacts and the costs of these impacts in fuel prices should be taken into consideration. Also these impacts are not only shown up by fossil fuels from automobiles, but are also shown up by the manufactures of transportation industry such as road infrastructures. Therefore, carbon taxation and other pricing practices for motorized mobility including production of transport industry is really vital for the essence of sustainable mobility and for our world. It is important to shift the financing and investments from transport networks, and motorized mobility to low-carbon mobility and non-motorized mobility modes such as bicycle.

2.1.1.2 Consideration of Land Use and Public Transport: Mode Shift

While building blocks for sustainable mobility, improving public transportation system could be dealt by increasing accessibility for everyone or increasing the rate of the usage of public transport. Increasing mobility for everyone through improvement of public transportation systems aims to encourage modal shift. As for increasing the rate of the usage of public transport system aims to reducing energy use [7], [71]. Moreover, encouraging public transportation by allocation of space could support cycling with reduction of automobile mobility. This means developing the transportation hierarchy.

Contrary to traditional transport plan, sustainable mobility approach can reduce the automobile ownership and automobile use by supporting cycling and walking with a new transport hierarchy, by slowing the movement in roads in urban areas, by integrating people and traffic to make streets more than roads, moreover a green space for people, by aiming accessibility to space, by considering social dimensions, and by considering travel as a valued activity and a derived demand. In opposition to

traditional transportation approaches, sustainable mobility uses demand management not demand based attitude to achieve effective access and effective use of the spaces and public transportation. Therefore, to make a reduction in traffic, congestion, and automobile use, the modal shift from traditional transportation planning to sustainable mobility approach should be supported with consideration of the best use of the released space [7].

Land-use regulations also provide a decrease in automobile use and so, low carbon emission. Land-use planning has a key role on prioritizing non-motorized transport that could reduce transportation demand. That means providing low-carbon emission and reducing energy use of transportation modes. Studies show that land-use planning have an impact on travel behavior [71], [69], [95].

Not only the consideration of land-use policies with the idea of sustainable mobility are efficient on reducing carbon-emission but also that has impacts on cycling through public transportation, increasing densities in cities, and mixed used planning, and housing locations. Defining the new housing decisions, effect irrevocably the sustainable mobility in the city by effecting travel patterns [7]. As the essence of the sustainable mobility, green modes or low carbon modes of transportations such as bicycle, should be mutually complementary with land-use planning.

Providing land for transport infrastructures is crucial in high dense cities. New investments on transport infrastructures affect the area and travel demand. Investments on transport around the cities lead to decentralization, and this ends up with increase in development of sub-urbans. Consequently, this leads to urban sprawl in an unplanned manner [60], 2013. The unplanned urban sprawl creates an inadequate public transport opportunities such as seen in Eryaman, Turkey. Integrated public transport is crucial to minimize the environmental impacts of transportation. Integrating transport modes allows the transport systems work efficiently.

2.1.1.3 Supporting Public Acceptability of Mobility

Education plays a key role to achieve health, social and economic benefits for public. The education should involve all children, older adults, ethnic groups, different

groups of people, and target groups through internet, social media, and awareness campaigns such as cycling day or cycle to work day. Another component is promotion of public involvement. The expectations, and thoughts of public or target groups should be taken into consideration by using clear descriptions and aims. Thirdly, policy measures should ensure clear aims, clear decisions, effectiveness of actions to adaptability of policies through public and business.

Fourthly, the benefits of sustainable mobility should be promoted by government through the all citizens. These benefits include clean water, clean environment, clean air, less and safe traffic. As all citizens take these advantages, government should show up and make that outcome be understood. Another key role is packaging. This manner includes promotion of public transport systems, and cycling. Encouragement of bicycle transportation, and integration of these modes should be supported through ensuring the availability and accessibility of these modes for everybody. Also enforcements with disincentive implementations as rising costs of automobile ownership or carbon taxes might help to support cycling.

If there is an unsustainable transportation system, firstly, people should be enlightened about sustainable mobility. To change their attitude to green and to usage of public transportation and cycling in their everyday life could be done by social norms and impressing them by informing about sustainable mobility. This change is important because only the government's regulations are not enough to change travel behaviors and perspectives of people about cycling in urban transport [71].

While considering new technologies, the most important part is developing attractive, and significant technologies to use them for reducing energy use in public transportation by conventional energy sources or by alternative energy sources. The important steps are development of technology, availability of the technology, and adoption of the technology by the targeted user groups. Also, this consideration could be based on three key features: the type of energy source, education for vehicle drive, and fuel. Technology is connected inevitably with transportation by the changed lifestyles of today's. Achieving any new knowledge swiftly through internet and new mobility culture (travelling for leisure time activity) deduce the importance of real time information. Operating transportation through real-time information also provides energy

consumption on transport modes both of public transport and cycling.

Adopting cleaner technologies for transport modes ensure reduction on noise and air pollution [5], [71]. Essentially, the most required action is combining of efficient technology with behavioral change. The promotion of bike share requires not only technology but public acceptability. As stated above, public acceptability is an important input for sustainable mobility vision through cycling. So, this consideration requires public involvement before and during the decision making process. Also, this involvement affects directly the outcomes for sustainable mobility. The increase of urban population makes more important these technologies to integrate the public transport vehicles with city and citizens to solve mobility problems.

About the bike share systems, technology plays an important role, of course. By the developments on technology, bike share has become more convenient for cyclists. Bike-share systems, presently, are integrated with cleaner technologies such as smart cards, solar-powered and mobile stations, GPS tracking, and electric bicycles. GPS tracking technology help users to plan their travel. Widespread availability of smart phones and internet access [67] enable users to reserve or specify available bicycles for specific days of the week or hourly.

2.1.1.4 Remarks of the Considerations

It is clear that all measures are important but public empowerment and involvement of the parties should be supported for changing mobility habits through cycling. It is important to empower people by technology. These discussions refer to come through automobile dependence and the congestion. As transportation becomes a valued activity, the reason why people travel and travel times should be concerned to come through automobile dependence and congestion to achieve sustainable mobility vision. All these mentioned considerations should be implemented in an integrated way, therefore new mobility could be built through low-carbon society. This integration has three requirements; adoption of the transport case, adoption of the environmental case, and adoption of the political case (see Fig 2.2). To build sustainable mobility through cycling successfully the integration of these three requirements should be taken into consideration as the related actions expressed in the discussion above. This

three provision comprise a basis for the examinations of the bicycle transportation as a part of sustainable mobility through case study cities.

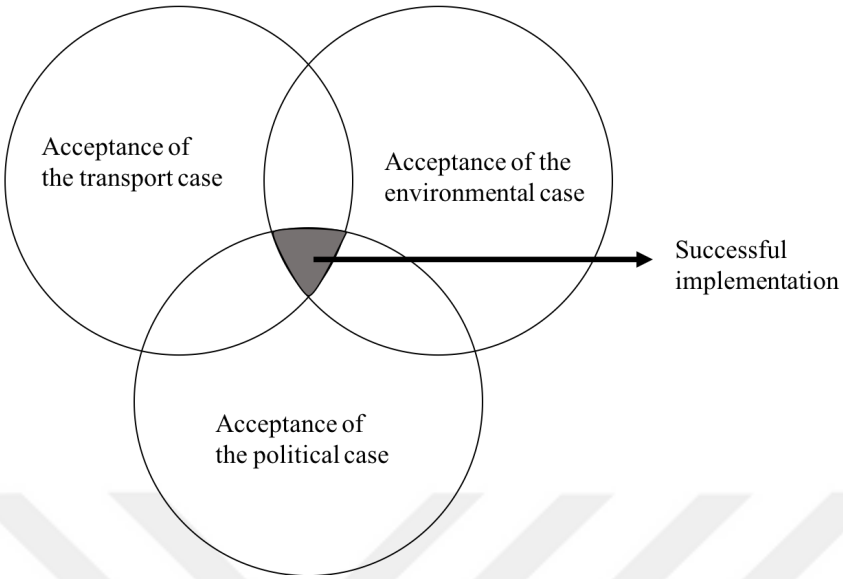


Figure 2.2: The provision for a successful implementation of sustainable transportation [4].

As a result of these considerations, a new perspective that planning road for transportation means no longer just for movement, but also means for public space and green environment. So, these considerations are inputs to investigate bicycle transportation within sustainable mobility vision through the case study cities which have different characteristics.

2.2 Benefits of Cycling: Cyclists as a Traveler

Bicycle as the essence of mobility is commonly mentioned by the indirect effects. But the measures to support bicycle should not be handled by only indirect effects of cycling but the advantages of cycling in itself as a traveling mode should be considered. The indirect effects of bicycle are congestion reduction, emission reduction, or improving health of society. Of course, these effects are influential but the advantages of cycling in itself are important to achieve a strong and planning. The point of view of considering mostly indirect effects could be caused by the concerns about that could not get positive reactions about investments on bicycle because the advantages

of bicycle by oneself is not efficient.

Low carbon forms of transportation require inexpensive investments and the instruction processes are faster, environment friendly and need less space than motorized transport modes. To achieve low-carbon city vision, integrating public transport with cycling and walking based on energy efficiency is an essential approach. At this point, the quality of the public transport and interchange between different modes of public transport and cycling and walking become really important. As Banister stated, doubtlessly bicycle is the mode of the low-carbon city transport for today and tomorrow [60], 2013. Bicycle is not a choice but to be act.

As the most used transport mode, automobile enables you having private place, independence, traveling with high speed, and high mobility. But the environmental impacts, and health impacts are nonignorable. Despite the attractive sides of automobile travel, an integrated and shared transport system, involving cycling with green approaches, the citizens could raise the quality of the city without motorized transportation. Instead of wasting time in traffic congestion caused by automobile dependent travel system, going in slow speeds with enjoying the travel, and high level of comfortable, accessible, secure travel and mobility could be achieved by shared and integrated transport system. In the developing world, time is precious and expectations of the society is changed from just traveling for commuting to having time for leisure activities, breathing clean air, accessing to green and open spaces comfortably and safely by cycling, walking or using public transits without thinking where to park their car, or without feeling the stress while waiting in the traffic congestion for hours.

Bicycle is an active transport mode and also a low-carbon mobility mode so promotes the cleaner air and so a healthy life style. Also, bicycle is the best answer to all concerns such as rapid carbon emission, air pollution, loss of open and green spaces, future mobility, quality of life, energy use and health of society. In terms of energy efficiency, a bike uses 35 calories per passenger-mile, and a car uses at least 1860 calories. For 1 kilometer, a bike uses 12 times less energy than a car uses. In terms of health, bicycle supports to avoid from high blood pressure, diabetes, cholesterol, and coronary diseases.

2.3 Bicycle and Public Transport

Bicycle is a short-distance or medium-distance transport mode so the areas that public transport modes such as bus, rail, or metro could not bring service to and far beyond the walking distance for everybody. When compared to automobile, bicycle and public transport integration provides higher mobility because in the destination planned to be gone may not be a parking area for automobile and this leads people to park far away the target destination and to walk. This might be longer than the walkable distance and so, this lead people to feel stressed. In this kind of condition, since bicycle does not require a big space to park or to cycle, you can go with a public transport mode and at the rest of the short distance to achieve the destination you can use your bike without feeling the stress of parking the car. On the other hand, the long trips which are hard to cycle are made shorter with the integration of public transport. Also, the cost of this integrated mobility is much more lower than car parking fees.

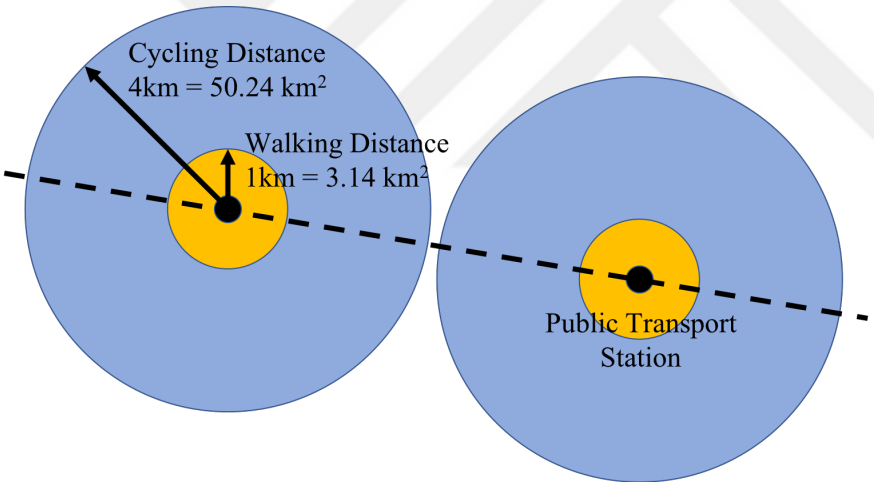


Figure 2.3: Potential catchment area of Public Transport Station (Adapted from Deffner et al. [48]).

Cycling supports the public transport by getting access to the areas that rail, metro and bus stations are far beyond walking range (see Fig 2.3). Accessing to public transport modes with bicycle provides an advantage to cyclists on bad weather conditions such as rain or snow, on sloping roads or during mechanical breakdown of bicycle, and also provides the cyclist to travel more distance than traveling by bike.

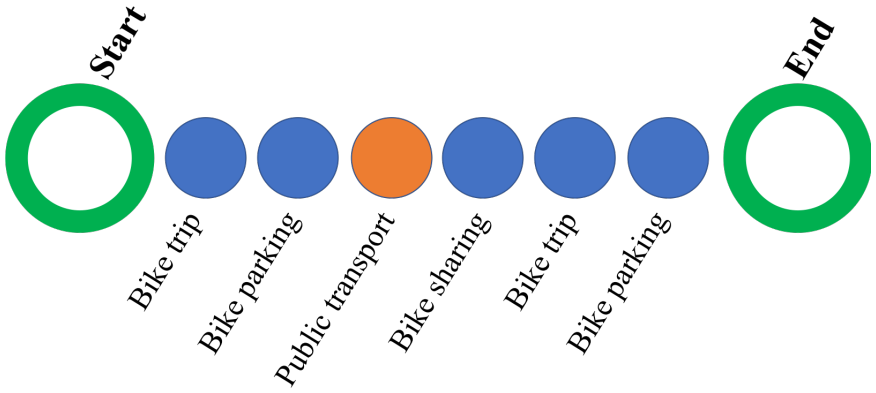


Figure 2.4: Public transport bicycle integration (Adapted from Deffner et al. [48]).

Integration of bicycle and public transportation is mutually advantageous, because this integration promotes cycling and public transport modes at the same time. This integration is an efficient solution in metropolitan areas, considering the size of the cities and the distances between residents and working areas. For an effective integration of bicycle and public transport, safety of cyclists must be considered. Bicycle could be used to as a catalyst to achieve a safety network policy. While integrating bicycle with public transport systems, the different needs of all modes of public transport systems and bicycle must be considered. This integration also make available more human scale transport system in the city.

In Europe, coordinating cycling and public transport began earlier than in North America. For instance, in Netherlands the proportion of cyclists reached to rail stations with their bikes is 39%, in Denmark this proportion is 25% and in Sweden 9% [68], [103]. In the United States, between 1995 and 2008, the proportion of trips increased by 38% [2], [3]. The work trips by bicycle increased 57%, from 2001 to 2009, in United States [148], [149]. With the rising in the demand for cycle facilities, most of the American cities adopted implementation measures from European cities.

To integrate bicycle with public transport four categories have been specified towards sustainable mobility. The four categories of measures are (1) bicycle parking on bus stops and rail/metro stations, (2) conditions for taking bikes on buses and trains, (3) bike-share systems near public transport modes, and (4) combining bicycle routes and public transport.

2.3.1 Bicycle Parking on Bus Stops and Rail/Metro Stations

One of the most important measure to the level of integration of bicycle and public transport is parking spaces on bus stops and rail/metro stations. Mostly, in Europe and Japan because of the crowd and so, high demand to public transportation buses do not have bike racks. Bike parking generally is provided in train stations or outside of the stations.

In Netherlands, mostly people cycle to suburban train stations and park in the station or outside the station, and continue their trip with rail to reach to the main train station in the city center. By the way, after they arrive to the city center they continue to travel with a bike that they have already parked in the main train station [17]. Bike parking spaces are placed at bus terminals, transit nodes, key stops. But mostly, they are placed at rail stations. By the year 2010, in Netherlands, the train stations had totally 325,000 bicycle parking spaces and in Denmark, the train stations had totally 76,196 bicycle parking [120], [46]. In United States, there were 26,495 bicycle parking spaces in train stations totally, and there were 38,280 parking spaces statewide. This number of bicycle parking spaces were very few regarding to the European cities. By the recent decade, the cities in Europe, North America and Japan have aimed to increase the qualities and the numbers of bicycle parking spaces.



Figure 2.5: Bike racks in Paddington Station, London [143].

The types of bicycle parking facilities at transit nodes can be divided into five categories. The first one is the simplest one, unsheltered/sheltered bike racks. An unsheltered bicycle parking facility has a disadvantage because it does not protect the bikes from bad weather conditions (see Fig 2.6). The sheltered bicycle parking facilities,



Figure 2.6: Bicycle parking in Deft train station [96].

have a roof and are mostly placed within rail station buildings (see Fig 2.7). For example, in Chicago, there are sheltered bicycle parkings or in station parking places specifically designed for 83 train station. The aim of placing bicycle parking spaces in the stations is to protect bicycles from bad weather conditions and to take the advantages of the security of station (see Fig 2.5). Another kind of bicycle parking is secured bike racks. The security can be provided by video surveillance or guards. In Europe, mostly in Germany, Denmark, and Netherlands, secure bike parking is popular to prevent bike theft. The third kind of bicycle parking facility is bike lockers. The bike lockers are made from metal or plastic container. These bike lockers are mostly placed in rail stations to prevent bike theft and could be rented for a month. In general, these containers store one or two bicycles. These bike lockers could be fully electronic and work with subscription.

In Washington, 86 of the Metrorail subway stations have 1,300 bike lockers. The fourth kind of bicycle parking facility is bike cages. Bicycle cages can store hundreds of bicycles, and include electronic card system that provides users to store their bike without subscription. Bicycle cages are secure, locked and covered by fences. In the metropolitan area of Copenhagen there are 42 bicycle cages. The last kind of bicycle parking facility is bicycle stations at public transport stations. Bicycle stations serve fully integrated facilities such as security, bicycle rentals, bike repairs, showers, bike washers, bicycle tour desks. Bicycle stations are sheltered, secured, and mostly coordinated with metro or train stations, but sometimes they could be placed in the

commercial zone of the city centers. In Amsterdam's Central Station there is a bicycle station with 10,000 bike capacity [17] (see Fig 2.8).



Figure 2.7: Sheltered bicycle parking at public transit stop, Portland [112].

With the increase in cycling demand, bicycle theft is also increased. Secure bicycle parking facilities are important to struggle with bicycle theft for a day long storage at transit nodes. Guarded bicycle parking spaces, bike lockers or bike cages are the alternatives to struggle with bicycle theft. Bicycle cages are less secured than bike lockers and guarded bicycle parking since a key card owner can open the cage and reach to the every bicycle in the cage. But the surveillance cameras deter from theft. With the improvement of the secure cages, they have become the most advanced and most secure bicycle parking facilities in public transportation nodes and stations.

The level of bicycle parking at public transportation nodes, and stops promotes cycling. [102], [103] and Givoni and Rietveld [61] have shown that good bicycle parking areas promote cycling and public transportation in Europe.

According to the studies by Taylor and Mahmassani [133] providing secure bicycle parking areas considerably increases the level of cycling. According to the report of Transportation Research Board, parking costs for bicycle are less than park and ride costs for automobiles for the passengers of public transport [138].



Figure 2.8: Bicycle station in Amsterdam's Central Station [117].

2.3.2 Conditions for Taking Bikes on Buses and Trains

Bicycles can be carried with bike racks on buses or on rail cars. Mostly, a bicycle can be stored on a rack placed on the front of the bus. Otherwise, some buses allow cyclists to carry their bikes on the luggage compartment or in the buses. Bike racks on buses are most popular in North America. The cities in North America, do not charge any fee from cyclist for using bike racks on the buses. By the year 2010, 72 percent of the buses are equipped with bike racks in United States. In Portland all the buses have bike racks [17]. Contrary to United States, in Europe nearly all buses do not have any bike rack. On this regard, United States is more bike friendly than Europe.

Carrying bikes on light rail, suburban rail trains, and in metro, is allowed outside of the peak hours in North American and European cities [121]. In the San Francisco bay area, suburban trains allow cyclists to travel with their bikes on the second level of the train without any charging fee.

Limited studies about the impact of carrying bicycle on public transportation have shown that bike racks on the buses have positive results. Carrying bikes on buses provides more passenger and reduces the cost of installing bicycle parking space on the public transport nodes or stops [66], [138]. Another positive outcome will be the preventing bike theft and provide cyclists to travel long distance with their bike.

But the high demand and insufficient capacities on the trains prevent traveling with bicycle.

2.3.3 Bike-Share Systems Near Public Transport Modes

Bike-share systems near the public transportation nodes and stops, provides cyclists an integrated travel without owning a bicycle. Placing bike-share systems' stations and docks near the public transport nodes and stops provide public transport users quick access to the nodes and stops and encourage the non-bike owners. Also, that promotes commuters to use bicycle without owing one in their daily routine. According to a study in Paris, most of the public transport users go with bike-share systems because they are cheap, convenient and faster than walking [136]. Usually, bike-share systems provide a 30 minutes free use to the users but the fees increase by the length of the riding. The new generation of bike-share systems such as Vélib' in Paris, Bixi in Montreal, Bicing in Barcelona, Velo'v in Lyon are the most popular ones and have extensive catchment area in the city near the train, rail, and metro stations. Bike-share systems help to efficiently integrate cycling with public transport and to achieve sustainable mobility.

2.3.4 Combining Bicycle Routes and Public Transport

To achieve an efficient integration between bicycle and public transport the last concern is bicycle paths and lanes through transport nodes and stops. The main consideration should be providing safe access through bus stops and transit stations to bike lanes and paths. It is important to avoid conflict of the bike lanes with bus lanes through bus stops for safety of cyclists. If there is enough space in bus line for bicycles than bus-bike lanes can be feasible. Mostly in Denmark, Germany and Netherlands bike lines are provided away from the road and bus stops to avoid the conflict with other passengers and traffic [122].

In European cities, bicycle paths and lines planned to promote daily travel habit with integrating bus stops and transport nodes. On the contrary, in United States the point of view to cycling is commonly recreational. The cities in United States, promote

cycling paths and lanes through recreational areas such as parks, lakes, rivers and other green spaces [119].

Briefly, bike network can be categorized into three by leading to public transport, parallel to public transportation and shared bus-bike lanes. First type of bicycle network consists of bicycle paths, on-street routes and lanes that are feed by the public transportation modes. These type of routes take the cyclist to transport nodes and stops. The second type of bicycle network, parallel to public transportation, consists of bicycle paths, on-street routes and lanes that are planned parallel through the public transport routes and planned to avoid conflicts of buses and bikes. Also, they relieve the crowd on the public transport modes. The third type of routes, shared bus-bike lanes, give access to only buses and bicycles if the lane has adequate space.

Providing safe cycling paths and lines in the city is really helpful to reduce the crowd in buses and rail systems by encouraging bicycle. For example, in New York and Vancouver cycling facilities as parking spaces and lanes are planned through the most crowded transport nodes to shift the demand from public transport to cycling ([123]). Ensuring synchronization of the cycling network is a key consideration to achieve an efficient integration between cycling and public transport.

2.3.5 Remarks of the Measures of Public Transport and Bicycle Integration

Both Europe and United States have paid attention to integration of bicycle and public transport. In European cities, the main concern is enhancing the quality and the number of bicycle parking at public transport nodes and stops. On the contrary, North American cities, are concerned about carrying bicycle on train, metro or buses. In fact, with the increased promotion of bicycle and public transport integration, safety of the bicycle parking spaces and bicycle routes has been begun to be considered all around the world. There are also some conflicts while integrating bicycle and public transportation modes. The cycle routes that are parallel to public transport routes make a shift from cycling to public transport modes. For example, in the cities of Denmark and Germany, the low-cost pricing for students through semester shift the cycling to public transportation [51], [120], [123].

Another conflict can be caused by carrying bicycles on trains and buses. At the peak hours, taking bikes on trains could not be allowed on or cyclist have to wait to find an empty bus to use with their bike. With the increase in the cycling levels, the need for sheltered, secured, and accessible bicycle parking facilities increase too. Also, a "complete station" provides bicyclists all they need such as showering, and repairing the bicycle. Complete stations would make transit stations more attractive for cyclists [18]). Another point is that investment for bicycle facilities with bike-and-ride consideration costs much more less than providing facilities for ride-and-share for automobiles [18]). Also bicycle facilities are environment friendly and meet well with the provisions of sustainable mobility.

2.4 Bike Sharing

In the world, growing concerns about climate change, air pollution, unsteady fuel prices, and energy security have led the governments, decision makers and policy makers to be interested in the sustainable transportation strategies. Sustainable strategies could be sorted as cleaner fuel technologies, transportation demand management (TDM), cleaner vehicle technologies, improving walking and cycling, integration of transportation strategies and land use, and compact land use systems to increase density and diversity of uses.

Bike share systems could address these concerns as a mobility strategy. In last decades, global bicycle usage has increased in spite of rapid increase in motorization. Bike share systems as a factor of increased bicycle usage provide integration of cycling with the transportation systems and encourage cycling by making bicycle available for everyone.

The main idea of the bike share is that everyone can use these bikes and pick up a bike from a place and return it to another place. The basic principle of bikesharing is the usage of the bicycle on an "as-needed" basis. Bike share systems as a sustainable and environmentally friendly public transportation mode provide short-term bicycle access.

The public-use bicycle idea began in 1960s with the "White Bikes" in Amsterdam.

The white bikes were just common bikes with white color and dedicated for the public usage. These bikes were placed unlocked in the inner city for the people to use them without any charging fee. However, having no locks, these bicycles were either vandalized, confiscated by the police, or appropriated for personal use.

In 1995, in Copenhagen, Denmark, public-use bicycles were established. These bicycles were designed and produced specially for public use and placed in specific locations where these bikes could be picked up or returned with a coin deposit, in the inner city. But unfortunately, these bikes were stolen or damaged.

Bike share has started with a free bike form and has evolved to more technologically advanced systems. Public bike systems are also called as "bicycle share systems" or "bike-share systems" in North America, "cycle hire" in the United Kingdom, "cycle sharing" in South Asia and "public bike" in China. Intelligent transportation systems support the use of bicycle as a short-distance transportation vehicle with high technology and provide bicycle access without requiring bicycle ownership. Even if bicycle is a quick, healthy or affordable transportation mode, in some cases you will hesitate to use your bike. For example, in a bad weather condition such as rainstorm or heavy fall of snow or the lack of a secure bicycle parking make you to figure out what to do with your bike at the end of the journey. At this point, public bike systems emerge as a solution to these problems by making bicycles available for one-way or round trip rental at public bike stations that are placed around the urban area. Moreover, for tourists who do not own a bike or access to bike, bike share programs improve a city's image and branding by providing an enjoyable cycling around the city.

Since bike sharing often serves as a means of "last mile" transportation, it spreads more quickly in urban areas where public transportation coverage is strong. Public bicycle stations are usually located at strategic points such as train, subway and metro stations, bus stops, residential areas, shopping centers, shopping streets, tourist areas. In other words, public bike stations located at the spaces which has a high density pedestrian flow.

These stations feature specially designed bicycle parking spaces where bicycles are locked electronically, and the bike taken from a station can be locked to another station at a different point. Each terminal contains maps that show the points where other

stations are located and available bicycles and the number of free parking spaces. It is necessary to have these maps on the bikes.

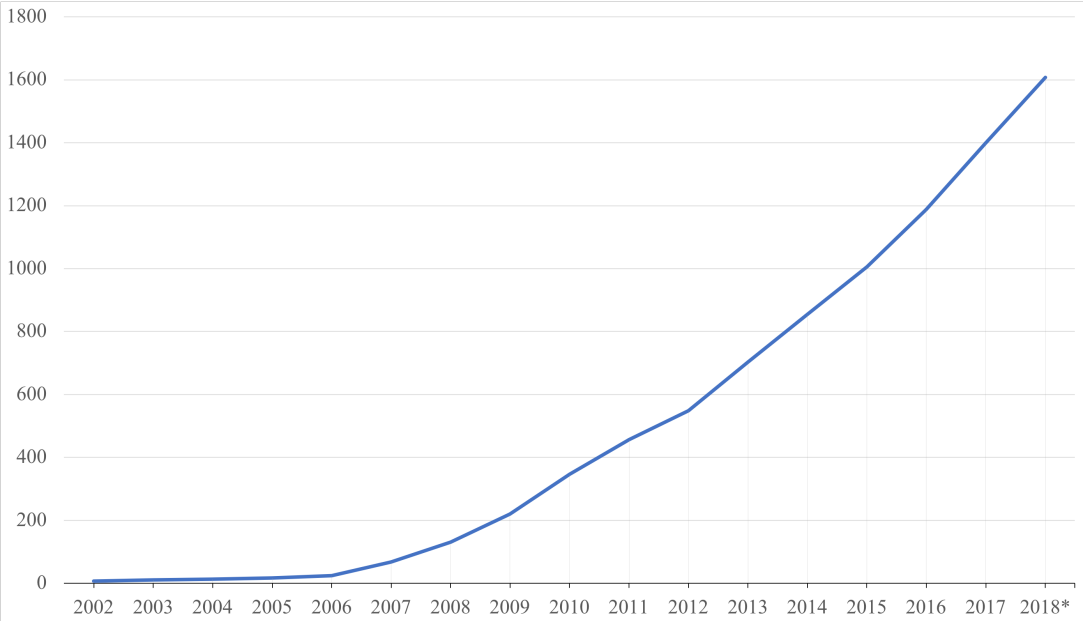


Figure 2.9: Estimated number of bike-sharing systems in operation around the world (*as of May) [56]

Public bike systems or bike sharing systems, can be used with smart cards, magnetic cards, or smart cards used in public transport systems, and payments can be made through these cards. Bike share has started with a free bike form and has evolved to a more technologically advanced system.The first bike-share was opened in the 1960s in Amsterdam, Netherlands. Until the turn of the century 2000s, bike-share growth was not popular. After the launch of Velo'v in Lyon, France, in 2005 and Vélib' in 2007 in Paris, there was a remarkable increase in the number of bike-share systems around the world as shown in Figure 2.9. By May 2018, there were more than 1,600 bike share systems under operation around the world, serving 18 million bicycles for public use (see Fig 2.11).

China has the largest bike share system and is clearly a leading country in terms of available bike sharing programs. According to a global study made by McKinsey in July 2018 asking respondents in cities how many bike-sharing trips they made annually, respondents in Shanghai said that they made more than sixty trips per year (see Fig 2.10).

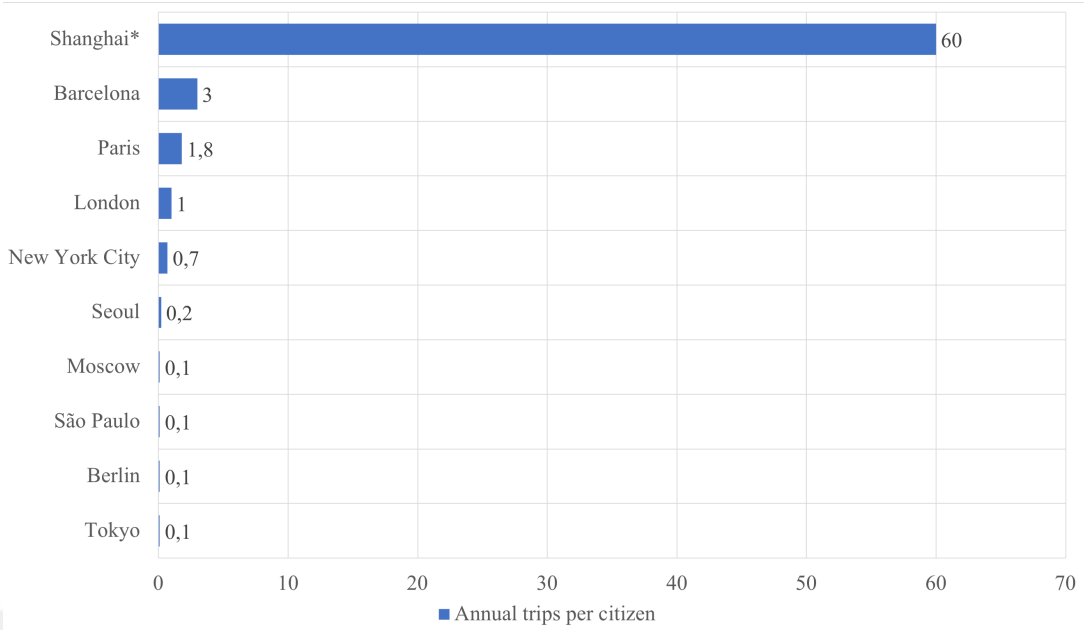


Figure 2.10: Number of bike-sharing trips (July 2018) (Adapted from Woetzel, J. and Kuzneysova, E. [153]).

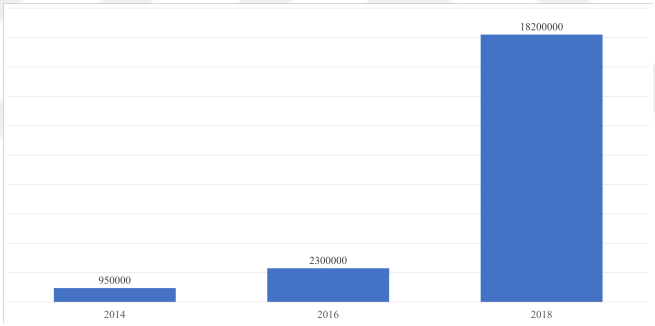


Figure 2.11: Number of public use bicycles worldwide [56].

Although travel distance by mode varies from country to country and city to city, most people are willing to walk up to 10 minutes. Cycling distances generally fall within the 1 km to 5 km range. Bicycle-sharing can therefore fill an important niche in the urban transportation system in terms of trip length and costs as shown in Figure 2.12 (Quay Communications Inc., 2008, cited in Midgley, [107]).

Cities that have adopted urban mobility plans that promote public transport and restrict car use with demand management and traffic calming measures, undoubtedly provide a bicycle friendly environment for the introduction of bicycle-sharing sys-

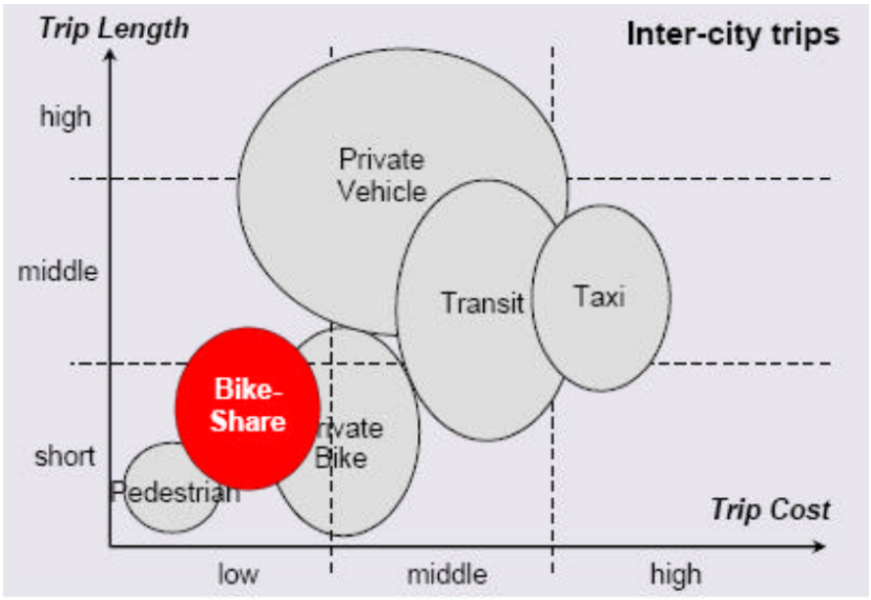


Figure 2.12: The role of bike share systems in urban mobility (Quay Communications Inc., 2008, cited in Midgley, [107]).

tems. Most bicycle-sharing cities have adopted broader urban mobility policies that promote cycling and limit car use.

2.4.1 Evaluation of Bike Share Systems

As of May 2011, 136 bike share programs were estimated in 165 cities world-wide, with 237,000 bikes. Asia represents the fastest-growing bike-share market with China, Taiwan and South Korea [18].

Table 2.1: The evolution of bike share programs

	1965 First Generation	1992-1995 Second Generation	1998 Third Generation	Present Fourth Generation:
	Free Bike Systems	Coin-Deposit Systems	Smart Card Systems	Demand-Responsive, Multimodal Systems
Components	Bicycles	Bicycles	Bicycles	Bicycles
		Docking Stations	Docking Stations	Docking Stations
			Kiosks or user interface technology	Kiosks or user interface
				Programs may include electric bicycles
Characteristics	Distinct bicycles (usually by color)	Distinct bicycles (color or special design)	Distinct bicycles (color, special design, or advertisements)	Distinct bicycles
	Unlocked bikes	Locked bikes	Locked bikes	Locked bikes
	Free of charge	Coin access	Smart card access	Linked to public transit smartcard
	No stations	Free of charge	Free (first 30 min)	Free (first 30 min)
		Specific stations	Specific stations	Specific docking stations that are more efficient (mobile, solar powered, etc.)
			Theft deterrents	Improved locking mechanism to deter bicycle theft
			Access kiosk	Touch screen kiosk-user interface
				Bicycle redistribution systems
				GPS tracking

Fourth-generation bike-share systems are differing from elder generations in that they are linked with public transportation. The aim of the fourth-generation bike-share systems is integration with public transportation, and other modes such as carsharing and taxis. To integrate bike-share systems with public transport modes, the stations of bike-share systems should be placed near to transit stations considering bus, train or metro arrivals and departures. Also a single payment method should be used in all public transportation modes and bike-share systems.

There are significant developments in fourth-generation of bike-share systems as a part of the cleaner technologies. These are solar-powered and mobile stations, movable stations, price reduction or extra time credit for riders to leave the bicycles at an empty station to use less the bicycle redistribution trucks as far as possible.

Fourth generation bicycle share systems are under development depending on the progression in innovations. The evolution of bike-share systems are summed up in Table 2.1.

2.4.2 Benefits of the Public Bike Share Systems

Public bike systems have environmental, social, and transportation related benefits. Public bike systems have advantages over the other types of public transportation modes. If public bike systems replace trips made by automobiles, there should be a reduction in GHG emissions.

