ASSESSMENT AND SIMULATION OF CAR ACCESS CONTROL POLICIES IN CITY CENTER: THE CASE OF TUNALI HILMI STREET IN ANKARA

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

BY

MURAT DOĞAN

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

FEBRUARY 2014

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submitted by Murat DOĞAN in partial fulfillment of the requirements for the degree of Master of Science in City Planning Department, Middle East Technical University by,

Prof. Dr. Canan Özgen _______________________
Dean, Graduate School of Natural and Applied Sciences

Prof. Dr. Melih ERSOY _______________________
Head of Department, City and Regional Planning

Assoc. Prof. Dr. Ela BABALIK SUTCLIFFE _______________________
Supervisor, City and Regional Planning Dept., METU

Assist. Prof. Dr. Hediye TÜYDEŞ YAMAN _______________________
Co-Supervisor, Civil Engineering Dept, METU

Examining Committee Members:

Assoc. Prof. Dr. Bahar GEDİKLİ _______________________
City and Regional Planning Dept., METU

Assoc. Prof. Dr. Ela BABALIK SUTCLIFFE _______________________
City and Regional Planning Dept., METU

Assist. Prof. Dr. Hediye TÜYDEŞ YAMAN _______________________
Civil Engineering Dept, METU

Prof. Dr. Ali TÜREL _______________________
City and Regional Planning Dept., METU

Turgay GÜNAL _______________________
Transport Planner

Date: 06.02.2014

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, Last Name:

Signature:

ABSTRACT

ASSESSMENT AND SIMULATION OF CAR ACCESS CONTROL POLICIES IN CITY CENTER: THE CASE OF TUNALI HİLMİ STREET IN ANKARA

DOĞAN, Murat
MS, Department of City Planning
Supervisor: Assoc. Prof. Dr. Ela BABALIK SUTCLIFFE
Co-supervisor: Assist. Prof. Dr. Hediye TÜYDEŞ YAMAN

February 2014, 138 pages

Since the Second World War, private car use has been increasing in the world, affecting particularly urban areas and their city centers, which suffer from severe levels of congestion, pollution and traffic safety problems. In order to solve traffic problems in city centers, there needs to be a policy for car access control, which can be achieved through Travel Demand Management and Traffic Management. This study, analyses possible effects of transforming the Tunalı Hilmi Street in Ankara into a pedestrian and transit-only street that is a scenario where only public transport buses are allowed into the street as vehicular traffic and the entry of other motorized vehicles restricted. For this purpose the current situation is analyzed through traffic counts focusing on transit traffic as well as the traffic that originate from within the neighborhood and the traffic that has its final destination within the neighborhood. By identifying the components of different traffic, a simulation is made to try and test possible effects of converting the street into a transit-only corridor. Various assumptions are made and each one is tried with this simulation technique in order to provide policy alternatives that can support this transit-only corridor scheme in Tunalı Hilmi Street.

Keywords: Car Access Control Policies in City Centers, Tunalı Hilmi Street, Pedestrianization, Transit-only Street, Travel Demand Management

ÖZ

KENT MERKEZİNDE ARAÇ ERİŞİM KONTROL POLİTİKALARININ DEĞERLENDİRİLMESİ VE SİMÜLASYONU: ANKARA'DA TUNALI HİLMİ CADDESİ ÖRNEĞİ

DOĞAN, Murat
Yüksek Lisans, Şehir Planlama Bölümü
Tez Yöneticisi: Doç. Dr. Ela BABALIK SUTCLIFFE
Ortak Tez Yöneticisi: Yrd. Doç. Dr. Hediye TÜYDEŞ YAMAN

Şubat 2014, 138 sayfa

II. Dünya Savaşı'ndan bu zamana kadar, tüm dünyada özel araç kullanımı artmakta ve bu artış özellikle trafik sıkışıklığı, kirlilik ve trafik güvenlik problemi yaşayan kentsel alanları ve kent merkezlerini etkilemektedir. Şehir merkezlerinde yaşanan trafik problemlerini çözümleyebilmek adına, araç erişimi kontrol politikalarını da içeren Yolculuk Talep Yönetimi ve Trafik Yönetimi politikaları uygulanmalıdır. Bu çalışmada Ankara'daki Tunalı Hilmi Caddesi'nin yaya yoluna ya da yalnızca toplu taşım araçlarının kullanımına izin verilirken diğer hiç bir motorlu aracın kullanımına açık olmayan bir caddeye dönüştürülmesinin olası etkileri çalışılmaktadır. Bu amaç doğrultusunda var olan durum araç sayımı ile analiz edilmekte, transit seyahatlerin yanında, alan içerisinden başlayan ya da alan içerisinde sonlanan seyahatler de analiz edilmektedir. Trafiğin farklı bileşenleri göz önünde bulundurularak yapılan simülasyon çalışması doğrultusunda Tunalı Hilmi Caddesi'nin transit geçiş koridoruna dönüştürülmesinin olası etkileri test edilmektedir. Çeşitli varsayımlar belirlenip simülasyon tekniği ile test edilerek Tunalı Hilmi Caddesi'nde otomobil erişiminin kısıtlanmasına ilişkin bir uygulamanın hayata geçirilmesi durumunda dikkate alınması gereken konular ortaya konmakta, böyle bir uygulamayla beraber benimsenmesi gereken destekleyici politikalar sunulmaktadır.

Anahtar Kelimeler: Kent Merkezine Araç Erişim Kontrol Politikaları, Tunalı Hilmi Caddesi, Yayalaştırma, Toplu Taşım Öncelikli Yollar, Yolculuk Talep Yönetimi

To Berkin ELVAN

ACKNOWLEDGEMENTS

I would like to express my appreciation to many people who supported me during the completion of this long thesis writing process.

First of all, I would like to express my heartfelt gratitude, love and respect to my thesis supervisor Assoc. Prof. Dr. Ela BABALIK SUTCLIFFE for her support from the beginning of my MS. I know that without the time and care she provided with constructive feedback and encouragement, I would not have completed this thesis. I feel very fortunate to be her student.

I would also like to thank my co- supervisor Assist. Prof. Dr. Hediye TÜYDEŞ YAMAN. She is very special person who was always ready to assist me in solving every kind of problem both during data collection and data analysis procedure. I was able to improve my thesis with her valuable feedback.

I also extend my gratitude to my committee members Prof. Dr. Ali TÜREL, Assoc. Prof. Dr. Bahar GEDİKLİ and Turgay GÜNAL for their valuable feedback, contributions and suggestions.

I am thankful to Res. Assist. Oruç ALTINTAŞI for his guidance and support during data analysis procedure.

I wish to express my deepest gratitude to my parent; my mother Fatma DOĞAN and my sister Kıvılcım DOĞAN. Their encouragement and support help me to finish this long thesis writing process. They always do whatever necessary to be successful through my life.

My special thanks go to Aysun TURUPCU. She always ready to help me with her moral support, and motivated me for making long journey to a MS much easier.

I present my sincere appreciation to all volunteer participants for their time, efforts and energy to help data collection. My co- supervisor and her students, my colleagues, my friends and also my relatives help me in this process and I owe them a lot in the completion of this thesis.

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CHAPTER 1

INTRODUCTION

The ever-increasing share of transportation in creating pollution, particularly carbon dioxide (CO_2) that results in global warming and climate change, resulted in a major change in transportation planning policies and approaches in the world. Before, the main tendency was supply-side policies, i.e. "predict and provide" approach in transport planning. The demand for travel was predicted and necessary road capacity was supplied accordingly. However, the increase rate in travel demand has been too high to be able to increase the supply, i.e. the road capacity that can accommodate the demand. Furthermore, every additional new road capacity has created more demand by making it easier, at least initially, to travel by personal transport modes. Congestion was inevitable. Therefore transport planning policies have changed from supply-side to demand-side policies, i.e. from the "predict and provide" approach to the "predict and prevent" approach. Instead of supplying more and more road capacity, controlling and, if necessary, reducing the demand has recently been the new transport policy, which includes traffic management and travel demand management measures.