Public bike systems have advantages over the other types of public transportation modes. The potentials of integrated public bike system are providing reduction in congestion, in costs of parking and road facilities, and in accidents and pollution problems [152].

With the evaluation and growth of bike share systems in the world, an increase in public awareness of bike share and the benefits of the systems as environmental, social and health related ones become important. Available but limited data suggest that bike sharing has changed behavioral trends.

The increase of awareness in public bike systems has led to evolvement in perception

of cycling as a transport mode. Also bike share systems provide bicycle access to people who may have a lack of access to a bicycle or bicycle parking.

According to a Vélib' survey, in 2008, 89% of Vélib' users have stated that the bike share system made it easier to travel in Paris. After the launch of Vélib' in Paris, bicycle riding increased by 70 percent and the bicycle mode share increased from 1 percent in 2001 to 2,5 percent in 2007. According to SmartBike data, nearly 79% of the respondents reported that the use of the bike share system in Washington, D.C., was more convenient and faster than other transport modes. For instance, during the first year of Velo'v, Lyon there were 44% increase in cycling. 96% of Lyon's bike share system members were new users who had not previously cycled in the city [127] .According to a report about Velo'v, bicycle use reduced the automobile mode share by 7 percentage points in Lyon.

Public bike systems as an alternative mode for short trips might shift the trips made by cars to bicycle. For instance, in November 2011, in Washington, bike-share system users chanced their behavior from using car to using bicycle and reduced the driven miles with car by approximately 4.4 million.

Bike-share systems have advantages on reaching places that are beyond to reach on foot. Also whenever the distance between them is beyond their reach on foot, cycling becomes efficient. Therefore, bike-share systems, improves mobility by being cheaper to extend the system than extending a public transport mode in the city. Public bike systems provide a complementary service for short trips instead of using transit and physical and mental health benefits as an active transport choice. Studies expressed that every day 20 minutes of cycling effects mental health positively.

2.4.3 Components of Bike Share Systems

Bike share system lexicon has three parts of definitions. First one is docking spaces, second one is the stations and the last one is terminals or namely kiosks.

Docking spaces consist of bike lockers that are specialized for bicycles of bike share systems (see Fig 2.13). Bike share system stations involve docking spaces, terminals and bikes. Bike share stations could be manual or automated, manual, and could

be located in the streets, on the sidewalks, or in open spaces (see Fig 2.14). Kiosks provide information for users about the bike share system and may serve as a payment device for users. Kiosks connects the bikes, the docking spaces, and control center of bike share system. Also, kiosks may show the locations of available bikes and stations of the system [81].



Figure 2.13: Vélib' bike share system docking spaces and bicycles in Paris, France [151].



Figure 2.14: Vélib' bike share system station in Paris, France [100].

Besides the physical components, there are five components for a successful bike share system. According to the Institute for Transportation and Development Policy

[81] these elements are station density, bikes per resident, coverage area, quality of bikes, and easy to use stations. Firstly, for every km2, 10 to 16 bike share system station should be implemented. Also, a station should be placed approximately every 300 meters distance. Secondly, the stations should have available bicycle considering the served area. The metropolitan regions and denser and larger cities have needs more bicycle with the consideration the trips from home to work and trips from work to home at peak times. The most populous destinations in the city need more bicycles. Thirdly, the coverage area of the bike share system is important. As stated by the Institute for Transportation and Development Policy [81], minimum 10 km2 area should be covered by bike share system to achieve a high performance. Fourthly, the bicycles of the system should be attractive, durable, and practical to use. The size, and design of the bicycles are important to prevent from theft. Lastly, the design of the stations should be easy to use. The payment, and checking out of the bike service should be easy and simple. Also, the stations should provide information about available bikes at other bike share stations.

2.4.4 Outcomes of the Investigation of Bike Share Systems

Since the first program was launched in Netherlands in 1965, public bike share systems have evolved and still there is an ongoing evolvement by the developments on the information technologies. These developments on planning, implementation, and operations of bike share systems led to various lessons. Six key lessons could be addressed: (a) bicycle theft and vandalism; (b) bicycle redistribution; (c) information systems; (d) insurance and liability considerations; (e) prelaunch considerations; (f) land provision for stations.

(a) Bicycle theft and vandalism:

Despite the developments on information technologies, third- and fourth-generation public bike systems must consider to prevent from bicycle theft and vandalism. In Paris, after 18 months the Vélib' bike share system has launched, over half the original fleet of 15,000 Vélib' bicycle have disappeared [8]. A survey of about Vélib' bike share system reported that since its launch in 2007, 7,800 bicycles were stolen and 11,600 bicycles were vandalized. To limit the impacts of bicycle theft and vandalism,

Hangzhou's bike share program provides inexpensive bicycles. Also, the bike share system of Hangzhou made the use of bicycles free for first hour to prevent bicycle theft. In general, evolving fourth-generation bike share system should take into consideration more durable bicycles to prevent high cost of maintenance and the locking systems to prevent bicycle theft [128].

(b) Bicycle redistribution:

By the growth of a bike share system and starting to cover larger areas, some problems may appear about the redistribution of bikes among stations. Redistribution of bikes among stations is an important issue. While redistributing bikes it is important to consider the demand patterns in the city [128].

In Hangzhou, for instance, according to an investigation there was a problem of lack of parking spaces, especially during peak hours. To find a solution, Hangzhou bike share program has implemented some strategies such as an alarm system for bicycle occupy or vacancy, manual return to busy stations during peak hours, and instant delivery (i.e., employing trucks to redistribute bicycles from one to another) [155].

In France, Vélib' to relocate bicycles between stations uses natural gas vehicles. In Montreal, the bicycle redistribution trucks uses on-board computers to determine the stations that are overcrowded or shortage of bicycles. Besides that, if the station is overcrowded, BIXI and Vélib' gives a fifteen minutes to users for relocating the bikes another nearby station that has available docks [128].

Most of the bike share programs use carbon-emitting vehicles to redistribute bicycles. Shaheen et al [126] pointed out that, it is important to integrate fourth-generation systems with technological developments in terms of relocation of bicycles and in the future, cleaner redistribution strategies could be used. Real-time information should be taken into consideration to resolve the problems about bicycle redistribution.

(c) Information systems:

By the development of third-generation bike share systems, the usage of real time information systems has become widespread. Most of the third-generation bike share systems provide real-time information on stations, by calling system hotlines, by di-

rect mobile messages to mobile phones, by mobile apps, or by websites (map programs like google maps). To achieve an efficient and user-friendly bike share system the developments on real-time information technologies should be considered.

(d) Insurance and liability considerations:

The growing popularity of bike share systems has raised insurance and liability concerns. For example, at present, for most of the popular bike share systems such as Vélib', BIXI, The Hangzhou Public Bike system helmet use is not mandatory for users over 18. This conflicts with insurance liability laws. On the other side, in Australia, Melbourne Bike Share system make helmet usage mandatory for all ages. But also it is criticized as helmet use is mandatory because Melbourne Bike Share system has poor performance. The concerns about safety should be considered as an important issue as a part of the traffic safety.

(e) Prelaunch considerations and pricing systems:

It is agreed that successful bike share systems point that the needs of the users are prior to and after development. Pre-launch marketing is an important and critical action to achieve successful bike share systems. For instance, it is hard to predict bicycle availability. Thus, BIXI bike share system mentioned that implementing mobile bike stations could be helpful to relocate bicycle with the consideration of usage patterns. In addition to that, [126] stated that incremental fees of the bike share systems lead the users for short trips to avoid paying high fees. Public bike share systems have different pricing systems. For example, in China, The Wuhan and Shanghai bikesharing systems have no deposit or usage fees (Wuhan model began to charge a deposit in 2011), while Hangzhou requires users to pay a refundable deposit and adopt a gradually increasing charging system after the first free hour. Public satisfaction with bike sharing in Hangzhou is as high as %80 and is no lower than that of Wuhan and Shanghai [155].

As a result of these, operating a public bike share system for-profit may cause less service use; on the other hand, if a public bike share system is entirely free to users for a longer time, this may reduce the bicycle turnover rate. From the China sample to sum up, for the future public bike systems, the proper pricing system could be free

use for an initial period, followed by a gradually increasing pricing.

(f) Land provision for stations:

In China, the operator of Shanghai bike share system has stated that the company cannot afford to land costs because the bike stations should be placed near rail or bus stations [155]. Contrary to Shanghai, Hangzhou and Wuhan models have not faced with these problems since the government provides the land at bike share stations. For planning a successful public bike share system these issues should be considered before the pre-launch of the programs.

2.5 Bicycle Network Planning

2.5.1 Bicycle Network

While planning a cycle network, the first consideration should be defining the cyclists' needs. Because bicycle has different requirements than other transport modes. The starting point to develop a cycle network is defining cyclists' needs and the aim must be developing cycle facilities according to the locations that present high cycle flows or expected to present high cycle flows. In terms of the needs of cycling, developing connection between potential destinations for cycling by ensuring secure, adequate, and qualified infrastructure for cycle tracks is important. Not only the connection of destinations by cycle network but also the quality and security of cycle infrastructure and cycle tracks are crucial for developing an effective cycle network.

2.5.1.1 Requirements of Cycle Network

A cycle network defines the safe and direct routes which are continuous and connected with each other in a city or an area. A network is formed by routes and not by lanes or tracks. A route may consist of a cycle track, bicycle lane in a heavy traffic, segregated track, and a bus-bike lane that reaches to a railway station.

The quality of bicycle infrastructure is the essential consideration for bicycle planning. By taking into consideration the cyclists' needs to create bicycle friendly in-

frastructure, five main requirements that were developed by Netherlands should be mentioned. These requirements are safety, cohesion, directness, attractiveness, and comfort (see Table 2.2).

Safety is the most essential requirement to consider. Cyclists can feel in danger and stressed when moving in the motorized traffic because of the mass and the speed of the vehicles. Lowering traffic speed below 30 km per hour, separating bicycles from high speed and heavy motorized traffic, or defining the intersections and crossings for cyclists to protect the danger of motorized vehicles could be a way to provide safety for cyclists.

To avoid conflicts at intersections, traffic lights and facilities for traffic calming would be used in terms of safety. Secondly, the speed limit of the motorized traffic is important for cyclists' safety. If the speed of the motorized traffic is over 50 km per hour, than bicycle users should be separated from motorized traffic. Thirdly, if it is not possible to separate different users of the road, than the best is to reduce the speed of the motorized traffic. Minimizing the difference between the speed of the vehicles and cyclists is essential at the points that present a danger for cyclists. The speed of the cyclist should be used as a base. According to Deffner et al (2012) [48], for a mixed use road, the maximum speed should be 50 km per hour. But the best speed is 30 km per hour because in case of accident this causes less severe injuries to cyclists. Fourthly, making recognizable and clear road categories is necessary to ensure safety. It is easy to make predictable the potential conflicts for cyclists and other road users in the presence of road hierarchy. Lastly, the lightning of the routes is important to make cyclists safe in the dark weather. A proposed route maybe the shortest one but may be unlighted. So proposing a longer route but a lively one makes cyclist feel safe and social.

The second requirement is cohesion. Cohesion is the most required principle after safety for network planning. The planning for a cohesive cycle network refers to reaching the desired destination by cycling. Cohesion also defines the good quality of connections between networks, public transport nodes and stops, commercial districts, and residential area. It is irrefutable that the connection between bicycle network and public transport nodes and stations is the vital notion for a cohesive net-

work planning. Cohesion is important for cyclists to find easily a route that has good quality to reach the desired destination.

Travelling patterns are important inputs for planning a cohesive network by defining the most desired destinations and connections. Besides, the density of the cycling network namely mesh width is important. Mesh width defines the distance between parallel routes (see Fig 2.15). If the mesh width is larger, than the network density (the total link length per surface unit) is lower and the level of cohesion is lower. To be able to speak about mesh width, there should be a built-up area. The recommended maximum mesh width for cycle networks is 250 meters [50].

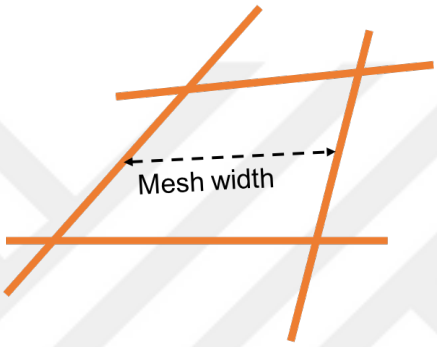


Figure 2.15: Mesh width.

Directness defines the direct route for cyclists through their destination. Network directness expresses distance and time between destinations by cycling. Cycling should have more direct route than travelling with car. So, cycling could be faster than travelling by car. To minimize the overall travel time for cyclists the route should be as direct as possible. Traffic lights, traffic volume, or stops at the crossings affect the directness of the route.

By using detour factor it is possible to estimate the directness in distance. Detour factor defines the relationship of the shortest distance over the network and the distance as the crow flies. The highest value of detour factor shows the highest directness of the network. According to the Dufour (2010) [50], in a dense cycle network, detour factor value should be maximum 1,4. As cycling should be attractive than car over short distance travelling, for a cycle network in a built-up area the detour factor should be less than one for cars.

In terms of time, directness is about optimizing the flow of traffic. The number of intersections per km that cyclists do not have right of way is applicable as an indicator. The number of intersections per km should be zero or too close to zero. Another indicator could be the stopping frequency per km. According to a study that conducted in Dutch cities (as cited in Dufour, 2010 [50]), the stop frequency is 0.40 to 1.56 stops per km for cycle networks.

The other requirement is attractiveness that includes design qualities, landscape, perceptions, image, and the security for all day long, especially at nights. These could be helpful to encourage bicyclists. The lack of attractiveness of routes could cause to discourage bicyclists. To keep minimum the conflict of motorized traffic and cyclist traffic is a way to make attractive the route for cyclists. Of course, that is not possible all the times because a major road could provide more direct connections to destinations.

The last requirement to create bicycle friendly infrastructure is comfort. Comfort expresses the cycling experiences in a positive or negative way. It is important to provide to bicyclists a pleasant, smooth, and delighted cycling experience. The materials of infrastructure, maintenance of infrastructure, and the number of stops could affect the balance of cyclists. The negative effect of a bad designed infrastructure, the material and too many stops can make cyclists mentally and physically feel tired, and stressed. Also, providing clearly seen signage for cyclists is helpful to ensure a comfortable cycling.

Theoretically, these requirements should be provided at the same time. But, in practical terms, this is not possible and may cause challenges. For instance, the most direct route could go through a busy road and this will be dangerous and less attractive for cyclists, or the most direct route goes through a public garden or a green area and this will make cyclists feel unsafe at nights. At this point, sorting the requirements could work [50]. Either for utility cycle network or recreational cycle network safety is the first priority. Cohesion, safety and directness are most relevant principles to design cycling at network level. On the other side, comfort and attractiveness are more relevant at the level of route design and road sections.

Table 2.2: The order of priority of quality requirements for bicycle infrastructure (Adapted from Dufour, 2010 [50])

Utility cycle network	Recreational cycle network
Safety	Safety
Directness	Attractiveness
Cohesion	Cohesion
Comfort	Comfort
Attractiveness	Directness

2.5.1.2 Functionality of Cycle Network

Handling cycling as a transportation mode means developing cycle network with functional trip purposes. These trips will be working, shopping, education, cultural trips, or social trips. For planning a utility or functional cycle network three steps should be taken into consideration. First step includes defining the major destinations and origins. In a city center, neighborhoods and districts would be considered as origin points.

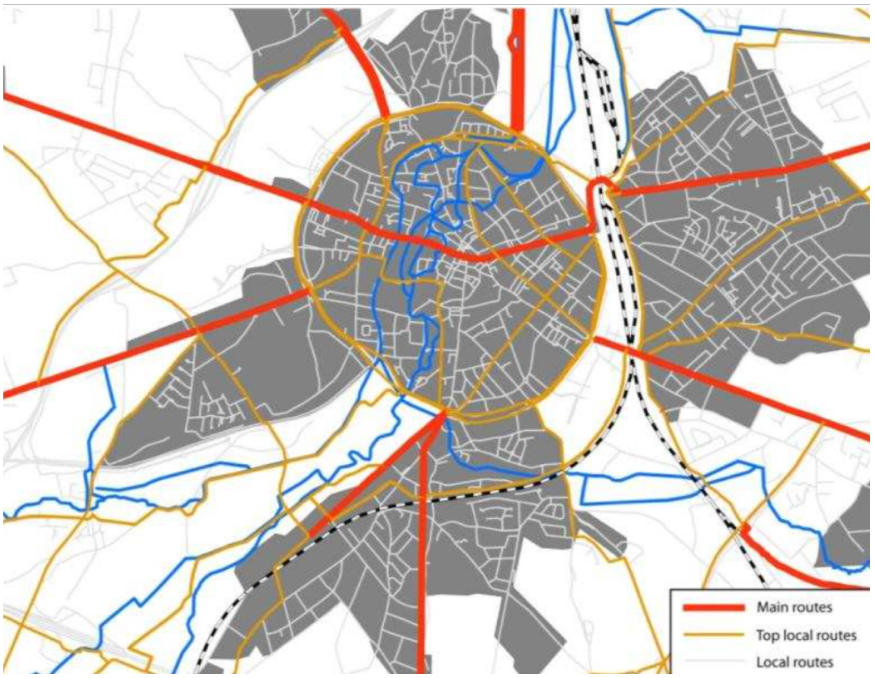


Figure 2.16: The hierarchy of cycle networks ([50]).

Main cycling destinations will be transport nodes, shopping areas, residential areas, business districts, and universities. These destinations should be linked on a map. Second step includes detailing the links with routes. The design of the routes depends on the number of the expected or current cyclists. If the number of current cyclists is available, this data will be useful for determining the routes. The third step is about the network hierarchy. Bicyclists have different needs from a cycle network. These are speed, safety, short trips, long trips, utility purpose or recreational purpose. With the consideration of these needs it is possible to categorize into three levels. These levels are main routes, top local routes, and local routes (see Fig 2.16).

2.5.2 Bicycle Facilities

Beside planning cycle network, designing physical cycling facilities is the other necessity for bicycle planning. In this part, design of physical cycling facilities are considered in four bases: route function, cycling specific facilities, designing solutions, intersections.

2.5.2.1 Design Requirements of Cycle Routes

With the consideration of cyclists' needs cycling route levels are divided into three according to functional trip purposes: main routes, top local routes, local routes. Every level has its own characteristics so every level of cycle routes need different considerations for designing. Main routes are long distance routes and named as highways. These routes for utility use connect centers 5 to 15 km, for recreational use are between city centers over 10 km to 50 km and long distance routes.

According to Dufour (2010) [50], the characteristics of main routes:

- provide maximum separation of bicycles from pedestrian and motorized traffic
- car free
- bicycle priority at crossings in quite roads
- bicycle bridges or tunnels for cyclists at crossings in busy roads

- the material is asphalt or concrete
- the width should be min 3 meters
- bicycle traffic flow for both directions

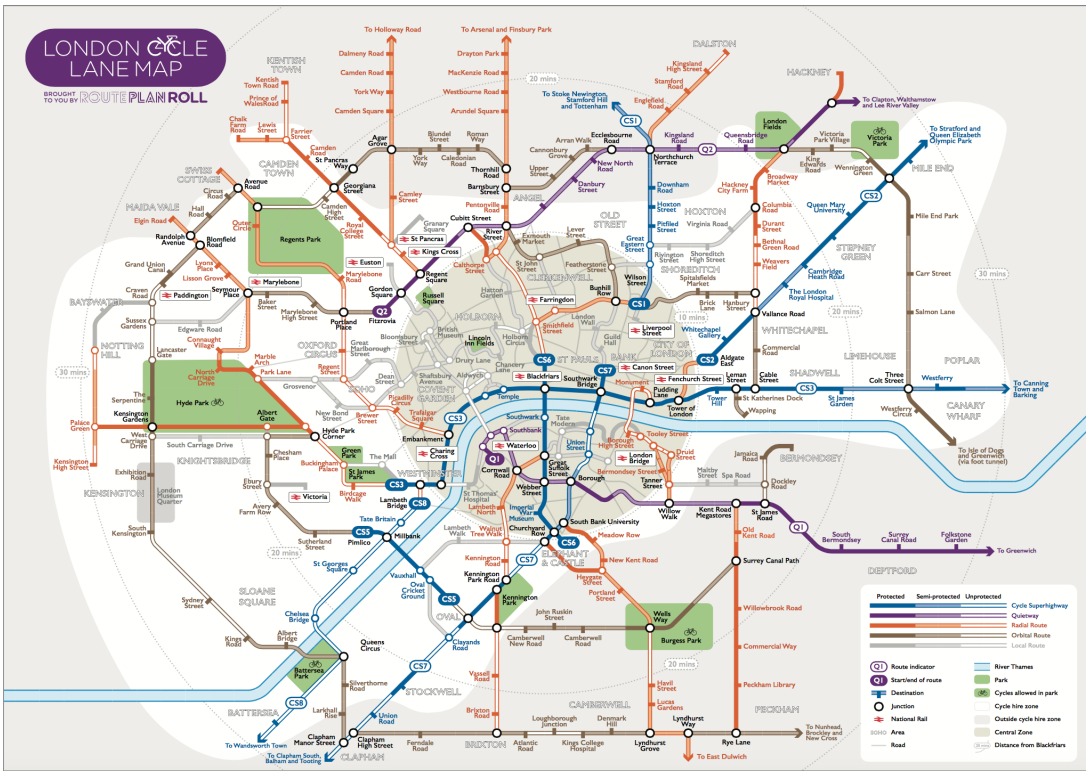


Figure 2.17: Cycle routes in London, United Kingdom [73].

The second level of route is top local routes or main local routes which ensure the fast connection between centers and districts. These routes generally take part along the roads with busy traffic. So, these routes should be bike lanes that are separated from motorized traffic. At the crossings, traffic light for bicycles and speed reduction is needed. If it is possible, separation of conflict points should be preferred. Examples of coherent cycle routes are shown in Figure 2.16. The third level route type is local routes. These routes ensure connection between neighborhoods and city districts. These routes take part in the areas where mixing the traffic is safe for cyclists.

City of London, United Kingdom, uses six measures to design cycle routes. These measurements are the volume and speed of motorized traffic, the appropriate width for bicycles, kerbside activities, minimised contact between heavy vehicles and cyclists,

minimised accident risk between cyclists and turning vehicles (see Figure 2.17).

2.5.2.2 Cycling Specific Facilities

The most common cycling facilities in general could be classified into four types: off-street path, cycle track, bike lane, narrow lane [141].

Off-Street Paths

Off-street paths are the cycle routes and separated from the street. In the U.S. it is mostly called as "shared-use paths" (see Figure 2.18). Usually they are applied along rivers, canals, rail road tracks, and parks. The design requirement for a cycle path is having minimum 3 meters (10 feet) wide to make the path available for comfortable two way cycling. Also, there should be a separated pedestrian way to avoid conflicts. Bicyclists can ride bicycles with high speeds. So, while building bike paths the important thing is the consideration of roadway engineering principles. Also, the junctions between bike path and motorized traffic at major roads, signalization must be ensured.

Cycle Track (Separated Bicycle Lanes)

Cycle tracks are physically separated bicycle lanes from the roadway. The physical separation could be implemented by raising cycle track to a higher level or by curb (see Figure 2.18). Cycle tracks ensure direct access to main streets. Cycle tracks are implemented in arterial roadways that have high speed (over 50 km/h) and volume of motorized traffic (Bikeway facility design: survey of best practice, 2010). Cycle tracks are one-way to cycle and have nearly 183 to 213 cm (6 to 7 feet) width. According to the NACTO [108] cycle tracks can be divided into three subsections: one-way protected cycle tracks, raised cycle tracks, two-way cycle tracks.

The disadvantage of cycle tracks is that the intersections constitute a problem for motor vehicle drivers, because cyclists are out of the vision of drivers due to physical separation. So, before intersections bending in the cycle tracks towards the road would be helpful. If it is needed a cycle track along a major road, than wholly segregation of cycle track and major road must be ensured for the safety of cyclists. The

distance between cycle track and major road must be between 4 and 8 meters.

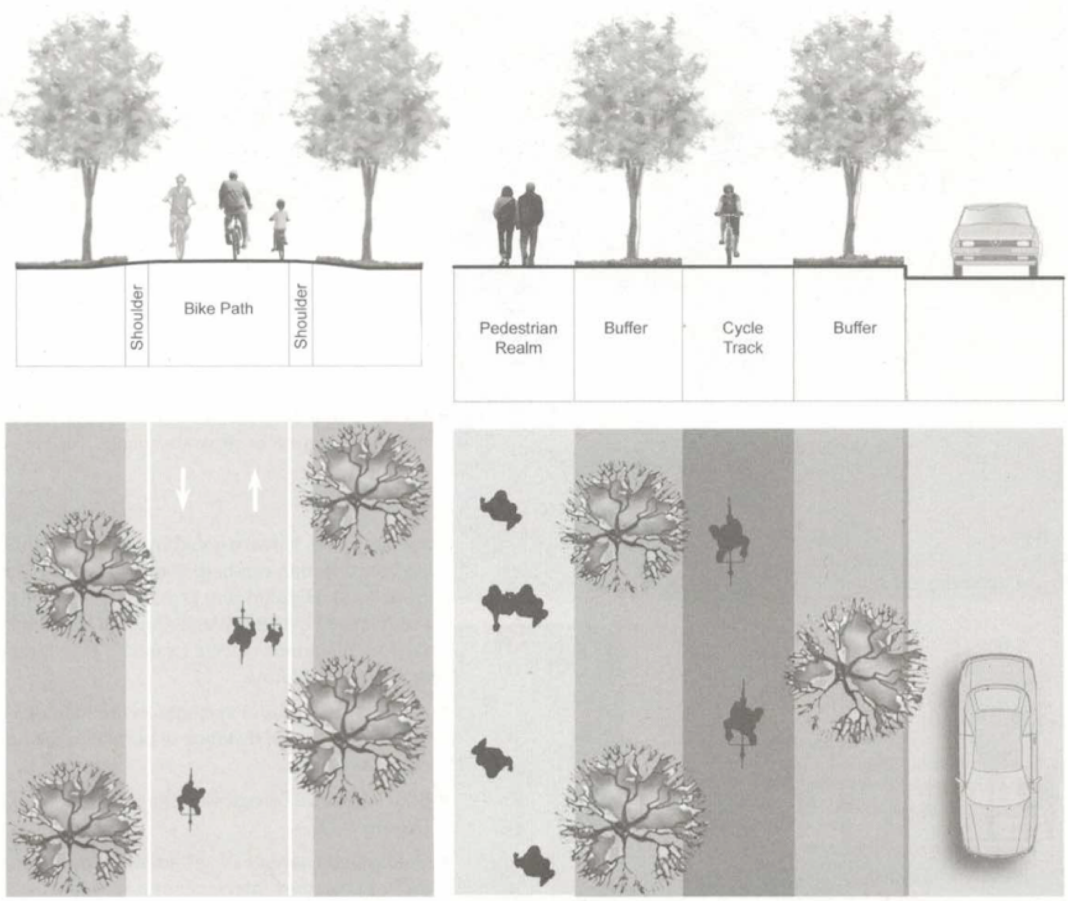


Figure 2.18: Typical bike path (left) and cycle track (right) configuration [141].



Figure 2.19: Major road and cycle track [21].

The cycle tracks should be implemented to the both sides of the road. The major roads cause barriers between two parts of the major road. So if it is needed at some points of the road, a safe cross for cyclists should be ensured (see Fig 2.20).

Bike Lanes

Bike lanes are used by bicycles specified by road markings. Riding on the bike lane is usually forbidden for motor vehicles but sometimes wider bike lanes could be used by motor vehicles. Separating the lane from the motor vehicles by grade or curb shifts the cycle lane to cycle track (see Fig 2.20). On a bike lane cyclists may feel stressed because of the thought of hitting by a car or hitting to suddenly opened door of car. To avoid the "dooring", the buffer space should be planned as 2-4 foot wide between the bike lane and car park and street. Bike lanes and conflict points are painted by green, red, or blue vary by country to enhance the visibility of the lanes.

Bike lanes are mostly proposed along the distributer roads because of the low traffic volume. The speed of the traffic must be reduced to 50 km per hour or less to implement bike lanes. Bike lanes have become an alternative when there is not enough space on the street for cycle track. But at this point providing the safety requirements is essential. Narrow streets forces motorists to drive close to the cyclists and cyclists need to cycle close to the edge of the street and parked cars. As a result of these, serious injuries may occur. When the bike lane is implemented along as a narrow lane, than speed reduction should be implemented to avoid collisions of motor vehicles and bicyclists.

Bike lanes may be implemented on one-way streets or two-way streets. When a bike lane is placed on one-way street that may be on right of the street or left of the street. Placing the bike lane on the right side of the street is better in terms of avoiding conflicts on bus stop, and car parking.

Narrow Lane

When the street is too narrow to build a bike lane, using traffic calming and giving priority to bicyclists could be a solution for safety of cyclists (see Fig 2.20). In a narrow lane motor vehicles could not pass bicycles if they do not slow down. A narrow lane should be maximum 3 meters and the traffic speed have to be less than

20 km per hour.

Narrow lanes are not shared lanes. Shared lanes present danger for cyclists if the speed of motorized vehicles are calmed.

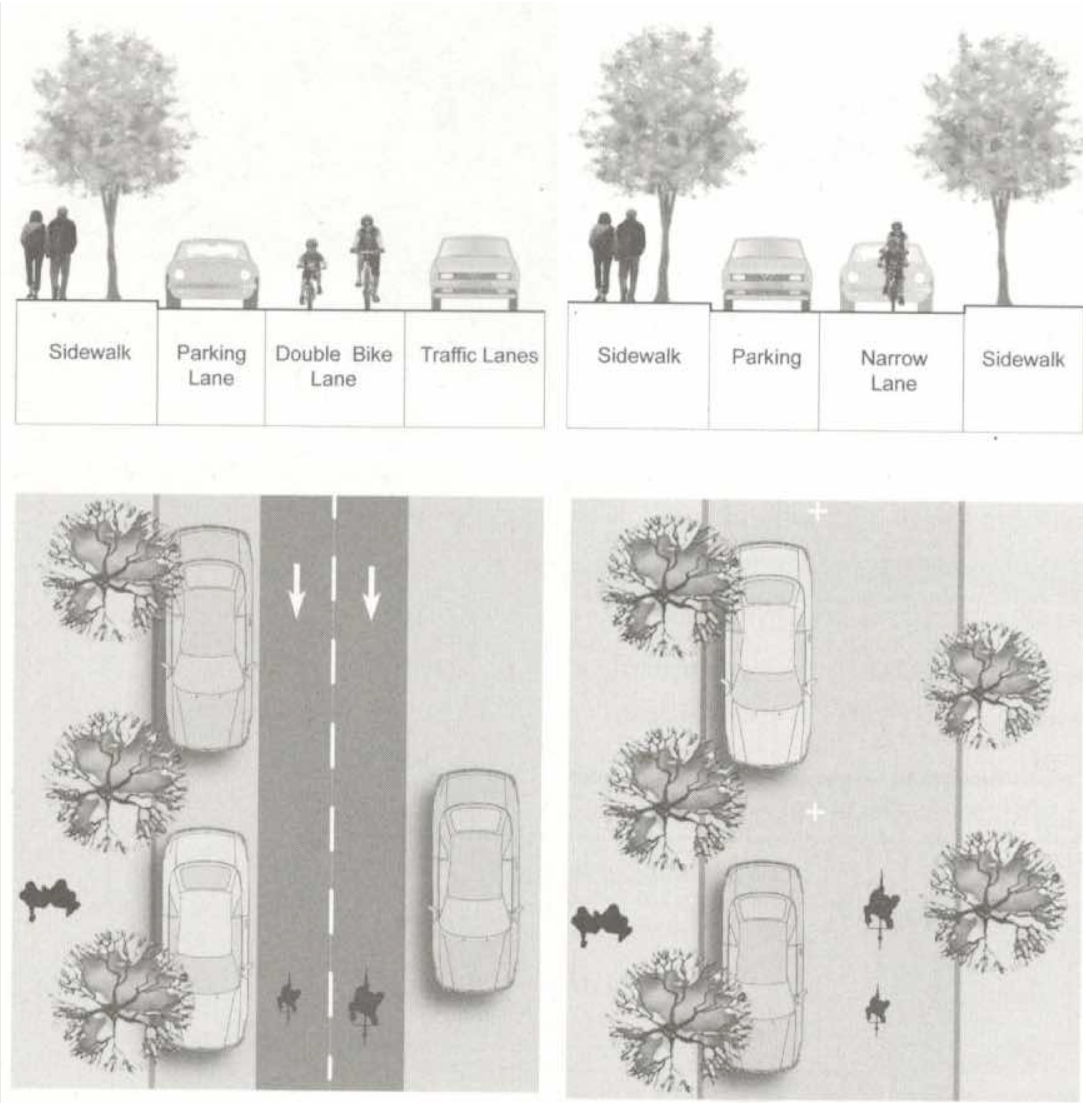


Figure 2.20: Typical bike lane (left) and narrow lane (right) configuration [141].

Cyclists' speed typically is between 5 mph and 20 mph. If the speed differential is less than 12 mph, then it is desirable for cyclist to use the road without any regulation. That defines narrow lanes. If the speed differential is greater than 25 mph, then a cycle track or buffered bike lane is appropriate. When the speed differential is between 12 mph and 25 mph, normal bike lanes are acceptable (see Table 2.3).

Wramborg's model for fatality probability vs. vehicle collision provides information about the probability of fatal injuries (see Figure 2.21). When vehicles are at the 30 km/h speed, there is 10% chance of fatality for cyclists [89].

Table 2.3: Bicycle facility selection based on speed differential [141]

Auto Speed	Narrow Lane	Bike Lane	Cycle Track
$\geq$ 40 mph		x	xx
30 mph		xx	x
$\leq$ 20 mph	xx	x	

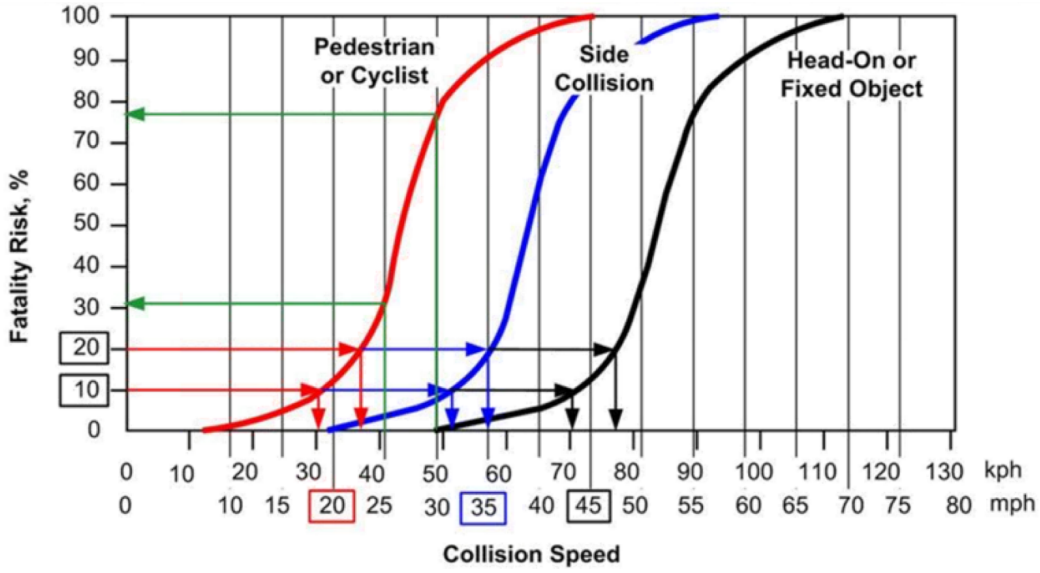


Figure 2.21: Wramborg's model for fatality probability vs. vehicle collision speeds [42].

2.5.3 Other Bicycle Facilities

Bicycle Boulevards

Bicycle boulevards are low-speed and low-volume streets and are prioritized for cyclists. Bicycle boulevards are traffic calmed streets. By using pavement markings, signs, and speed management, bicycle boulevards create a continuous bike route (see Figure 2.22).

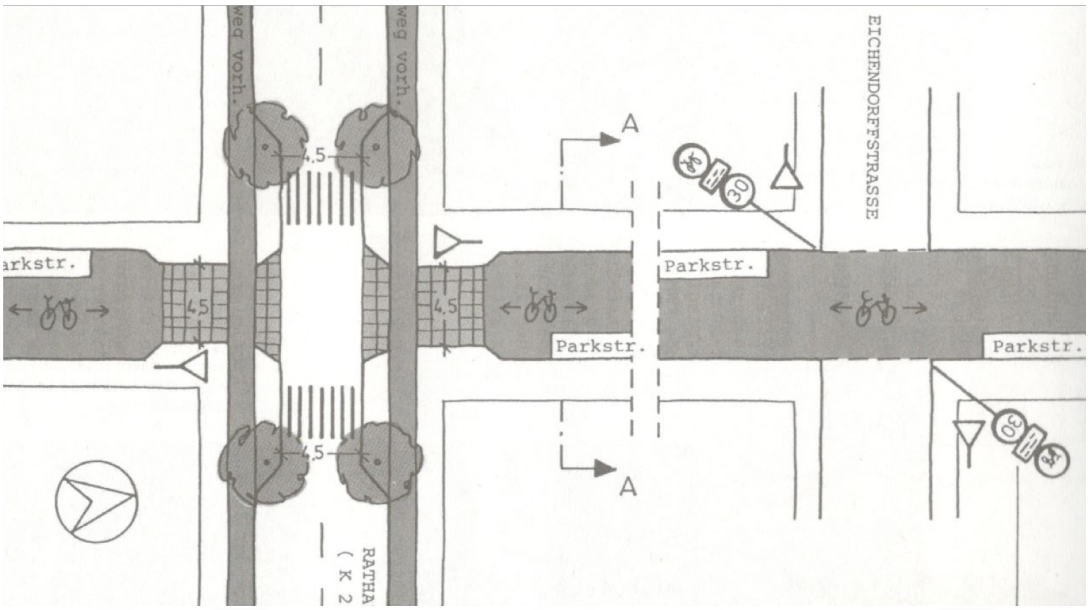


Figure 2.22: Typical bike boulevard organization [141].

Bus/Bike Lanes

Bicycles and buses can be mixed when the speed of the motorized traffic is under 30 km/h. Bus bike mix should not be preferred because speed and breaking distance of the buses create danger for cyclists. Mostly to reduce the travel time for buses special bus lanes are preferred. This lanes provide shortcuts for buses. These shortcuts provide an advantage for cyclists too. They could pass without waiting on the car queue by using these shortcuts. In such cases safety of cyclists must be provided. To provide bus and bike mix, the bus lane have to be wide enough for buses to overtake bicycles and the speed of the buses have to be below 30 km/h. However, cycle tracks and bike lanes must be the first choice for safety and comfort of the bicyclists. So, preferably bike routes should be separated from bus lanes to ensure safety for cyclists.

Advanced Stop Lines for Bicycles

An advanced stop line provides cyclists a safe waiting area at intersections before they turn to left. Also an advanced stop line helps cyclists to pass without waiting on the car queue at intersections and turn left safely at green light. To implement an advanced stop line, the speed difference at intersection should be less than 50 km/h.

2.5.4 Intersections and Junctions

Intersections need more care than other bicycle facilities. Because of their very nature, most of the conflicts and accidents occur at intersections and junctions. According to CROW [48] 58% of these accidents occur at intersections in built-up areas and 95% of these happen at intersections with 50km/h roads. Intersections contain motor vehicles as cars, trucks, buses or trams and other users as bicyclists and pedestrians. These different users have to be directed at intersections. Controlling the intersections avoid the accidents caused by motor vehicles hitting bicycles.

While designing crossings and intersections, the safety of turning right and left must be ensured. The design should vary according to the function of cycle route, intensity of motorized traffic, and speed on the road.

Briefly, there are three considerations while designing intersections for cyclists. These are safety, directness, and comfort. To ensure the safety at intersections, visibility is the key term. Motorists must have a clear vision to see cyclists. Secondly, the speed of the motorized vehicles should be minimized as closed as to cycling speeds of 20-30 km per hour. Thirdly, bicycle specific regulations should be implemented such as cycle stocking lanes, advance-stop lanes, cycle bypasses, and traffic islands.

The second consideration of designing for cycling at intersections is directness. The waiting time at the intersections is really impactful on the travel time of cyclists. The design of the intersections should be considered so as to minimize waiting time. The measures to minimize waiting time are right of way for bicyclists, green wave at traffic lights, remote cyclists detection at traffic lights, central traffic islands, and direct crossing at the intersections. Lastly, comfort of the cyclists should be taken into account. It is about curve radii that allows cyclists turn easily. Applying the curve radii at intersections helps cyclists without slowing down and being forced out their path [50].

There are three principles to consider while planning intersections: function, form, use. Function principle defines that the design of intersection must be understandable for all users of the road. Form of the intersection requires road hierarchy and uniformity. Road hierarchy should be recognizable for users and should make users

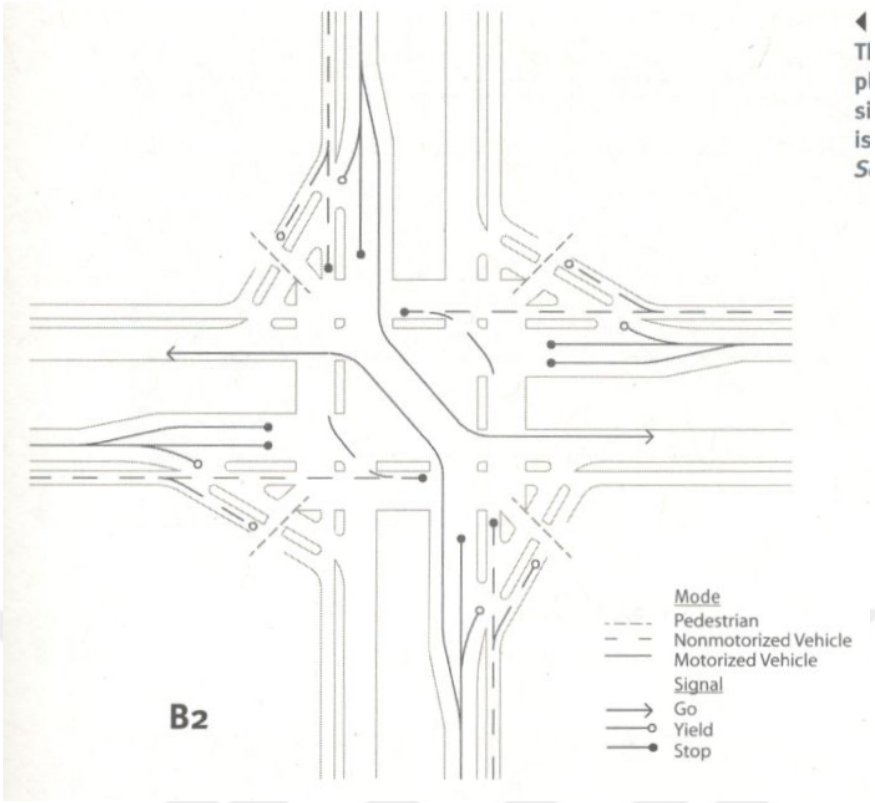


Figure 2.23: Separation of non-motorized and motorized vehicles at intersection [141].

to understand clearly the intersection uniformity. Form of the intersection depends on road hierarchy and traffic volume. To apply the use, the speed should be at the minimum speed of each participants during the interchange.

To handle large intersections, the safest way is to take them by dividing into small parts. These are turn lanes, medians, refuge islands. Also, signal systems are very helpful to increase the visibility of cyclists.

While designing intersections for cyclists prioritizing all turnings for cyclists and implementing specialized facilities for cyclists might cause complexity. The best way to apply the principles is providing traffic calming and providing eye contact between motorists and cyclists. According to Tumlin (2012) [141], there are some key intersection design considerations. These are:

- Ensure to maintain clear sight lines for motorized traffic and make cyclists vis-

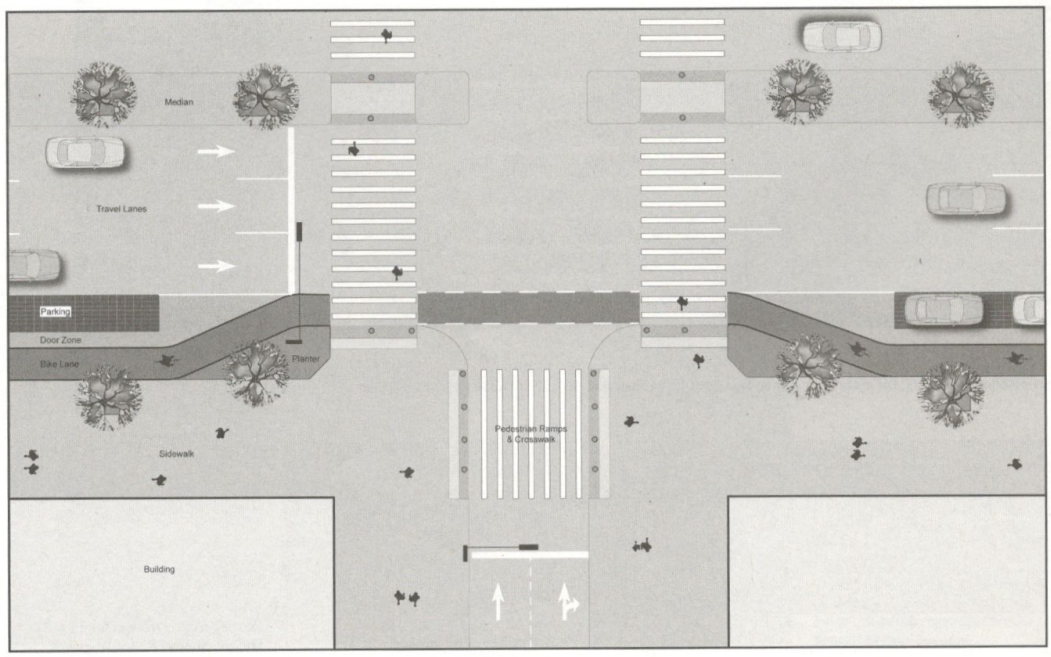


Figure 2.24: Cycle track organization through a junction [141].

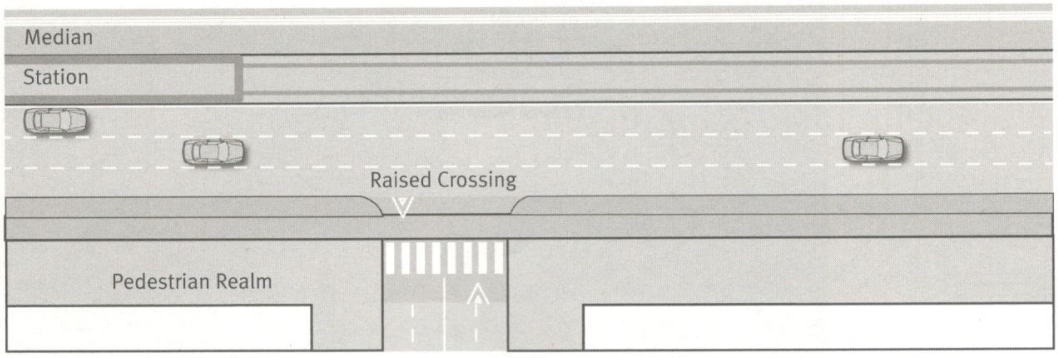


Figure 2.25: Cycle track through a miner junction [141].

ible at junctions.

- Ensure that motorists turn slowly with clear sight to give priority to cyclists.
- Provide a bike box for cyclists at the intersections ahead of motorists to increase safety.
- Provide queue space for cyclists at intersections to turn left. That will inform the motorists about why cyclists wait there.

- Limit right turns on red for motorists besides providing bike boxes and queue space.
- Provide bicycle signals at complex intersections
- Separation of bicycle facility from traffic flow is needed to be handled very carefully by providing adequate sight line for both motorists and cyclists and providing signalization to prevent conflicts between all users.

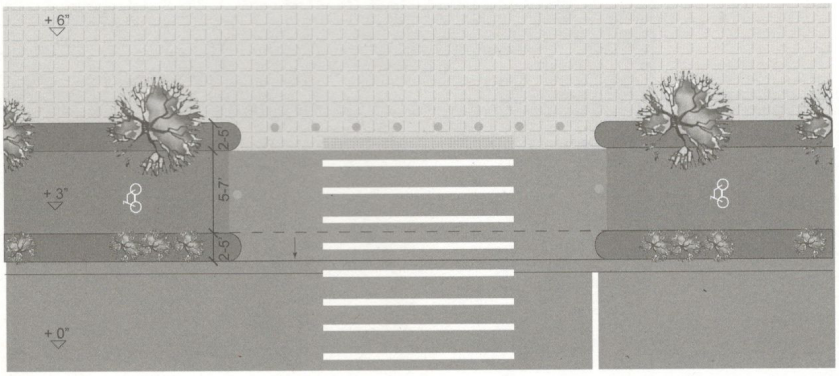


Figure 2.26: Crosswalk and cycle track junction [141].

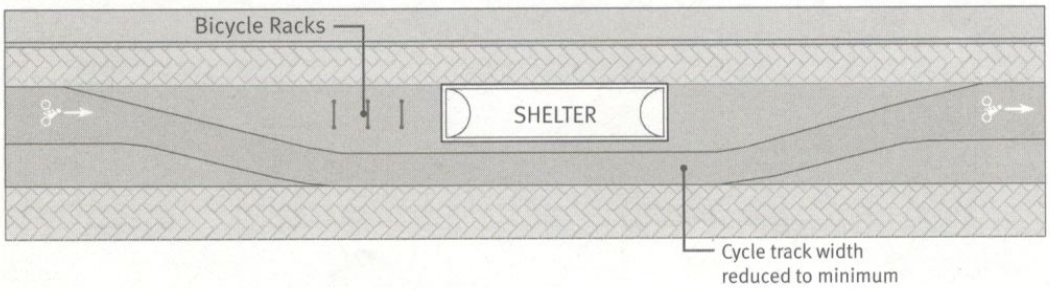


Figure 2.27: Cycle track route and bus stop configuration [141].

Dividing large intersections into small parts includes separation of signal operation too. It is important to take into account that the travelled way is defined by these divided islands (see Figure 2.23).

At a junction continuousness of a cycle track and safety of the all users, cyclists, motorists and cyclists, have to be ensured (see Figure 2.24). On the other hand, at a minor junction a cycle track should be prioritized with a raised crossing (see Figure 2.25).

If there is a midblock crosswalk, than pedestrians have priority on cycle track or bike lane (see Figure 2.26). If there is a bus stop through the cycle track route, cycle track should go behind the bus stop (see Figure 2.27).

2.5.5 Bicycle Parking

Bike parking and storage is an essential part of bicycle network. Bicycle is a light non-motorized vehicle and occupy a small space. The first consideration is bicycle theft. Ensuring a secure bike parking is the most important issue besides providing safe cycle network. The existence of a secure bicycle parking at destination encourages bicycle usage. The second consideration is the management of the bicycle parking at a public space such as transport nodes, railway stations or metro stations in the city center. The organization of bicycle parking at these spaces is important so as not to create conflict for pedestrians.

Bicyclists need a convenient, secure and protected bicycle parking. They want to park their bicycle as near as possible to the destination that they arrived. Also, they want to park their bicycle into a secure and protected bicycle park. So they could get back their bike without damage and dry.

The management of bicycle parking could be handled by the consideration of parking durations as short term parking and long term storage besides cyclists needs. Short-term parking facilities makes available cyclists to keep eye contact with their bicycle. When cyclists stop for a quick shopping they do not want to tackle with locking the bicycle and they want to be as close as possible to their bicycles.

For long-term storage cyclists need security and not speed or proximity. Cyclists needs a bicycle parking area with high security level near to their work or home for a day long or a night.

There are some considerations to specify the location of the bicycle parking. For a successful integration of bicycle with public transportation systems, the location of bicycle parking is important. The location of bicycle parking must be in the places where people study, work, shop, and live. To specify a bicycle parking observation, access, visibility, security, lightning, and weather have to be considered. The first

consideration is the observation of where cyclists park their bicycle, and survey with cyclists, and cyclist groups. Secondly, accessibility of the bicycle parking is important. To achieve this consideration, bicycle parking should be located as close as possible to the entrances of buildings without causing a conflict for pedestrians, and when there is no available place on the sidewalk then car parking spaces should be replaced with bicycle parking. Thirdly, to avoid from theft, bicycle parking should be located in a place with high and clear visibility, or near to car parking with security, or security cameras should be installed. Also, bicycle parking area should be well lighted to ensure security of bicycles at night, and bicycle parking area should be protected from bad weather conditions. Land-use and geography are the variables that affect the amount of bicycle parking. The required number of bicycle parking spaces are shown in Table 2.4.

Table 2.4: Bicycle parking per land use [141]

Land Use	Number of Bicycle Parking Spaces /Land Use Units	Provider
Residential (multifamily)	1 space per 3 units	Private developer
Commercial /retail	1 space per 4,000 square feet of leasable space	Private developer
Office	1 space per 5,000 square feet of leasable space	Private developer
School	1 space per 10 students	City /school
Park	1 space per acre	City
Recreation center	1 space per 1,000 square feet of usable floor area	City

Bicycle parking types could be investigated in three categories: (a) racks, (b)lockers, and (c) garages and shelters. Bike racks could be sheltered or unsheltered. Unsheltered bike racks mostly, placed on sidewalks, open parking lots, and plazas. The most effective bike racks should be support bicycles, should be anchored and should allow to lock both wheels of the bicycles. Bicycle lockers ensure high level security than bike racks. They protect bicycles from bad weather conditions. Bike lockers could be locked via electronic card locks or single-key individual long term use and provide a daily or longer term parking. Bicycle garages and shelters occupy more space than bike racks. The installation cost of the garages and shelters are higher than the cost of locker. Bicycle garages consist from bicycle racks that are fully or partially enclosed.

2.6 The Effect of the Natural and Built-up Environment on Bicycle

Bicycle and Natural Environment

There is a prejudice about cycling such that cycling is appropriate in flat countries with mild climate. On the contrary, cycling mode share could be high in countries that are not flat and have cold climate. For instance, Sweden has a cold climate. In Västerås, Sweden, mode share of bicycle is 33 percent. In Basle, Switzerland, the mode share of bicycle is 23 percent. Basle is located on banks of a curve in Rhine.

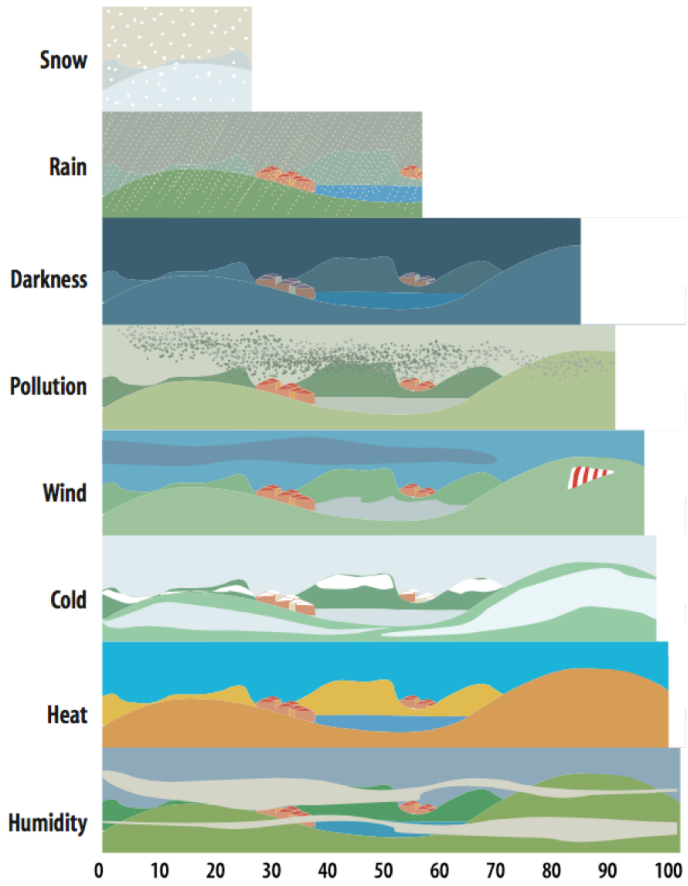


Figure 2.28: The influence of atmospheric conditions on cycling [49].

In Bern, Switzerland the mode share of bicycle is 15 percent and most of the roads have 7 percent gradient. In United Kingdom, averagely 156.2 days per year [144] it rains and the rainy weather is unpredictable. Even so, in Cambridge, UK bicycle mode share is 27 percent.

Denmark and Netherlands are two most popular countries with cycling. They in general have flat topography type but, there are strong winds both in summer and winter months. Because of strong Atlantic low-pressure systems, Netherlands faces with strong gales, and winds. Likewise, Denmark is buffeted by strong winds. These strong winds create challenges for bicyclists such as much more energy to cycle. These challenges do not prevent the countries from cycling. To cope with bad weather conditions, suitable clothes for this such as a rain jacket, or waterproof trousers could be helpful. Also, after a few minutes of cycling, it will helpful to feel warmer on a cold day. Besides the suitable clothes, suitable infrastructure could cope with negative impacts of weather conditions. Coordinating cycling and public transport stops and nodes is a way of coping with bad weather conditions.

Bicycle and Urban Form

In a dense land-use city, the distances between activity areas will be short. On the other side, in a sprawled city, cycling could not be able to compete with other transport modes because of the long distances between activity areas. Therefore, it can be said that land-use patterns are really important determinants of cycling because these patterns are really hard to be changed or overbuilt. This condition affects building adequate and safe bicycle infrastructure. Compact cities can have advantages on increased demand for accessibility with increased specialization of production and market. On the contrary, low-density areas needed to increase more the specialization of production and market to achieve aimed increase in accessibility. With the increase of trip distances incline to make powerless the capacity of bicycle to compete with other transport modes. Land-use planning with aiming to generate compact cities is the prior condition for preventing accessibility demand from causing more long-distance trips. To tackle with these challenges, a growing city with consideration of the measures and land-use patterns should be planned more densely [52].

2.7 Bicycle and Socioeconomic Factors

There is a prejudice such that the bike is for low income group because the affordability of bike is cheaper than other transport modes, especially then automobile. In fact,

when we analyze the European countries, for example, Copenhagen or Amsterdam, cycling is a leisure time activity for everyone and a transport mode for commuting. In Amsterdam, the cycling mode share of commuters was %34 in 2009.

According to a study conducted in Sweden, the most crowded cycling group of people consists of young and low-income ones. This could be seen as the result of the lower availability to access to automobile. Also, as a foresight, it can be stated that an increase in automobile ownership will cause decrease in cycling. But, in Stockholm, the capital of Sweden, with the increase of automobile availability for young people, cycling level is also increased too. In the study, the reason has shown that the availability of automobile is relevant to the location of residents. For example, in the uptown, automobile ownership is higher [52]. Consequently, there is not a direct relationship between income and cycling mode share. The age factor and location of residents should be considered to be able to speak of the relationship between income and cycling. In fact, in this consideration bicycle culture is more effective than these factors.

About the cultural factors, Parkin (2012) mentioned about the status effect. Until for a few decades, bicycle used to be seen as a low status travel mode. But, the thoughts about automobile used to be as a high-status travel mode. So, if a person could not afford to own an automobile, then thought to buy a bike and cycle to work or to leisure activities. Further, if a person could afford to live in a house in city center or near, could think cycling to work, but if could not afford to live in there, then prefer to live in suburban and buy an automobile. Because the cost for owing an automobile and living in suburban is much more cheaper than buying or renting a home in the city center. But, with the increasing popularity of fitness and health-consciousness changed the state of bicycle in a positive way. The promotion of cycling out of the city center, such as in sub-urbans could be achieved by integration of public transport and cycling towards sustainable mobility.

CHAPTER 3

INVESTIGATION OF BICYCLE TRANSPORT IN SELECTED CITIES

3.1 Introduction

To succeed on bicycle planning as a part of sustainable mobility in terms of city planning, the case study cities investigated in the content of the four main considerations: policies and planning, land use and public transportation: mode shift, usage of technology, public acceptability. The analysis of the case study cities is not only aimed to investigate how to endure the existing cycling condition but to be a guide for bicycle planning in terms of sustainable mobility.

3.1.1 Data Gathering and The Features of the Case Study Cities

Cycling in a large city is different than in small cities in some conditions. In large cities there are always various educational level, incomes, races/ethnicities, younger population and life styles ([16], [113]). Furthermore, Large cities are leading and spreading about economic and social trends through the country. Transportation systems, infrastructures, and land use patterns in large cities in general discourage cycling ([17]). Also, of course congestion is not just a problem for big cities, it is a problem in the areas of ever size. The problem could be even worse in the regions over 1 million populations [134]. But the congestion could be more problematic in big cities due to higher motor vehicle traffic volumes. The distances of trips are longer based on the greater areas in big cities. Lastly, in general, public transportation services are more extended and provide more competition to cycling in larger cities ([17]).

Large cities show benefits besides challenges to cycling such as that benefit from the economic and environmental advantages cycling has to offer. Bicycles requires less space in traffic and also for operation and storage than motor vehicles. This might help to reduce the congestion in traffic in peak hours. As the supply of bicycle infrastructure is less expensive than motorways, the shift form car dependent transportation to cycling might provide financial relief to big city governments (Buehler and Pucher, 2012a). Due to the fact that bicycle is affordable for everyone, supporting cycling reveal the potential to provide mobility for low-income households that are frequently concentrated in large cities [130], [150].

The case study cities to examine cycling trends within sustainable mobility measures has been chosen among United States, Europe and Northern Europe. First case study city Portland is from a car oriented country United States, the second one is Paris from France where has no history of utilitarian, daily cycling, and the last one is Copenhagen from Denmark where have a historical cycling culture. United States and France greatly increase cycling levels in their major cities instead of not having a cycling culture. On the other side, Denmark improved existing cycling infrastructure and increased already high cycling levels.

Data gathering for the case study city analysis are from (1) State, local government, and municipality statistics and reports; (2) transportation plans, bicycle plans, official documents, and transportation sections of each city's municipalities official website; (3) national level cycling organizations and research centers.

The investigation of case study cities divided into four main titles. These are (1) planning and policies, (2) public transportation, (3) bicycle network, (4) public acceptability. While examining bicycle networks in case study cities, the major transit stations and cycling facilities are visually observed to analyze the essential requirements of bicycle network planning among case study cities. The transit stations chosen among the major transit stations in the case study cities. It is important to develop connection through transit stations for cycling by ensuring secure, adequate, and qualified infrastructure for cycle tracks. Not only the connection of destinations by cycle network but also the quality and security of cycle infrastructure and cycle tracks are crucial for developing an effective cycle network. The visual analysis at the chosen transit sta-

tions of case study cities has been made by visual observations by using google earth and google street view with the consideration of essential requirements of bicycle network: safety, directness, cohesion, attractiveness, and comfort.

3.2 Copenhagen

Copenhagen, the capital city of Denmark was founded around 1160. In Copenhagen the metropolitan area population is 2.057.737 and city population is 623,404 by 2019 [129]. The first bike path was implemented in 1892 and by 1910, the first separated bike paths were built. In 1890 there were 2,500 bicycles in Copenhagen, and in 1907 the number of bicycles had reached to 80,000.

In 2015, Copenhagen city council was announced their goals as becoming a hub for international investment and knowledge and becoming the world's best bicycle city. Also Copenhagen municipality were planning to make the city CO_2 neutral by 2025.

Even though ambitious goals were presented by Copenhagen municipality, the City accepted as the most bicycle friendly city internationally [43]. In Copenhagen 1.39 million km per day cycled in 2017 and bicycle share of trips to work or education was 43% in 2017 [27].

According to the "Copenhagenize Index" in 2017, Copenhagen holds the first place due to investments and innovations in the city. The ranking system is based on 14 parameters that include safety, cargo bikes and logistics, bicycle culture, facilities, infrastructure, bike share programs, gender split, advocacy, modal share for bicycles, social acceptance, urban planning, and traffic calming. Copenhagen invested in to the new bridges designed for bicycles. Some of these bridges are already built or under construction. These bridges for bicycles fills the missing mobility links for bike transportation in Copenhagen. Also, since 2015, the City has piloted Green Wave system, launched digital traffic congestion signs, and opened new bicycle superhighway routes.

The City of Copenhagen have a bicycle friendly culture for decades. Jan Gehl who is a urban designer and architect influenced bicycle culture in Copenhagen. His stud-

ies mostly focused on cyclists and pedestrians in terms of reorienting the City. The term “Copenhagenization” is defined by Jan Gehl represents design approaches to make cities more accessible by cycling [86]. Also, advocacy groups are affected the bicycle culture with influencing the City’s decisions by giving a change to express themselves.

In Copenhagen, the Cycling Embassy of Denmark is developing cycling strategies and promoting cycling by cooperation with governmental agencies, non-governmental agencies and private companies. The City, considering the high interest in cycling, organized a bicycle planning team from city planners who are focus to implementation of bicycle planning projects (Breukel, 2010, as cited Gunn [65]). Also, these bicycle planners ensure the public participation with plans and proposals for plans with online and open access [45].

In the City of Copenhagen, children know how to cycle before beginning kindergarten. It could be said that bicycle is integrated with culture of the City. Also, the cyclists are educated on how to cycle safely in motorized traffic, and traffic laws (Breukel, 2010, as cited Gunn [65]).

Most of the residents of Copenhagen have knowledge of environmental sustainability. The City aims to be carbon neutral by 2025, lower the overall energy consumption and improve green mobility. These goals are not just the City’s goal but also the residents’ goal. It stated that, taking care of the environment is a shared responsibility of residents who must effort to be ecologically sustainable. Because the aims of the city are transparent, most of the immigrants shares the same values as residents [25]

Planning and Policies

In Copenhagen cycling is implemented into city planning and integrated with traffic planning. The bicycle network was completed between 1960s and 1970s. In 1997, The Traffic and Environmental Plan mentioned to link up cycle routes through, develop green cycle routes, improving bicycle parking facilities, and extend the City Bike Project among residential areas. The aim of the plan is addressing increased public transport and cycling not motor traffic for traffic growth. Meanwhile the city passed the first Cycle Track Priority Plan. Also, in 2000, Green Cycle Routes plan

was proposed. In year 2002, a subplan to improve cycling conditions was published. In this plan for the first time bicycle traffic development mentioned for the first time [22].

In 2001, the City developed a traffic safety plan. This plan aims to reduce cyclist causalities by 40% between 2001-2012 [22]. At the end of 2001, in the City, 9km of bike lanes and 307 km of bicycle tracks were built. By the year 2011, "Good, Better, Best-The City of Copenhagen's Bicycle Strategy 2011" was published. The goal of the publication is to highlight what is required to increase the modal share for bicycles. This publication has these keywords: sense of safety, quick, comfortable, and lifestyle and image. These keywords were addressed as themes to be improved through prioritizing and innovation.

To achieve the goal that creating the world's best bicycle city and encouraging more people to cycle, the strategy of the City aims to improve the marketing related to image, lifestyle, and the advantages of cycling in Copenhagen. Also, the plan aims to enhance campaigns as "Your Bicycle City, Your Mother's Bicycle City" to encourage a sense of ownership. In the city even if the cyclists are generally satisfied with cycling in the city, in some areas these satisfaction is falls. As the City aims to have more people cycling to work and study in 2025, the satisfaction level must be increased by improving comfort level. To achieve this goal, the plan [23]. includes smoother asphalt on the cycle tracks, effective bicycle parking, parking, changing rooms, bike repair, and bike services as air pumps fountains, weather reports. The City of Copenhagen aims to complete PLUSnet for cyclists by 2025. PLUSnet contains Bicycle Superhighways and Green Routes and most congested cycling routes. PLUSnet project aims to ensure secure and comfortable cycling in the city. The map in below shows the PLUSnet network's improvements between now and 2025.

In Copenhagen, the main reason 48% of cyclists prefer ride bicycle is easiest and fastest way to travel in the city. As travel time is related to speeding, the City is planned to provide the shortest possible travel time from A to B. In order to achieve this goal, it is planned for 2025 that long distance commuting, promotion of e-bikes, real-time traffic information via digital platforms, bicycle superhighways, small and large short cuts, green waves for cyclists, new cycle tracks, traffic calming, speed

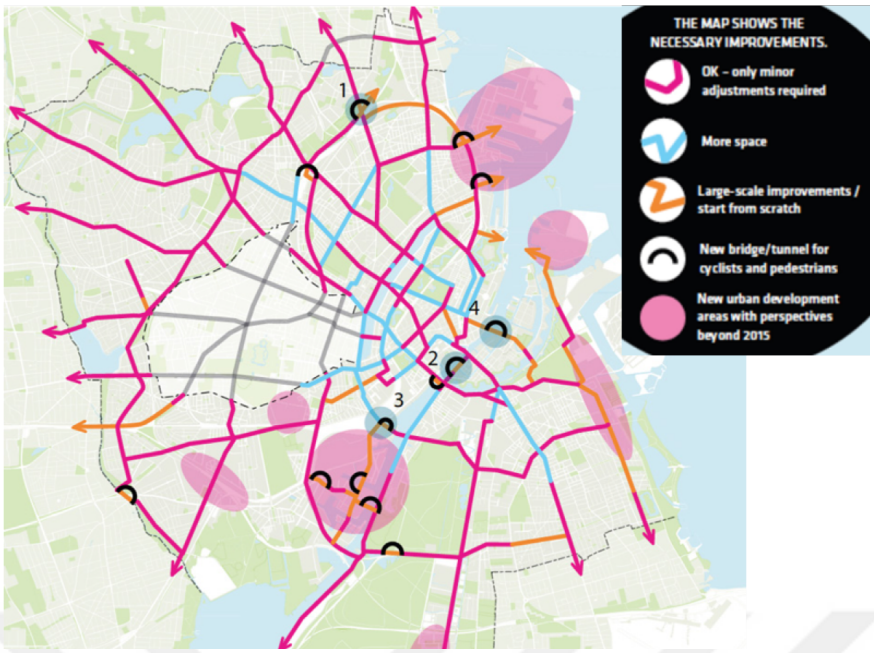


Figure 3.1: The PLUSnet cycle network Development Strategy Map ([27]).

bumps, better integration of metro, train, bus and bicycles, a bike share program, better bicycle parking facilities at transit stations. On the other hand, the city government plans to reevaluate land uses in the City for increased population density [23]. The goal about cycling for 2025 is that increasing work and educational trips by bicycle to 50%.

In Copenhagen, there are 76 off-street bike paths and cycle tracks per 100,000 residents and, 4 on road bike lanes per 100,000 residents [27]. Bicycle network comprise of separated bike paths and cycle tracks. The tradition of the separated bike paths and cycle tracks are dating to 1930s [22]. The cycle tracks are separated from motorized traffic and integrated to the public transportation ensures an extensive cycling network. At the most part of the bicycle network in Copenhagen, cycle tracks are implemented between the roadway and sidewalk on both sides of the street. The wide of the cycle tracks are 2,2 and 2,5 meter that are mostly curb elevated between 7-12 cm. Along the busy corridors, the wide of the cycle tracks are 3 meters ([22], ([24].

Copenhagen has 400 kilometers of cycle paths which separated from car lanes and sidewalks. The City enhanced 117 most important intersections for cyclists. These intersections have traffic signal priority, special blue markings for bicycles, and ad-

vance stop lines. The city also synchronized traffic lights for cyclists to provide green wave at major arterials (City of Copenhagen 2010a). The bicycle network of Copenhagen provides cyclists a comfortable riding without mixing with heavy car traffic volume. Also, in Copenhagen there are 6, 960 bicycle parking spaces per 100,000 per residents [26].

Public Transportation

The first finger plan was developed in 1947 and published in 1948 as a regional plan. In this plan, it is aimed to (i) urban growth is planned along the city fingers to link rail way system and radial road network and (ii) separate the development areas along city fingers with green wedges [45].Briefly, the development of the urban area was planned along five suburban railroad. Between these railroads, these green wedges were ensured as recreational areas. This plan influenced the later regional plans and development in the region.

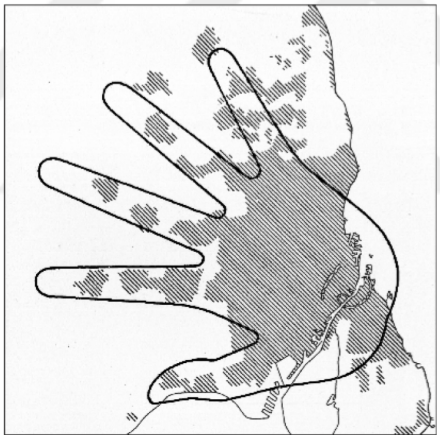


Figure 3.2: Sketch from the first Finger Plan created by the Regional Planning Office in 1947 [45].

The finger shape city structure has led the traffic smoother in Greater Copenhagen and has make the public investments in traffic infrastructure. Also, the plan influenced the prevention of urban sprawl and protect the recreational area between the city fingers [45].

Copenhagen follow ups the principles for dense and sustainable city around stations. These principles are focused on the public transport and cycling and prevention of

urban sprawl through open and green spaces on the basis of urban development in the City. This attitude supports the goal that creating the world's best bicycle city.

In Copenhagen, there are five types of public transport. These are: Buses, the metro, S-trains, long-distance trains and Bycyklen. In the city there are three type of busses: A-buses, S-buses and night buses. The A-buses are the primary buses in central Copenhagen and drives for every 3-7 minutes during rush hours. The S-Buses are faster than A-buses with fewer stops but run less frequently. All public transport modes have same ticket system in Copenhagen.

Copenhagen metro has two lines as M1 and M2. The metro system is going underground. New metro lines and stations are under construction and planning to be open in 2019. About the S-trains run in the Greater Copenhagen area. S-trains run frequently and have so many stops. In Copenhagen, bikes are allowed for free on S-trains. This already attract many people to combine public transport and bicycle for travelling between work and homes.

According to Cycling Embassy of Denmark, 30% of commuters use bicycle between their homes and transit station, and 10% use bicycle between the transit station and their homes. The cycle trip to and from the station is approximately one to three kilometers. According to Center for Transport Analytics data [137], in Copenhagen, to and from home mode shares stated as walking 49%, cycling 27%, car 8% and bus 16% and to and from destination mode shares are stated as walking 75%, cycling 10%, car 3%, and bus 11%.

The city also has been emphasized bicycle-train integration with digital journey planners to compete with other transport modes in the city [124].The City of Copenhagen mentioned the factors that affects the extent of the bicycle-train trips the factors are depend on railway factor as, travel time, frequency, comfort and reliability context factors as culture, demography, local status of cycling, and lastly first and last mile factor as the bicycle parking facilities at the station, the quality of the cycle link to and from the station.

To travel with bike on the Copenhagen Metro and regional trains a bike-ticket is needed. During peak hours bicycle not allowed on the Metro. A reservation for



Figure 3.3: Central bicycle facility at the Lyngby Station in Copenhagen [124].

travelling with your bike is not required. Intercity train require reservation to travel with a bicycle because the capacity is limited for bicycle on these trains. As a part of bicycle public transport combination, in Copenhagen some of the station have a central bicycle parking facility. For instance, Lyngby Station in Copenhagen have spacious bicycle basement in the building. That has a good access to roads. Besides this, the city implemented bicycle parking facilities at bus stops.

Bike share system in Copenhagen is the first modern bike share system in the World. With the context of bicycle and public transport integration, The City of Copenhagen emphasized on bike share system. Copenhagen's bike-share system was named Bycyklen. It was launched on 1 April 2014. The Bycyklen are could be rent from one docking station and returned to a different station. The Bycyklen bicycle has an electric motor and will assist you up to 22 km/h and automatically switches off when the brakes are in use. In the Bycyklen bike-share system, it is possible to book a bike half an hour before you need the bike. The price is DKK 15 per. reservation. If the chosen Bycyklen station has no available bikes at the reservation time, it will warn you about this. In Copenhagen, at the transportation stations there are Bycyklen station and bicycles.

Bicycle Network



Figure 3.4: Bycyklen station at Vesterport S-train station, Copenhagen (google maps).

In Copenhagen there is 14.6 km long inner Ring Route that connects urban areas in Frederiksberg and Copenhagen municipalities. The route is one of the five super-bike trails that were inaugurated in 2017. Increase in the number of cyclists at %21 since the route was upgraded to super-bike trail. An average of 6.4 km per bike is cycled on the route. There are 57,500 kilometers of bicycle every day along the route %21 of new cyclists on the Inner Ring Route were driving earlier in the car.



Figure 3.5: The network of the Inner Route [79].

Copenhagen, the “City of Cyclists” implemented one of the world’s most innovative



Figure 3.6: The Inner Route in Copenhagen [79].

bicycle infrastructure. In 1920, the City built the first bike path. By 2009, in Copenhagen the total length of bike path was 340 [65]. The cycle tracks are between 2.3 to 3 meters wide and grade separated from motorized traffic and specified by blue color at intersections in the city. The traffic lights in the city are synchronized for bicyclists considering their speeds (Buhler and Pucher, 2012). The City of Copenhagen transformed parking spaces to bike parking areas, increasing car parking fees, and reduce the number of car lanes [65].