This policy of "predict and prevent" aims to reduce the demand for travel in general, and the demand for travel by private cars in particular. Effective methods in reducing overall demand include urban planning approaches to create a more compact urban form with a high degree of mixed-use, so that the distances between residential areas and working places, town centers, schools, etc. are minimized, and so usage of non-motorized modes of transport, i.e. walking and cycling, become viable options. In addition, encouraging extensive use of information and communication technologies (ICT) may help reduce the demand for travel by substituting it with e-shopping, e-banking, distance-learning, and working from home. However, these approaches are not enough for managing travel demand. Increasing the usage of public transportation and non-motorized modes (walking, cycling) while reducing the usage of private car has become a policy accepted worldwide to manage travel demand in the face of increasing car usage and associated congestion and pollution problems.

Car usage and associated problems of congestion, pollution and traffic safety, affect city centers particularly and travel demand management policies often target travels to and through the city centers. These policies aim at improving public transport, walking and cycling conditions and access to the city centers, while making it less attractive and less convenient to drive cars to and through the city centers. One of the most effective tools in attaining these aims is to pedestrianize city centers or convert central boulevards into transit-only corridors. This way, access provided by public transport and non-motorized modes of transport improve in the city centers, and car access control results in relatively less attractive conditions for car drivers. This demand management technique can discourage car usage when travelling to and through city centers and encourage the usage of other modes, thus may result in a decrease in car usage and traffic problems.

Turkey also suffers from an increase in private car use, congestion and pollution. Moreover private car use increases rapidly because of local plans instead of master plans. Partial planning solves short term problems in the study area; on the other hand in long term it affects the related parts and increases the problem. The most significant example of partial planning is designing grade-separated junctions through the city centers. By this approach congestion in that junction may be solved in the short term, but after a while the same junction gridlocks together with former and latter ones. This is both due to partial planning and due to the fact that building a grade-separated junction results in a road capacity increase, which may initially relieve congestion and therefore attract more drivers (including those who may have chosen public transport, such as rail systems, over cars due to congested conditions) and hence create more travel demand. Supply-side interventions, such as increasing road capacities through grade-separated junctions, tunnels, and road-widening, are therefore, not solutions to traffic problems in urban areas; on the contrary they create a vicious circle in which the road supply is increased to match the demand, but then results in an increase in demand, making the road supply inadequate again. Unfortunately, many Turkish cities have been experiencing this vicious circle: city authorities attempt to solve congestion in city centers by increasing road capacities; however, traffic volumes and consequently congestion increase.

As the capital city of Turkey, Ankara also suffers from increase in traffic volumes, car usage and congestion. Numerous grade-separated junctions have been built in central Ankara; and as a result the city center is being used like a transit road, turning into a highway. City centers are areas where major pedestrian circulation takes place. In addition city centers are supposed to be hubs for public transport systems. Therefore, they must be designed for public transport and pedestrian access, and not for car priority. Another problem in Ankara is the lack of incentives for using public transport. There are no combined ticket systems and no smart card technology, although there are plans to introduce these. Meanwhile, there is no car parking policy to discourage those who drive to the city center and park their cars there. As a result, the current system does not encourage people to use public transportation, while the grade-separated junctions and cheap parking opportunities make them prefer to travel with their private cars into the city center.

One of major activity areas within the city center of Ankara is Tunalı Hilmi Street, which is less than 2 km south of the Central Business District (CBD), Kızılay, and therefore functions as an extension of the CBD. In the current traffic circulation system, the Street is an important collector road for the city center. Because of one-way regulations, Tunalı Hilmi Street carries all the traffic of the south-eastern part of the city to the city center. Therefore it is vital for city center traffic circulation. On the other hand Tunalı Hilmi Street has become a center of commercial activities, varying from business and working places, banks, shops, to cafes and restaurants; and as a result it functions as the city center and pedestrian density is very high there.

These two functions conflict with each other. One of the views considers Tunalı Hilmi Street as an important collector road for the city center circulation system. Others think it should be pedestrianized because of commercial and leisure activities, high-street shopping functions, and associated pedestrian density. Of course there may be other problems, such as increasing traffic volume on other roads, if Tunalı Hilmi Street becomes pedestrian. Perhaps due to such concerns, this issue has been on the agenda for a long time, but no actions have been taken.

Therefore, this study assesses the possibilities of traffic restriction, i.e. car access control in Tunalı Hilmi Street. The study has three main aims:

- To review and highlight effective transport policies and techniques that can help manage travel demand and traffic in city centers, with a particular focus on pedestrianization or creation of transit-only streets;
- To demonstrate traffic count and simulation methods as a decision-making tool that can help evaluate possible consequences of traffic and travel demand management techniques;
- By using these count and simulation methods in Tunalı Hilmi Street, to demonstrate the use of these techniques as well as shed some light to traffic problems, components, and consequently possible solutions for Tunalı Hilmi Street in Ankara.

Chapter 2, the following Chapter, therefore, reviews the evolution of transport policies and provides a comprehensive understanding of travel demand management and traffic management techniques. Various policies and techniques are reviewed and the importance of an integrated approach that combines all these in a comprehensive policy package is highlighted. The main focus is, however, on car access control policies and measures in city centers.

Examples to these measures of car access control in city centers are provided in Chapter 3. A number of best-practice cases are presented and their experiences with car restriction measures are described.

Chapter 4 introduces the methodology of the study that is to be implemented for the case of Tunalı Hilmi Street in Ankara. A detailed traffic survey and vehicle counts have been carried out in order to reveal components traffic, such as through traffic and traffic that originate from or end in the Tunalı Hilmi Street and its environs. Hence an

Origin-Destination matrix has been obtained for the peak hours, which is when the traffic problems are worst in the area. After analyzing the base case, by applying the car access control policies, four assumptions are tested and assessed. These assumptions that the redesigning of the Tunalı Hilmi Street would have to be carried out with changes to the traffic directions in the surrounding streets. Therefore the differences and effects of existing situation and interference of traffic directions are observed.

Assumption 1: In this assumption, it is assumed that the existing demand, i.e. the existing level of traffic would not change at all in spite of the closing of Tunalı Hilmi Street to vehicular traffic (except for public transport buses) and so the simulation is made by distributing all the existing demand to the alternative.

Assumption 2: In this assumption, it is assumed that through passengers (those who only pass through) using Tunalı Hilmi Street as a transit road would choose an alternative route since this area does not offer them a direct through route anymore and therefore the through traffic is eliminated and the remaining demand is distributed.

Assumption 3: Car access control policies, including pedestrianization and creation of a transit-only corridor are also likely to discourage more people to use their private cars. Therefore in this assumption, beside the elimination of through traffic, a further 20% decrease is assumed in private car numbers as a result of the new character of the area, which is transit-friendly and not very car-oriented any more. The remaining demand is distributed.

Assumption 4: In this assumption a further step is applied: A better car parking control and enforcement in the side streets can help eliminate the usage of two lanes (on both sides) of streets for parking and hence side streets' capacity may be slightly improved while car access is restricted in Tunalı Hilmi Street.

Tunalı Hilmi Region has high pedestrian density and in this study private cars are not allowed to enter this street. One of the most important topics about this issue is that traffic volume of the Tunalı Hilmi Street would be distributed to alternative streets. Accordingly, the study aims at finding these effects by using the minimum path approach.

Moreover some of the private car users may be discouraged to come to this street by their cars and private car use in this area may decrease. All these effects require certain assumptions to be made when simulating traffic effects of such a regulation.

Chapter 5 first introduces background information on Ankara and Tunalı Hilmi Street, and then presents the implementation and results of the study carried out in Tunalı Hilmi Street. Traffic counts, their indications, the traffic simulation under the above assumptions are described and discussed.

Finally Chapter 6 presents the main findings of the study. Based on the study carried out in Tunalı Hilmi Street, the suitability and practicality of the traffic analysis method used here is discussed. Similarly, based on the results of the analysis, the suitability of the four assumptions are discussed and evaluated for Tunalı Hilmi Street. The study concludes with recommendations of traffic management in this street, as well as recommendations for the usage of this traffic simulation tool in decision making in other parts of Ankara, Turkey and the world.

CHAPTER 2

URBAN TRANSPORTATION PROBLEMS AND THEIR SOLUTIONS IN A HISTORICAL CONTEXT

Urban transport is an essential part of urban daily life. Because of the need of commuting, people need to use transportation daily. Any problems, such as congestion, comfort, quality, etc. therefore affect daily life of citizens. In this chapter urban transport, associated problems and solutions are presented generally in a historical context. In the first part history, development and problems of the transportation modes are described; and in the second part solutions of these problems are discussed briefly.

2.1. History of Urban Transportation Systems and Problems

Transportation is basic daily routine of all people that supply their commuting needs or help them reach essential services like shopping and recreation. Transportation can be defined as an act of moving something from one location to another. People, goods or information are what is transported. This may be between homes, workplaces, schools, etc., as well as between factories and warehouse in the case of goods transport. Transportation may be made by road, rail, air, sea, pipeline or telecommunications equipment. Transported materials, destinations, origins and modes may differ, but the main aim is generally to minimize transportation cost (both in monetary terms and in time) while also meeting the demand which mostly depend upon the distance between the origin/source and the destination. Transportation costs are; vehicle expenses, travel time costs, road and parking facility costs, crash costs and environmental costs. (Victoria Transport Policy Institute, VTPI, 2012)

2.1.1. The automobile-era and associated problems

Before the Second World War, transportation was not associated with problems of congestion and environment. The main issue was to supply public transport to meet the travel needs of people. After the Second World War, mass production of private cars and increase of welfare of people increased the use of it and the automobile-era started.

In the late 1950s, after the increase in car ownership and its usage, the main transport planning method was “predict and provide” which first forecasts how much traffic there will be and then builds enough road space to accommodate it. This method intended to meet the ever-increasing demand for car usage that was being experienced in the late 1950s and then the 1960s and 1970s. However due to physical and economic constraints road capacity would be expanded at a rate less than the rate of traffic demand and growth. Goodwin (2004) also mentions about this issue by stating that; congestion is likely to get worse, not better day by day because the ratio of vehicles to mile of road can only increase. He also adds that the “predict and provide” method inevitably started to become “predict and under-provide”.

Contrary to expectations, “predict and provide” method was not successful. Because demand was increasing highly, on the other hand supply was limited. A statistical proof of lack of supply rate compared to the demand rate from Banister (2001) is that; “Traffic levels in many car-dependent countries have doubled (1975-1995), but the expansion of the infrastructure has been more modest, typically a 10-15% increase in the road network (mainly the motorways) … resulted in the inevitable increase in congestion and this situation is well illustrated with data from Great Britain (Table 1)” (p.9).

Table 1: Banister- Measures of congestion and traffic in Great Britain

	1977	1987	1997
Cars per km of road	39.4	49.4	58.6
Vehicles per km of road	52.2	62.8	72.9
Passenger km per km of road (thousands)	1 375	1 710	1 939
Distance travelled per person per year (km)	7 536	8 507	10 512
Percentage of all distance by car	70.5	75.6	81.9

Note: (a) Length of road includes trunk and classified roads (about 45%) and unclassified roads (about 55%).

Source: Banister (2001), p.10

Studies in the late 1980s and early 1990s also showed that under congested road conditions, every addition to the road capacity (via additional traffic lanes or intersection projects such as fly-over junctions) create more traffic (Cervero 2003; Goodwin 1996). This is because road capacity increase initially creates a relief in congestion; however, this relief results in more people choosing to drive since it creates a perception that traffic congestion problem is solved. Consequently, those who chose public transport modes, such as rail modes that are not affected from road congestion, and those who may not make an urban trip due to congested conditions would chose to use their cars and drive after a road capacity increase expecting that road congestions would be better. As a result, the capacity increase on congested corridors only create a relief in the short term, and actually create more traffic, known as “induced traffic” in the long term (Cervero 1993; SACTRA 1994; Goodwin 1996).

As a result of the above criticisms of the prevailing methods of road building and capacity increases, during the 1990s, as Owen (1995) states; “new realism” has emerged and the method of “predict and provide” has been substituted by the method of “predict and prevent”, which means the aim of “meeting the demand” has changed to the aim of the “managing the demand”. The main objective in this measure is; reducing the total amount of traffic by a combination of measures some of which can be restrictive while others can be providing improvements and increasing attractiveness and quality of the travel conditions.

Besides its benefits to individuals, transportation poses serious problems for environment, economy and society. As Schiller, Bruun and Kenworthy (2010) notice "Almost all of the motorized ways or modes in which individuals, goods or materials move around our cities and Planet Earth consume considerable amounts of energy and resources, most of which are not renewable. Most of these modes are highly dependent on fossil fuels and are deeply implicated in the process of greenhouse gas emissions and their atmospheric accumulation." (p. xxi).

According to Hensher and Button (2003), Traffic congestion not only increases the emission, but also because of wasted time and money, it has an economic and health cost. Moreover it amplifies stress and other illnesses on users and non-users.

The above changes towards the "predict and prevent" approach, also coincide with the contemporary transport policy for environmentally, economically and socially "sustainable transportation". Sustainability is defined by Newman and Kenworthy (1999) as; "any economic and social development should improve, not harm, the environment" (p.1). In transportation, the meaning of the sustainability concept is the same and is seen inevitable in the face of problems caused by car-dependency (Table 2).

Table 2: The problems of car dependency in the aspect of environmental, economic and social aspects

Environmental	Economic	Social
• Oil vulnerability • Photochemical smog • Toxic emissions such as lead and benzene • High greenhouse gas contributions • Urban sprawl • Greater storm-water problems from extra hard surfaces • Traffic problems such as noise and severance	• External costs from accidents and pollution • Congestion costs, despite endless road building • High infrastructure costs in new sprawling suburbs • Loss of productive rural land • Loss of urban land to bitumen	• Loss of street life • Loss of community • Loss of public safety • Isolation in remote subur • Access problems for car-less and those with disabilities

Source: Newman and Kenworthy (1999), p.109

According to report of Organization for Economic Cooperation and Development and European Conference of Ministers of Transport (OECD/ECMT) (1995); there are seven basic objectives to be met to establish a policy that addresses the principles of sustainable development:

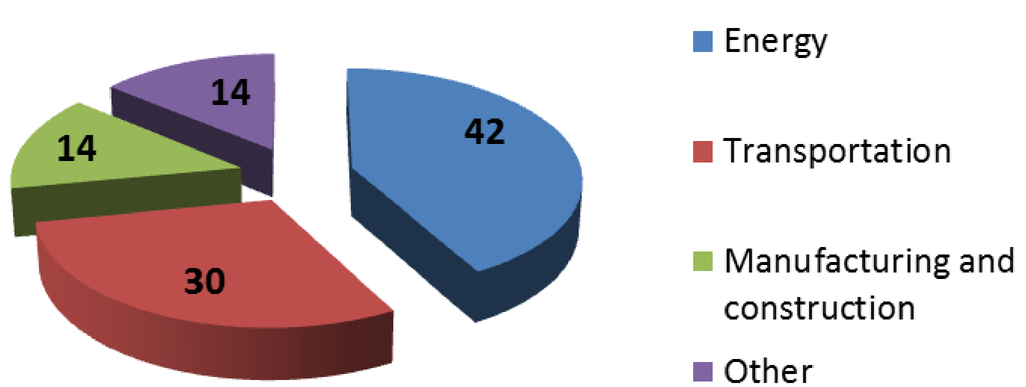
1. reduce the need to travel,
2. reduce the absolute levels of car use and road freight in urban areas,
3. promote more energy efficient modes of travel for both passenger and freight,
4. reduce noise and vehicle emissions at source,
5. encourage a more efficient and environmentally sensitive use of the vehicle stock,
6. improve safety of pedestrians and all road users,
7. improve the attractiveness of cities for residents, workers, shoppers and visitors (pp.133-134).

As it is mentioned above; there are three main effects of transportation which are environmental, economic and social effects.