In Copenhagen, there is a popular bicycle path, namely “Cycle Serpent” is 230 meter long and launched in 2014. In a day 20,000 cyclists passes the cycle path [25]. In Copenhagen, at the big intersections cyclists have extra 5-6 seconds green time than the motorists. So, cyclists be able to cross safely the intersection before the motorists cross. In Copenhagen, every street that have enough place have bike lanes besides bike boulevards. Despite of the narrow streets of the Copenhagen, the City implemented bike lanes almost every street [1]. The city does not have on-street parking at every street. This creates enough space for a bike lane. Some of the streets in Copenhagen on some parts of its have on-street parking as car parking or bike parking. This

creates a protected space for cyclists by separating the from motorized traffic.



Figure 3.7: “Cycle Serpent” bike path in Copenhagen [25].

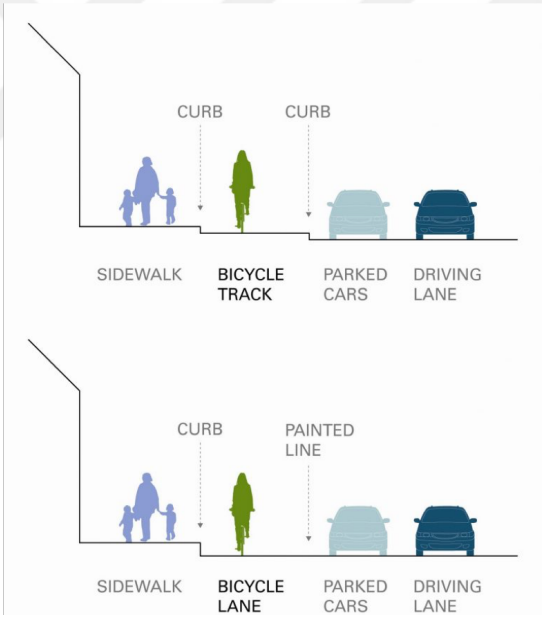


Figure 3.8: Differences between cycle track configuration and bike lane configuration in Copenhagen, Denmark [58].

The City of Copenhagen, for cyclists to turning left a waiting space is applied at intersections. The waiting space determined by blue colored bicycle crossing and pedestrian crossing ([24]). Also, the cycle tracks shift to bike lane through the inter-



Figure 3.9: Cycle tracks in Copenhagen, Denmark [59].



Figure 3.10: Bike lane between sidewalk and motorized traffic [1]



Figure 3.11: Bike lane between on-street parking and sidewalk [1]

sections.



Figure 3.12: Bus/bike lane in Copenhagen [87].



Figure 3.13: Advanced stop lane in Copenhagen [50].



Figure 3.14: Gyldenløvesgade intersection with waiting space for cyclists, Copenhagen [24].



Figure 3.15: The change of cycle track to bike lane through the intersection, Copenhagen [106].



Figure 3.16: Enhanced bicycle crossing at a large intersections, Copenhagen [97].

The installed bicycle parking facilities in Copenhagen provided for public and the important consideration about site selection is creating minimum obstruction for pedestrians and motorized traffic. The City of Copenhagen have 4,000 bike-parking facilities these serve to 50,000 bikes. There are colored bicycle parking facilities with different shapes such car shape. The car shaped bicycle facilities shows that the space for a parked car provides space for 8-10 bicycles [24], [125]. Copenhagen provided bicycle parking facilities at bus stops and transit stations.



Figure 3.17: Car shaped bike parking, bike racks, Copenhagen [125].



Figure 3.18: On-street bicycle parking on the corner of the pedestrian street, Copenhagen ([24]).



Figure 3.19: Bicycle parking facilities at bus stops, Copenhagen [131].

Nørreport Station, Copenhagen-Analyze of cycling facilities and transit station

Nørreport Station involves S-train, metro, and main line railway station in district of Indre By, in the hearth of Copenhagen. The name of the station is given by the historic Nørreport city gate. This station is one of the busiest transport hub in Denmark and daily, serves 250,000 people. The station has bicycle parking facilities, and also out of the rush hours cyclist can carry their bicycles on board. The station is improved, starting by 2012, for an accessible space for cyclists and pedestrians.



Figure 3.20: Nørreport Station, Copenhagen (map style with google; google earth).

In Figure 3.21, the first picture of the analyzed area, the bicycle lane and enhanced bicycle crossing that differentiated by blue color is seen. The bike lane is separated from the motorized traffic by different grade and the lane have a strong relation with the station area. Cyclist can park their bicycle without conflicting with the motorized traffic. Also, in the picture 1, docking station of Bycyklen bike-share system is seen and sheltered bike parking area can be seen. In the second picture, enhanced bicycle crossing with blue color is seen. This bicycle crossing enables to the cyclists a safe journey from other directions through to the transit station. The boundary of the pedestrian area is identified by urban furniture and vegetation. Also, the bicycle lane is separated by different grade from bus lane. In the picture 3, unsheltered bicycle parking area and the entrance of the station is seen.

In the fourth picture, difficult intersection for cyclist is seen. Bicycle lane is separated from the bus lane and bus stop, so cyclists do not affected by the movements of the

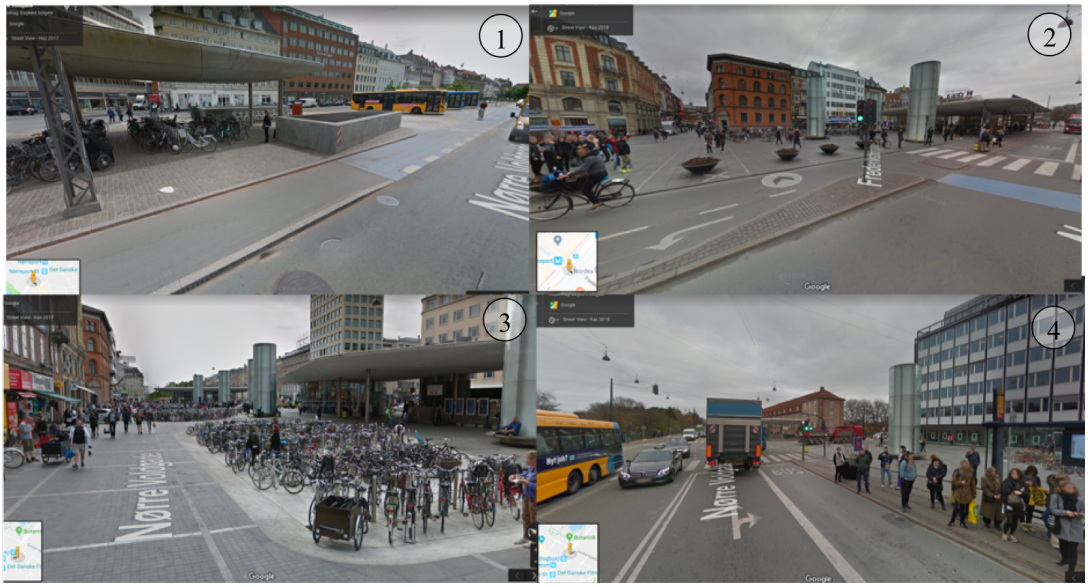


Figure 3.21: Visual analysis at Norreport Station, Copenhagen.

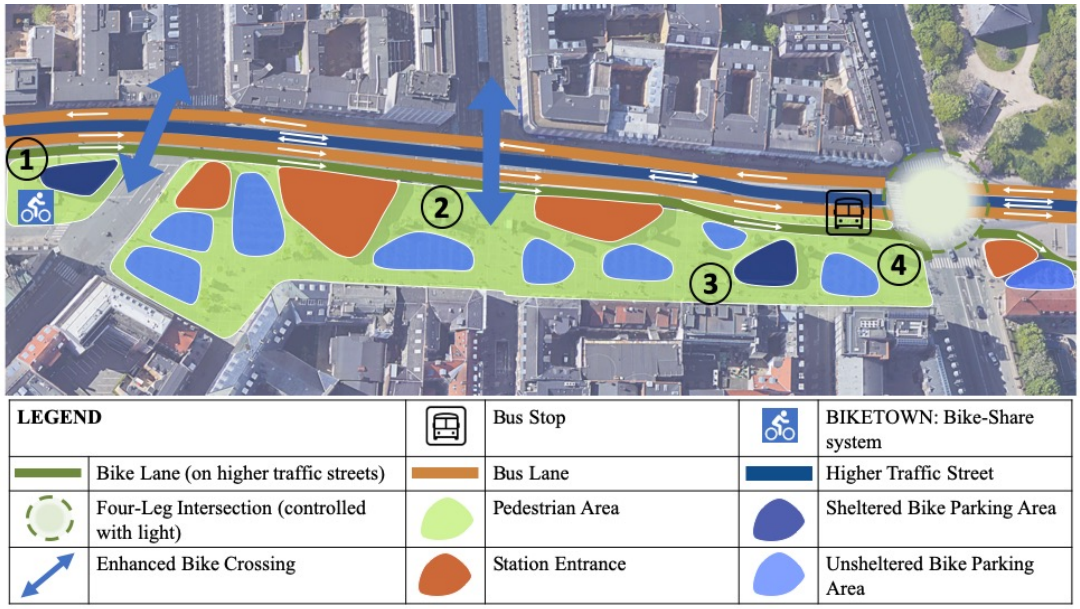
people on the bus stop. The bicycle parking areas are monitored with the security cameras at the transit station. So, it enables a safe bicycle are for the cyclists at the station.

The physical connection along the station is strong and safe through the cycle lane, and bicycle enhanced bike crossing. Also advanced stop line for cyclists at intersection and the traffic lights enables a safe crossing at the four-leg intersection. All these visual observations shows that there is a relief of movements in the area, and there is a safe and strong linkage between the station and cycling lanes (see Figure 3.22).

Public Acceptability

The city of the Copenhagen conducts a survey biannually through cyclists to regulate their cycling policies. The cyclists review the bicycle transportation in the city and make suggestions. The survey is about the integration of cycling and public transportation, bicycle parking facilities, safety, maintenance of bicycle facilities. This biannual surveys conducted since 1995 and provided cycling planners to make progress on bicycle planning.

By 2010 a project started to solve problems about bicycle parking : “bicycle butler”. This project planned for changing the cycling behavior in a positive way by warning



LEGEND		Bus Stop		BIKETOWN: Bike-Share system
	Bike Lane (on higher traffic streets)		Bus Lane		Higher Traffic Street
	Four-Leg Intersection (controlled with light)		Pedestrian Area		Sheltered Bike Parking Area
	Enhanced Bike Crossing		Station Entrance		Unsheltered Bike Parking Area

Figure 3.22: The visual analysis of the Nørreport Station, Copenhagen.

wrong parked bicycles on rocks with a sticker, by moving the bicycle left on the way and by oiling the chain of bikes and pumping types of bikes.

Also, the City to promote cycling uses its own campaign term: “to Copenhagenize”. This campaign is to promote cycling by showing the attractiveness and benefits of bicycle. The term “to Copenhagenize” shows the citizens that how their city Copenhagen as the best cyclable city promotes cycling around the world.

The City implemented a campaign for children and adolescents to remark cycling safety by taking attention on using lights on bicycle at dark. They use buses and advertisement pillars to announce the campaign. The City developed a campaign for the newcomers to Copenhagen. The aim of the campaign is teach their bicycle culture to newcomers of the city. They give a set of cycling package that includes how to travel with bike on the rail metro station, how to park their bicycle, cycling routes, bicycle light, maintenance kit for bikes.

In 2017, The Municipality of Copenhagen to expand the cycle tracks in the City, accomplish citizens’ involvement. These citizens spotted the unsafe points, the places needed a cycle track or wider cycle track. The analysis of citizens implemented into the Bicycle Track Priority Plan.

In Copenhagen, with bycyklen.dk website of bike share system of the city you can find the nearest stations and also you can download bycyklen.dk to your iPhone and android phone. It is also possible to find the Bycyklen stations and other public transport modes, the available docks and bikes of Bycyklen by using the citymapper.com web site and apps for smart phones. While Citymapper web site shows the bus, city bike, metro, and etc. stations, but it does not provide the user a journey planning. In the website there is no integrated information between the different transportation modes.

The City of Copenhagen has various journey planners. One of them is Rejseplanen provides to users travel time, price estimate, map display and any changes. This app is available for via website, android and ios (Public transport in Copenhagen and on Zealand, (n.d.)).

3.3 Paris

The İle de France Region area is 12 000 km2 and includes 10,9 million inhabitants [146]. In the center, there is the City of Paris with 2,140,526 residents [54]. The region includes 300 cities and 11.8 million inhabitants. The City of Paris surrounded by two belts. The transport modes in the City of Paris, are Regional Express Rail Passenger Trains (RER), Metro, tramway, buses, and self-service bikes

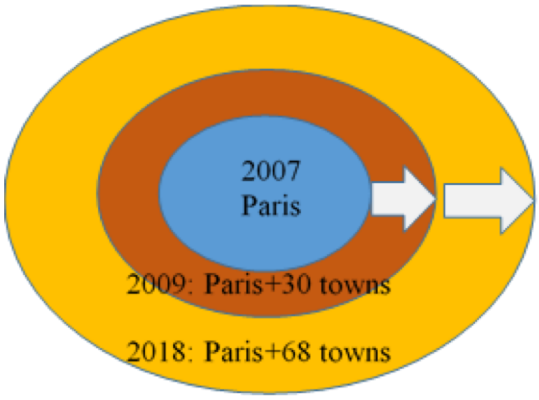


Figure 3.23: The area of Paris to the Greater Paris.

Paris aims to be the World cycling capital in 2020. The city aimed to double its bike routes by 2020 and increase cycling mode share to 15% [157]. By 2015 the City

increased cycling route to 700 km. Cycling has grown at an exponential rate since the 1990s, so much so that between 1991 and 2010 daily travels made by cyclists have been multiplied by a factor of 10.

Planning and Policies

In 2015 The City of Paris has launched Cycling Plan for 2020. In the plan the one of the main objective is providing secure cycling conditions on the most circulated streets on the existing cycling network in Paris. In the Plan, the proposed bike network consist of continuous protected bike paths from North to South and from East to West. The Plan aimed to provide comfortable and secure bicycle lanes ant paths with enough widths [114].

2015-2020 cycling strategy aims to double the length of the cycle network and triple the number of daily cyclists. Safety of the cycle network is the essential concern of the cycling strategy. Also, the plan aims to reduce air pollution in the city. The five-year plan aimed to increase mode share of cycling to 15% by 2020. It is stated that the City want to reduce air pollution by promoting cycling. The plan includes new cycling infrastructure, integration of cycling and public transport, improvement of safety, implementation of two way cycle paths and bicycle parking facilities. The measures are being taken to reduce the speed of motorized traffic on Paris streets and to redesign roads to improve safety of cyclists [80]. According to the plan, the existing zones are going to be 30 km/hour to make the roads available for different users. Also, in the one way streets with the implementation of two-way bike lanes the speed limit is planned to be 30 km/hour. The city wants to create dedicated cycle paths, green routes, closing some roads to traffic, secure bicycle parking facilities at transit stations.

Paris to promoted policies of cyclists friendly rules and changed the traffic rules. These regulations are giving way to cyclists at traffic lights, by implementing 7000 advanced stop lines, limiting speed 30 km/h at two-way cycle lanes in all streets, creating 30 speed limit zones and against the flow of traffic cycle lanes for all the city, limiting the speed in the entire city with maximum 50 km/h, and implementing advanced stop lines [44].

Paris to promote cycling since 1995, improving cycling infrastructure. In 1999 the city had 151 km bike lane, and in 2008 the total length of bike lanes are 439 km. The city increased the total length of bicycle lanes to 700 km in 2015. In Paris, the bicycle network consists of shared bus bike lanes, bike only lanes on the street, bike lanes on sidewalks, and counter flow bike lanes. The city increased its bike parking spaces on sidewalks from 2,200 to 10,000 between 2000 and 2010. Besides, implemented 22,700 other parking spaces. [123], [109].

Public Transportation

Because of the small size of the central area and high densities in residential areas, in the City of Paris it is easy to use public transport. So there is a low dependence on the car in the city. The wide boulevards was planned in the 19th century, helps to reallocation of road space without reducing the spaces for cars.

The public transport network in Paris consist of Metro, RER (Suburban Express Railway) , tramway and buses. Metro system have 16 metro lines and some 300 metro stations. Taking bicycle to Metro trains is not allow except line 1 of Metro on Sundays and holidays until 16.30. The Suburban Express Railway allows bicycles to take on board Monday to Friday, except rush hours. Buses and Trams are not allowed bicycle to take on board.



Figure 3.24: A cyclists at Paris Metro [93].

Paris is a dense city with short distances and this provides advantage for public transportation. Dense network of public transportation provides travelling with cheap

prices. On the other hand, congested urban space creates challenges for parking.

The goal of the Urban Transport Plan for the Ile-de-France Region, reducing the car ownership, and encourage public transportation and green transportation modes as cycling and walking [147].

Table 3.1: The metropolitan area and the city of Paris, [101]

Urban Area	Country	Total Population (millions)	Rapid Transit Type	Population Within 1km of Transit Stations	Percent of Population Near Rapid Transit (PNT)	Weighted Density (Residents/ km2)
Paris (City)	France	2,239,837	Metro + Tram + Suburban Rail	2,239,837	100%	29,732
Paris (Metro)	France	12,101,942	Metro + Tram + Suburban Rail	6,002,920	50%	10,474

Within the city of Paris 61% of all trips are made by walk and only 27% by public transport. Cycling mode share is 3% in Paris. The trips made between suburban areas are done by automobiles with 82%. In Paris there are good radial provision to travel in and out of the city. But because of the orbital routes not supported sufficiently, to go between suburbs by public transport people have to travel into the city center and go out again.

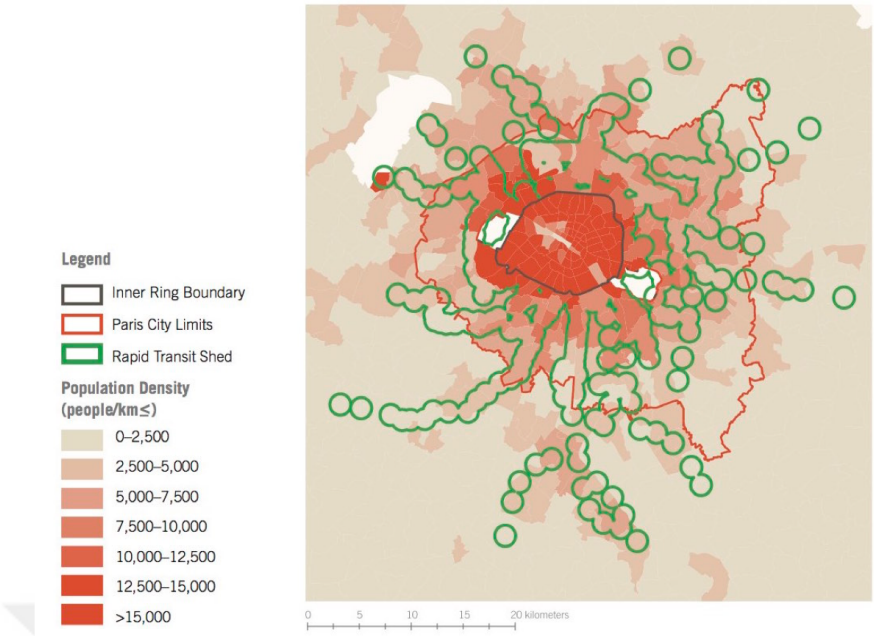


Figure 3.25: Paris Region transit sheds and population density [101].

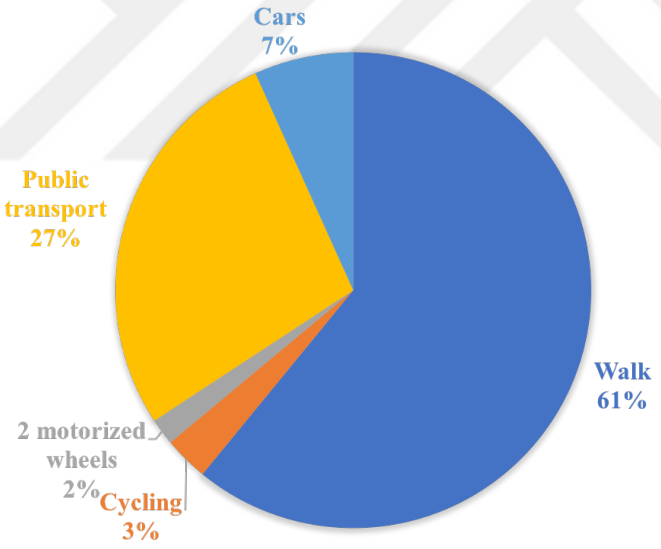


Figure 3.26: Mode shares in Paris (2010) [109].

In Paris the bike share system's name is Vélib' which is the largest one after the bike –share system in China. The network of self-service bicycles of Vélib' launched on 15 July 2007. In 2009 the Vélib' system was set up in 30 towns in the close suburbs. Vélib' bike share system well integrated with the public transport stations and nodes.

The types of transportation replaced by the Vélib' are mainly public transport and walking. This trend has become stronger since 2007. Travel by car (private cars and taxis) were less replaced by the Vélib' than in 2007 (drop of 1% in the replacement rate for each). Mode shift to cycling in Paris is shown in Table 3.2.

Table 3.2: Transportation modes replaced by Vélib' [116]

79% use a Vélib' instead of the metro (71% in 2007)
28% use a Vélib' instead of the bus (26% in 2007);
29% use a Vélib' instead of going on foot (23% in 2007);
9% use a Vélib' instead of a car (12% in 2007);
5% use a Vélib' instead of a motorcycle (6% in 2007);
1% use a Vélib' instead of a taxi (2% in 2007).

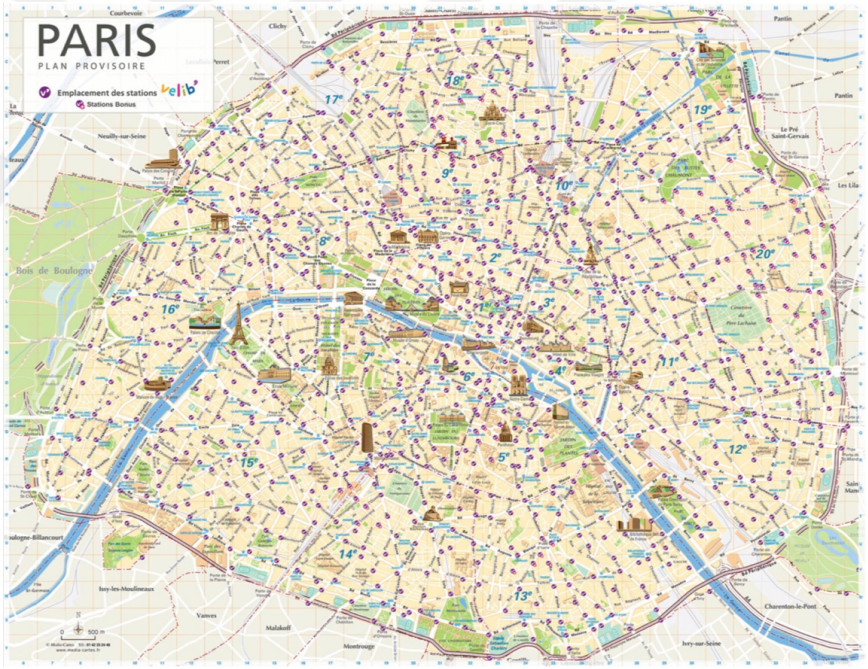


Figure 3.27: The Station Map of Vélib' [115].

The challenges about the Vélib' System are vandalism and regulation of stations. About vandalism awareness campaign has conducted aiming to promote the users to use Vélib' bicycles carefully. For the regulation of the stations, the Vélib' system gives and individual time bonus to park Vélib' in drops stations. Between 2017 and

spring 2018, 1,400 stations were created for new Vélib' fleet. By 1st January 2018 the new public service was available. The new Vélib' metropole's operator is Smovengo. These new Vélib' fleet is consisted of smart, connected generation of mechanical and electric bicycles.

It is stated by Smovengo that Vélib' services are the most rational way to share the public space and make self-service bicycles more visible without inconveniencing other users such as pedestrians, ordinary cyclists, and drivers of motorbikes or cars. Sharing public space is crucial in dense urban environments where every square meter counts. The locations of Vélib' stations are chosen with the consideration of providing the optimal access to users.



Figure 3.28: Vandalised Vélib' bike [53].



Figure 3.29: The new Vélib' Metropole [100].

By the year 2018, new Vélib' Metropole has begun to operation and the old Vélib' system stations and bicycles has changed to new Vélib' Metropole system stations and bicycles. By 2018, 1,400 stations had been placed for new Vélib' system. By 1st January 2018 the new public service was available. The new Vélib' metropole's operator is Smovengo. These new Vélib' fleet is consisted of connected generation of

mechanical, smart, and electric bicycles. The Subscriptions offered within the scope of the Service are as follows:

Table 3.3: Subscription of Vélib' system [135]

Package	Description
V-Libre	• Cycle hire; • Access to the Park + system solely to pick up a Cycle; • Usage billing from the first minute of use.
V-Plus	• Cycle hire; • Access to the Park+ system to pick up and return a Cycle.
V-Max	• Option to earn Bonus Minutes; • Annual commitment; • Subscriptions available at reduced rate and concession rate

The new Vélib' metropole system is free for first half-hour and not request cash of the deposit. The charges of the system differs from mechanical bicycle and electric bicycle.

Table 3.4: Charges of New Vélib' Metropole [135]

Subscription	Mechanical Cycle	Electric Cycle
V-Libre	As from the first minute, charging by 30-minute period	
V-Plus	The first 30 minutes are free	The first 30 minutes are charged as from the first minute
	Beyond that, charging by 30-minute period	
V-Max	The first 60 minutes are free	The first 30 minutes are free
	Beyond that, charging by 30-minutes period	

Bicycle Network

In Paris, most of the cycling routes are for recreational purposes. An example for a cycle route with recreational purpose is namely "Off-the-beaten-track Paris" [159]. This cycle route is mostly consist of physically separated bike lanes with 7 km. This cycle route go through metro line 2 in northern side of Paris.

In Paris, examples for bike paths could be seen in the "Cours Albert 1er" and in "Allée des Fortifications". In the "Cours Albert 1er", bike paths is separated from motorized



Figure 3.30: Off-the-beaten-track, Paris [159].

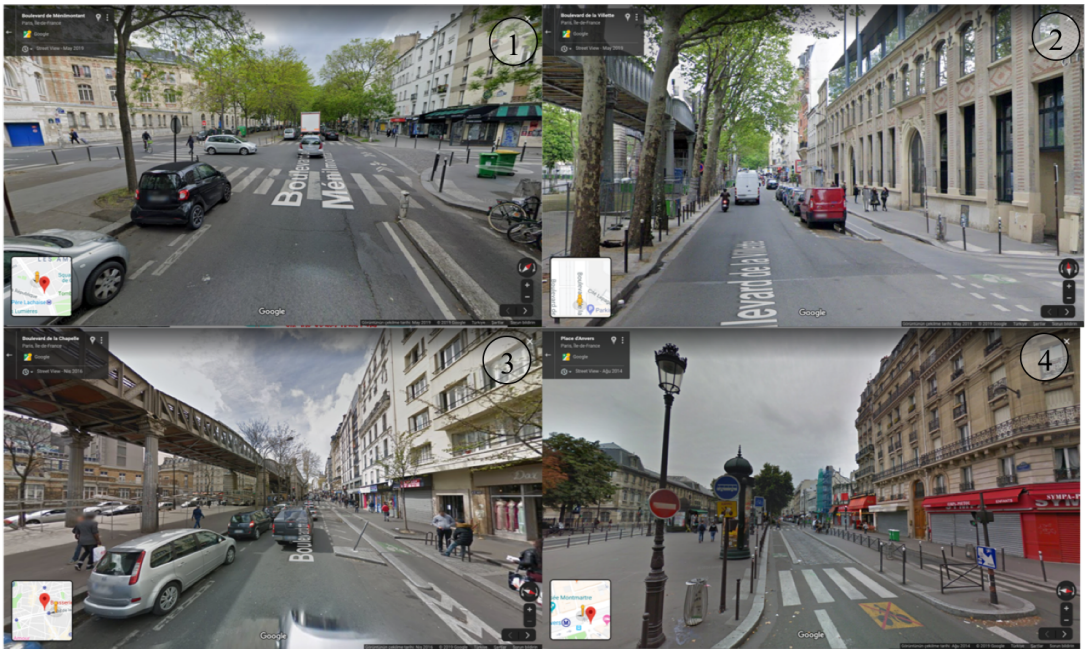


Figure 3.31: Off-the-beaten-track Paris [63].

traffic and pedestrian traffic with barriers and trees. In “Allée des Fortifications” bike path is separated from motorized traffic and pedestrian traffic by trees.

In Paris, moat of the cycle tracks are applied as physically protected from motorized traffic. These streets are protected cycle tracks by raised curb or parked cars. The city of Paris implemented physically protected bike lanes depending on the content of the street. In the some streets cycle tracks protected by raised curbs, and in some of the streets cycle tracks protected by parallel parked cars [105].



Figure 3.32: Bicycle path at Cours Albert 1er, Paris (google maps).



Figure 3.33: Bike path in Allée des Fortifications, Paris [77].

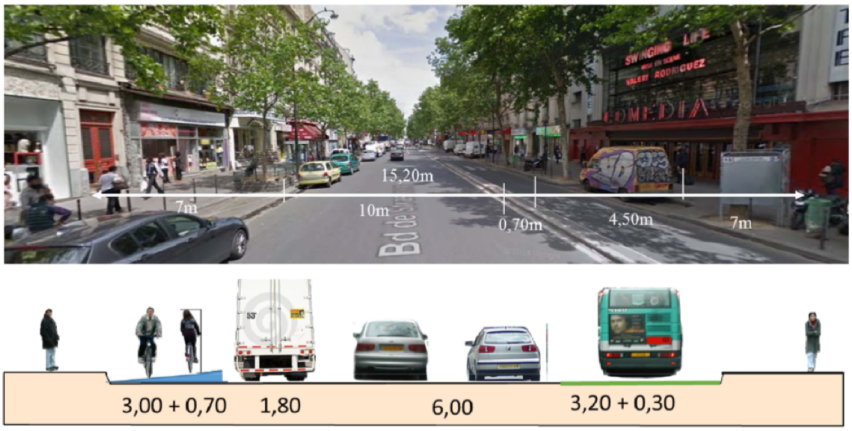


Figure 3.34: Paris, Boulevard de Sebastopol [44]

In Paris, there are contra-flow bike lanes on one way streets. In Paris, these contra-flow bike lanes are marked with “sauf velo” under a road sign and with arrows long the one side of the street. Contra-flow bike lanes are applied on one way streets. Contra-flow bike lanes give a change cyclist to shortcut the high volume of motorized traffic.



Figure 3.35: Curb-protected two-way cycle track (left) [105] and curb protected one-way cycle track [47].



Figure 3.36: Parking-protected two-way cycle track (left) and Off-street two-way cycle track past Vélib' station (right) in Paris, France [105].

The safety of the contra-flow bike lanes have been proven by the experiences of the various countries and cities which was implemented contra-flow bike lane [48]. The contra-flow lane make available direct visual contact between bicyclists and motor vehicle drivers. Thus, cyclists could be able to see and predict from the coming cars or "dooring". In Paris, parallel car parking is located on the left side on some of the streets and contra-flow bike lanes are applied opposite side of the parked cars. The city also has been added speed bumps to slow automobile traffic beside the contra-flow bike lanes. In the some of the streets, contra-flow bike lanes are located on along the parallel parked cars without a shy zone. Thus, even the cyclists have visual contact "dooring" would be dangerous for them.



Figure 3.37: Contra-flow bike lane, Paris [10], [15]



Figure 3.38: Contra-flow bike lane along left side of the car park (left) and bike lane on the left side of the street and parked cars [105].



Figure 3.39: Bike/ bus lane with space to overtake bicycles, Paris [48]



Figure 3.40: Bike lanes continue through complex intersection (left) and Raised curbs, clear markings for bike lanes through an intersection (right) [105]



Figure 3.41: White painted bike lane stencils across intersection (left) and Pavement markings for off-street cycle track next to crosswalk markings (right) [105]



Figure 3.42: Véligo bicycle park, Paris [98].

In Paris, some of the intersections are controlled with clear markings for bike lanes. These intersections are provide clear visibility for all road users [105].

In Paris the Veligo bicycle parks have fast, easy-to-use bike racks, secure shared sheds with plenty of parking spaces, in closed areas that only registered users can access,

secure individual sheds. Veligo is opened 24 hours and located near to the Paris train stations. The aim of the Veligo secure bicycle parking facilities is to integrate bicycle and RER.



Figure 3.43: Bike racks in car park, Paris [98].

Saint-Lazare Station, Paris-Analyze of cycling facilities and transit station

Gare Saint-Lazare is the one of the largest and the second busiest railway station in Paris. Daily it serves to 275,000 passengers and 1,600 trains. There are suburban train services, intercepts train services , international high speed trains. Also, Saint-Lazare railway station have a metro station. The station located in the center and close to the various bus stops and RER E. The intersection at Saint-Lazare railway station is a difficult intersection because the requirements of a qualified bicycle infrastructure were not taken into consideration according to the visual analyze of the intersection.

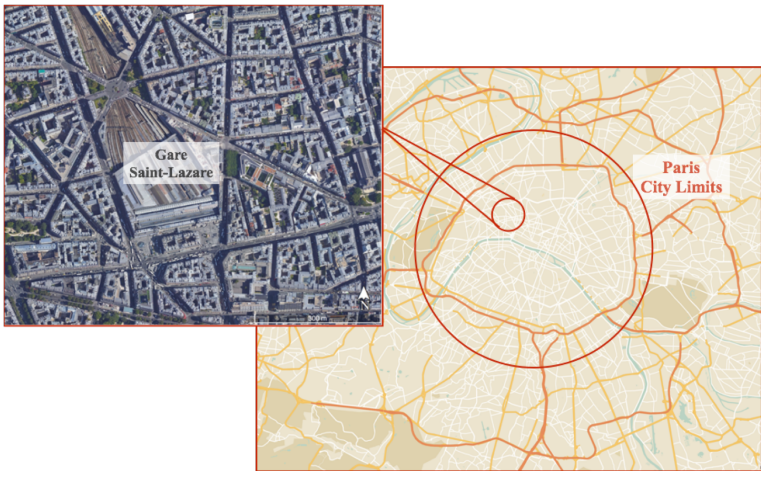


Figure 3.44: Saint-Lazare Station, Paris (map style with google; google earth).

In Figure 3.45, in the first picture, there is not a bicycle lane through the station. Cy-

clists uses the bus lane to travel. Also, the bus lane occupied by cars. In this part of the station area the functions and uses are not as it should be. The shared road way has a lower speed. In picture 2 shows that there is signal for bicycles and the waiting space for cyclists. The pedestrian crossing the floor is differentiated by bicycle symbols that means this part is leaved for cyclists to wait while pedestrians are crossing. As seen in the picture, this four legged intersection has a difficult connections. In the picture number 3, also seen in the picture 4, automobiles stopped on the traffic light and occupied the cycling lane. In the pictures 5, the difficult connection on the cycle lane can be seen as that an automobile and a pedestrian blocks the cyclists in a dangerous way. In the picture 6, the continuity of the bicycle lane blocked by automobiles. So, cyclists have to cycle on the motorized traffic. The parked cars on the cycle lane can endanger the cyclists by opening their door suddenly through the road. Also, a bicyclist waits on the wrong side of the road because of the high level of motorized traffic. As a consequences of these, the five essential requirements could not be provided.



Figure 3.45: Pictures from the intersection at the Saint-Lazare Station (google earth, street view).

Public Acceptability

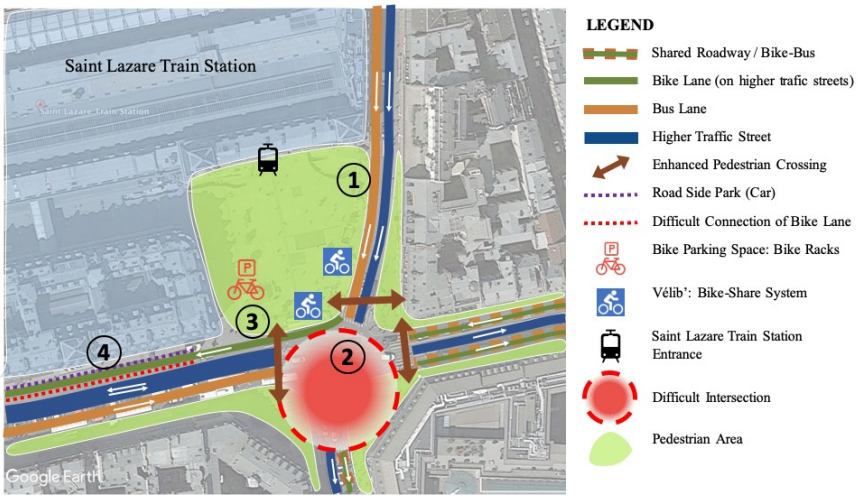


Figure 3.46: The implication of the visual analyses at Saint-Lazare Station, Paris.

In Paris, there are different kind of organizations that offers programs and courses for adults and children. The most popular one is Insertion et Culture Velo, that provides training courses for children and adults for cycling in the city. In Paris, there are cycling groups for that have different skill levels. One of the high-profile cycling group is the Convergence with 20,000 cyclists. This kind of cycling groups organize ride events with non-profit organizations. In Paris, every summer for four weeks Paris-Plages event is organized along the Seine River and approximately 5 million non-motorized participants attends to the event (Pucher et al., 2012, p 319-345).

Some of the cycling advocacy organizations are Mouvement de Defense de la Bicyclette (MDB), Club des Villes Cyclables (CVC), Animation, Insertion et Culture Velo (AICV), and The Fédération Française des Usagers de la Bicyclette (FUB).

To promote cycling every Sunday, the Champs-Elysées is closed to motorized traffic to provide enjoyable times to residents and tourists with bicycles. At the end of the September, 650 km of roads closed to motorized traffic for carless day [80].

Geovelo is the first calculator of French bike routes “geovelo.fr” website that calculates the best route considering lane you are using. By using this website you can choose a cultural or nature cycling routes and you can learn the type of lane. Geovelo, bike GPS is also available as android app and ios app.