2.1.2.1. Environmental effects

Environmental problems are a major concern in today's world. Global warming and the changing of the climate threat the world by ending the life in the near future. There are a lot of variables which cause CO2, the leading greenhouse gas that contributes to climate change. Energy use, heating, using in the industry and transportation are most important ones. Improvements in technology and awareness of people to the environment have started to change these rates of usages. Alternative energy sources like sun, water, and wave are started to be used instead of carbon based sources. Rates of energy usage, heating and industrial usage among pollution have decreased, on the other hand because of the increase of private car usage, the share of the transportation sector in greenhouse gas emissions has been increasing. This reality spots all attention on transportation. According to the International Transport Forum (ITF) (2005), share of transportation in CO_2 emissions is 30% in European Union and OEDC countries. Moreover in some of the countries the transport sector is responsible for more than %40 of CO_2 emissions.

Graphic 1 : Carbon dioxide emissions in OECD countries according to sectors



Source: ITF (2005)

Table 3 : Carbon dioxide emissions globally and from transport, 1990-2000

Country	1990	2000	Increase	Transport 1998	% of total CO_2 emissions
EU15	3115	3161	+1.5%	872	27.8%
USA	4826	5665	+17.4%	1771	32.2%
Japan	1019	1155	+13.4%	278	24.7%
Russia	1284	1506	+17.3%	219	14.9%
China	2290	3036	+32.6%	137	4.5%
India	583	937	+60.7%	n.a.	n.a.
Total	20721	23422	+13.0%		

Transport – million tonnes of CO_2

EU15	Rail	Road	Air	Inland navigation	Total	% of all emissions from transport
1990	8.9	625.0	82.2	19.6	735.7	23.9%
1995	8.4	675.6	96.2	20.5	800.7	26.2%
2000	7.0	762.3	126.0	15.1	910.5	28.7%

Source: EC (2003)

The major effect of transportation on environmental pollution is the releasing of greenhouse gases. However, not only the greenhouse gases but also the noise pollution is an effect of the transport sector on the environment.

2.1.2.2. Economic effects

According to Mitropoulos (2011) "Transportation supports the economy and for the economy to grow, fast, safe and reliable movement of people and goods is required. Departments of transportation maintain, rehabilitate and manage existing infrastructure to address increasing traffic demand and design new transportation networks to increase mobility and offer accessibility to all communities." (p.19). On the other hand, the economic effect of the transportation sector is another concern for sustainable transportation. Vehicles are working by petroleum based fuels. These fuels are all finite resources of the world, which means that a motorized vehicle user contributes to the finishing of the finite world resources. Although there are some innovations like electric or hybrid cars, they are not widespread yet therefore petroleum based fuels are still intensely used. An example of economic effect of the transportation from Davis, Diegel and Boundy (2011) is that;

> The transportation sector consumed 52% of the world‘s liquid (crude oil and lease condensates, natural gas plant liquids, and refinery gain) energy in 2005 and its consumption is projected to increase, more rapidly than other sectors, consuming 57.9% of the world‘s liquid energy by 2030 (EIA, 2008.) The petroleum share of transportation energy consumption in the U.S. for 2010 was 93%. The transportation share of total U.S energy consumption was 27% and of that share 61% was used by cars and light trucks (p. 20).

Other than finishing finite world resources, accidents and pollution are the external costs of transportation. In addition to these, high infrastructure cost and loss of urban land by construction of new roads are also the economic disadvantages of the transportation.

2.1.2.3. Social effects

Social effect is the other sustainability factor of the transportation. According to Harris and Goodwin (2001), environmental and economic sustainability have an important role by protecting environment and avoiding economic turmoil, on the other hand, considering the equity factor, social sustainability is also very important, because, no system can be sustainable as long as it provides the same opportunities to all socioeconomic groups.

Mitropoulos (2011) also comments in this topic that; the aim of the Social Sustainability is trying to create a healthy, safe, fair, accessible and equal environment for all people to participate, interact and receive social services such as education, employment, recreation and cultural development.

It can be argued that car dependency decreases the chance of interaction with other people. Using public transportation make people feel that they live in a society while more walking creates opportunities to be engaged in society, resulting in a feeling of belonging. All of these improve the health of individuals and societies. Conversely, less walking and less usage of public transportation results in the loss of community life and street life.

The other social effect of the transportation is private car ownership of the low-income group. It can be difficult to afford the expenses of the car. Howland (2010) also consider this topic in his study and mentions mismatch of the advantages to accessibility to jobs by car with cost of car ownership for low-income households.

Another important social impact of car-dependent growth is related with equity in accessibility opportunities. With increasing car usage, public transport usage decreases and local authorities often decide to cut down services on public transport when there is lower demand. This results in deteriorated accessibility conditions for those who are captive public transport riders, i.e. those who do not own a car as well as those who may not be able to drive car, such as the elderly and children. Relatedly, social segregation effect is the other effect of the transportation. Calthorpe (1991) examples the culture segregation as old from young, home from job and store, rich from poor and owner from renter.

2.1.2. Negative effects of car oriented development on city centers

After the automobile era, due to the rate of increase of private car usage, many traffic problems as well as environmental economic and social problems occurred as mentioned above. City centers are particularly affected from these problems. To supply the demand, policies that launched road expansions and junctions further triggered travelers to use their private cars to the city center.

As a result major problems associated with car usage intensify in city centers: traffic congestion, CO_2 emission and noise pollution get worse, also accidents are often more frequent in city centers, which bring motorized and non-motorized traffic together. When city centers are designed around car access, the inequality of access for other users, such as pedestrians, cyclists and public transport users, become a real problem. All these result in loss of community and life in city centers that lose their commerce and economic vitality.

2.2. Contemporary Approaches for Solving Urban Transportation Problems

As mentioned above, with the mass production of private cars and welfare increase after the Second World War, private car use increased and cities have suffered from congestion and associated economic, environmental and social outcomes. It is understood that transportation problems are not short-term problems. By changing the transportation planning approach from “meeting the demand” to “managing the demand”; cities and especially city centers have become more livable places.

This change is not easy, because; it is always difficult to change the ingrained behaviors of people. Travelers have difficulty in changing their travel behaviors. Goodwin (2004) states that, when the travelling conditions change; people can change their driving styles, alter their routes, the time they travel, the frequency of trips, the method of transport, the sequence of activities on a round trip and many others. Goodwin follows his statement with an example of sudden change: London Evening Standard (3 February 1997) give a head line of “the traffic has disappeared and we don’t know where it has gone”, when Hammersmith Bridge in London was closed for repairs.

To solve the problems of transportation, although it can be difficult for travelers to adapt, some radical changes are needed. Banister (2001) stated:

> Radical alternatives are required. Transport systems management was used in the 1970's to increase the capacity of the road network through low-cost schemes such as area traffic control, restrictions on parking, and extensive one-way systems. This was followed by demand management in the 1980's to promote high-occupancy vehicles, new public transport systems, parking controls and pricing, and extensive pedestrianization and calming schemes. In the 1990's, there have been more demand management schemes (e.g., park and ride, bicycle priority, central area management, access restrictions) and a reliance on technological solutions (e.g., route guidance, parking guidance). But there is an institutional reluctance to implement a road pricing policy or to use the planning system to limit the growth of traffic at source (e.g. through clear strategies on sustainable development) (p. 15).

By adopting the "predict and prevent" approach, two main methods have emerged in transport planning, which are traffic management and travel demand management. While traffic management deals with mostly network based problems, travel demand management deals with the demand for travel, i.e. the demand that causes the traffic.

2.2.1. Travel demand management

To change travel behavior via policies and programs of people for more efficient transport system, Transportation Demand Management (also referred to as mobility management) is defined (Schreffler, 2000; Cairns, et al, 2004; USEPA, 2004; VTPI, 2012). Travel demand management measures mostly try to change the demand for travel. They aim to discourage car use and encourage public transportation, cycling, and walking. Considering the increasing private car use, existing road capacity should be better used and allocated to priority users. Travel demand management emerged with the aim of better use of existing capacity and trying to change the demand for travel. Banister (2001) stated that; by the new realism approach, it is almost impossible to increase the road supply to a level which approaches the forecast increases in traffic.