RAPT (Autonomous Parisian Transportation Administration) is a state owned public

transport operator in Paris. RAPT is the fifth public transport operator in the world. This company provides an app for IOS and androids. This app gives real time information about the metro, bus, tramvay, RER, and airport lines. You can plan your trip with this app according to what transport mode you want to use. This apps suggest best cycling route between your destinations. Also, when you choose to travel bicycle it shows you the comparison of CO_2 emission by the car trip and cycling.

3.4 Portland

Portland is U.S. state of Oregon's largest and most populous city. As of July 2017, estimated population of Portland was 647,805. That makes Portland the 26th largest city in the United States. The estimated population of Portland metropolitan area of Greater Portland was 2,753,168 in 2017 (U.S. Census).

Portland is the first U.S. city to represents a comprehensive plan to reduce CO_2 emissions and fought for green building initiatives. The City has ranked as most bicycle-friendly city in the United States in 1995 and 1998 by Bicycling Magazine [94]. Also, Portland named as a "platinum" bicycle friendly community by the League of American Bicyclists.

Between 1990 and 20008, the cycling mode share increased from %1.1 to %6.0 between 1990 and 2008 in Portland. By 2017, 6.3% of commuters, approximately 22,647 workers chose to use bike in Portland. This is the highest percentage in American cities. Furthermore, in 2017 374% more people used bicycle to work than in 2000 ([11].

In the city of Portland, residents understands that bicycle have an great impact while dealing with the challenges because of the car dependence. The City promotes intensive media coverages and political support to expand bike roads ([37]).

In 2006, the City conducted a survey with residents. According the results of the survey, 43% of the residents feel cycling is important as a way of life. Also, the results showed that 81% of the school age children have educated about bicycle safety ([32]).

Planning and Policies

In the Portland, land use planning approaches aimed to limit urban sprawl. The spread of suburban development limited by urban growth boundaries. In 1975, the City of Portland implemented a plan with the aim of achieving a balance of highways and public transit. Before this plan the City of Portland was adopted freeway dominated transportation plan.

Portland best known for its smart growth policies to reduction of automobile dependence. These policies are urban growth boundary extensive public transit service, and transit-oriented developments (TODs) along the transit corridors [88].

Portland's urban growth boundary has been seen as the most significant land use reforms which aimed to limit urban sprawl by containing future development within the boundary and protecting farmlands and open space from development. This policy was approved by the state in 1980. There has been a difference of opinion about Portland's urban sprawl in the planning field. Smart growth proponents' arguments have been that urban growth boundary has supported to control urban sprawl and protect open spaces and natural resources [88].

Portland focused on rise against letting cars dictate urban form. In 1973, TriMet launched an action plan, Immediate Action Plan. This plan mentioned developing a balanced transportation system which consist of transit ways network in major travel corridors [139]. City of Portland was the first major urban area in the United States that adopted this kind of philosophy. The City of Portland by the end of 1970s adopted a new approach about regional land use and transport planning for ensuring the livability of the city.

Portland's first Comprehensive Plan was established in 1980. This plan developed with the consideration of statewide land use planning. The new Comprehensive Plan for 2035 show interdependence to link land use and transportation. The aim of the linking land use and transportation improves the walkability and bike ability of the City of Portland. Also, the Plan improved the transit friendliness in the city. In the plan, new growth in the city is aimed to be used to expand access to neighborhoods and employment and lead to growth to corridors and centers ([39]).

The City of Portland launched the first Bicycle Master Plan in 1996. This plan aimed

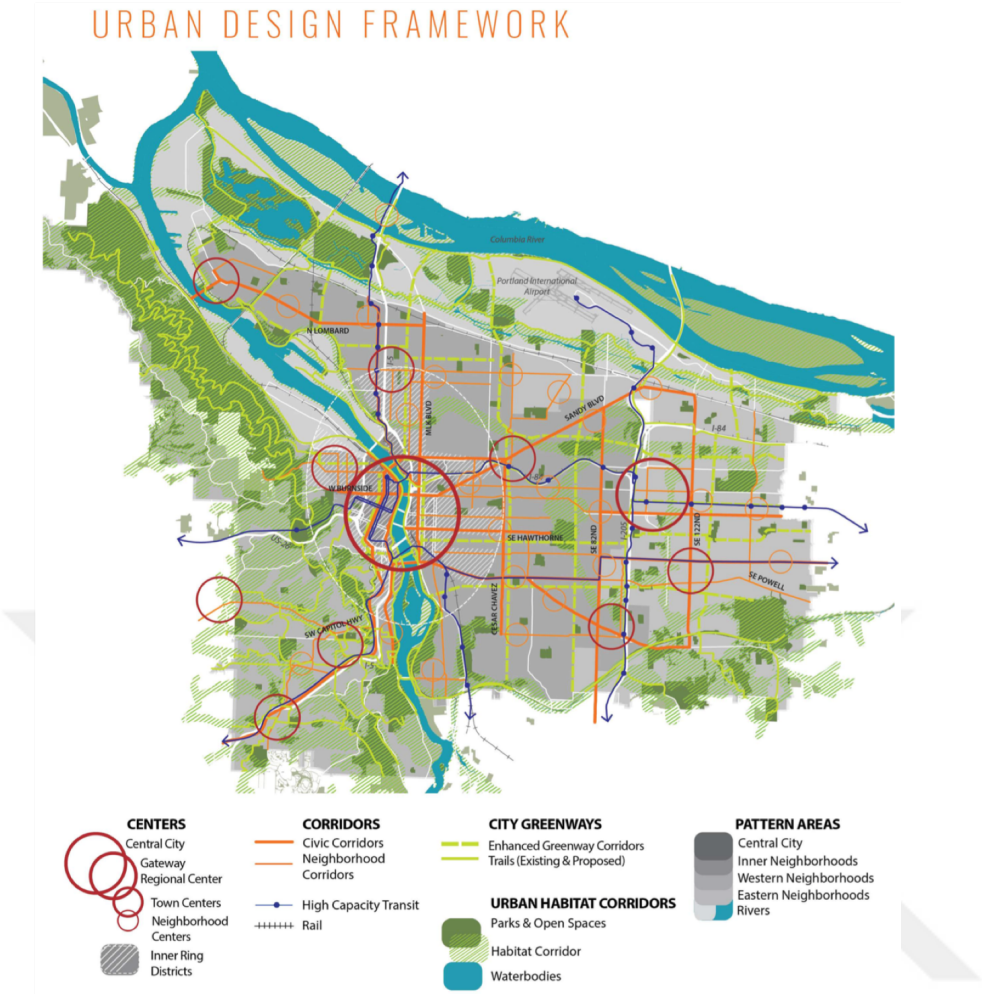


Figure 3.47: The urban design framework ([39]).

to develop an interconnected bicycle network by using innovative policies and programs in terms of promotion of cycling. Between the publication and completion period of the plan, Portland expanded the bikeway network by more than 300 miles. The bicycle network provides access to bicycle facilities within three to six blocks from anywhere in the city (city cycling, 2012). In 2008, the League of American Bicyclists gave platinum-level status to Portland as a Bicycle Friendly Community ([37]).

Amsterdam, and Copenhagen was addressed as having high bicycle mode split around the world and the Portland Bicycle Plan was influenced from these cities. The plan envisioned that expanding the planned bike network from 630 to 962 miles considering three key strategies ([37]). The network proposed in the plan for 2030 based on six

initial considerations: connectivity, classification conflicts, existing traffic conditions, existing traffic infrastructure, directness, and mobility.

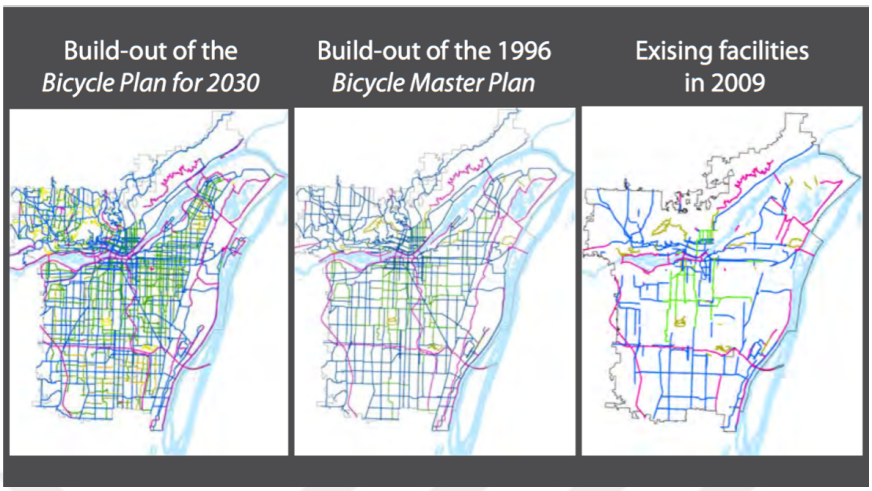


Figure 3.48: Bikeway network comparison ([37]).

The approach for developing the bicycle plan for 2030 is based upon two related assumptions that is attracting residents to bicycle for transportation who were not bicycling in 2009, and that to developing bikeways with sense of safety and comfort to attract future cyclists. In the plan it is mentioned that in order to building this network, bicycle policies will be updated, a design guidance for new street designs will be developed and also, education programs will be supported linking to construction of new projects. Proposed bikeway network includes three main facility types. These are trails, low-stress shared roadways and separated in-roadway bikeways on major collectors.

Portland have 52 on road bike lanes and 21 off street bike paths and cycle tracks per 100,000 residents. Portland consists of mostly on-street bike lanes ([17]). The city implemented traffic calming policies at neighborhoods. The traffic calmed residential streets are one of the main part of bicycle network in Portland. Bike boulevards traffic calmed and prioritized for cyclists. In the City of Portland, the bicycle network includes existing 58 km bicycle boulevards and planned 30 km ([35]). Also, there are buffered bike lanes in the City ([35]). At major intersections, there are advanced stop lines for bicycles that is implemented to provide safety for cyclist and cyclists visibility for motorists. The city has 17 bike boxes with advanced stop lines.

Public Transportation

Portland's public transportation systems include the bus, MAX light rail system, streetcar, commuter rail, aerial tram and biketown bike share program. Long-term bicycle parking spaces at public transit stations increased from 24 in 1996 to 213 in fall 2009 ([37]). TriMet's bus fleet equipped with bike racks that can carry two bikes. Also TriMet stations gives you an option to park your bike at the station in case of no available space for your bike on the train. There are secure parking systems at Metropolitan Area Express (MAX) stations and transit centers. You can park your bike by using your own lock or BikeLink keycard for 24 hours a day and continue your journey with one of the public transport modes.



Figure 3.49: Bicycles on TriMet Bus and on the Portland Aerial Tram [104].

Portland was grow up around a streetcar system, but after automobiles become dominant than urban transportation. As a result of Interstate Highway programs in 1956, the city adopted highway building as a solution for the transportation needs of growing regions. As a consequence, the City faced with growing automobile use and congestion. The Transportation Plan for 1990 recommended 54 major new highway projects.

With the 1975 Interim Transportation Plan, the City suggested future development and land use in the region should be tied to corresponding transportation development [139].

According to study made by Myung-Jin Jun [**?**], empirical analysis suggested that high accessible highway interchanges and the residential area where mostly single families live come with result driving alone to work. Hence, to lower the choice

of driving alone planning neighborhoods with diversified land use, extended public transport services, decreasing the direct access to highway interchanges is needed.

Besides that, making settlements compact via the urban growth boundary and transit-oriented developments (TODs) has no direct relationship with reducing the choice of driving alone. Also the study shows that adopting extended public transport system and mixed land use manner in residential areas is much more helpful to deter automobile usage than adopting these manners in working destinations [88]. The city aimed to connect land use and transportation to improve the walkability bikeability and transit friendliness in the City of Portland.

Since the first Bicycle Master Plan in 1996, integration of bicycle and public transport has been made progress in Portland. Since then, more than 40 miles of new light rail and streetcar lines have been constructed and more than 125 miles of new bikeways have improved connections to transit. Long-term bicycle parking spaces at public transit stations increased from 24 in 1996 to 213 in fall 2009 ([37]).

Portland has increased the numbers of the secure and sheltered bike parking facilities at transit stops and station. Also, The City improved connections to transit with bikeways and there is an option to park your bike at the station in case of no available space for your bike on train. Because during peak hours on board rail vehicles could not have extra space for bikes. In addition, every TriMet buses have bike racks to allow you travel with your bike.

Bicycle Network

According to Strava, in Portland there are 10 different cycling routes. One of them is namely bike path tour route with 50 km length. It is an example to top local route [78]. This route passes through important places in the city such as hospitals, interstate Rose Quartet TriMet station, housing zones and the primary indoor sports arena in Portland, Moda Center. In the residential area the speed limit for motorized traffic is limited with 25 km/h. This bike route consists from bike lanes.

In Portland, I-205 cycle path is the first section of an interstate cycle path. The total length of the I-205 cycle path is 30 km (18.5 miles) and links five cities. This path build in 1980s in Oregon to provide connection between commercial and public areas

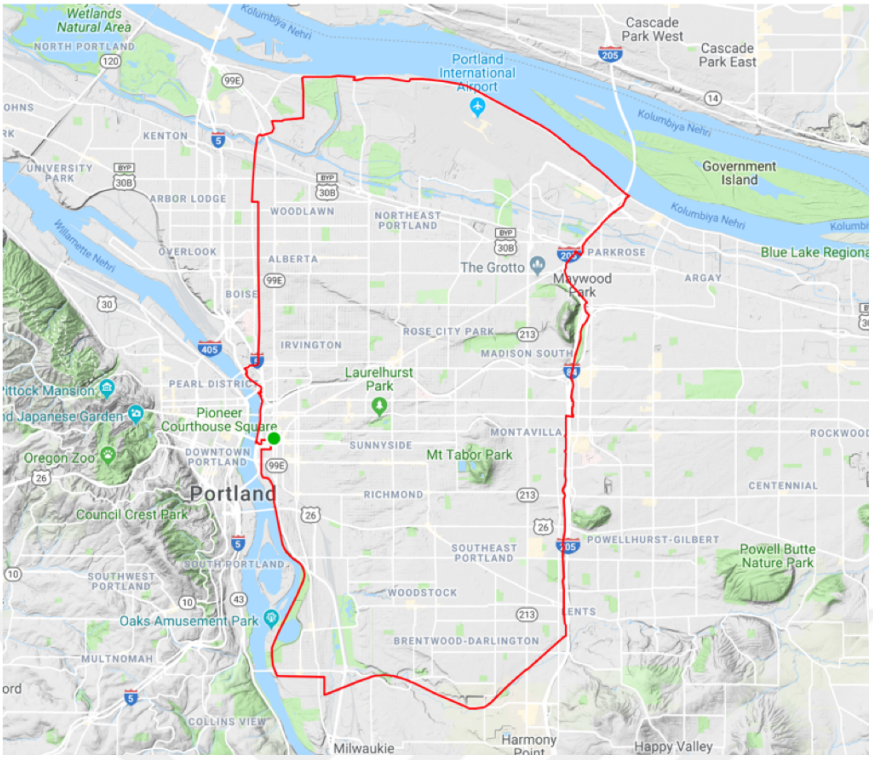


Figure 3.50: A top local route in Portland [78].

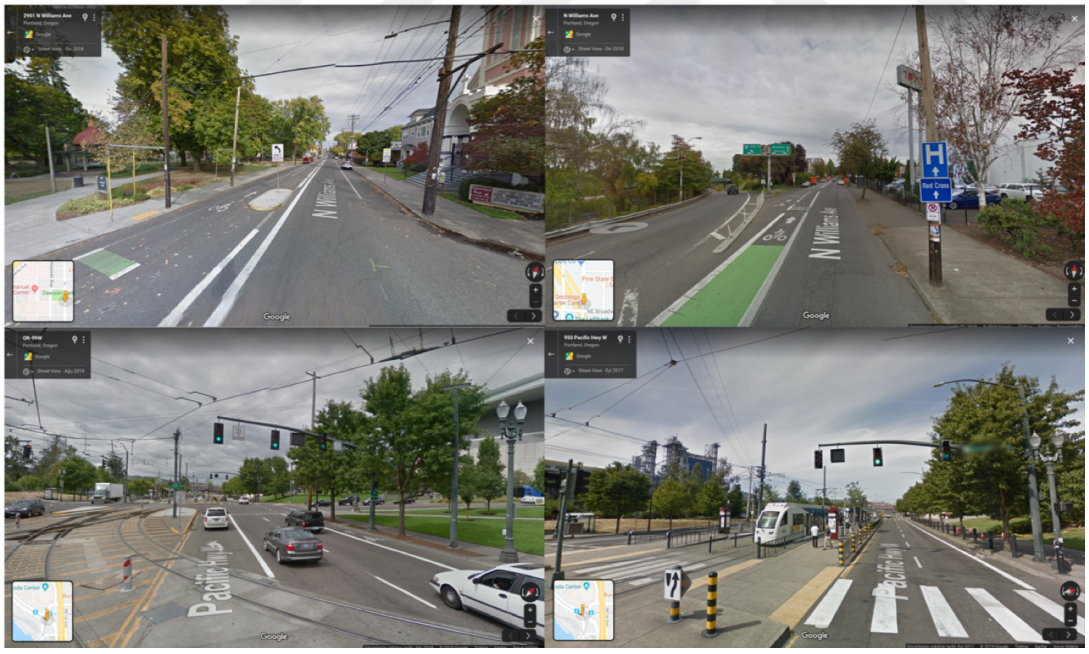


Figure 3.51: Different points from bike path tour route in Portland (google maps street view).

by cycling and walking.



Figure 3.52: I-205 path, Portland [104].

In the downtown core of Portland, cycle tracks are separated from car traffic by car parking and narrow median. Narrow median protects cyclists from car doors. In Portland the first cycle track installed SW Broadway near Portland State University.

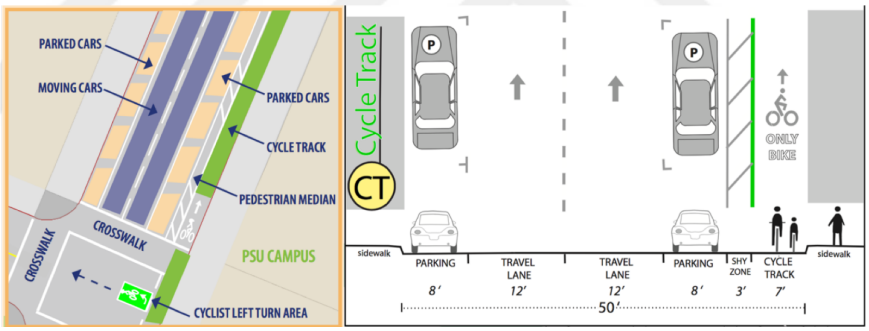


Figure 3.53: Cycle track configuration in Portland, [40], [33]

The Bureau of Transportation demonstrated buffered bike lanes in downtown of Portland. They stated that buffered bike lanes are installed to provide more comfortable and protected cycling. While planning buffered bike lanes, the Bureau of Transportation of Portland considered that which facility is more comfortable and congestion, traffic patterns, the commercial environment and usage. The Portland city pay regard to provide more inviting and calmer environment for both bicyclists and pedestrians.

The city of Portland, planned bus/bike lane project aimed to provide more reliable bus ride and safety for cyclists. This lanes have extra space as passing zone for cyclists to



Figure 3.54: One way cycle track in SW Broadway near Portland State University, Portland, (bikeprotland.org).



Figure 3.55: Two way cycle track in Portland, [108].

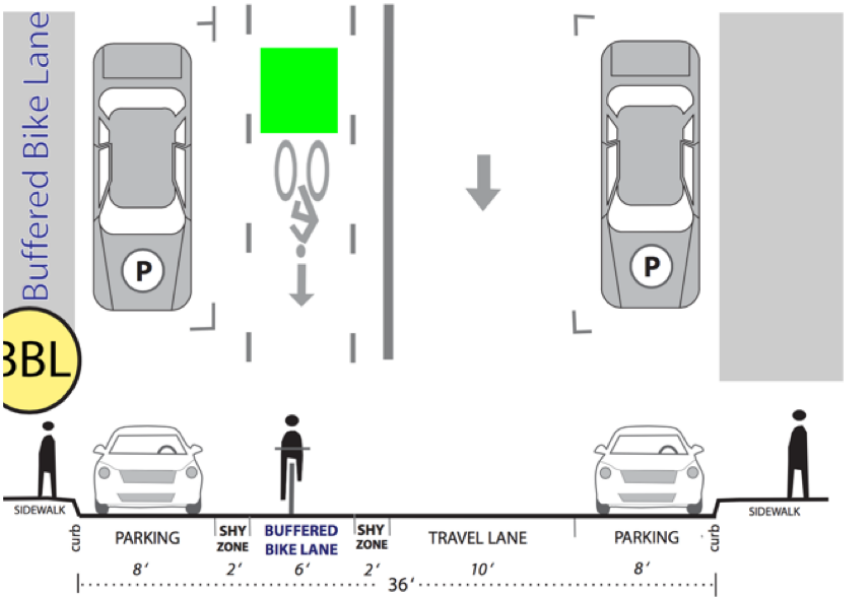


Figure 3.56: Buffered bike lane Portland, Oregon ([34]).



Figure 3.57: Buffered bike lane in Portland, Oregon [108].

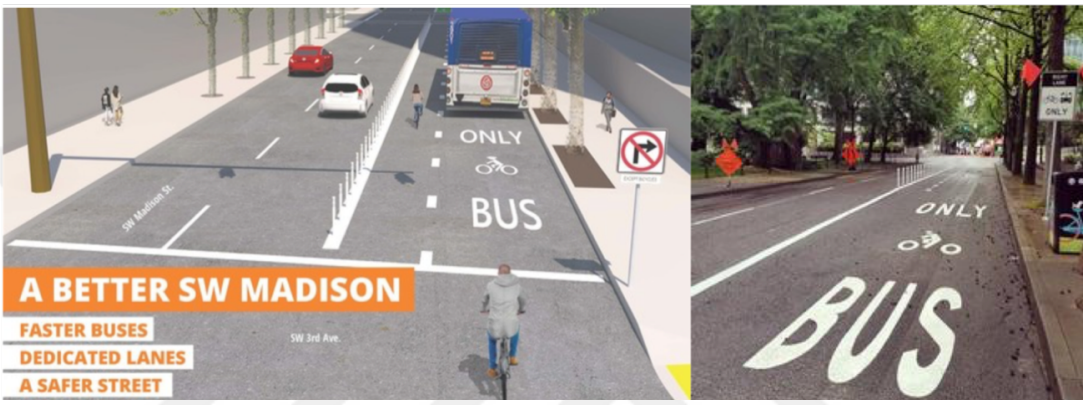


Figure 3.58: Bus/bike lane with space to overtake, Portland (source: [41]).

bypass buses that stopped at bus stops.



Figure 3.59: Advanced stop lane, Portland ([36]).

In Portland, there are traffic signals for cyclists at advanced signal detection in the bike

lanes. These signal are applied to signalized intersections with high speed and high volume cycling routes. Traffic signals for bicycle provide bicycle priority for cyclists at busy intersections. There are also traffic signals at crossings in major streets for cyclists. This traffic signal control for cycling provides cyclists cross the streets in attractive, safe and comfortable manner. In Portland, 31 intersections designed for bicycle specific traffic signals to reduce conflicts between cyclists and motorists. The aim of the Portland Bureau of Transportation is improving safety. There are bicycle boxes at 33 intersections to ensure visibility of cyclists [11]

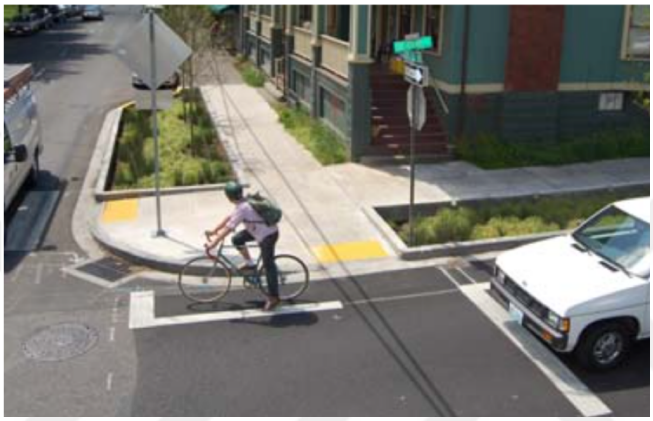


Figure 3.60: Bicycle box at intersection, Portland [11].

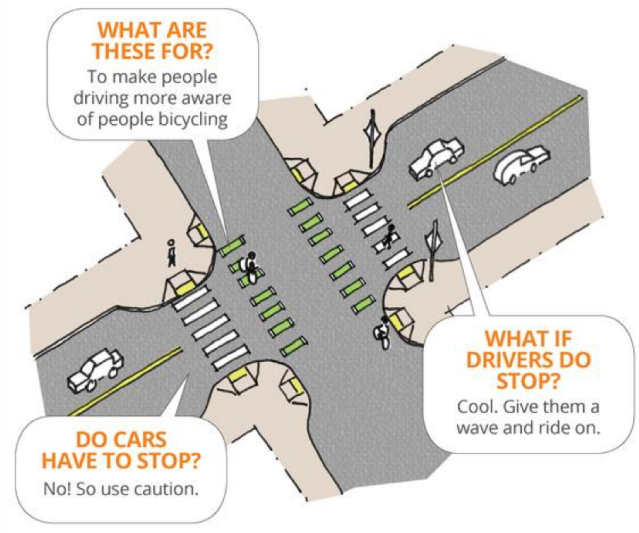


Figure 3.61: Green stripes for bicycle crossings, Portland [38].



Figure 3.62: Bike racks placed in car park space, Portland [99].



Figure 3.63: On street parking, Portland [110].

In Portland, there are three different ways to implement bicycle parking facilities. The first one is promoted by the Portland Bureau of Transportation, the second one is made through zoning code requirements, and lastly it is implemented by non-required private initiatives. The City's Bicycle Transportation policy remark bicycle parking just by a single objective. This plan proposes that these objectives should be integrate with existing parking policies of the City.

In 2004, the City launched the Bicycle Parking Fund which aims to provide accessible bicycle parking facilities for short terms use. This parking facilities located within the right of way in case of the insufficient place on private property. Especially, at the Pedestrian Districts and Main Streets providing secure bicycle parking facilities enable cyclists to access the destinations.

Rose Quarter TC MAX Station, Portland-Analyze of cycling facilities and transit station

The Rose Quarter TC MAX Station, the analyzed area, is located in the central city, near to the Willamette River. The station is a junction point of civic corridors, enhanced greenway corridors, and bike trails in Portland. Central city is the most urbanized area and includes tall buildings and residential development with high density. The city center comprise finance, government, culture, and commerce buildings. The city center has a 200' by 200' block structure system. The 200' grid system in Portland shows a fine-grained and human-scale fabric. Street system is highly interconnected in central city.

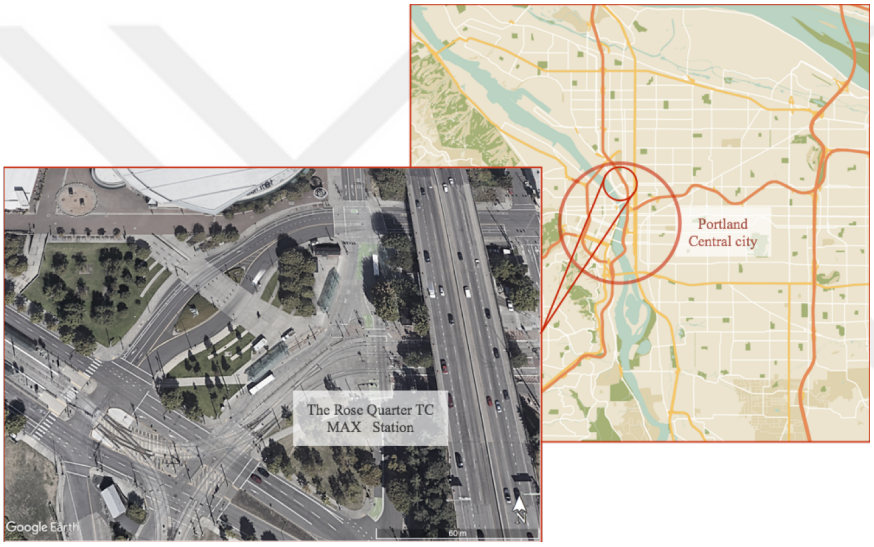


Figure 3.64: The Rose Quarter TC MAX Station (map style with google; google earth).

The area around The Rose Quarter TC MAX Station is analyzed to investigate the essential requirements of bicycle network that safety, directness, cohesion, attractiveness, and comfort.

In Figure 3.65(1), the bike-share systems of Portland BIKETOWN is seen. There is only the docks and bikes of the bike-share system. The terminal or namely kiosk of BIKETOWN where the user can get information about the system is not placed. The terminal gives the users a chance to plan their trip with letting know to park the bike at which BIKETOWN station at the end of their journey. Figure 3.65(2), the

relationship between bus stop and bike lockers can be seen. The bike lockers placed on the pedestrian area to provide a safe parking for cyclists by avoiding from higher traffic street. As seen in Figure 3.65(4), the protected and buffered bike lane guides the cyclists through the bike lockers with the patterns of pavement and the traffic lights. Figure 3.65(3), the patterns of the pavement and the ramp gives a change to cyclists go through to park to lock their bicycle. These shows that the link between cycle lanes and bicycle facilities.



Figure 3.65: Pictures of the visual analysis at the Rose Quarter TC MAX Station (google earth, street view).

As seen in the figure, a bicyclist could be able to see the edge of the street and what human activities occur while cycling along the bike lanes or towards bike parking space. The activities of buses or pedestrians in front of the light rail train station can be seen clearly while cycling. Separation of cyclists from the chaos of the bus stop, the pavement patterns of the cycle lane, the junction point of train station, the transparency through the pedestrian area, and well-designed functions and uses shows that around the station comfort, safety, and cohesive concerns of network planning are well defined. The physical connection through the station is strong and safe along the cycle lanes, bicycle enhanced bike crossing, and the guidance of traffic lights. So, as there is relief of movements in the area, there is strong linkage between the station and cycling lanes.

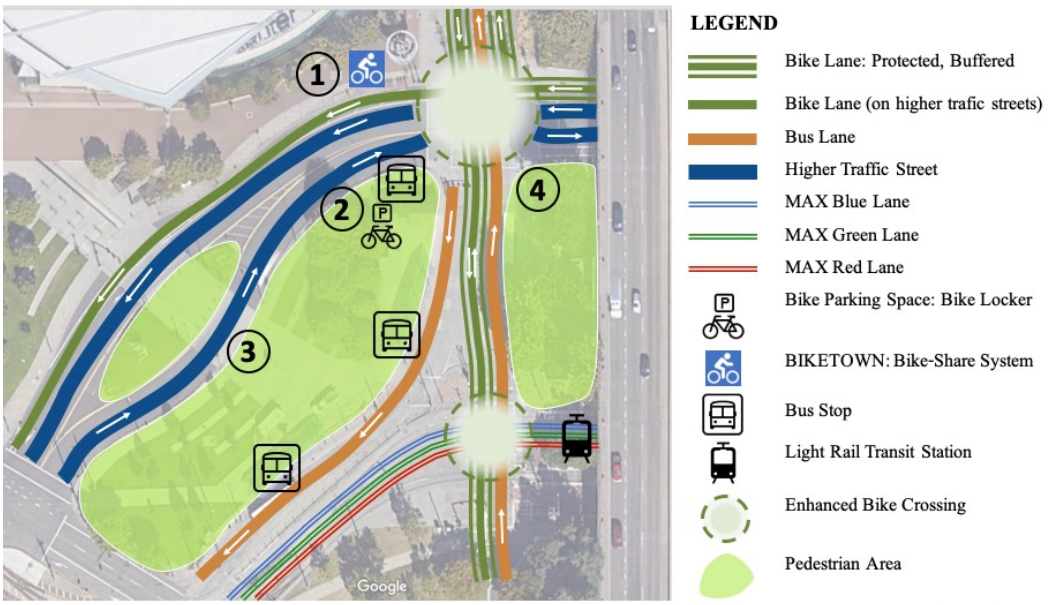


Figure 3.66: The visual analysis of the Rose Quarter TC MAX Station.

Public Acceptability

In the city of Portland there are various organizations these are The Bicycle Transportation Alliance, City Fleet, Woman on Bikes, Community Cycling Center, Exchange Cycle Touring Club, the Oregon Department of Transportation, the Portland Planning Bureau and TriMet. The organization, Women on Bikes supports annual urban bicycle training for woman. The free program Portland by Cycle, provides education and encouragement for beginning bicyclists. There is a program for downtown commuters who encourage their co-workers to bike to work as well provides incentives. “Biking is Back” is a program aims to encourage seniors to use 3 wheeled bicycles that is more comfortable and stable than 2 wheeled bicycles. In the City of Portland, there is not any bike safety program for children. Accordingly, the City of Portland needs to pay regard to safety programs for children ([37]).

The Bureau of Transportation (PBOT) to encourage more people to cycling as a transportation mode, allow property owners to install bicycle parking racks with innovative and aesthetic designs. The City of the Portland aims to make cycling more attractive and accessible and improve trip planning apps and maps. The City publishes a guide about Oregon Laws for cycling, a guide that shows how to use bike helmet properly, a guide about safe riding skills and techniques for children, and a calendar of bicycle

events and group rides.

The City currently has an online web site and smart phone app,'bycycle.org' which provides info of cycling routes, planning bicycle trips. But, the City wants to develop a 24/7 automated trip planning service via phone by implementing emergency roadside assistance for bike maintenance and repair ([37]).

In Portland, there are events for promoting cycling such as cycling through the specified parks and planning activities in the parks such as live music, free fix stations for bicycles and exercises in the park. The Community Cycling Center is a non-profit organization and aims to expand the access to bicycle. With the events they organize, they give a chance to people experience the benefits of bicycle such as the feelings of enjoyment, health, and freedom. They also, gives a full-service bicycle. They have some programs such as allowing the kids to ride to school, adults to ride work. The Community Cycling Center organizes the events such as cycling every Sunday through the specified parks. Also they organize a fair every season for collecting unused bicycle and giving them a new owner. They organize bicycle activities every year and running races. At the end of the day, every racer gets a prize [118].

The City of Portland have an interactive digital bike map, that shows the bicycle network with including what type of bicycle facility provided where. Bike friendly streets, local paths, bike boulevards, cycle tracks and also safety tips and laws about cycling could be accessed by the interactive map at gis.oregonmetro.gov [76].

In Portland, there is a journey planner app by Trimet. TriMet, Tri-County Metropolitan Transportation District of Oregon, operates public transport modes as local bus, light rail, and commuter rail in Portland. This public agency provides trip planner for IOS, android, and web. This app provides you to plan your trip by combining bike and transit, bike and train only, and bike only. TriMet app is available via IOS, android and web. New version of TriMet trip planner at trimet.org provides also to plan your journey by interactive map of Portland [140].

3.5 Conclusion

Portland was grow up around a streetcar system, but after automobiles become dominant than urban transportation. As an outgrowth of the Interstate Highway programs in 1956, highway building became the logical solution to the growing regions transportation needs. With growth of auto use, the city faced with growing congestion.

Portland, the car oriented North American city, with growing congestion due to growing car use, the country's first statewide land use planning laws, draw attention to the need for developing a balanced transportation system and transform regional land use and transportation planning to promote and preserve its livability. The city envisioned to link land use and transportation. With these developments, the City of Portland supported policies and plans that promoted cycling. Overall, Portland gained great progress about increasing the cycling level in the city.

Copenhagen, compared to Portland, have higher cycling levels and a long history of cycling. Copenhagen holds the first place due to investments and innovations by designing strategies to make the city more accessible by bike. The city emphases on public involvement. The city biannually conducts surveys with cyclists to improve cycling in the city. The city implemented integrated, comprehensive policies, plans, programs and long term package infrastructure to encourage bicycle as a transportation mode in the city.

Paris without any history of utilitarian cycling, made great development in cycling level in the city. The city has the most famous and second largest bike share system, Vélib'. Vélib' bike share system was promoted cycling all around the city with attracting the people who had never cycled or rarely cycled. Vélib' bike system has the great impact on increase of cycling level in Paris. Paris to promoted policies of cyclists friendly rules and changed the traffic rules. Also, the City of Paris increased the bike lanes and bike paths as the main attitude of the city. The city also promotes cycling with advocacy organizations that organizes cycling activities and events, cycling trainings to improve cycling condition.

Main findings of investigations:

- Copenhagen
  - The most bicycle friendly city internationally
  - 400 kilometers of cycle paths which separated from car lanes and sidewalks
  - 1.39 million km per day cycled in 2017
  - Holds the first place due to investments and innovations in the city
  - Synchronized traffic lights for cyclists to provide green wave at major arterials
  - Well-connected, integrated and comprehensive network for cycling
  - The wide of the cycle tracks are 2,2 and 2,5 meter
  - Conducts a survey biannually through cyclists to regulate their cycling policies
  - To expand the cycle tracks, accomplish citizens' involvement
  - Teaching their bicycle culture to newcomers of the city
  - Educated cyclists on traffic laws
- Paris
  - 700 km of cycling route (2015)
  - Total length of bicycle lanes to 700 km in 2015
  - 10,000 bike parking spaces on sidewalks from 2,200 to 10,000 and 22,700 other parking spaces
  - 7000 advanced stop lines, limiting speed 30 km/h at two-way cycle lanes in all streets, created 30 speed limit zones
  - Bike share system's name is Vélib' which is the second largest in the world
  - Training courses for children and adults for cycling in the city
- Portland
  - Most bicycle-friendly city in the United States

- The cycling mode share increased from %1.1 to %6.0 between 1990 and 2008
- Linking land use and transportation to improve cyclability
- Developing bikeways with sense of safety and comfort to attract future cyclists
- The bicycle network provides access to bicycle facilities within three to six blocks from anywhere in the city
- Bike boulevards traffic calmed and prioritized for cyclists
- The traffic calmed residential streets as main part of bicycle network
- Bicycle education implemented by a variety of organizations
- Events for promoting cycling

Copenhagen, Paris, and Portland like most of the other European and North American cities have made a great development about integration of cycling and public transportation. European cities Paris ang Copenhagen have interested in increasing the number and quality of bicycle parking facilities in transit stops. North American city Portland have focused on bicycle facilities on buses and rail vehicles besides increasing the quantity and quality of bike parking in the city and transport nodes.

Portland has increased the numbers of the secure and sheltered bike parking facilities at transit stops and station. Also, The City improved connections to transit with bikeways and there is an option to park your bike at the station in case of no available space for your bike on train. Because during peak hours on board rail vehicles could not have extra space for bikes. In addition, every TriMet buses have bike racks to allow you travel with your bike.

In Paris, Except Metro Line 1 taking bikes on the board is not allowed. And in the city buses do not have a bike rack and not allowed taking bikes on board. Also Tramway is not allowed to travel with bicycle. The city is integrated bicycle and public transport by providing Vélib' bike share system and bicycle parking facilities all around the city especially near to transit stations. The bicycle parking facilities are not adequate as shown before in the analysis of cycling facilities and transit nodes area. The city mostly implemented bike racks around the city and transit stations

except Veligo secured bicycle sheds.

The City of Copenhagen, influenced people to cycling as a transport mode by integrating bicycle and trains. Bicycle is allowed to take on board at Metro, S-trains and regional trains.. With the context of integration of bicycle and public transport, The City provide bicycle parking facilities at transit stations and bus stops. Also bike share system Bycyklen combined with transport stations.

Table 3.5: Bicycle and public transportation relation in case study cities

	Parking at public transportation stops				
Parking at public transportation stops			Copenhagen	Portland	Paris
	Train, metro and bus stations	Parking at rail stations	√	√	√
		Parking at bus stops	√	√	-
	Types of parking facilities	Unsheltered/ sheltered	√	√	√
		Guarded	√	√	√
		Bike lockers	√	√	√
		Bike cages	√	√	√
		Central bicycle parking	√	-	-
Taking bicycles on vehicles	Bike racks on buses		√	√	-
	Bikes on Rail cars		√	√	√
Bike Share system at transit stations			√	√	√

CHAPTER 4

INVESTIGATION OF BICYCLE TRANSPORTATION IN TURKEY

4.1 Introduction

In Turkey the elements of bicycle transport planning as a part of sustainable mobility are examined in case study cities. The case study cities chosen among the municipalities that have promoted cycling as an urban transport mode in their city. These cities are İzmir, Konya and Kayseri. In Konya cycling is popular since 1920. Instead of having no history of cycling, Kayseri and İzmir gain great success on promoting cycling as a transport mode. Date gathering from the city case studies by (1) local government statistics and reports; (2) transport plan, bicycle plans, and transportation sections of each city's municipalities official websites; (3) interviews with city's municipalities.

The investigation of case study cities divided into four main titles. These are (1) planning and policies, (2) public transportation, (3) bicycle network, (4) public acceptability. While examining bicycle networks in case study cities, the major transit stations and cycling facilities are visually observed to analyze the essential requirements of bicycle network planning among case study cities. These requirements are safety, directness, cohesion, attractiveness, and comfort. As It is important to develop connection through transit stations for bicycles by ensuring secure, adequate, and qualified infrastructure for cycle tracks to increase cycling levels.

The visual analysis at the chosen transit stations of case study cities in Turkey has been made by visual observations by using google earth and google street view with the consideration of essential requirements of bicycle network: safety, directness, cohesion, attractiveness, and comfort. The transit stations chosen among the major

transit stations in the case study cities.

4.2 İzmir

In İzmir urban development was accelerated from 17th Century. Geographically İzmir located right on the middle of the Aegean coast, on the westerns edge of Anatolia. İzmir province covers 12,012 square kilometers area. İzmir is the third largest city in Turkey and the largest of the Aegean. The estimated population in İzmir was 4.320.519 in 2018 [142].

Geography is the defining characteristics of the City's development. The perpendicular position of the mountains in relation to the shore make the inner regions more accessible, and allow the mild climate of the sea to affect the interiors.

İzmir creates a significant passenger and cargo traffic. As a heart of the Aegean Region, İzmir lies on the north-south traffic axis, connecting agriculture, industry and tourism zones with each other. Moreover, the port serves cruise tourism and exports, and Adnan Menderes Airport provides international connections to the City. İzmir is connected to all neighboring provinces by direct highways.

The number of automobiles per a hundred thousand people was 13.951 according to 2012 data [85]. Averagely everyday 1,250 thousand passengers transported. 74% of these passengers use roads, 23% use rail systems, and 3% use sea routes in 2015 ([28]). 74% of the public transportation in the City is provided on ESHOT's buses. Over the years use of the subway and suburban rail (İZBAN) systems has increased ([28]).

The most used transportation mode is public transportation with 35 percent in 2017. The second most used transportation mode is pedestrian and bicycle use ([30]).

The growth in motorization in İzmir in recent decades generated congestion problems. In 2000, the Metropolitan Municipality of İzmir launched "Transformation in Transportation" scheme to make public transportation attractive more than automobile. This framework aimed to integrate public transport network in the City.

In 2016, İzmir participated in the "EUROPEAN CYCLING CHALLENGE 2016" competition. The competition held in İzmir and people in the İzmir cycled more than 72 thousand kilometers in a month and finished 17th place among 52 European cities. İzmir is the first city in Turkey which participated in this competition. Also İzmir is the first city in Turkey for studying Cycling Master Plan. In 2017, İzmir have been started to study for İzmir Cycling Master Plan.

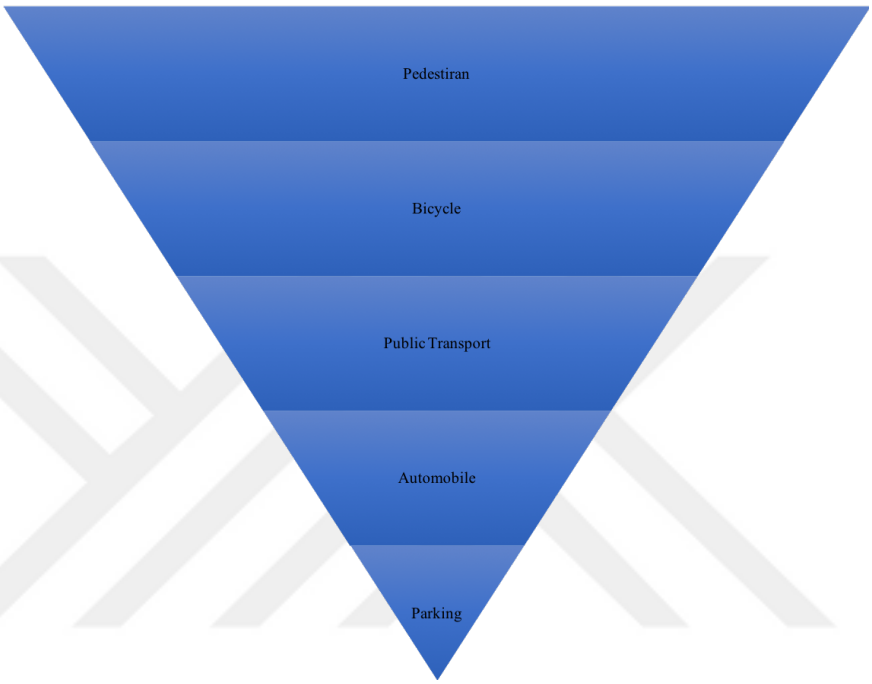


Figure 4.1: The attitude of İzmir Transport Master Plan (Adapted from [30]).

Planning and Policies

In 2016, İzmir established Sustainable Energy Action Plan. Within the plan, the city estimated the greenhouse gas emission in İzmir. The estimated share of greenhouse gas emission of transportation in 2016 was 3.782.849. According to the plan the city expecting to decrease %15 of greenhouse gas emission of transportation. In 2016, the total CO_2e of transportation sector was 4.309.141 tone, and that is equal to 19% of the total CO_2e in İzmir. This makes transportation sector the second most greenhouse gas emitter because of fossil fuel usage of automobiles as the most used transport mode in İzmir ([29]).

To decrease the greenhouse gas emission of transportation, in the 2016 Sustainable

Energy Action Plan five transportation objectives has defined. The first one is to increase the share of public transportation mode in the city with integrating railway systems and other public transportation modes until 2020. The second one is to reduce motorization by promoting cycling and pedestrian transportation. The city aimed to increase bicycle use by %2. Related to the 2030 Transportation Master Plan, Sustainable energy action plan made some recommendations to increase bicycle usage. These recommendations are enhancing the accessibility to railway stations, planning the bicycle network especially long the routes that students use, adding bike racks to existing buses, planning bicycle network through the new neighborhoods, completing bicycle infrastructure as road markings and waymarks until 2020. The third recommendation is using alternate energy sources for public transportation. The fourth one is implementing "Fully Adaptive Traffic Management, Supervision and Information Systems" as stated in the 2015-2019 İzmir Strategic Plan ([28]), too. Lastly, the plan recommended to provide training for drivers of public transportation vehicles. As a consequence of these goals by 2020, the city expecting to a 648.080 tone total decrease of CO_2e ([29]).

According to the interview with urban transportation department of Metropolitan Municipality of İzmir, The City of İzmir aims to provide an integrated policy and planning vision. They want to integrate public transportation with cycling within providing bicycle facilities at transit station and stops. They mentioned that the building policies and visions about transportation should be main concern.

The 2030 İzmir Transportation Master Plan aims to reduce CO_2 emission by 18% (133 tone CO_2/hour) with promoting non-motorized transportation, public transportation and integration of all transportation modes in the City.

By the 2030 İzmir Transportation Master Plan a series of decisions taken into consideration. These decisions include public transportation, transfer points, pedestrian and bicycle transportation, parking systems, highway infrastructure, traffic systems, intracity freight management, urban and suburban transportation.

In the 2030 İzmir Transportation Master Plan considering travel demands and existing highway network and their functions, a classification for public transportation suggested. The network divided into six categories: main lines, feeder lines, urban

lines, transit lines, express lines, private lines. This classification of the public transportation shown in Figure 4.2.

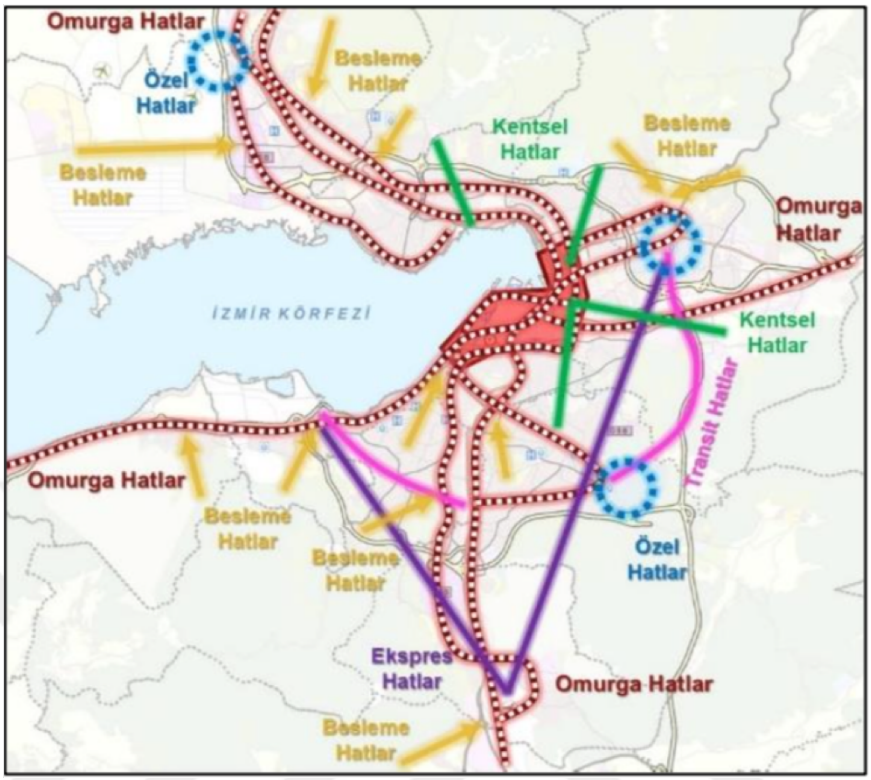


Figure 4.2: Classification of the public transportation network ([30]).

The existing and suggested transit point aims to improve the integration of public transportation modes. The Plan proposed three type transit points depending on their capacity, location and function.

Main Transit Point (TM): built on the main public transportation network. It includes intersections of more than one rail systems. Also these hubs include a large variety of commercial activities.

Transit Point Between Modes (TR): This type of hub is similar to Main Transit Point but differently it is small scaled than TM. This hub located on main networks and promote the usage of the sub-centers.

Transit Point (TN): It is a transfer point between same or different transportation modes. In this hub there are low passenger movement and this hub promotes transportation between town centers.

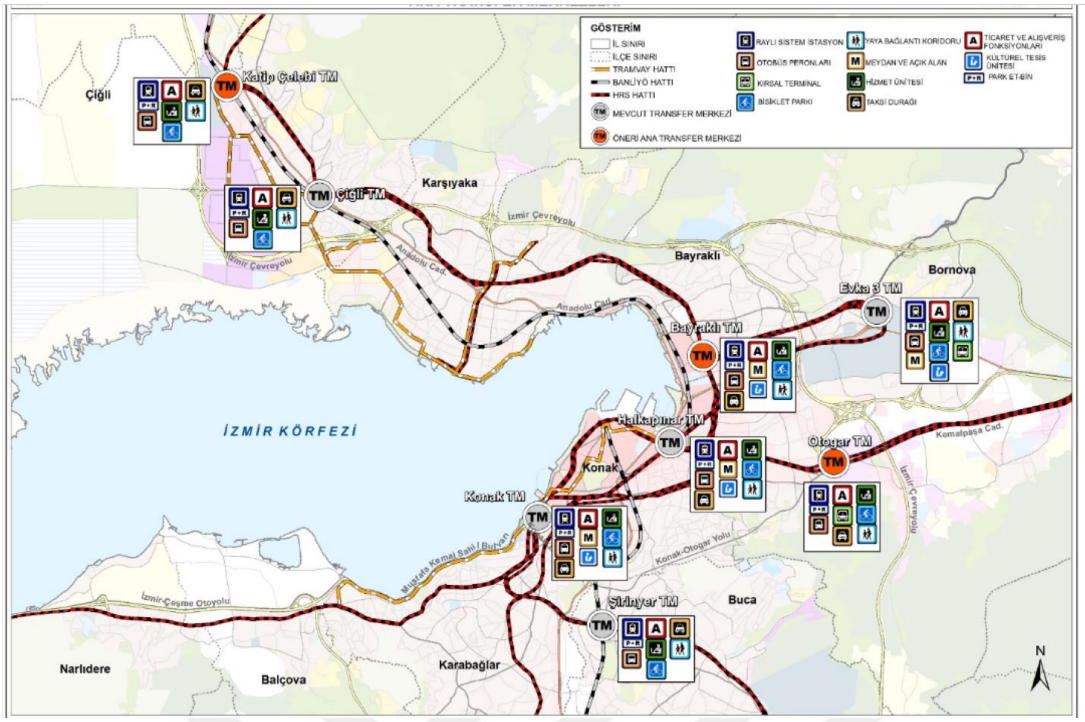


Figure 4.3: Proposed and current main transport points ([30]).

According to İzmir Transportation Master Plan, 2017, the City made some recommendations about bicycle transportation; // • Developing bicycle transportation infrastructure to support cycling // • While constructing bicycle infrastructure standards must be taken into consideration // • The integrity of the cycle tracks must be taken into consideration // • Bicycle transportation must be integrated to public transportation modes, pedestrian transportation, and car parks // • Bicyclists could be able to transfer all along the line of public transportation system with their bicycle. // • Cycle tracks must have parallels with main transportation routes. // • Bicycle transportation master plan must be constituted. // In the Plan there are recommendations to increase of cycling mode share about BİSİM (İzmir bike share system). // • Installing new Bisim stations and bikes // • Implementation of smartcard to integrate BİSİM and public transportation. // • Decreasing the fee of the BİSİM for schoolers //

The recommendations of 2030 İzmir Transportation Master Plan aims to decrease automobile mode share and increase public transportation and non-motorized transportation in the city. Also the Plan aimed to increase the share of rail systems and sea transport in public transport modes.

Table 4.1: Existing and proposed Bisim stations

Existing Bisim stations	29
Short term proposed stations	32
Midterm and long term proposed stations	10
Total planned stations for 2030	71

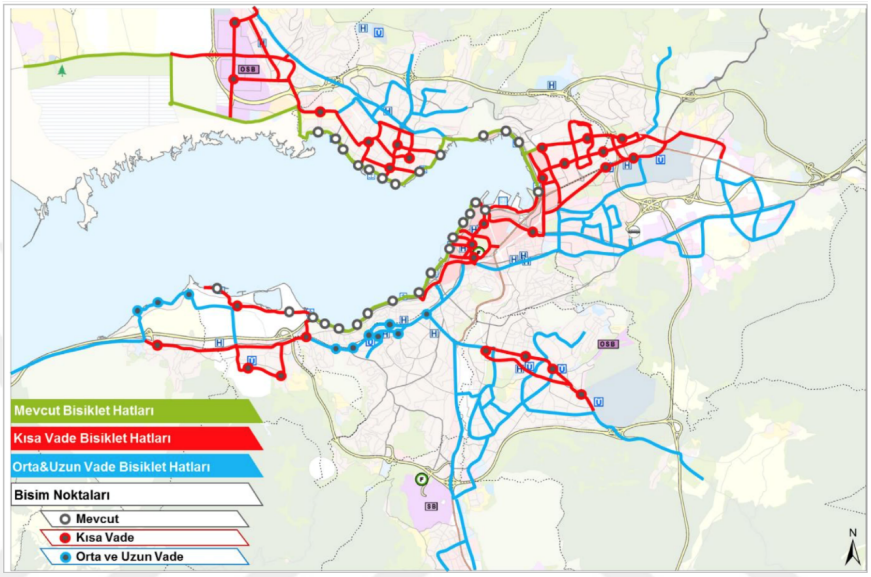


Figure 4.4: Existing and proposed Bike Share System bicycle network, Bisim, stations ([30]).

In 5 March 2019, İzmir Metabolic Cycling Scan published on issuu.com. The İzmir Cycling Scan is a large scale assessment developed by FABRICations and WIRI Turkey Sustainable Cities to evaluate potential for the adoption of cycling as a vehicle for sustainable urban development in İzmir. As İzmir already has ongoing initiatives for promoting cycling. This study evaluated additional functions that cycling could take over in a multi-modal transportation framework. İzmir municipality has been developing a cycling master plan to integrate the coastal cycling system with the rest of the city. And also the city wants to become a part of the Eurovelo network. The İzmir Cycling Scan study based on the experiences on mobility and cycling in Netherlands and Africa.

Public Transportation

Urban public transportation in İzmir is under the authority and responsibility of the Metropolitan Municipality. Public transportation modes are bus, ferry, metro and suburban train line Izban. Mass transportation systems continues to developing to make travelling comfortable, safe, and fast system. Public bike system BİSİM was launched in 2014 and aimed to be integration with public transportation modes. Along the coastline, from İncirli to Sasalı, a continues bike route planned.

According to İzmir İzmir Sustainable Action Plan, it was recommended to increase bicycle use in daily transportation by 2 percent until 2020.

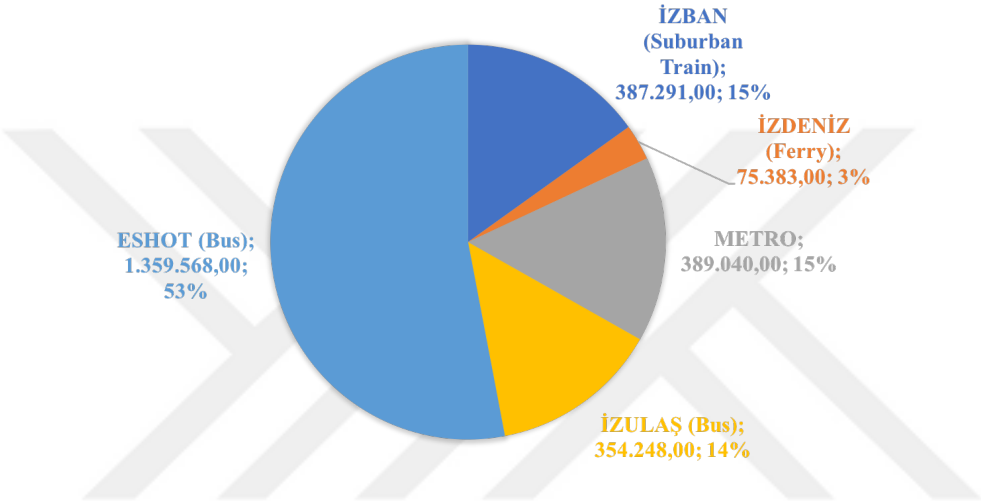


Figure 4.5: Modal share of public transport modes [85].

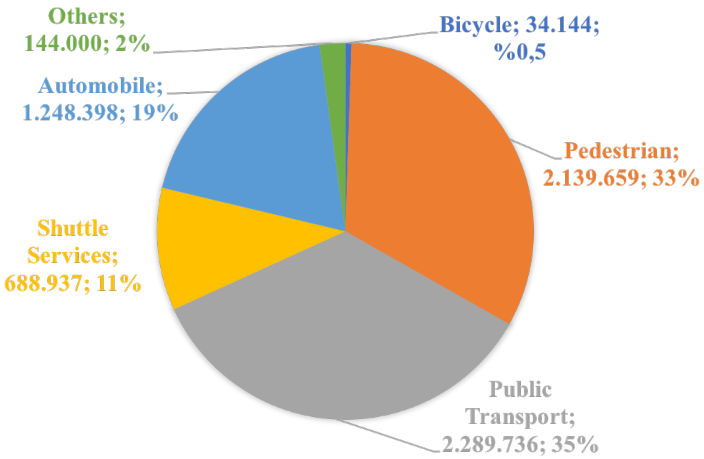


Figure 4.6: Mode shares of transportation by 2017 ([30]).

According to İzmir transportation master plan ([30]) single-centered development in

İzmir could cause decrease in car ownership, increase in journey time, increase in traffic volume, decrease in mode share level of public transport, and decrease in cycling and walking mode shares levels. Depending on the increase of urban population, a rapid increase of car ownership is expected. The number of the automobiles in 2015 was 642.998 and in 2030 it is expected to increase to 1.443.172. So the City of İzmir aimed to integrate land use decision and transport plan. The level of cycling mode share was 1% in 2017.

According to the interview conducted with urban transportation department of Metropolitan Municipality of İzmir, there is a lack of that integration of cycling and vehicle transportation by sea. So their aim is to provide integration of cycling and vehicle transportation by sea through the Action Plan. Also, it is stated that the free transfer between public transport modes in 90 minutes should be provided to BİSİM, too. According to 2015-2019 Strategic Plan ([28]), the city aims to put into operation electric-powered buses to achieve environment-friendly transportation. Also the City wants to be the first city in Turkey for implementing the smart, environment-friendly and disabled-friendly "Fully Adaptive Traffic Management, Supervision and Information Systems".



Figure 4.7: ESHOT bike racks on buses [13]

The city plans out to make transportation affordable for residents with the smart stop system and the 90-minute practice in transportation. Also the city wants to increase the number of bicycles and stations in the BİSİM project to encourage the use of bicycles. ESHOT buses with bike racks serve on certain times depending on weekdays and weekend. The time lines of these buses shown on the ESHOT website. There are 60 buses with bike racks that could carry two bikes. You can travel with your bike on Metro and IZBAN.



Figure 4.8: Bikes on board, İzmir Metro [30].

With the slogan of "Bicycle city İzmir" İzmir Municipality in 18 January 2014 started to operate BİSİM. Until 2019, 1.3 million bicycle rented from BİSİM stations. The total number of BİSİM bicycles is 500 and there 34 BİSİM station in 2019. The price of the renting BİSİM bicycles is 3 TL for per hour. You can rent bicycles by using BİSİM Kart or you can pay with credit card. You can also use İzmirimkart but to activate this card for using BİSİM at least you need to have minimum 20 TL in the card. With the website of the BİSİM you could find the available Bisim stations and bikes.



Figure 4.9: Bicycle stations of Bisim .

Bicycle Network

By the year 2013, bike routes in İzmir were planned around the bay area: from Karşıyaka to Sasalı, from Konak to Alsancak Seaport and to Üçkuyular. In 2013,

bicycle routes had a total length of 25.8 km. İUAP aimed to increase bike routes. According to the 2009 Transportation Master Plan the suggested new bike routes consist of four sections. These sections were north line (22.9 km), east line (24.5 km), south-east line (13.9 km) and south line (37.5 km). In 2013, the planned total bike route was reached to 98.8 km [85].

Table 4.2: Proposed bicycle network according to 2030 İzmir Transport Master Plan ([30])

Term	Road lenght (km)
Existing	51
Short term proposed	154
Midterm and long term proposed	248
Total bicycle network for 2030	453



Figure 4.10: Cycle path along the cost line and bicycle counter, İzmir

In the cycle route along the cost lane there are bicycle counters that shows the number of bicycles passed daily and yearly. According to İzmir Transport Master Plan, the aim is to ensure secure bicycle parking facilities at public transport stopes and stations, recreational areas, shopping centers, and cultural centers. Also, The Plan aims to integrate the pricing system of bike share system with public transportation, and take bikes on the public transport vehicles.

According to the interview with urban transportation department of Metropolitan Municipality of İzmir, they installed bicycle parking facilities at some schools through their submission to municipality. But because the implementation costs are too high

to supply by the municipality. About bicycle parking it is stated that they planning to provide bicycle parking facilities at transport nodes, stops, and ferry terminals. They also implemented solar powered bicycle signals.



Figure 4.11: Proposed secure bike parking, İzmir [30]



Figure 4.12: Bike racks outside of the Bornova metro station, İzmir [30]



Figure 4.13: Bicycle parking consists of racks, İzmir

İzmir Konak Metro Station - Analyze of cycling facilities and transit station

İzmir Konak metro station is located in the city center. This station is one of the five main transit nodes in İzmir. This transit node connects commercial and shopping area, BİSİM public -bike share station, metro station, bus stops, and pedestrian are.

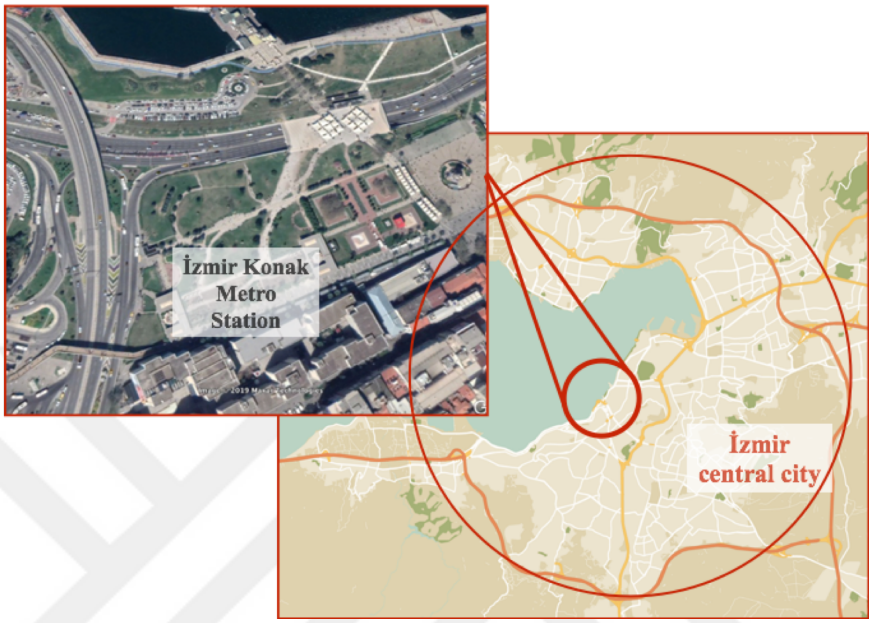


Figure 4.14: Konak Metro Station, İzmir (map style with google; google earth).

Providing safety of the bicycles is another main concern. The safety of cyclists should be provided through the way to transport station. This can be provided by bike lanes that is separated from higher traffic street when the road is convenient or by providing a lane beside the bus lane.

In Figure 4.15, in the first and second picture, the bike-share system BİSİM is seen. The BİSİM station have docking spaces and the kiosk where the user can be able to get information about the system. The system placed on the pedestrian area that connects to the metro entrance and bus stops. As seen in this pictures, in the transit node area there is not a bicycle parking space and specified bicycle lane.

In the third picture, there is a bridge for pedestrians, cyclists and for the people with disabilities. This physical connection provides cohesion at the transit node area by strengthening the physical connection of transit node. The transit node area linked to the bicycle track on the coast line by the pedestrian area. Along the pedestrian

area and shopping district there is not a cycle lane, so it may cause conflict between pedestrians and cyclists.

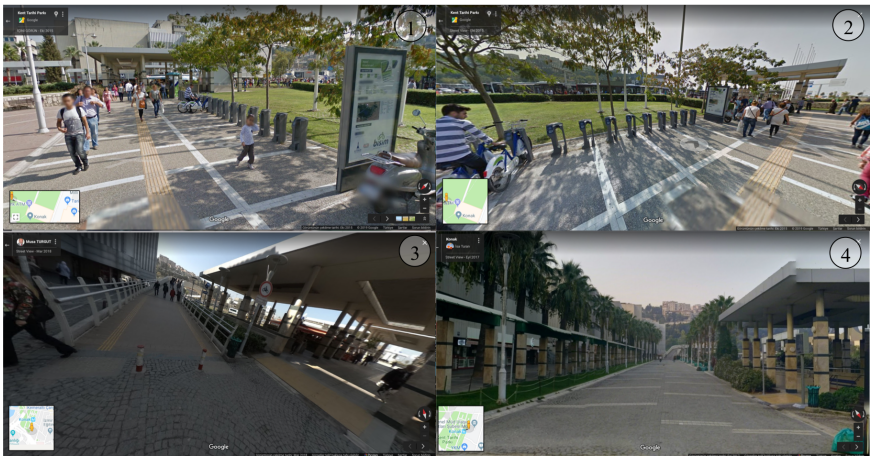


Figure 4.15: Pictures of the visual analysis at the Konak Main Transit Node (google earth, street view).

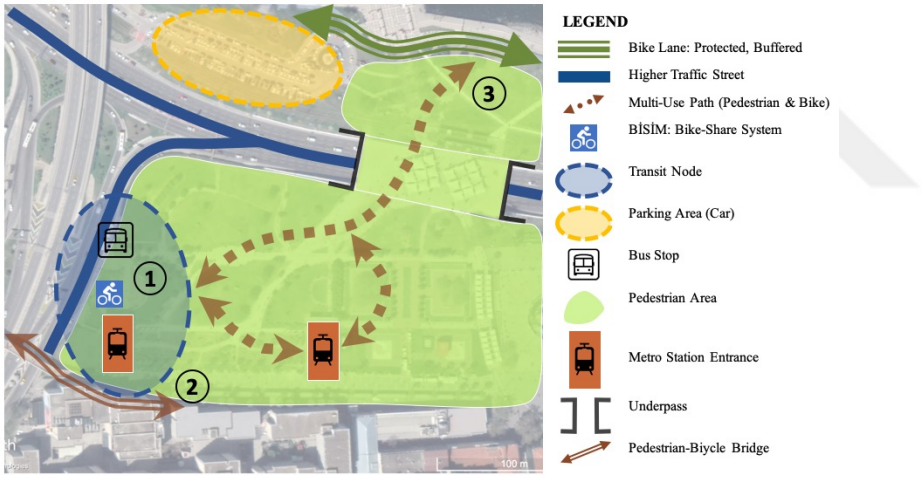


Figure 4.16: The visual analysis of the Konak Main Transit Node.

The physical connection between different transport modes on the transit node is strong. Controlled human activities and well-designed bus stop line prevent the conflict of buses, pedestrians and cyclists. The landscape along the metro entrance and bus stop ensures high transparency. So instead of the lack of cycle tracks, a cyclists So, people that exit the metro station can easily find the direction of the bus stops and BİSİM station. On the pedestrian area the lack of the bicycle tracks causes high complexity for cyclists. The linkage between the transport modes provides cohesion

in the manner of the bridge for cyclists and pedestrians, well designed functions and uses. Also, in the docking station of BİSİM, it is clear to define the position of the metro station entrance or bus stop for cyclist with well-designed functions and uses.

Public Acceptability

İzmir is the first city in Turkey joined to Eurovelo European bicycle route. İzmir Bis Fest organized between17-20 October 2019 in Karşıyaka Bostanlı Recreation area and skatepark. Metropolitan Municipality of İzmir, Municipality of Karşıyaka, city council, nongovernmental organizations, and bicycle manufacturers attended to İzmir Bis Fest.

At the İzmir Bis Fest, bicycle and traffic education for children, education about cycling safety education for adults, and first aid training were provided. Municipality of Karşıyaka and BİSİKOOP, Akademi Karşıyaka and Metropolitan Municipality of İzmir organized Bis Fest to promote cycling in the city and to adopt cycling culture [84], [75].

In İzmir there are various bicycle groups that promote cycling. Some of them are İzmir Perşembe Akşamı Bisikletçileri (PAB), İzmir Çarşamba Akşamı Bisikletçileri (ÇAB), Pedal 35, Group of İzmir'de işe Bisikletle Gidenler, and the group of İki Teker Bir Yer. Perşembe Akşamı Bisikletçileri is one of the major bicycle groups in İzmir. The meeting point of the group is at Göztepe Ferry Port. The group members cycle every Thursday in the city center. Pedal 35 is a bicycle group aims to support cycling as a kind of sport. The members of Pedal 35 meets in Bostanlı and cycles in the city center. At the weekends, they cycle for 100 km length to different destinations. The members of Çarşamba Akşamı Bisikletçileri meet in Bornova every Wednesday and cycle in the city center. The group of İki Teker Bir Yer, addresses love of the nature and animals. The group involves approximately 500 members. The members of the group cycle for nature related organizations. The members of İzmir'de İşe Bisikletle Gidenler aims to support cycling as a transportation mode. They address the challenges that they have faced while cycling in the city [82].

The City of İzmir has a smart transport system İZUM. İZUM app and website provide users to plan your trip by metro, train, ferry, tramway and bus. But this system is not

integrated with bicycle transportation. With using İZUM app you can see the traffic situation, free places to park, accidents, and travel times (izum.izmir.bel.tr, 2019)

4.3 Konya

Konya is the seventh most populous city with a 2.205.609 of population in Turkey [142]. The City is located in south-western edge of the Central Anatolian Plateau. Konya is the largest plain with 41.001 km2 of total area (Konya Plain) in the country. Konya generally has a broad and flat land consisting of lowlands and plateaus. Southernmost part is mountainous, surrounded by Taurus mountains Konya plain is a flat plain with a height of 900-1050 m.

From 1920, in Konya is the popular with bicycle transportation in the city center. The number of bicycles in Konya reached to 650.000 in 2011. The flat plain of Konya was encouraged bicycle use to transport between city center, fields and vineyards. Also Metropolitan Municipality of Konya organizes every year a bicycle festival to support cycling.

Planning and Policies

In the Konya, Karaman Region Plan, development of environment-friendly mass transit systems and concentrated policies in all city centers, particularly regional development main centers shall be encouraged. Due to this recommendation, the Plan proposed supporting bicycle use and encouraging mass transit (underground and above ground) to minimize traffic based air pollution. Also, in the Plan cycling shall be encouraged as a tourism activity.

In the Strategic Plan 2015-2019 ([31]), Metropolitan Municipality of Konya proposed initiatives for transportation that includes building 240 km of bicycle network, and offering 500 smart bikes in the City. Also, the Plan was aimed that development of transportation network. To achieve the aim, the City wants to plan and build 50 km per year.

As stated at the interview had done with urban transportation department of Metropolitan Municipality of Konya, bicycle mode share is 33,2% because it is free to use and

the economic challenges that people faced. In Konya bicycle use is an economic necessity. The proposed bicycle action plan in 2019 prepared by a private planning company. The planning company conducted a survey with 2000 people in Konya. According to survey results 80% of the participants are cycling for transportation, 18% for sporting, and 7% for shopping. In the Bicycle Action Plan they aimed to increase the modal share of cycling transportation by encouraging people. Also, the plan aims to promote cycling as a tourism activity by linking the historical locations in Konya. According to analyze of 60 section of motorized traffic, at some intersections daily 3000 bicycle passes. The planning company specified location for bicycle parking facilities and bicycle lanes in neighborhoods.

It is stated by urban transportation department of Metropolitan Municipality of Konya, the first cycle word used in 2002 Transport Master Plan. Also The City of Konya is the first city that proposed and completed a Bicycle Action Plan in Turkey.

The survey results showed that 41% of the participant think that cycling in Konya is not safe and 25% of the participant think that bicycle network is not cohesive. According to these results in the Bicycle Action Plan, the planning company aimed to provide a cohesive cycle network by regulating existing bicycle lanes and proposed lanes.

Public Transportation

In Konya, Public transportation network consist of buses, street railway, and electric buses. Also, metro line is under construction in Konya. The spatial development of the city, after 2000, is shaped by urban transformation projects.

Urban transformation projects, have significant impacts on transportation systems and land use decisions [154].

According to the interview, it is stated that there is no policy and planning for public transport and bicycle integration in Bicycle Action Plan. In the plan it is proposed that in streetcar and on the buses with racks bicycles could be carried.

Public bike share system in Konya has been launched in 2012 and operated by nextbike network. But with the Bicycle Action Plan new operator is going to be chosen by

Metropolitan Municipality of Konya,

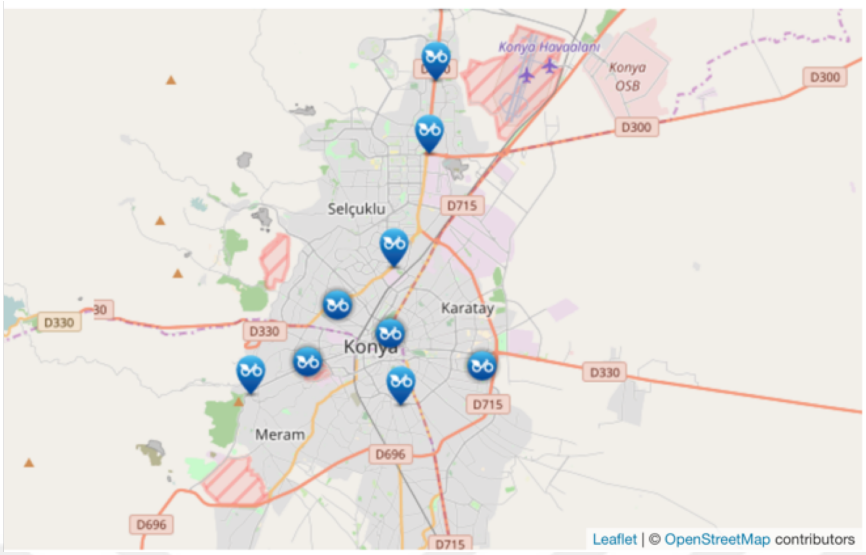


Figure 4.17: Locations of Nextbike stations in nextbike website [111].