Even if road construction policy is successful, the amount of traffic per unit of road will increase, not reduce.

Classifying the Travel Demand Management is varied in the world. One of them is from the Victoria Transport Policy Institute system which describes 4 strategies; “1 - improving and expanding travel options, 2 - incentives to use active and efficient modes, 3 - land-use and parking solutions and, 4 - policy and institutional reform” (Victoria Transport Policy Institute, 2012, Schiller *et al* 2010, p. 30).

In this study Travel demand management measures are described in six main topics which are pricing policies, physical regulations, encouraging public transportation, encouraging walking and cycling, plan for land-use patterns that encourage more public transportation usage, walking and cycling, encourage extensive use of information technology. These are described below.

2.2.1.1. Pricing policies

Pricing policies mostly aim to discourage people from using their private cars. Although it is one of the methods of travel demand management, it should be supported with other travel demand management measures, especially with a good public transportation system. Vehicle ownership taxes, fuel taxes, parking charges, congestion charging and pricing of public transportation are some of them.

Vehicle ownership taxes and fuel taxes are often seen not very effective as the market adjusts to these changes by producing cheaper cars or more fuel-efficient cars. As a result they may not have a significant effect on car usage; and when they have they mostly affect the lower income groups.

Parking charges should be considered especially in Central Business Districts and should be introduced with a good public transportation service, pedestrian areas, park and ride system etc.

Congestion charging can shift people to public transportation, but as discussed in economist (1997) this measure is suggested for both reducing the congestion and improving sustainability but it should be considered as the latest panacea. Other than that, if service is not adequate buses/trains may be too crowded. Therefore this method should be supported with good public transportation system.

Pricing of public transportation is another important measure to encourage people to use public transportation. By this application; all public transportation vehicles use the same payment system on their services and integrated them to each other. Although it still has a limited integration of ticket system, the Ankara case can be observed as an example for integrated ticketing. There are two kinds of ticket prices which are full fare (1.75 TL) and discount ticket (1.30 TL). For full fare tickets; in 75 minutes, the system enables transfers two times and each transfer price is 0.59 TL instead of 1.75 TL. For discount tickets; no payment is required for transfers (EGO, 06.06.2013). These applications may be combined tickets, travel cards (daily, weekly, monthly, yearly) that provide unlimited trips and reduced transfer fares.

2.2.1.2. Physical regulations

Physical regulations are another measure of travel demand management. As road space is limited, it is appropriate to use it more wisely. Pedestrianization, roads designated to public transportation, roads with High Occupancy Vehicle lanes and reduction of parking space are some of measures.

Pedestrianization is one of the physical regulation methods. Throughout history all city centers are designated for pedestrians. While considering the transport system in city centers, pedestrians should be considered in the first step. This subject is discussed more detail in the following chapter.

Roads designated for only public transportation is another physical regulation. City centers should be the most accessible places. If private car access through city center wanted to be decreased, an alternative should be suggested. A good public transportation system is the key of the travel demand management and without it, the other measures are useless. Therefore if a road designated for only public transportation, the priority encourages people to use it. This subject is also discussed more detail in the following chapter.

The other physical regulation is roads with high occupancy vehicles. Most of the congestion problems are not only because of the private car use, but also because of single occupancy per vehicle. Lanes designated only for high occupancy vehicles may encourage car-sharing and would be an appropriate method for congested roads with high proportion of single occupancy vehicles. Buses and other public transportation vehicles are also included in this measure so that they also benefit from a lane that runs faster in traffic.

Reduction of parking spaces can be an effective physical regulation. Especially in city centers, finding a proper parking place is a problem for drivers that may discourage them from driving their cars into the city centers if such parking opportunities are limited. One of the important components of travel demand management is the management of parking places mostly in city centers. Decreasing the number parking places and increasing the price of parking can be a strong policy to discourage people from using their private cars when travelling to city centers. On the other hand, like pedestrianization, this measure cannot be applicable by itself. Without a good public transportation service, this measure may cause a decrease of city centers vitality due to less car visitors and this area may turn into a blighted area.

2.2.1.3. Encouraging public transportation

Encouraging public transportation in city centers is an indispensable component of travel demand management, which means that other applications may not be effective without good public transportation service. To improve the use of the public transportation, Newman and Kenworthy (1999) suggest seven factors:

- Operation and service delivery issues,
- Station and bus stop environs,
- The quality, comfort, age and security of transit vehicle,
- The priority given to transit in traffic management policies,
- Passenger information, marketing and public education,
- Ticketing system,
- Overall management and planning strategies (pp. 161-2).

In this study, encouraging public transportation is divided into five main topics which are building new systems, improving service levels, integrating systems, providing park & ride and bus/tram priority or signaling priority are some of the applications of encouraging public transportation.

If the existing service level is not sufficient building new systems should be the first step. Although fixed cost of the building new system is high, considering the economic, environmental and social cost of increasing private car use, it is mostly favorable in long term. New systems can be bus services, bus lanes, trams, light or heavy rail transit systems like metros according to demand.

Service level of public transportation system is also important to encourage people to use it. People mostly use their private cars because of low service level of public transportation. Long time waiting, low comfort and safety problems shift commuters to their private cars. Good service like more frequent, more comfortable and safer quality attracts drivers to use public transportation.

Public transportation is not an only vehicle, it is a system. This system should be integrated with each other to encourage people to use it. All districts in a city cannot be connected directly to each other. This connection is enabled by integration of the modes and systems. Heavy/light rail transit systems are mostly served to main arteries and in their stations, buses and para-transit vehicles are used as feeder systems. In addition to integration of the systems, routes and ticket integration is important. Routes should be defined very well to enable passengers to switch between them. Also different kinds of tickets for different modes make passengers feel uncomfortable. Not only being different, but also price of the ticket is important. Price integration should be applied. Travel cards (daily, weekly, monthly, yearly) that provide unlimited trips can be used.

Park & ride and kiss & ride systems are feeder applications of public transportation systems. Passengers use their private cars for a lot of reasons. Transport policies should not force them to completely abandon using their private cars. Instead of this, they should be discouraged to use their cars particularly when travelling to city centers. Park & ride is a system that people drive their private cars to the parking places which is located to fringe of the city center and use public transportation, cycling and walking. This system requires parking areas at fringe of the city center and well integration of this place with city center by public transportation and walking/cycling paths. Banister (2005) states that;

> Park and ride is seen as a policy to reduce city center congestion as cars are left at peripheral car parks and public transport is used to get people to the center. On its own, this policy may simply release more traffic space for other road users so that there is little net benefit, and it may also result in longer journeys as car users (and public transport users) are attracted to the park and ride site (Goodwin, 1998). If the policy objective is to reduce the use of the car in the city center, the park and ride scheme should be combined with priority to public transportation the routes into the city (reallocation of road space) and strict city center parking control (to reduce the attractiveness of the city center for car users) (p. 83).

Kiss & ride system should also be provided as this allows drivers to arrive at stations with their private cars and drop passengers to the station who can they ride public transport. In short, accessibility of stations at peripheral areas is important to attract car users to public transport. Park & ride and kiss & ride systems are feeder applications of public transportation systems. As it is mentioned above it is not fair and logical to totally force people not to use private cars. Instead of this, park & ride and kiss & ride systems can be applied.

To encourage public transportation some priorities may be given to them in traffic. Most of the public transportation vehicles like bus and tram are on the traffic with the private cars. To attract people with faster and more frequent public transportation service, these services can have priority and hence can be able to supply more reliable services. These measures include bus lanes, busways and changes like signaling priority for buses and trams.

2.2.1.4. Encouraging walking and cycling

Although after Second World War the main aim in transport planning was designing the city centers for cars; negative consequences of this approach was realized. There is now an understanding that city centers should mostly be accessible by public transport, walking and cycling. Beside the public transportation services, walking and cycling are also indispensable components of travel demand management.

Increasing pedestrian routes, areas and crossings and providing more priority to pedestrians at crossings can encourage walking in city centers. Integration of the pedestrian areas with pedestrian routes and feeding them with commercial activities can create more livable city centers.

Encouraging cycling is another application in travel demand management. Until recently cycling was often not considered as a transportation mode; however, it is now recognized as an effective system that can be used for travel needs. In addition, it is promoted as a healthier transportation mode that allows people to have physical exercise in their daily lives. Developing bicycle routes, lanes, parks and priority to cyclist are main applications to encourage using of bicycles as a transportation mode in city centers. In addition, many cities today introduce city-bike programs, where the city authority provides bicycles that citizens can pick up from one point and leave at another point in the city. This requires becoming a member and certain charges are applicable;

however, they are generally much cheaper than other transport alternatives and provide high flexibility and accessibility.

Parkin (2010) also mentions this topic in his study;

> The personal effort that a traveler puts into a journey is something very intrinsic to them and their body and, on this basis, it is quite conceivable that the additional disutility that they may place on an increase in effort may be more highly valued than a commensurate proportional increase in journey time. It will also be important to attempt to balance the perceived disutility of energy required for a journey against the ambience of the journey; the value of additional energy expenditure may be acceptable, if it occurs while travelling in an attractive environment (p. 172).

This topic is also mentioned in the next chapter.

2.2.1.5. Plan for land-use patterns that encourage more public transportation usage, walking and cycling

Land use planning is the upper scale perspective of the travel demand management. As it is mentioned above transportation is a daily routine need of the people. Everyday people commute to their jobs and schools. In addition to that they need to travel for their recreational/entertainment needs. Therefore land-use planning is important because it determines the distances between homes and workplaces and other areas that people travel to.

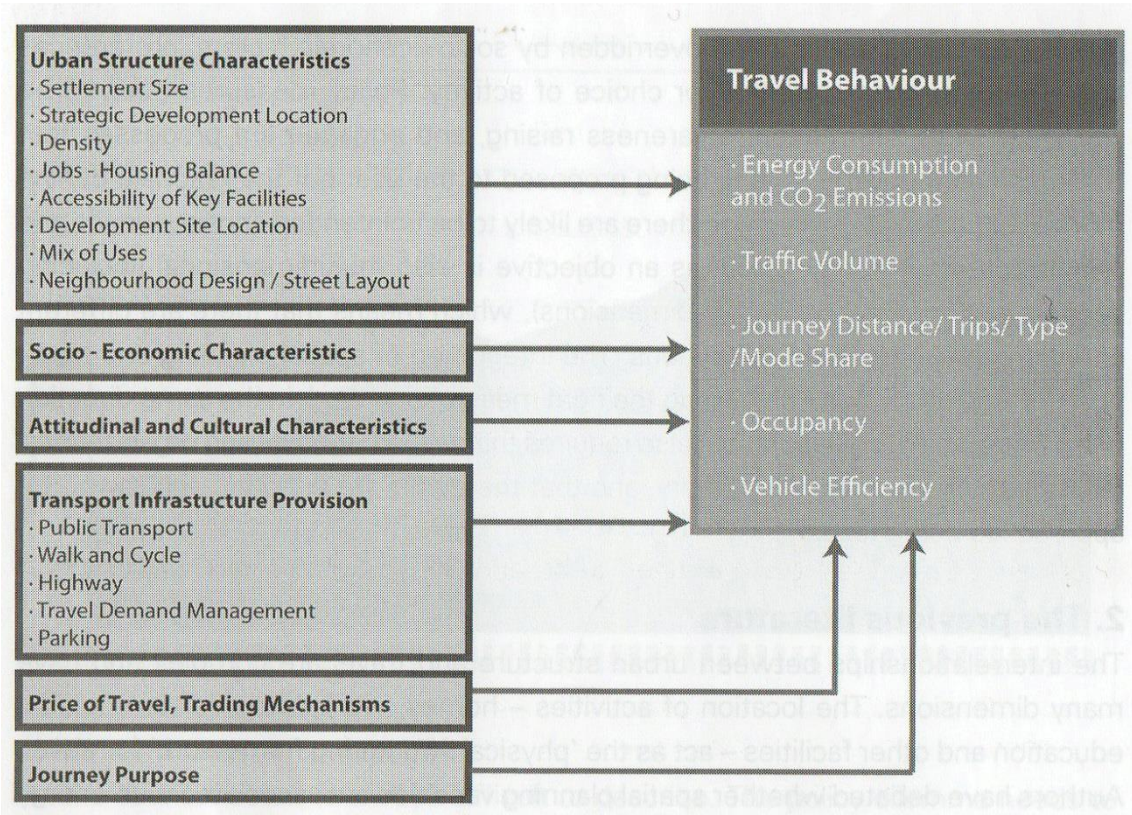
After the Second World War, flexibility provided by the increased car usage resulted in sprawl of urban areas. Sprawl and dispersal of activities resulted in high distances between different land-uses and since serving all these dispersed uses with public transport became difficult, urban sprawl created even more car-dependent urban areas. Today in order to prevent sprawl and dispersal of urban activities, two main approaches are considered, which are compact cities and mixed use of development. These two applications not only decrease the length and time of the transportation, but also encourage people to use modes that are alternatives to the car, namely walking, cycling and public transportation

Hickman, Seaborn, Headicar and Banister (2010) state in their studies that;

> Socio-economic, attitudinal and contextual characteristics all play important roles in the demand for travel, alongside the requirement of the trip. However, the empirical evidence demonstrates that there are significant correlations between spatial planning and travel, even after accounting for wider influences (Ewing and Cervero, 2001; Bohte et al., 2009; Naess, 2009; Cao et al., 2009 and others), but often the direction of the relationships and implied causalities are much less clear (p. 35).

They also present some of the factors influencing travel demand from the perspective of the urban planning as shown in Figure 1. According to this figure; urban structure characteristics like settlement size, strategic development location, density etc. are some of the important factors that influence demand for travel.

Figure 1 : Urban structure as an enabler of sustainable travel



Source: Givoni and Banister (2010), p. 36

One of the examples of these land-use policies was applied in Stockholm (Stockholms Stadsbyggnadskontor, 1972) and its basic principles were;

- Locate workplace close to houses.
- Minimize distances from houses to shops.
- Concentrate service functions in easily accessible areas and make premises easily convertible to meet new service needs as times change.
- Create housing variety with two-storey dwellings with good ground contact; four to six storeys around courtyards, and ten to thirteen storeys near stations.
- Urban environment to have rich variations in form and color.

- Multifamily housing to be no more than 300 meters from a station.
- Single-family housing to be no more than 300 meters from a bus stop (or a station).
- A bus-rail interchange to be available in all communities.
- Centers to be linked and permeated by a coherent network of foot and bicycle facilities separated from roads with the convenience of seniors and people with disabilities in mind.

As it is seen in the Stockholm example, land-use planning is the upper scale travel demand management measure, and it can have an effect on travel distances and transport modes to be used.

2.2.1.6. Encourage extensive use of information and communication technology (ICT)

Technological improvements also have positive effects on transportation by not only improving the quality, safety and environmental friendly features, but also decreasing the demand for travel by using information and communication technologies. People use transportation vehicles to go to work, school, shopping, entertaining, or socializing. Today, many of these activities can be supplied at home by information and communication technologies. E-shopping, e-banking, distance learning and chatting on the internet are some of these activities. Moreover some firms allow their workers to work at home on certain days of week. Banister (2005) explains ICT technologies in three topics. First one is production; ranging from e-commerce and just-in-time production (manufacturing systems), through logistics and fright distribution to e-marketing and publicity (Table 4). Second one is living (and travelling) which is also divided into three main groups; public transport and private transport planning relate to the impacts for transport rather than on transport (Table 5). The last topic is working and is also analyzed in three applications which are e-office, e-meeting and e-information (Table 6).