The system works with ELKART or with a credit card. ELKART is available in public transport modes too. There are sensors on the stations that enables a quick rental of bike with ELKART. To rent a bike by using ELKART, you just need to hold your ELKART in front of the sensor that placed on the stations. Another way to rent a bike is using credit card. If you do not have an ELKART you should use your credit card on the kiosks that placed on the stations, and then you are free to take a bike on the station.

It is possible to register the nextbike on the website of nextbike or on the station. If you are registered already on the website of nextbike, you should place your ELKART in front of the sensors on the stations and enter your phone number and PIN. To return the bike, you should follow the same steps. After a successful return, a signal shown on the rack. The prices of the nextbike system in Konya is shown in Table 4.3.

You can return the bike at one of the official locations which shown on the location list on the Nextbike website. Otherwise, you need to pay 4 TRY per km, at least 20 TRY to return the bike at non-official locations. Another further service fee is equity contribution by damage or theft: 300 TRY. Nextbike system consists of 40 stations, and 500 bikes. On the website of the Nextbike system there is an online map that shows available bikes on the stations and nearest bike stations' locations.

Table 4.3: The prices of the nextbike system to rent a bike [111]

1 rental per day 30 minutes	free
Per ongoing hour	1,5 TRY
24 hours	15 TRY
1 week (7 days)	60 TRY
1 month (30 days)	180 TRY

Bicycle Network

In the Strategic Plan 2015-2019 ([31]), Metropolitan Municipality of Konya proposed initiatives for transportation that includes building 240 km of bicycle network, and offering 500 smart bikes in the City. Also, the Plan was aimed that development of transportation network. To achieve the aim, the City wants to plan and build 50 km per year. In the City the total length of bike lanes are 515 km as stated by the mayor of Metropolitan Municipality of Konya [92].

The number of existing bike share system stations is 40 and number of bicycles is 80. They planned to increase the number of stations to 500 and bicycle to 1000. According to interview, the planning company proposed bicycle boulevard in Fetih Street in Konya. Also, it is stated that the existing bicycle lane in Şefikcan Street is a misapplication and it is not provide safety concerns for cyclists. Also it is stated that in the Bicycle Action Plan there is no concern about providing secure bicycle parking facilities in the city, especially at transportation stops and stations. According to interview, it is not possible to cycle to municipality building and there is not a bicycle parking facility around the building.

In 2018, Metropolitan Municipality of Konya to promote cycling placed bicycle repair station in to the 26 different points in the City. The people of the city could use the stations with free of charge. The stations have a variety of repair materials for bicycles.



Figure 4.18: Bike lane at Şefikcan Street occupied by parked cars

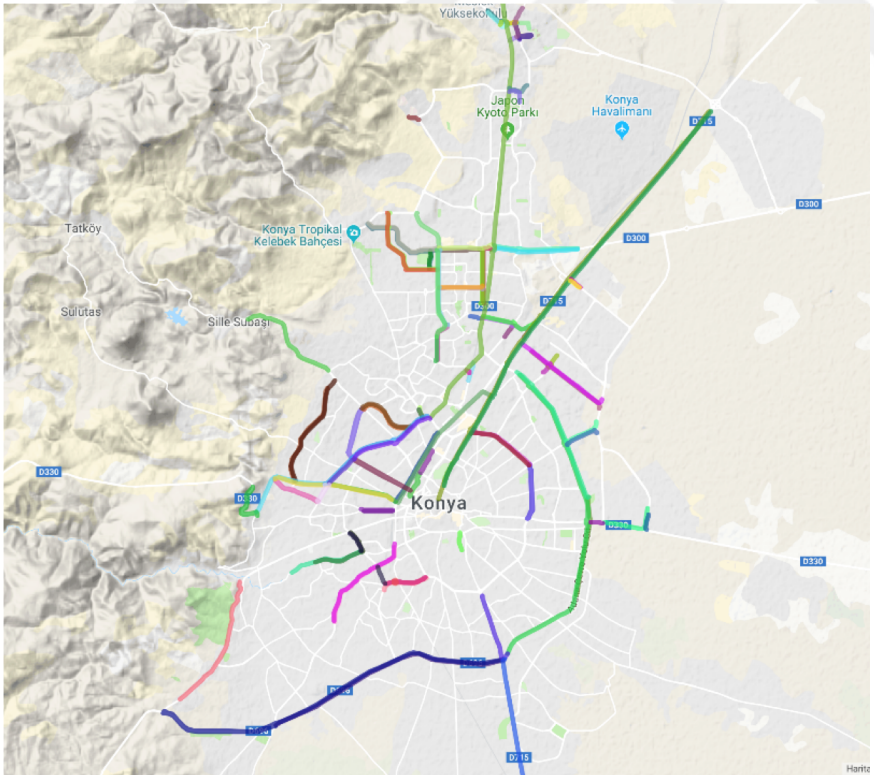

Yükseköğretim
Japon Kyoto Parkı
Konya Havalimanı
Tatköy
Konya Tropikal Kelebek Bahçesi
Sulutaş
Sille Subaşı
Konya
D300
D330
D330
D330



Figure 4.20: Bicycle repair stations in Konya [20].

Aydınlık Evler Tram Station - Analyze of cycling facilities and transit station

Aydınlık Evler Tram station is located at the North side of the residential area in Konya. At the South east side of the tram station Yeni İstanbul Street and Aydınlıkevler underpass, at the North west side of the station Konya Kent Plaza shopping center is located.

In Figure 4.22, the location of the cycling track is seen as at the other side of the Yeni İstanbul street. The sustainability of the cycling track is ended suddenly with the motorized traffic. Accessing from this cycle track to the tram station is complicated because of the uncontrolled roundabout. There is not any enhanced crossing or signage for cyclists. A cyclist for accessing the tram station needs to cross four crossing designed for pedestrians. At the end of the cycle track to pass the first crosswalk they have to go through the motorized traffic. The advertising boards and street lamp cuts the continuous of the cycling track. Bike-share system of Konya, NEXTBIKE station is located on the North part of the roundabout. To this part of the roundabout there is no pedestrian or cyclists crossing. Access to the NEXTBIKE station is dangerous both for pedestrians and cyclists. A pedestrian who wants to continue to travel by bicycle is do not have a safe access to NEXTBIKE station.



Figure 4.21: Aydınlık Evler Tram Station, Konya (map style with google; google earth).



Figure 4.22: Pictures of the visual analysis at the Aydınlık Evler Tram station (google earth, street view).

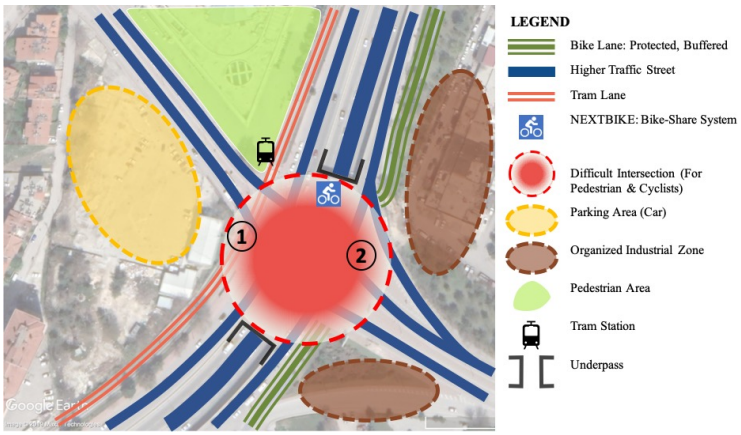


Figure 4.23: The visual analysis of the Aydınlık Evler Tram station, Konya.

Around the station area there is no bicycle parking space for who wants to park their bike and continue with Tram. The roundabout between cycle track and station is blocked the connection. Because of the automobile oriented design, lack of bicycle facilities, it is hard to mention the existence of safety, attractiveness and cohesion. In this investigated area there are complexity of the crossings, lack of signage for bicycles, the lack of linkage between cycle track, bike -share station and Tram station. The high speeds and volume of the traffic, the lack of enhanced bike crossing, the discontinuous cycle track are not provide the safety concerns for cyclists.

Public Acceptability

In Konya, there are various bicycle groups. Some of these groups are Perşembe Akşamı Bisikletçileri, Çarşamba Akşamı Bisikletçileri, and Konya Bisiklet Topluluğu. The member of Konya Perşembe Akşamı Bisikletçileri meets every Thursday at KültürkPark Kütüphane to cycle in the city. Çarşamba Akşamı Bisikletçileri aims to promote cycling as a transportation mode in the city. The members of the group meets every Wednesday at Cumhuriyet Parkı to cycle in the city center of Konya. They also organizes cycling events four weekends. In the City of Kayseri, Konya Bicycle Association that aims to support cycling as a kind of sport. The website of this association, inform cyclists about bicycle news, events, and bicycle races.

The City of Konya has a smart public transportation system ATUS, to provide users to plan their trip in the city. This systems shows the routes that public transport modes pass, departure times, estimated arrival times of the public transport at expected station or stop, and nearest bus stops to your location. The system also provide you to learn the arrival time of the bus at the bus stop via sms. This smart transport system does not provide any information about bicycle transportation and integrated route planning between bicycle and public transportation [74].

4.4 Kayseri

The population of Kayseri was 1 389 680 in 2018 [142]. Kayseri is the fifteenth most populous city in Turkey. Kayseri Transportation Master Plan launched in 2008, by Metropolitan Municipality of Kayseri. The main objectives of the Plan include, min-

imizing the effects of the urban transportation on the environment and the city, prioritizing public transportation, prioritizing bicycle, prioritizing pedestrians, decreasing automobile usage in the city by limiting vehicle entry in the city center and by promoting public transportation, integration of all public transportation modes and integration of public transportation with pedestrians, bicycle, and automobile.

Planning and Policies

To preserve the historical city center in Kayseri, the Plan aims to limit the vehicle entry in the Center by time limits, charges etc. Also the Plan aims to prioritize bicycle and pedestrian in the center and reduce the emission. In the city center the City wants to make slow down the vehicle traffic by moving transit vehicle traffic outside of the city center.

The parking policies in the Plan aims to prioritize bicycle and pedestrian in the centers and reduce emission. The parking policies in the Plan tend to reduce vehicle traffic and enhance the environment. Accordingly, the City wants to ensure integration of public transportation and automobiles by park and ride policy. The planned park and ride facilities should be located on the junction points of rail systems and main roads.

In the Kayseri Transportation Master Plan, bicycle considered as a transportation mode. The Plan aims to increase bicycle commuting by planning cycling paths and a cycling network. Also the city wants to promote cycling by "bicycle day, bicycle festive, bicycle race". The Plan considered about raising awareness about global warming and air pollution and about the role of bicycle to fight about these concerns. In the "8. Five Year Development Plan Preparation Document", it was stated that cycling should be developed as the one of the least endangered transportation mode for environment.

The first goal about bicycle transportation in the Kayseri Transportation Master Plan is increasing the share of bicycle in urban transportation modes. The second goal is, promoting bicycle commuting. The last one is ensuring bicycle safety. To achieve these goals, the Plan stated some strategies. The first one is planning separated bicycle lines and paths on the main roads that have busy traffic. The second one is regulating intersections for bicycle. The third strategy is when there is not enough space on

the road for a bicycle line than an alternative bicycle path should be planned. Fourth strategy is planning bicycle infrastructure such as secure bicycle parks, bicycle lines, bicycle paths, intersection regulation for bicycles. Lastly, planning and implementing the systems that provide carrying bicycles on public transportation systems.

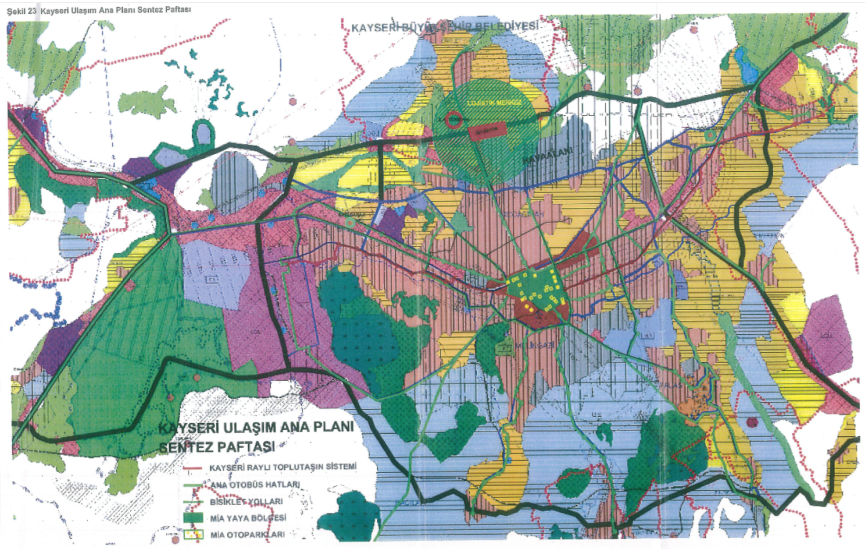


Figure 4.24: Kayseri Transportation Master Plan [19].

According to the research for the Kayseri Transportation Master Plan, the share of bicycle use is 0,16% in 2008. In the Plan while proposing bicycle network, the potential routes chosen considering the mostly used routes by students and working population was considered. The Plan proposed a bicycle network around the city and in the neighborhoods. While proposing a bicycle network in the neighborhoods, the Plan considered to link schools, sub-centers, and residences. In the Plan the proposed bicycle roads categorized by the length of the shared road.

Public Transportation

In Konya public transport network consist of buses and streetcar. The policies about public transportation seeks development of the public transportation systems and increase of the share of the public transportation in urban transportation. These policies contain integrating public transportation with other modes of urban transportation, integrating public transportation terminals and transit areas with bicycle and pedestrian considering accessibility and convenience. The plan intends to make the city center a junction point of pedestrian, bicycle, and public transportation. In the neighbor-

hoods the routes of public transportation modes should be direct and for every 250m distance public transportation should be accessible.



Figure 4.25: Transfer points in Kayseri [19].

Public bike sharing system in Kayseri launched on 2010 to decrease the traffic congestion in the city center and develop green transportation network in the City. In 2015 Kayseri Transport Inc. started to operate the bike share system. In 2015, KayBis system consists of 51 stations, 600 bikes, and 90 km of bike network in 2018. In Turkey, Kayseri is the first city that adopted a bike share system.

According to interviews conducted in Metropolitan Municipality of Kayseri and Kayseri Transport Inc., it is stated that the main aim of the implementing Kaybis bike share system is to enhance public health and promote cycling as a urban transport mode in related to the Transport Master Plan of Kayseri. The City is promoted bike share system not for make profit but for raising awareness among the public. The Metropolitan Municipality of Konya operates bike share system with Kayseri Transport Inc. with affordable costs. The first 30 minutes are free and after 30 minutes the cost increases 0,50 TL. Also aimed to make it used no longer than 3,5 hours by increasing the charges after 3,5 hours by 3 TL for every hour [90]. Kaybis bike share system has been designed, programmed, manufactured, and operated by Kayseri Transport Incorporated Company. they also provide this system to different cities.



Figure 4.26: Kaybis station, docks and bikes .

Table 4.4: Charges of KayBis [90]

KayBis Card	Charges
30 min	free
30 min - 60 min	50 kr
60 min - 90 min	1,0 TL
90 min - 120 min	1,5 TL
120 min - 150 min	2,5 TL
150 min - 180 min	3,5 TL
180 min - 210 min	5,0 TL
210 min +	+3,0 TL
Credit Card	
first 1 hour	2,0 TL
after 1 hour for every 1 hour	+1,0 TL

The stations of Kaybis bike share system are located at transit stations and bus stops to integrate with public transport system in the city. 50% of the docking spaces at the Kaybis stations have no bicycles locked because to provide users always an empty

docking spaces at any Kaybis station. There are 53 204 Kaybis bike share system users and mostly used for economic necessity. The City implements new Kaybis stations by considering the requests of the public. According to interview, the city want to develop the existing third generation bike share systems to fourth generation bike share system by removing the kiosk at stations and docking spaces.

To use the KayBis bikes you need to register with your national id card on a Kart38 department. To get a Kart38 you need to be 17 years old at least. After your registration you need to wait up to 2 days. The other option to use KayBis bikes you can use your credit card. But the charging fee for credit card is higher than Kart38 (Table 4.4) [90].

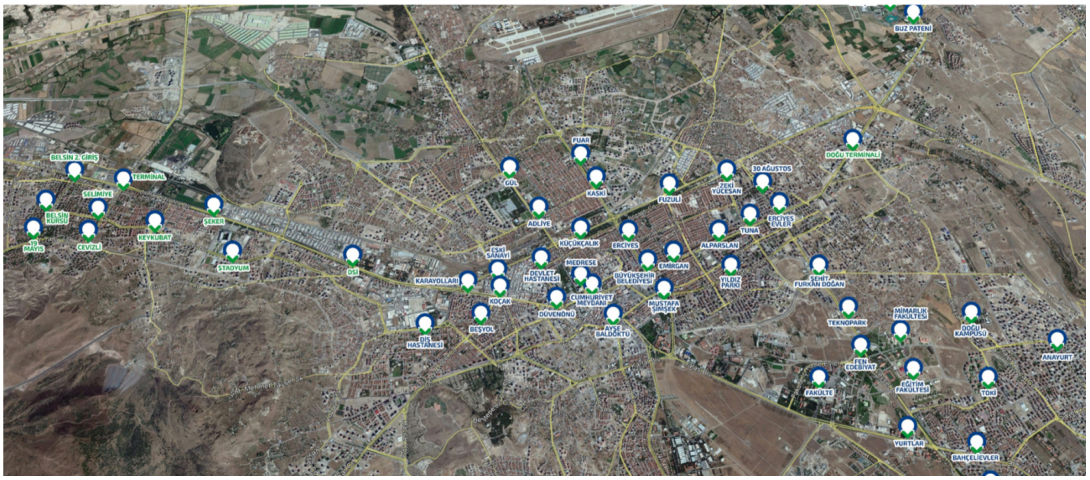


Figure 4.27: KayBis stations [91].

In kayseriulsim.com you could be able to plan your trip by using Kaybis bicycles. In the website also, you could be see the available bicycle numbers in the stations. In the web site the only available language is Turkish. The KayBis system has closed every year in November and start to provide service every year in April. Kayseri Ulaşım A.Ş. also, operates bike share systems in Mersin, Muğla, Gaziantep, and Malatya. The KayBis stations and bicycles have some features. In the stations, there is smart lock point. These kiosks have a suitable lock for different amount of bicycles, have advanced and safe locking systems, have been integrated electronic service, have battery support against power cut, have information transfer through GPRS. Also the kiosks occupy minimum space and user friendly.

Bicycle Network

In the city the bikeways that is not separated from motorized traffic. There are 90 km of bikeway on the streets with 50 km/h speed. In the city, the speed limit is 50 km/h.



Figure 4.28: Park and ride by Kaybis bike share system at Humat parking garage (left) and bike racks at Forum Kayseri (right) .

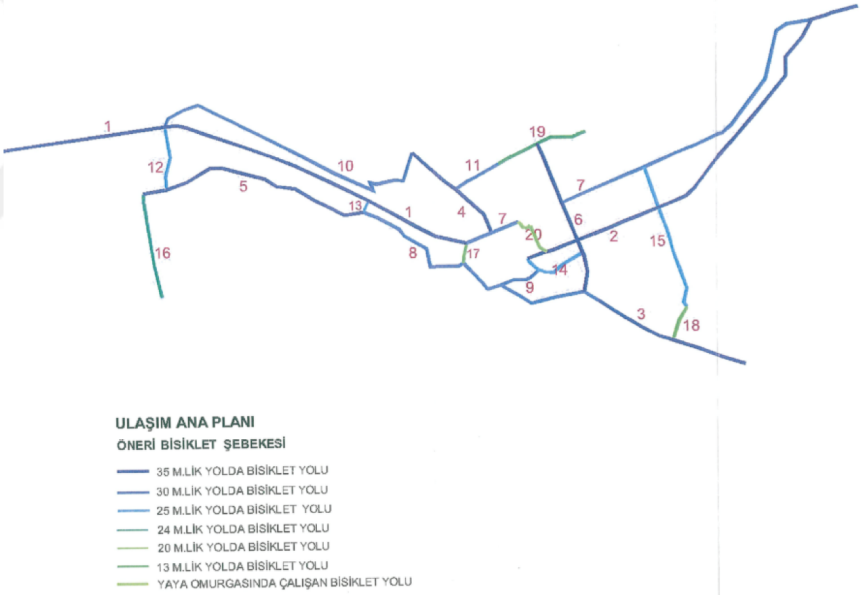


Figure 4.29: Proposed bicycle network to link the transit stations and stops [19]

The space for bikeway are supplied from sidewalks. The locations of bikeways defined to link the bike share stations that already located at transit stops and stations. The city have bike lane parallel to light rail way. At the city center, the Humat parking garage have Kaybis station to provide motorists to park their car and use Kaybis bikes to travel and park the bike at any of Kaybis stations in the city center. The City

of Kayseri have no aim to provide bicycle parking areas in the city. Mostly the commercial buildings provide bike racks in front of their buildings such as Kayserium Shopping Center.

Kayseri Büyükşehir Belediyesi Tram Station- Analyze of cycling facilities and transit

Büyükşehir Belediyesi Tram station is located in the heart of the city. The station named with the Metropolitan Municipality of Kayseri Building. The station is serves to Metropolitan Municipality of Kayseri and Forum Kayseri Shopping Center. The station entrance is located on the roundabout that is the crossing of Sivas Boulevard and Mustafa Kemal Paşa Boulevard. In Figure 4.31, the crossings are enhanced for pedestrians with lightening. For cyclists, there is only ramps with blue colored on the edge of the sidewalks. The access to the station can be via walking, bus or cycling.

Through the station there is not access with cycling track. People are cycling at the sidewalks or motorized traffic. The land grade of the pedestrian area is same with motorized traffic. This is effects the safety of the area and controlling the movement of the pedestrians. Even if the area is in the same grade with motorized traffic, functionless barges placed two side of the pedestrian area. This barges cannot block the vehicles to drive through the pedestrian area. Also because of the same grade level pedestrians do not use the crosswalks.

Bike-share system of Kayseri, Kaybis, is located on the pedestrian area at the roundabout. The station has kiosk that enables the users to find the locations of the other stations or have information about the system. Except of the Kaybis docking spaces in the station area there is not a bicycle parking area. People lock their bicycle to the street furnitures on the pedestrian area.



Figure 4.30: Kayseri Büyükşehir Belediyesi Tram Station (map style with google; google earth).



Figure 4.31: Pictures of the visual analysis at the Büyükşehir Belediyesi Tram station .

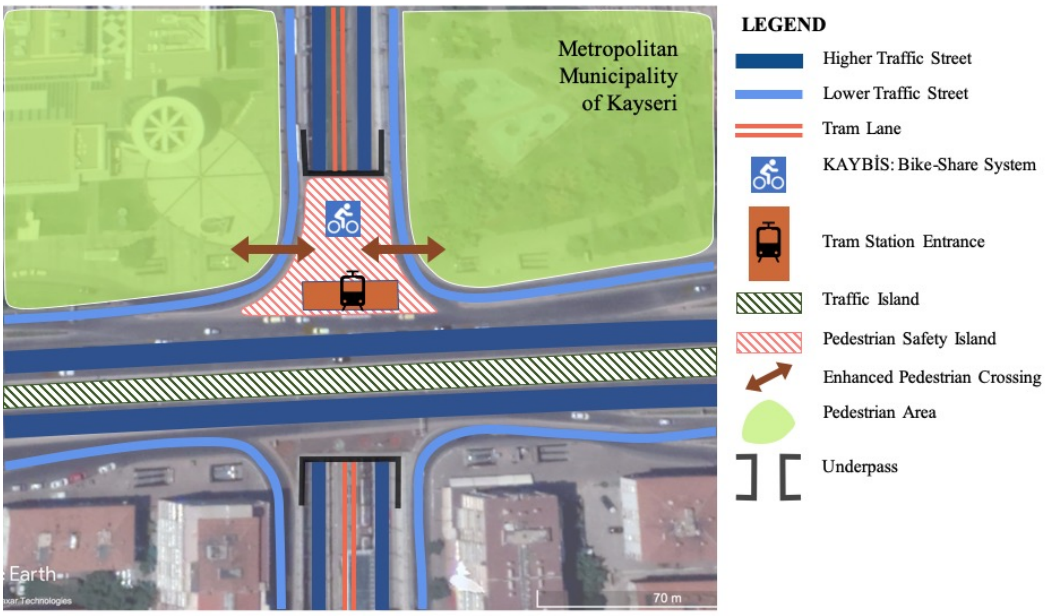


Figure 4.32: The visual analysis of the Büyükşehir Belediyesi Tram station.

Around the station area, there is a clear vision for cyclists by human -scaled vegetation and the linear link of the open spaces. This promotes the connectedness but on the other side, the lack of cycle tracks and enhanced bike crossing affects safety and cohesion of the area. The movements of pedestrians cannot be controlled through the crosswalks and there is a lack of functions and uses.

Public Acceptability

The Metropolitan Municipality of Kayseri organizes Festa 2200 Bicycle Festive in Erciyes every year in the month of July. This festive takes four day long. During the festive cyclists ride in Kayseri and to the Erciyes mount.

The Sport Inc. of the Metropolitan Municipality of Kayseri organize cycling events in the city in special days and national days to promote cycling as a healthy way of transportation. Metropolitan Municipality of Kayseri Transportation Inc. every year organizes Kayseri Bicycle Festive. The first one is organized in the year 2006. In the Kayseri Bicycle Festive, Kayseri Transportation Inc. installed biking trail for cyclists to acrobatics show by bicycles; [57], [14], [158].

In Kayseri, there various bicycle groups promotes cycling by cycling in the city. Soem

of these bicycle groups are Kayseri Perşembe Akşamı Bisikletçileri, Seyyah Bisiklet ve Dostluk group, Özkayalar bicycle group, and ARGOS. The members of bicycle group Kayseri Perşembe Akşamı Bisikletçileri meet every Thursday in front of the Kayseri Forum Shopping Center and start from this meeting point to cycle in the city to promote cycling as way of transport mode. They also cycle within the city in special days and national days.Özkayalar bicycle group's most of the members are children. The members of Seyyah Bisiklet ve Dostluk group in the week days cycle in the city but they mostly cycle for long trips to different cities. The members of the ARGOS group cycle in and around Kayseri. [12]

Metropolitan Municipality of Kayseri launched an information system https://cbs.kayseri.bel.tr. By using this information system, you can plan your trip by bike, tram, and bus.

4.5 Conclusion

The findings of examination of the elements of bicycle transport planning as a part of sustainable mobility in the case study cities from Turkey are given below. The case study cities have both gain success on promoting cycling in different extents and different approaches.

The City of İzmir, planned transport nodes that are provide integrate transport modes at the same space. These transport nodes includes BİSİM stations and bicycle parking facilities. Bicycle network planned in short and long term with the aim of linking the existing and proposed transport nodes. The City wants to improve the integration of bicycle and transportation by ferries and provide free transfer between public transport and BİSİM in terms of bicycle and public transportation.

Main findings of city case study analysis:

- İzmir
  - Most used transportation mode is public transportation with 35 percent in 2017
  - First city in Turkey participated in "EUROPEAN CYCLING CHALLENGE 2016"

  - First city in Turkey plans to launch Cycling Master Plan by 2017
  - Sustainable Energy Action Plan (2016) aims to reduce motorization by promoting cycling
  - 2030 İzmir Transportation Master Plan aims to reduce CO_2 emission by 18% with promoting cycling by integrating the coastal cycling system with the rest of the city
  - The level of cycling mode share was 1% in 2017.
  - 500 BİSİM bicycles and 34 BİSİM station in 2019
  - 51 km length bike route

- Konya
  - From 1920, in Konya is the popular with bicycle transportation
  - Strategic Plan 2015-2019 aimed cycling a tourism activity.
  - Bicycle mode share is 33,2%
  - First city that proposed and completed a Bicycle Action Plan in Turkey.
  - 515 km length bike route
  - 40 stations and 500 bikes of Nextbike bike share system
  - Bicycle repair station in to the 26 different points in the City organizes every year a bicycle festival to support cycling.

- Kayseri
  - Transportation Master Plan aims increasing the share of bicycle, promoting bicycle commuting, ensuring bicycle safety
  - 90 km of bike route
  - The bikeways that is not separated from motorized traffic.
  - The locations of bike lanes defined to link the bike share stations that already located at transit stops and stations
  - Promote cycling by “bicycle day, bicycle festive, bicycle race”.

Konya, with its history of bicycle, aimed to develop its bicycle network. Bicycle Action Plan (2019) aims to increase cycling level in Konya. The City wants to increase

cycling safety and provide a cohesive bicycle network by regulating existing bike-ways and proposed bike lanes. Existing bicycle lanes and its continuity analyzed by an private planning company. As the literature review and analysis of city case studies from Europe and United States showed that bicycle transportation planning and policies should be provided by government and municipalities and bicycle planners. The city has no provision about bicycle parking facilities and integration of bicycle and public transportation in the Bicycle Action Plan (2019). Bike share system and public transport modes could be used with same smart card in the city. But there is no free transfer between bike share system and public transport modes.

Kayseri promoting cycling by bike share system Kaybis to raise awareness among the public. Bike share systems located at tram stations and stops and parallel to tram line. While implementing new Kaybis stations, the City considers the requests of public. Kaybis is free for first thirty minutes to promote cycling as a transport mode in the city. Bike ways are not separated from motorized traffic by physical separators as shy zone or buffering. As a result that creates danger for cyclists.

CHAPTER 5

CONCLUSION

5.1 Summary

The main aim of the study is to evaluate the elements of bicycle transport planning to improve the sustainable mobility. The thesis has analyzed the effects of the considerations in terms of improving sustainable mobility to promote cycling in urban transportation and to understand these factors with case study cities. Cycling for transportation as a part of sustainable mobility has a number of advantages over other transportation modes. Cycling is ecologically sustainable because it is the most energy efficient transport mode. Bicycle provides a high level of mobility and requires less space compared to other transport modes. Bicycle parts are recyclable and any toxic substances are not used for the operation or the maintenance of the bicycle. Bicycle is socially sustainable because it improves physically and emotionally human health. Also, it is an affordable transport mode for anyone who want to buy. Bicycle is economically sustainable because it could be implemented at all densities. Bike-transit integration provides a salvation of the investment in high frequency of transit services. Bicycle infrastructure is inexpensive compared to the other urban transport modes.

Globally, the environmental and health impacts of traffic congestion increased the concerns of the health of the human and earth. These impacts as climate change by green-house gasses, stress disease, traffic congestion, fatal and sever accidents, obesity related to automobile, loss of land and water quality make countries willing to become cities of bicycles as part of the sustainable development and mobility. Based on these facts, the thesis focused on understanding the benefits of cycling as a part of

sustainable mobility by investigating case study cities and defining measurements to achieve a successful sustainable mobility for cycling in urban transport.

The process of the study is started with the overview of cycling and sustainable mobility. The factors that supported cycling as a way of sustainable mobility are clarified in terms of urban transportation and planning. After analyzing the theoretical background, the case study cities are investigated in the context of the four main considerations, policies and planning, land use and public transport, usage of technology, and public acceptability, to succeed on bicycle planning as a part of sustainable mobility in terms of urban transport and planning. As a result, these evaluations in case study cities supported the determinants that promote cycling in urban transport in terms of sustainable mobility. These analyses have shown that to ensure the requirements to promote cycling a comprehensive approach is required. From this point of view, besides four measures for sustainable mobility vision a comprehensive approach includes planning bicycle network. Hence, this study has investigated the requirements of bicycle network planning and bicycle infrastructure by exemplifying with case study cities. Finally, all these considerations for promoting cycling as a part of sustainable mobility in terms of urban transport and planning are examined in the case study cities from Turkey by interviews and analyzing written documents.

5.2 Findings

The main findings have been drawn from the literature review and analysis of the city case studies. To identify the encouraging measurements and subjects to promote cycling as a part of sustainable mobility, two different groups of country and cities have been evaluated from Europe and United States. First group has a high level of cycling mode share as an urban transport mode and has increased the already high level, the second group has increased the level of cycling mode share without any cycling history in the city. Copenhagen from Denmark, has a historical cycling culture and has increased already high level of cycling mode share in the city. Paris without any existing cycling history has improved cycling and increased the level of cycling in urban transport. Portland from a car oriented country, without any existing cycling history same as Paris, has improved cycling and increased the level of cycling mode

share in urban transport.

The analysis of case study cities and literature review reveals the main findings to encourage cycling as an urban transport mode in terms of sustainable mobility. The findings of the study organized in eight topics. These are:

1. Provide comprehensive approach of sustainable mobility measures,
2. Improve the integration of bicycle and public transportation,
3. Encourage bike-share systems,
4. Support information and cycling events,
5. Provide education about cycling,
6. Promote traffic calming measures, car-free zones,
7. Build an integrated network with bicycle facilities,
8. Ensure public participation.

(i) Provide Comprehensive Approach of Sustainable Mobility Measures

Literature review and the analysis of case study cities in Europe and United States have shown that the measures of sustainable mobility should be implemented in an integrated way. Transportation policies, land use policies, promotion of public acceptability (involvement), promotional campaigns and programs, usage of technology are the main features of the case study cities that have gained success at improving cycling and increasing cycling levels.

The evaluated case study cities from Europe and United States in Chapter 3, have adopted a comprehensive attitude. Land-use policies and public transportation relation have been supported through planning and policies in the case study cities. Portland, has linked land use and transportation by policies and plans to promote cycling in urban transport. Copenhagen has implemented by integrated and comprehensive policies, plans, programs, public involvement and long term package infrastructure to encourage bicycle transport as a part of sustainable mobility. Paris has implemented policies that promoted cyclist friendly rules and changed the traffic rules, coordinated

bike share systems and transport stations, and has promoted cycling with events and organizations in terms of public involvement. In Paris, high level of public transportation mode share has provided an opportunity to integrate bike share system with transit stations.

All these measures should be implemented because their impact on promotion of cycling are synergistic and interactive with each other. For instance, the quality and extent of the bicycle network affects the impacts of bicycle parking facilities in the city.

The two European cities Copenhagen and Paris have developed more comprehensive and coordinated bicycle transport in the city than Portland in the United States. However, Portland instead of its car oriented transport and policies, has gained great progress to achieve a comprehensive approach for cycling as a transportation mode.

(ii) Improve the Integration of Bicycle and Public Transportation

Bicycle and public transport integration provides higher mobility. This integration is an efficient solution in metropolitan areas, considering the size of the cities and the distances between residents and working areas. In Europe, coordinating cycling and public transport has begun earlier than in North America. With the rising in the demand for cycle facilities, most of the American cities adopted implementation measures from European cities.

The first important measure in terms of the integration of bicycle and public transport and cycling as a transport mode, is bicycle parking facilities at transit stations and bus stops.

Second measure is carrying bicycles on board and on buses. This integration has advantages such as reducing the cost of installing bicycle parking facilities, preventing bike theft, and providing cyclists to travel long distances with their bike. However, high demand and insufficient capacities on the trains prevent taking bicycles on board.

Combining bicycle routes and public transport is the third consideration. This consideration represents safe access through bus stops and transit stations through bike lanes and paths. It is important to avoid conflict of the bike lanes with bus lanes

through bus stops for safety of cyclists. Providing safe cycling paths and lines in the city is really helpful to reduce the crowd in buses and rail systems by encouraging bicycle. Ensuring synchronization of the cycling network is a key consideration to achieve an efficient integration between cycling and public transport. Bike-and-ride consideration costs much more less than providing facilities for ride-and-share for automobiles.

Both in Europe and in United States, cities have paid attention to integration of bicycle and public transport. In European cities, the main concern is enhancing the quality and the number of bicycle parking at public transport nodes and stops. On the contrary, North American cities, have concerned about carrying bicycle on train, metro or buses. In fact, with the increased promotion of bicycle and public transport integration, safety of the bicycle parking spaces and bicycle routes has begun to be considered all around the world.

Copenhagen, Paris, and Portland, like most of the other European and North American cities have made a great development about integration of cycling and public transportation. European cities, Paris and Copenhagen have interested in increasing the number and quality of bicycle parking facilities in transit stops. North American city Portland has focused on bicycle facilities on buses and rail vehicles besides increasing the quantity and quality of bike parking in the city and transport nodes.

Portland has increased the number of the secure and sheltered bike parking facilities at transit stops and stations. Also, the city has improved the connections to transit with bikeways and there is an option to park your bike at the station in case of unavailable space for your bike on train. During peak hours on board rail vehicles could not have extra space for bikes. In addition, every TriMet buses have bike racks to allow you travel with your bike.

In Paris, except Metro Line 1, taking bikes on the board is not allowed. And in the city buses do not have a bike rack and are not allowed taking bikes on board. Also, tramway is not allowed to travel with bicycle. The city has integrated bicycle and public transport by providing Vélib' bike share system and bicycle parking facilities all around the city, especially near to transit stations. The bicycle parking facilities are not adequate as shown before in the analysis of cycling facilities and transit nodes

area. The city has mostly implemented bike racks transit stations.

(iii) Encourage Bike-Share Systems

There was a remarkable increase in the number of bike-share systems around the world by 2005. As of May 2011, 136 bike share programs were estimated in 165 cities world-wide, with 237,000 bikes. By May 2018, there were more than 1,600 bike share systems under operation around the world, serving 18 million bicycles for public use. After the launch of Vélib' in 2007 in Paris, bicycle riding has increased by 70 percent and the bicycle mode share has increased from 1 percent in 2001 to 2,5 percent in 2007. Bike share systems provide integration of cycling with the transportation systems and encourage cycling by making bicycle available for everyone. Bike share systems as a sustainable and environmentally friendly public transportation mode that provides short-term bicycle access. Bike-share systems near the public transportation nodes and stops, provides cyclists an integrated travel without owning a bicycle. Bike-share systems are efficient to integrate cycling with public transport to achieve sustainable mobility.

(iv) Support Information and Cycling Events

Providing information through public is important to promote cycling in urban transport. To increase cycling levels, interactive maps that shows bikeways, bike share system stations, bicycle parking areas, dangerous crossings or intersections should be provided through web sites and apps. Transportation sections of each case study city's municipalities official websites provide journey planner applications. The journey planner provides to plan your trip by combining bike and transit or by only bicycle. The official websites of the transportation departments also provides information about cycling events, developments about bicycle facilities, and proposed projects about bicycle. In Copenhagen, Paris and Portland there are organizations, cycling groups that organize events about cycling safety, promoting cycling by showing the attractiveness and benefits of bicycle, training courses for children and adults, organizing ride events, closing motorized traffic a day in a week.