Table 4 : ICT and production: Implications for transport

Application	Role of ICT	Impacts on transport
e-commerce and e-everything	Internet, sms, email etc	May reduce the need for the movement of goods in certain cases – for example, music is downloaded from the web, and orders are transmitted electronically
Just-in-time production	Technology for stock control, ordering and tailored production	More frequent deliveries; smaller loads –faster delivery – more air movements
Logistics and freight distribution	Real-time route guidance, track and trace technology – optimizing delivery vehicles and routes	Savings in reliability and travel time, but may add to journey distance. Possibilities for trip chaining and load matching. Also savings in terms of vehicles and route choice
e-marketing and publicity	Internet, email, sms, etc	Could potentially reduce the amount of other sorts of marketing/publicity material produced. More likely that e-marketing will be an additional source of information rather than a substitute

Note: Spam mail can also reduce the efficiency of ITC and hence reduce its usage.

Source: Banister (2005), p. 175

Table 5 : ICT and living: Implications for transport

Application	Role of ICT	Impacts on transport
Public transport planning	Integrated public transport planning information	Modal shift in favour of public transport and shorter wait times – improved quality of services
Private transport planning	Real-time route guidance and hazard warning	Savings in congestion and travel time – but may add to journey distance
e-everything: shopping, medicine, education, banking, entertainment, chat rooms, network games etc	Internet, sms, email, iDTV etc	Reduces the need for individuals to travel for many transactions, but the existence of these services requires more people to work outside 'regular' work hours – with implications for transport modes. May also lead to 'new' journeys to replace the ones that would have been necessary in the absence of the e-Activity or to completely new demand resulting from social networking
'Last minute' deals: flights, hotels, holidays etc	Internet, sms, email, etc	Assist companies to increase capacity and revenues – create additional travel

Source: Banister (2005), p. 180

Table 6 : ICT and working: Implications for transport

Application	Role of ICT	Impacts on transport
e-office	Internet, email, mobile communications, portable computers etc. Teleservicing	Possibly a reduction in travel frequency but longer distance travel could also result (when individuals move further for work), and/or substitution of work travel with other travel – with the time saved by not travelling to work. May also lead to the use of more on-the-move working options during long distance travel
e-meeting	Videoconferencing	Potential reduction in travel distance but limited in application – many face-to-face meetings may be more useful and productive – telephones have not reduced the need for meetings. There may also be some substitution of meeting travel with other travel – with the time saved by not travelling to a meeting
e-information	email, ftp, extranet etc	May reduce the need for meetings to exchange routine information

Source: Banister (2005), p. 184

2.2.2. Traffic management

Traffic management measures mostly aim to accommodate the demand for travel in the most efficient way. Therefore existing network is designed effectively without having to build new roads or increase road capacity. The other aims of traffic management measures are minimizing congestion, emission and accidents. There are mainly three traffic management measures which are; regularity measures, physical methods of traffic control and driver information systems.

2.2.2.1. Regularity measures

The first traffic management measure is regularity measures which include speed limits, restrictions on left-turns, one-way streets, tidal-flow operation and waiting restrictions-parking control.

- Limitation of the speed of the cars may reduce the number and severity of accidents; however it does not help to solve congestion.
- Restrictions on left turns may reduce congestion and queues but it should be noted it may increase trip lengths and may transfer congestion to other roads.
- Application of one way street systems may increase the capacity and decrease the congestion, but if the spare lane is used for parking, congestion remains. In addition when implemented in residential areas, it may result in traffic safety problems as the increased road capacity would allow higher speeds.
- Tidal-flow operation is assigning lanes according to demand. For example, when demand is high in one direction in morning peaks and the other direction in evening peaks, one of the lanes may be assigned to the traffic on the higher demand direction.
- Waiting restrictions-parking control also helps to ease traffic flow but it should be implemented carefully as trade along the roads may be adversely affected due to limited parking and waiting.

2.2.2.2. Physical methods of traffic control

Physical methods of traffic control include traffic calming, pedestrian priority and cyclist priority.

- As Newman and Kenworthy (1999) defined; traffic calming is the process of slowing down traffic to enable more safe and conducive street environment for pedestrians, cyclists, shoppers and residential life. Although it may result in more queues at certain areas, traffic calming helps to reduce traffic speeds and number and severity of accidents. Some of the traffic calming instruments are:

  - To reduce vehicle speeds : road humps, bumps and speed tables
  - To create road conditions which encourage motorist to drive carefully : build-out (a feature extending into the road on one side, narrows the road)
  - To reduce the number and severity of accidents : central islands
  - To enhance the environment: road markings and different surface treatments.

- Pedestrian priority and cyclist priority at crossings and junctions are other physical methods of traffic control that help to provide safe road conditions for non-motorized modes.

2.2.2.3. Driver information system

According to Hoose (2010), it is a necessity of everyday life that using the information and control techniques to manage the movement of people and goods on the road network. Driver information systems are signaling, automatic vehicle identification, roadside guidance system and in-vehicle route guidance system.

- Signaling is the first driver information system instrument
- Although it is against privacy, automatic vehicle identification also helps to enforce parking and speed laws
- Roadside guidance system is a dynamic response to congestion and it temporarily overcomes congestion problem
- In-vehicle route guidance system enables less routing, shorter/direct journey, less emission per car; but it also encourages car use when travelling to center.

All these measures help to accommodate travel demand without making major new transport infrastructure or manage travel demand by encouraging the usage of transport modes that are alternatives to the car. Amongst all these measures, those that serve car access control policies have been receiving popularity in the world recently since they can be very effective in changing travel demand, i.e. users' choices of transport modes, particularly in journeys made to or through the city centers. Car access control in city centers can make car usage less attractive and convenient, while the allocation of road space from cars to public transport and/or non-motorized modes can make alternatives to the car much more attractive and convenient to use. These policies are described in the following chapter together with good-practice cases from around the world.

CHAPTER 3

CAR ACCESS CONTROL POLICIES IN THE CITY CENTERS

As mentioned in the previous chapter, contemporary transport planning policy aims to decrease congestion and associated problems through management of the demand for travel. The very first aim of this approach is decreasing the private car use.

Restriction of private car ownership is not an objective in contemporary transport policy as everybody can have the right to purchase a car. Moreover having a car can be important for certain users, providing opportunities for health trips or in emergency situations. Private car use and having a private car are very different subjects. Demand management approach deals with the private car use especially in peak hours in travels made to the city center or travels on congested corridors. Peak hours are the time period, which the highest volume of the traffic is seen on the road. This is mostly due to commuter traffic. Traffic volume of the city centers are mostly considered with the efficiency of this period and designated according to it. As Duany (1991) mentions to accommodate peak rush hours, cities have been reconstructed.

City centers are major places that attract and generate traffic, because, most work places, businesses, public institutions, and commercial activities are located there. Also even educational and recreational activities may be seen in city centers. Therefore the demand of transportation is very high. Unless the traffic and travel demand are controlled, city center is congested. To prevent this problem, traffic management and travel demand management measures are applied.

Public transportation is the indispensable tool of travel demand management to decrease the private car use in the city center. Without a good public transportation system, other applications may not be effective. This topic is discussed in the next parts.

Pedestrianization in city centers is an effective application to discourage people to use their private cars. This application not only decreases the private car use, but also increases the livability and the commerce potential of the city center, provided that it is supported with good public transportation service. Otherwise city center turns into a blighted area. This topic is also discussed in the next parts.

People go to the city center for a variety of reasons. When they drive their private cars to the city center they need to leave it to a safe place. The other effective policies for car access control in city center are waiting restriction, parking control and reduction of parking spaces. By these applications, knowing to have difficulty to find a safe parking place, people tend to use public transportation. Also by controlling the street parking and applying waiting restriction, traffic flow will be more fluent.