(v) Provide Education for Cyclists and Motorists

Promoting cycling education among children and adults is important. Educating chil-

dren about cycling and about the importance of it for human health and earth health is easy than educating adults because of habits learned earlier in the course of life.

Education for motorists is important to make them cycling, and make cycling attractive for them. So, besides educating cyclists about safe cycling, educating and enlightening motorists about sustainable mobility is important to change the travel behaviors and perspectives of people about cycling in urban transport.

Both of the case study cities promotes education among children and adults. Every year when a new class of Danish children starts school, they are also preparing themselves to getting to school for the first time. Traditionally, the year group of children is primarily being taught traffic safety. In Paris, there are different kinds of organizations that offer programs and courses for adults and children. The most popular one is Insertion et Culture Velo, that provides training courses for children and adults for cycling in the city. Bicycle education in Portland has been implemented by a variety of organizations. Women on Bikes is an organization that provides annual urban bicycle training designed for women. Portland by Cycle is another free annual educational and encouragement program for beginning cyclists. Also, in partnership with the "The Street Trust Safe Routes to School" offers Bicycle Safety Education at schools in Portland. Bicycle Safety Education (BSE) is generally taught to 5th grade students during the school day.

(vi) Promote Traffic Calming Measures, and Car-Free Zones

It is important to implement traffic calmed streets, less car parking, and car free zones to provide safe and convenient streets for cyclists. Even if there is no bikeway along streets, these measures promote cycling in an indirect way. Also, implementing car free zones and traffic calming measures are provided by car restriction. Improving safety for cyclists by traffic calming and creating car-free zones is as influential as building cycling infrastructure to increase cycling levels as a way of improving cycling safety.

(vii) Build An Integrated Network with Bicycle Facilities and Intersections

All the case study cities from Europe and United States have a high level of cycling mode share in urban transportation. Bicycle network has a great impact on promotion

of cycling as transportation mode. A bicycle network defines the safe and direct routes which are continuous and connected with each other in a city. In terms of the needs of cycling, developing connections between potential destinations for cycling ensuring secure, adequate, and qualified infrastructure for cycle tracks are crucial.

Besides providing connections between destinations by cycle network, the quality and security of bicycle infrastructure and cycle tracks are crucial for developing an effective cycle network to promote cycling as a transport mode in the city. Integration of bike paths, bike lanes and paths at intersections is essential to promote cycling as a transport mode. The most preferred bicycle specific facilities are separated bicycle lanes and cycle tracks since they provide high level of security for cyclists. Also, advanced green lights, traffic signals for cyclists, advanced stop lines, bikeway markings are other influential measurements to build an integrated bicycle network in the city. An integrated network encourages non cyclists too. Therefore, integrated network have a great impact on increasing the cycling levels as a transport mode in the city by ensuring safety of cyclists.

(viii) Ensure Public Participation

Public involvement is important to comprehend the expectations and thoughts of the public or target groups because the government's regulations are insufficient to shift the perspectives of people about cycling in urban transport. The expectations and thoughts of public and cyclists should be taken into consideration during planning and implementation stages. Also, the policy measures should ensure clear aims, clear decisions, effectiveness of actions to adaptability of policies through public and business. Public participation could be promoted in neighborhood scale or city scale. At neighborhood scale, interaction between cyclists and bicycle planners or government officials from municipalities will be much better than city size scale. Also, the promotion of the events to promote participation is important. In fact, ensuring public participation of cyclists at all ages is essential for bicycle transport planning as a part of sustainable mobility. Promoting surveys or events in neighborhood scale enable determining the needs and expectations of cyclists at all ages. Before attracting motorists to cycle, supporting and paying attention to the existing children, teen and adult cyclists is required because they are the ones who cycle and know their needs about

cycling in the city.

Copenhagen is the best example among case study cities. The city conducts a survey two times in a year among cyclists to regulate their cycling policies and bicycle planning. The expectations of cyclists and the difficulties that they experienced while cycling are investigated. Therefore, cyclists review the cycling in the city and make suggestions. The survey is about the integration of cycling and public transportation, bicycle parking facilities, safety, maintenance of bicycle facilities.

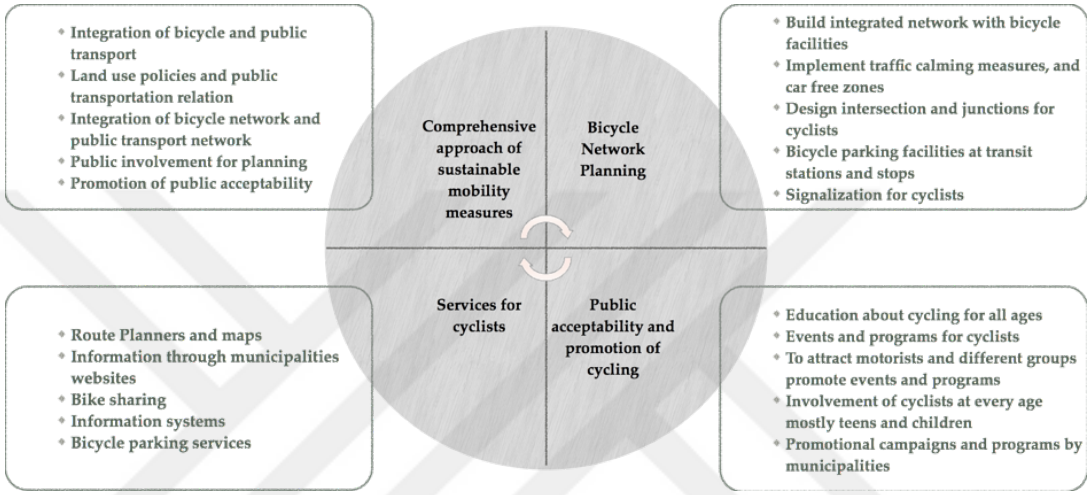


Figure 5.1: A proposed system for cycling.

The examination of the elements of bicycle transport planning as a part of sustainable mobility in the case study cities from Turkey has shown that both of the case study cities have gain great success on promoting cycling in different extents and with different approaches. With the consideration of the eight main findings to encourage cycling as an urban transport mode in terms of sustainable mobility for İzmir, Konya and Kayseri the problems are defined in 6 topics.

(i) The lack of a comprehensive approach to land-use policies and public transportation through planning and policies. (ii) The integration of bicycle and public transport is not coordinated with providing bicycle parking facilities in the city and in transport stations and stops. (iii) The case study cities from Turkey do not have not any regulation about cycling education for motorists and cyclists. (iv) The cities do not promote traffic calming measures or car free zones. (v) The existing bicycle network is not integrated with bicycle facilities and intersections with considering safety of cyclists.

(vi) Public participation is not sufficient at planning and implementing stages.

İzmir, Konya, and Kayseri have promoted bike share systems and integrated these systems with public transport stations. This three cities have planned and proposed bicycle routes to link transport stations and stops. Kayseri has an advantage with its wide streets and sidewalks on implementing bikeways. As seen in the European and United States cities natural environment has not posed an obstacle to provide a cohesive, safe, direct, attractive and comfortable bicycle network. Between income and level of cycling there is a not direct relationship but in Konya and Kayseri, people cycle with an economic necessity. Also bicycle culture in Konya has supported bicycle use as an urban transport mode. But existence of bicycle culture is not the main factor to promote cycling.

5.3 Discussion

Making mobility equally accessible for everyone, children, elder people, women with child, and for low income people is really hard to tackle. Increasing mobility for everyone is an important gap to be considered sensitively. This problem occurs all over the world, both in developed countries and developing countries. Promotion of cycling as a transport mode in the city and integration of cycling and public transport modes is a path to make mobility equally accessible for everyone in the city. Since this integration promotes public transportation, compared to automobiles bicycles are more affordable, require less space, and the parking fees are lower. The integration of bicycle and public transport ensures higher mobility than automobiles. Bike share system is one of the significant contributor for promoting cycling and increasing mobility for everyone by feeding public transport modes.

The land use pattern is related to travel choices in the city. High density and mixed land use promotes bicycle transport in the city. As the investigation of the case study cities from Europe and United States show, supplying bicycle specific infrastructure is a significant contributor to promote cycling in urban transportation.

The form of transportation and land use patterns related to the automobile dependence leads to congestion on roads, accidents and environmental impacts. Infras-

tructure construction as a traditional solution for these problems has ended up with a large scale transport network. Building new roads to reply the increased demand of transportation causes losses of the build environments such as public green spaces, pedestrian areas, heritage patterns and buildings in the cities and ends up with a high volume of circulation of vehicles on the roads. This circulation and the high speed of traffic in the large scale transport networks make it difficult to promote bicycle as a transport mode in the city. Besides these, urban sprawl makes it difficult for cycling to compete with other transport modes because of the long distances between activity areas in the city. It is hard to change or overbuilt the existing land use patterns, large scale transport networks and infrastructures. This affects building adequate and safe bicycle network and infrastructure.

When there are difficulties about the existing built-up environment and large scale transport networks, instead of large scale approaches, planning small changes provides significant improvements on bicycle transport planning. Building a bicycle network without having a history of cycling could be at the neighborhood level, the considerations should be oriented around cyclists' needs instead of motorists'. Also, that the consideration about where the development goes should be addressed when the built-up environment enables promotion of cycling.

Building bicycle routes for long distances along the transport networks with high speed and congestion is not a choice to promote cycling because bicycle is a short distance transport mode. Bicycle routes should be built between disconnected and proximate developments and bicycle infrastructure should be built at key locations. Bicycle network would be link destinations for the people who are interested in using bicycle as a transport mode and to attract non cyclists. It is important to consider and understand the necessity of separation of bicycle traffic and motorized traffic in a city with high level of automobile use.

To achieve higher mobility, bicycle and public transport have to be integrated by implementing bike share systems, and secure bicycle parking facilities at transit stations and stops. For daily transport between work and home, people do not want to ride bicycle for long distances along motorized traffic. Rather than that people could prefer to cycle to public transport stations and stops. Especially in metropolitan areas,

integration of cycling and public transportation is an efficient solution to improve sustainable mobility considering the size of the cities and the distances between residents and working areas. Bicycle offers healthy public and healthy earth by building blocks for sustainable mobility. In the consideration of the increased concerns about climate crisis, bicycle is not a choice but to be act for tomorrow.

REFERENCES

[1] Alpert, D. (2016) Copenhagen uses this one trick to make room for bikeways on nearly every street. Retrieved from https://ggwash.org/view/43010/copenhagen-uses-this-one-trick-to-make-room-for-bikeways-on-nearly-every-street [Accessed 28.08.2019].

[2] APTA (American Public Transportation Association) (2009) Public Transportation Fact Book. Washington. D.C.

[3] APTA (American Public Transportation Association) (2011) Public Transit Statics.. Washington. D.C.

[4] Banister, D. (2000). Sustainable Mobility. Built Environment (1978-) Vol. 26. No. 3. Sustainable Mobility in the EU. pp. 175-186. Alexandrine Press Stable URL: https://www.jstor.org/stable/23288398 [Accessed: 27-06-2019]

[5] Banister, D. (2011) Cities, Mobility and Climate Change. Journal of Transport Geography 19 1538–1546. doi:10.1016/j.jtrangeo.2011.03.009

[6] Banister, D. 2005. Unsustainable Transport: City Transport in the New Century. Routhledge

[7] Banister, D. 2008. The Sustainable Mobility Paradigm. Transport Policy. 15 73-80

[8] BBC News (2009) Thefts Puncture Paris Bike Scheme. Available at: http://news.bbc.co.uk/2/hi/europe/7881079.stm [Accessed: 12 September 2018].

[9] Berger, G., Feint, P., Holden, E., Rubik, F. (2014) Sustainable Mobility - Challenges for a Complex Transition. J. Environment Policy Plan. 16, 303-320. DOI: 10.1080/1523908X.2014.954077

[10] Bicycle Lanes (n.d.) Cycling in Paris. Retrieved from http://cyclinginparis.blogspot.com/p/cycle-lanes.html [Accessed 17.10.2019].

[11] Bicycles in Portland Fact Sheet, 2019. Portland Bureau of Transportation. Retrieved from https://www.portlandoregon.gov/transportation/article/407660

[12] Bir Seyyahın Günlüğü (2017) Retrieved from http://www.kayserigundem.com.tr/kayserideki-bisiklet-gruplari-ve-etkinlikleri-makale,3458.html [Accessed 17.08.2019].

[13] Bisiklet Taşıma Aparatı Kullanımı (n.d.)Retrieved from https://www.eshot.gov.tr/tr/bisiklettasimaaparati/150/471 [Accessed 12.07.2019].

[14] Bisiklet Turu (n.d.) Retrieved from https://sporaskayseri.com/icerikler/bisiklet-turu [Accessed 22.09.2019].

[15] Britton, E. (2014) Bicycle Contraflow Lanes: Death Wish or Life Line? Retrieved from https://worldstreets.wordpress.com/2014/09/20/bicycle-contraflow-lanes/

[16] Brooking Institution (2010) State of Metropolitan America. On the Front Lines of Demographic Transformation. Washington, DC. The Brookings Institution

[17] Buehler, R. and Pucher, J. (2012a) Big city cycling in Europe, North America, and Australia. In: J. Pucher, and R. Buehler (Eds). City Cycling. Cambridge. Massachusetts. The MIT Press. (pp 287-318)

[18] Buehler, R. and Pucher, J. (2012b) International Overview: Cycling Trends in Western Europe, North America, and Australia. In: J. Pucher, and R. Buehler (Eds). City Cycling. Cambridge. Massachusetts. The MIT Press. pp 287-318.

[19] Büyüknalbant, S. (2010) Kayseri Kentinde Ulaşim Altyapının Yolculuk Davranışı Üzerine Etkilerinin Araştırılması (master's thesis) Gazi Üniversitesi

[20] Büyükşehir'den 26 Noktaya Bisiklet Tamir İstasyonu (2018) Metropolitan Municipality of Konya. Retrieved from http://www.konya.bel.tr [Accessed 12.06.2019].

[21] Cambridge Cycling Campaign (2014) Making Space for Cycling: A guide for new developments and street renewals. Cyclenation. Retrieved from www.makingspaceforcycling.org

[22] City of Copenhagen (2002). Cycle Policy 2002-2012. City of Copenhagen, Building and Construction Administration, Roads and Parks Department.

[23] City of Copenhagen (2011) Good, Better, Best. The City of Copenhagen's Bicycle Strategy 2011-2015. The City of Copenhagen. Technical and Environmental Administration Traffic Department.

[24] City of Copenhagen (2013) Focus on Cycling. Copenhagen guidelines for the design of road projects. City of Copenhagen. Technical and Environmental Administration Traffic Department. The Bicycle Programme.

[25] City of Copenhagen (2015a) City of Copenhagen municipal plan 2015:The coherent city. City of Copenhagen.

[26] City of Copenhagen (2015b) Copenhagen. City of Cyclists. Bicycle Account 2014 The City of Copenhagen. Technical and Environmental Administration. Mobility and Urban Space.

[27] City of Copenhagen (2017) Copenhagen City of Cyclists, Facts and Figures, City of Copenhagen, The Technical and Environmental Administration

[28] City of İzmir (2015) Strategic Plan 2015-2019. City of İzmir. Metropolitan Municipality of İzmir.

[29] City of İzmir (2016) Sustainable Energy Action Plan. Metropolitan Municipality of İzmir. Sürdürülebilir Enerji Eylem Planı. İzmir Büyükşehir Belediyesi Çevre Koruma ve Kontrol Dairesi Başkanlığı Sağlıklı Kentler ve Temiz Enerji Şube Müdürlüğü

[30] City of İzmir (2017) İzmir 2030 Transportation Master Plan Final Report Executive Summary (İzmir Ulaşım Ana Planı 2030). Metropolitan Municipality of İzmir. Boğaziçi Proje A.Ş.

[31] City of Konya (2014) 2015-2019 Stratejik Plan. Metropolitan Municipality of Konya.

[32] City of Portland (2007). Portland's platinum bicycle master plan. existing conditions report. City of Portland, Bureau of Transportation.

[33] City of Portland (2009a) Broadway cycle track. City of Portland. Portland Bureau of Transportation. Retrieved from www.gettingaroundportland.com [Accessed 18.09.2019].

[34] City of Portland (2009b) Proposed Buffered Bike Lane: SW Oak - Stark. City of Portland. Portland Bureau of Transportation. Retrieved from www.gettingaroundportland.com [Accessed 18.09.2019].

[35] City of Portland (2010a). Bicycles. City of Portland, Bureau of Transportation.

[36] City of Portland (2010b) Bikeway Facility Design: Survey of Best Practice. Appendix D. Portland Bicycle Plan for 2030. Retrieved from https://bikeportland.org/2009/08/31/first-look-at-portlands-inaugural-cycle-track-22932

[37] City of Portland (2010c) Portland bicycle plan for 2030. City of Portland. Bureau of Transportation.

[38] City of Portland (2016b) Cross-Bikes: Portland's New Green Stripes. City of Portland. Portland Bureau of Transportation. Retrieved from https://www.portlandoregon.gov/TRANSPORTATION/article/585677 [Accessed 18.09.2019].

[39] City of Portland (2018). Comprehensive Plan 2035. City of Portland. Bureau of Transportation.

[40] City of Portland (n.d.-a) Brochure cycle track. City of Portland. Portland Bureau of Transportation. Retrieved from www.gettingaroundportland.com [Accessed 18.09.2019].

[41] City of Portland (n.d.-b) SW Madison Bus/Bike Lane Project. City of Portland. Portland Bureau of Transportation. Retrieved from https://www.portlandoregon.gov/transportation/article/731989 [Accessed 18.09.2019].

[42] Community planning memorandum (2017) Retrieved from https://www.clark.wa.gov [Accessed 18.03.2019].

[43] Copenhagenize Index (2017) Retrieved from https://copenhagenizeindex.eu [Accessed 26.03.2019].

[44] Cycling Plan 2015 – 2020 (n.d.) A New plan to Triple Cycling in Paris by 2020, Mairie de Paris, Direction de la Voirie at des Deplacements.

[45] Danish Ministry of the Environment (2015) The Finger Plan. A Strategy for the Development of the Greater Copenhagen Area. Danish Ministry of the Environment.

[46] Danish Ministry of Transport (2010) Overview of the Number of Passengers, Car Parking Supply and Bike Parking Spaces at Danish Train Stations. Copenhagen: Danish Ministry of Transport.

[47] David Baker Architects (n.d.) Urban cycling. Retrieved from https://www.dbarchitect.com [Accessed 14.10.2019]

[48] Deffner, J., Hefter, T., Rudolph, C., Ziel, T., Eds. (2012): Handbook on Cycling Inclusive Planning and Promotion. Capacity Development Material for the Multiplier Training within the Mobile2020 Project. Frankfurt. Hamburg.

[49] Dekoster, J. and Schollaert, U. (1999) Cycling: The Way Ahead for Towns and Cities. European Commission.

[50] Dufour, D. (2010) PRESTO Cycling Policy Guide. Cycling Infrastructure. Retrieved from www.presto-cycling.eu

[51] Dutch Bicycle Council (2010) Bicycle Policies of the European Principals: Continuous and Integral. Amsterdam. Dutch Bicycle Council.

[52] Ed. Parkin, J. (2012). Cycling and Sustainability. Bingley. Emerald Group Publishing Limited.

[53] Ellie (2018) Velib apocalypse: Why Paris destroyed its bicycle network Retrieved from https://medium.com/@elie/velib-apocalypse-why-paris-destroyed-its-bicycle-network-43ad1d7c916f [Accessed 13.05.2018].

[54] Estimation de la population au (2019) Retrieved from https://www.insee.fr [Accessed 26.10.2019].

[55] European Commission (2007) Green Paper-Towards a New Culture for Urban Mobility. Brussels. European Commission.

[56] Felix, R. (2018) Bike-Sharing Clicks Into Higher Gear. Retrieved from https://www.statista.com/chart/14542/bike-sharing-programs-worldwide/ [Accessed 16.03.2019].

[57] Festa 2200 Bisiklet Festivali yine Erciyes'te (2019) Retrieved from https://www.kayseriolay.com/festa-bisiklet-festivali-yine-erciyes-te-h51123.htm [Accessed 17.08.2019].

[58] Gehl chart (2010) Cycling Embassy of Denmark. Retrieved from http://www.cycling-embassy.dk/2010/11/15/cycle-tracks-that-come-to-you-as-you-go/gehl-chart/ [Accessed 24.08.2019].

[59] Gemzøe, L. (2010) Cycle tracks that come to you as you go. Retrieved from http://www.cycling-embassy.dk/2010/11/15/cycle-tracks-that-come-to-you-as-you-go/ [Accessed 28.08.2019].

[60] Givoni, M. And Banister, D. 2013. Moving Towards Low Carbon Mobility. Edward Elgar Publishing

[61] Givoni, M. And Rietveld, P. 2007. The Access Journey to the Railway Stations and Its Role in Passengers' Satisfaction with Rail Travel. Transport Policy 14 (5):357-365.

[62] International Energy Agency (2018) Global Energy and CO2 Status Report 2017

[63] Google. (n.d.). [Google Maps Boulevard de la Villette, Paris, France]. Retrieved September, 2019, from https://goo.gl/maps/fDQruWjMJqQB8usg8

[64] Greene, D.L. and Wegener, M. (1997) Sustainable Transport. Journal of Transport Geography. 5:177–190.

[65] Gunn, A. (2018) Bicycle Planning in European Cities and Its Applicability to American Cities. California Polytechnic State University. San Luis Obispo College of Architecture and Environmental Design. City and Regional Planning.

[66] Hagelin, C. (2007) Integrating Bicycles and Transits through Bike-to-Bus Strategy. Transportation Research Board Annual Meeting CD-ROM, paper 07-3130. Washington, D.C. National Academy of Sciences.

[67] Hallock, L. And Inglis, J. (2015) The cities Where New Technologies and Tools Can Reduce Your Need to Own a Car. The Innovative Transportation Index. Frontier Group. U. S. PIRG Education Fund.

[68] Hegger, R. (2007) Public Transport and Cycling: Living Apart or Together? Public Transport International 2: 38-41

[69] Hickman, R., (2007) Reducing Travel by Design; A Micro Analysis of New Household Location and the Commute to Work in Surrey. Unpublished PhD Thesis. Bartlett School of Planning. University College London. November.

[70] Hickman, R., And Banister, D. (2014) Transport, climate change and the city. Routledge (p.234)

[71] Holden, E. (2007) Achieving Sustainable Mobility: Everyday and Leisure-Time Travel in the EU. Ashgate: Aldeshot. UK.

[72] Holden, E., Gilpin, G., And Banister, D. (2019) Sustainable Mobility at Thirty. Sustainability 2019, 11, 1963. doi:10.3390/su11071965

[73] Hoole, G., (2017) This Map Will Show You Where All Of London's Safe Cycle Routes Are. Retrieved from https://secretldn.com/map-will-show-londons-safe-cycle-routes/ [Accessed 12.10.2019].

[74] http://atus.konya.bel.tr/bisikletyollari/ [Accessed 12.06.2019].

[75] http://bisifest.com [Accessed 08.11.2019].

[76] https://gis.oregonmetro.gov/bikethere/ [Accessed 24.10.2019].

[77] https://www.isabelleetlevelo.fr/2019/06/05/la-plus-belle-piste-de-paris-se-retrouve-sur-le-point-de-couler/, Google Maps -street view [Accessed 04.10.2019].

[78] https://www.strava.com/local/us/portland/cycling/routes/1843 [Accessed 04.10.2019].

[79] Indre Ringrute C94 (n.d.) Retrieved from https://supercykelstier.dk/indre-ringrute-c94/ [Accessed 16.09.2019].

[80] Inside UCI (2019) Ten UCI World Championships and four UCI Bike City labels awarded at the 188th UCI Congress. Retrieved from https://www.uci.org/inside-uci/press-releases/ten-uci-world-championships-and-four-uci-bike-cty-labels-awarded-at-the-188th-uci-congress [Accessed 16.03.2019].

[81] ITDP (Institute for Transportation and development Policy) (2014) The Bike-Share Planning Guide. Institute for Transportation and development Policy. www.itdp.org

[82] İzmir Bisiklet Grupları (2016) Retrieved from https://hayattirbisiklet.blogspot.com/2016/10/izmir-bisiklet-gruplari.html?m=1 [Accessed 08.11.2019].

[83] İZKA (İzmir Development Agency) (2014) İzmir Situational Analysis 2013

[84] İzmir'in Bisiklet Festivali Karşıyaka'da başladı (2019) BirGün. Retrieved from https://www.birgun.net/amp/haber/izmir-in-bisiklet-festivali-karsiyaka-da-basladi-272966 [Accessed 08.11.2019].

[85] İZUM (2019) Retrieved from https://izum.izmir.bel.tr [Accessed 08.11.2019].

[86] Jan Gehl (2008) Project for Public Spaces. Retrieved from https://www.pps.org/article/jgehl [Accessed 18.11.2018].

[87] Jensen, S.U., Rosenkilde, C., and Jensen, N. (2010) Road safety and perceived risk of cycle facilities in Copenhagen. Trafitec. City of Copenhagen. Retrieved from https://nacto.org [Accessed 06.09.2019].

[88] Jun, M. (2008) Are Portland's Smart Growth Policies Related to Reduced Automobile Dependence? Journal of Planning Education and Research 28:100-107. Association of Collegiate Schools of Planning. DOI: 10.1177/0739456X08319240

[89] Jurewicz, C., Sobhani, A., Woolley, J., Dutschke, J., And Corben, B. (2016) Exploration of Vehicle Impact Speed – Injury Severity Relationships for Ap-

plication in Safer Road Design. Transportation Research Procedia. 14. 4247-4256. 10.1016/j.trpro.2016.05.396.

[90] Kayseri Ulaşım (n.d.) https://www.kayseriulasim.com/tr [Accessed 12.06.2019].

[91] Kayseri Ulaşım A.Ş. (2018) Bisiklet İşletme Analizi

[92] Kınacı, M. (2019) Bu şehirde her hanede bir bisiklet var. Retrieved from https://www.aa.com.tr/tr/turkiye/bu-sehirde-her-hanede-bir-bisiklet-var/1495399 [Accessed 08.07.2019].

[93] Lam, B. (2019) Bikes on Paris Trains Metro RER Bus and Trams. Retrieved from https://parisbytrain.com/bikes-on-paris-trains-metro-rer-bus-trams/

[94] Leclerc, M. (2002) Bicycle Planning in the City of Portland: Evaluation of the City's Bicycle Master Plan and Statistical Analysis of the Relationship between the City's Bicycle Network and Bicycle Commute. Field Area Paper. Masters of Urban and Regional Planning. Portland State University.

[95] Litman, T.A. (2007) Land Use Impacts on Transport: How Land Use Factors Affect Travel Behaviour. Victoria Transport Policy Institute, Canada, April.

[96] Lobont, L. (2014) Retrieved from https://www.flickr.com [Accessed 12.04.2019].

[97] Maclean, A. (2016) Aerial Views Of Why Europe Has a Small Carbon Footprint. Retrieved from https://e360.yale.edu [Accessed 18.09.2019].

[98] Mairie de Paris (n.d.) Paris Capitale Duvelo 2020.

[99] Making Streets Safer with On-street Bike Parking (n.d.) Retrieved from https://www.streetfilms.org/portland-bike-parking/) [Accessed 18.09.2019].

[100] Markham, D. October 2017. 30 percent of the new bikes in Paris' Vélib' Métropole bike-share system will be electric. Retrieved from https://www.treehugger.com/bikes/30-new-bike-share-fleet-paris-will-be-electric.html [Accessed 30.03.2019].

[101] Marks, M. (2016) People Near Transit: Improving Accessibility and Rapid Transit Coverage in Large Cities. ITDP. www.itdp.org

[102] Martens, K. (2004) The bicycle as a Feedering Mode: Experiences from Three European Countries. Tranportation Research Part D: Transport and Environment 9 (4): 281-294

[103] Martens, K. (2007) Promoting Bike and Ride: The Dutch Experience. Transportation Research. Part A: Policy and Practice 41 (4):326-338

[104] Maus, J. 2013, Ride takes closer look at I-205 path, the 'Grandaddy of MUPs'. Retrieved from https://bikeportland.org/2013/06/18/ride-takes-closer-look-at-i-205-path-the-grandaddy-of-mups-88632

[105] McGreal, R. (2015) Bicycle-Friendly Paris Refuses to Stand Still, Retrieved from https://www.raisethehammer.org/article/2707/?view=flat

[106] McKibben, B. (2016) Retrieved from https://www.scoopnest.com [Accessed 18.09.2019].

[107] Midgley, P. (2011) bicycle-sharing schemes: enhancing sustainable mobility in urban areas, Background Paper No. 8, United Nations Department of Economic and Social Affairs.

[108] NACTO, National Association of City Transportation Officials, 2011, Urban Bikeway Design Guide,

[109] Najdovski, C. (2017) Roads and Mobility. Paris Policy. Mairie de Paris

[110] Naparstek, A. (2006) Streetfilms: On-Street Bicycle Parking, Portland. Retrieved from https://nyc.streetsblog.org/2006/12/20/streetfilms-on-street-bicycle-parking-portland/ [Accessed 18.09.2019].

[111] Nextbike https://www.nextbike.com.tr/en/konya/prices/ [Accessed 12.06.2019].

[112] Ngo, T. L. (2009) Retrieved from https://www.flickr.com [Accessed 12.04.2019].

[113] OECD (Organization for Economic Co-operation and Development) (2006) OECD Territorial Reviews. Competitive Cities in the Global Economy. Paris: OECD

[114] Paris Convention and Visitors Bureau (n.d.) Suggested cycling routes for exploring the capital. Paris Official website of the Convention and Visitors Bureau, Retrieved from https://en.parisinfo.com/what-to-see-in-paris/info/guides/paris-cycling-exploring [Accessed 18.09.2019].

[115] Paris Plan Provisoire of Velib (n.d.) Mairie de Paris.

[116] Paris transport monitoring center (2011) Paris Transport and Travel Report.

[117] Parking your bicycle in Amsterdam (n.d.) Retrieved from https://www.holland-cycling.com/amsterdam/getting-around-amsterdam/parking-your-bicycle-amsterdam [Accessed 12.04.2019].

[118] Portland Community Cycling Center (n.d.) Retrieved from https://communitycyclingcenter.org/about/board-of-directors/ [Accessed 24.10.2019].

[119] Pucher, J. And Buehler, R. 2006. Why Canadians Cycle More Than Americans: A Comparative Analysis of Bicycling Trends and Policies. Transport Policy 13 (3): 265-279.

[120] Pucher, J. and Buehler, R. 2007. At the Frontiers of Cycling: Policy Innovations in the Netherlands, Denmark, and Germany. World Transport Policy and Practice 13 (3): 8-57

[121] Pucher, J. And Buehler, R. 2009. Integrating Bicycling and Public Transport in North America. Journal of Public Transportation 12 (3): 79-104

[122] Pucher, J. And Dijkstra, L. 2000. Making Walking and Cycling Safer: Lessons from Europe. Transportation Quarterly 54 (3): 25-50

[123] Pucher, J. Lanversin, E. Suzuki, And T. Whitelegg, J. (2012) Cycling in Megacities: London, Paris, New York, and Tokyo. In: J. Pucher, and R. Buehler (Eds), City Cycling. Cambridge, Massachusetts, The MIT Press, (pp 319-345)

[124] Røhl, A. and Severinsen, (n.d.) A Bike Plus Train –an Attractive Model. Cycling embassy of Denmark Retrieved from https://cyclingsolutions.info/bike-plus-train-an-attractive-model/ [Accessed 09.10.2019].

[125] Ruggieri, G. (2017) The State Of Art Of Copenhagen's Cycling Infrastructure And Possible Application In Other Urban Contexts

[126] Shaheen, S., Guzman, S. and Zhang, H. (2010) Bikesharing in Europe, the Americas, and Asia, Past, Present and Future. Journal of the Transportation Research Board. 2143. 159-167. DOI: 10.3141/2143-20

[127] Shaheen, S.A. and Guzman, S. (2011) Worldwide Bikesharing. Access 39, Fall, 2011, The University of California Transportation Center. 39. 22-28

[128] Shaheen, S.A., Zhang, H., Martin, E. and Guzman, S. (2011) China's Hangzhou Public Bicycle Understanding Early Adoption and Behavioral Response to Bikesharing. Journal of the Transportation Research Board. 2247. 33-41. Transportation Research Board of the National Academies. Washington. D.C. DOI: 10.3141/2247-05

[129] Statistics Denmark, 2019. Retrieved from https://www.statbank.dk/FT [Accessed 12.10.2019].

[130] STTP (Surface Transportation Policy Project) (2004) Mean Streets. Washington, DC: STTP

[131] Superskiftet (2017) En guide til planlægning af gode skifteforhold mellem cykel og bus. Mobilitet Trafik og Plan. Retrieved from www.moviatrafik.dk [Accessed 11.09.2019].

[132] Şenbil, M. ve Yetişkul, E. (2016). İstanbul için gece parklanma davranışları modellemesi, İMO Teknik Dergi, Yazı 457, 7515-7532.

[133] Taylor, D. And Mahmassani, H. (1996) Analysis of State Preferences for Intermodal Bicycle-Transit Interfaces. Transportation Research Record 1556: 86-95

[134] Texas Transportation Institute (2009) Urban Mobility Report. College Station, TX: Texas Transportation Institute

[135] The Vélib' service (n.d.) Retrieved from https://www.velib-metropole.fr/en/service [Accessed 18.05.2019].

[136] TNS Sofres (2009)Vélib Satisfaction Survey . Paris: TNS Sofres.

[137] Transportvaneundersøgelsen 2010-2016 (n.d.) TU. Retrieved from https://www.cta.man.dtu.dk [Accessed 12.04.2019].

[138] TRB (Transportation Research Board) (2005) Integration of Bicycles and Transit. TCRP Synthesis Report 62. Washington, DC: TRB, National Research Council.

[139] TriMet (2016). Regional Planning Tour Fact Sheet. Regional transportation and land use planning. TriMet.

[140] Trimet Trip Planner (2019) Retrieved from https://trimet.org [Accessed 12.04.2019].

[141] Tumlin, J. (2012) Sustainable transport planning : tools for creating vibrant, healthy, and resilient communities, John Wiley and Sons, Inc.

[142] TÜİK (2018) http://www.tuik.gov.tr

[143] Two strikes for cyclehoop in paddington station. (2013) Retrieved from https://www.cyclehoop.com/2013-networkrail/ [Accessed 12.04.2019].

[144] UK Met Office (n.d.) Retrieved from https://www.metoffice.gov.uk [Accessed 14.09.2019].

[145] United Nations (2014). World Urbanization Prospects: The 2014 Revision, Highlights. Department of Economic and Social Affairs, Population Division (ST/ESA/SER.A/352).

[146] United Nations (2018) Population Division. The World's Cities in 2018—Data Booklet. Department of Economic and Social Affairs. ST/ESA/ SER.A/417.

[147] Urban Transport Plan for the Ile-de-France Region (n.d.) Retrieved from https://use.metropolis.org/case-studies/urban-transport-plan-for-the-ile-de-france-region [Accessed 14.06.2019].

[148] USDOC (U.S. Department of Commerce) 2010a. American Fact Finder: 1990 Decennial Census, Journey to Work. Washington, DC: USDOC, US Census Bureau.

[149] USDOC 2010b). USDOC (U.S. Department of Commerce) 2010b.

[150] USDOL (U.S. Department of Labor) (2010) Consumer Expenditure Survey. Washington, DC:. U.S. Department of Labor, Bureau of Labor Statistics

[151] Vélib' : finalement, le service sera complètement opérationnel début 2019, Retrieved from https://france3-regions.francetvinfo.fr/paris-ile-de-france/paris/grand-paris/velib-finalement-service-sera-completement-operationnel-debut-2019-1535078.html [Accessed 30.03.2019].

[152] VTPI (2018) Public Bike Systems, Online TDM Encyclopedia, Victoria Transport Policy Institute. Retrieved from https://www.vtpi.org/tdm/tdm126.htm [Accessed 17.05.2018].

[153] Woetzel, J. and Kuzneysova, E. (2018) Smart City Solutions: What Drives Citizen Adoption Around The Globe? McKinsey Center for Government.

[154] Yenice, S. M. (2012) Konya kentinin planlama tarihi ve mekansal gelişimi, Yenice, Erciyes Üniversitesi Fen Bilimleri Enstitüsü Dergisi, 28(4):343-350

[155] Zhang, H., Shaheen, S.A. and Chen, X. 2014. Bicycle Evolution in China: From the 1900s to the Present. International Journal of Sustainable Transportation. 8. 317-335, DOI: 10.1080/15568318.2012.699999

[156] Zheng, J., Atkinson-Palombo, C. McCahill, C. And O'Hara, R. 2011. Quantifying the Economic Domain of Transportation Sustainability. Journal of the Transportation Research Board. 2242. 19-28

[157] 2020: Paris, the World's Cycling Capital (2019) Retrieved from https://worldinparis.com/paris [Accessed 18.02.2019].

[158] 3. Kayseri Bisiklet Şenliği (2018) HaberTurk. Retrieved from https://www.haberturk.com/kayseri-haberleri/15333344-3-kayseri-bisiklet-senligi [Accessed 22.09.2019].

[159] 4 great cycling routes for exploring Paris (n.d.) Cycling routes and tips for exploring Paris by bike. Official website of the Convention and Visitors Bureau. Retrieved from https://en.parisinfo.com/what-to-see-in-paris/info/guides/paris-cycling-exploring [Accessed 24.09.2019].

CURRICULUM VITAE

PERSONAL INFORMATION

Surname, Name	:	Andiç, Didem
Nationality	:	Turkish (TC)
Date and Place of Birth	:	26 July 1990, Ankara
Marital Status	:	Married
Phone	:	+90 536 912 86 99
E-mail	:	e225361@metu.edu.tr

EDUCATION

Degree	Institution	Year of Graduation
B.S.	Gazi Uni. City and Regional Planning	2015
High School	Gazi University Foundation High School, Ankara	2008

FOREING LANGUAGES

Advanced English

PUBLICATIONS

1. Afacan, D., Şenbil, M., "Ankara'da Kent İçi Ulaşımda Bisiklet Kullanımının Artırılmasına Yönelik Öneriler", (IMO, 2011).
2. Afacan, D., Şenbil, M. "Public Bike Systems in Ankara", The 26th Annual Congress of AESOP (2012).

HOBBIES

Cycling, Ottoman Calligraphy, Photography, Painting