Another car access control applications are pricing policies. Goodwin (2004) states for new generation, there may be two important policies to solve congestion which are to push people to travel by slower methods and make them pay for what they now think of as free. To discourage people to use their private cars to the city center, some pricing policies can be applied like parking charge and congestion charge. Parking in city center is a need. Although by controlling parking and reducing the parking spaces, still parking is an indispensable need in the city center. Increasing the price of these parking places, also drivers will be discouraged to use their private cars to the city center. The other pricing method is congestion charging. Road pricing is an effective method of travel demand management. This is almost the latest solution of the car access control policies. Many cities like London, Stockholm and Singapore have applied this measure in city centers and succeeded in reducing traffic through discouraging car usage. Banister (2005) states that:

> London has provided the first real example of cordon pricing in a major European city (February 2003). Each vehicle is charged a fixed amount for crossing the cordon into the city center. Prior to congestion charging, it was estimated that about 15 per cent of commuters to Central London came by car (about 50,000 vehicles in the peak hour), and these vehicles spent about half their time in queues (stationary or slow moving) with an average speed of about 15 km per hour. The Road Charging Option for London Report

(ROCOL, 2000) estimated that a £5 per car charge would reduce traffic by 12 per cent, speeds by 3 km/h, and give a net annual benefit of about £130m (table 7). …… About 50,000 fewer cars are entering the charging zone, with many people switching to alternative public transport and other modes that are exempt (taxi, cycle, motorcycle), or diverting from the zone. Some 15,000 extra bus passengers are now travelling into the congestion charging zone during the morning peak, with faster journey times (excess waiting time at stops has reduced by 30 per cent) and lost kilometers due to traffic delays reduced by 60 per cent. Only 4,000 fewer people are entering the zone (TfL, 2003).

One of the limitations of this method is equity concerns. It may be discussed that the method mostly discourages lower income users. Although it seems, charging to the entrance of the city center is not a fair solution for all users, it is a necessity if there is congestion because of the private car usage. Also it can be considered as a fair charging method, because there are two main phrases in literate as "polluter pays" and "congester pays". These approaches balance the effect of the private car users and public transportation users. Banister (2005) also emphasizes equity issues and declares that by reinvesting the revenues in transport projects, equity concerns are solved, particularly for low-income car owners.

Table 7 : Estimated traffic impacts and economic benefits of a £5 area license for Central London

Impact	Central London		Inner London	
Change in traffic levels	Base vehicle km		Base vehicle km	
am peak (07.00–10.00)	– 0.8m	(–10%)	– 5.9m	(–3%)
14-hour (06.00– 20.00)	– 3.6m	(–12%)	– 25.5m	(–3%)
Change in average traffic speeds	Including junction delays		Including junction delays	
am peak (07.00-10.00)	from 15 to 18 km/h		from 21 to 22 km/h	
14-hour (06.00-20.00)	from 16 to18 km/h		from 22 to 23 km/h	
Economic benefits per year	£125m to £210m; mid point £170m			
Area licensing annual operating cost	£30m to £50m; mid point £40m			
Overall annual benefit	£95m to £160m; mid point £130m			

Source: Banister (2005), p. 132

Table 8 : Congestion charging in London

The congestion charging scheme is designed to target transport priorities in Central London – reducing congestion, improving bus services, improving journey time reliability, and to increase the reliability and efficiency of freight distribution. It also raises funding for investment in transport in London. The boundary is formed by the area within the Inner Ring Road of Central London, covering 21 km^2 or 1.3 per cent of the total area of London. There are 174 entry and exit points, with a daily charge of £5 for each registered vehicle – the penalty for non-compliance is £80, reduced to £40 if paid within two weeks and raised to £120 if not paid after 4 weeks. The total budget was about £200 million, including £100 million for complementary traffic management measurements. The operating costs are about £80 million per annum and a £12 million budget for communication and marketing (London Assembly, 2002)

Impact of congestion charging six months on (February to August 2003)

- Congestion in the charging area has reduced by 30 per cent. It is lower than at any time since the mid 1980s. But taxi journeys have increased by 20 per cent, and van and lorry movements have decreased by 10 per cent. Cycling has increased by 30 per cent.
- The number of motor vehicles entering the area during the charging hours (07.00 to 18.30 on Mondays to Fridays) has dropped by 16 per cent – note that buses, taxis, residents (10 per cent charge), and 13 other categories of vehicles are exempt or have discounts.
- Car journeys to and from the charging zone are quicker and more reliable, with travel times reduced by 14 per cent and reliability increased by 30 per cent.
- Public transport is coping with the increase in passengers.
- Bus services are more reliable as a result of less congestion.
- No significant traffic displacement around the zone has been observed.
- Provisional data show a 20 per cent reduction in accidents in the zone.
- The various payment schemes seem to be working, with a reduction in call centre enquiries from 167,000 to 70,000 per week.
- Penalty notice charges have averaged at 106,200 per month, and payments for 60 per cent of these are made within a month – a current proposal (February 2004) will substantially raise the penalty and enforcement charges.
- The public remain supportive of the scheme – 50 per cent of London residents support it and 30 per cent oppose it.
- Average net revenues will be £68m in 2003/2004 and about £90m in 2004/2005.

Source: Banister (2005), p. 133

In traffic all modes move together. If a shift is wanted from one mode to the others, priority should be changed. In city centers there are junctions and crossings. These are the main intersections between motorized and non-motorized modes. If pedestrianization and cycling is wanted to be encouraged and private car use is wanted to be discouraged, priority of former should be increased in both crossings and junctions.

The last car access control policy is traffic calming. Traffic calming policy's main aim is to decrease the traffic speed and number of accidents. Therefore it results in more queues and congestion. Some of the examples of this applications are; road humps, bumps, road narrowing, throttles and chokers. These applications decrease the traffic speed and indirectly priorities of the non-motorized modes are increased. Also private car users are discouraged to use their cars on a slow, narrow and bumpy road. Speed limits can also been considered in this policy. Limitation of the speed in the city center as the other traffic calming policies, leads to both a decrease in the number of accidents and priority to the non-motorized modes.

All these methods should be considered together and integrated applications of them are more successful.

3.1. Private Car Restriction via Pedestrianization

Throughout history, city centers have been designed for pedestrians. Commercial, entertainment, recreational, public etc. needs of people have always been supplied there. Since city centers are the destination of many daily urban trips, pedestrian density and movement are very high there. With the increasing of mass production of car and relatedly using of it, many city centers in the world have become car-oriented centers. Cities have started to suffer from both congestion and safety of the pedestrians. It is again understood that pedestrians should be prior element of city centers and most of car-oriented city centers have turned back to pedestrian friendly places.

Of course pedestrianization cannot be the only solution. People need to come to city centers. If it is not supported with sufficient public transportation system, city center turns into a blighted area. Goodwin (2001) stated that there may be two oppositions about pedestrianization which are loss of trade and insupportable stress in other streets, often described as “traffic chaos”. However, Goodwin claims that; a good-quality pedestrian-only space in the heart of a city center is very widespread and common nowadays and it can no longer be treated by experiment. On the contrary, these places attract commercial and cultural activities, work properly and win votes.

As mentioned above, city center is mostly the core of the commerce. Many retail stores from the giant brands to small retailers are located there. Rents of these shops are often high because of the potential costumers. These customers are mostly the pedestrians that traveled to the city center for any reason. Increase the pedestrian movement in city center results in the increase of potential customers of the shops in city center. Therefore commerce is increased and city center will be a living place.

Not only the commerce, but also the entertainment facilities are often located in the city center. These facilities increase the livability of the centers and by keeping the city center alive at nights, can prevent the increase of crime rates. Pubs, restaurants, discos, night clubs, cafes, amusement arcades etc. are some examples of the entertainment facilities.

Most of the public institutions, main offices of the banks and big companies are also located in city centers, because they need to be accessible to all people living in the city. Governorship, Municipalities, Ministries and tax payment offices are some of public institutions that most of the people living in the city need to visit. Because of the easy accessibility, main office of the banks and big companies prefer to be located in the city center.

City centers in many countries are known to have large parks and squares as public spaces. These parks and squares create an open space and enables citizens to socialize and rest. Pedestrians also can move easily in these places compared to the narrow pavements of roads.

Education facilities also increase the importance of the center. Not only the universities, high schools and primary schools, but also private teaching institutions (dershane), such as centers for driver license, dance, music, and handicraft etc. courses are often located in city centers to benefit from the advantage of centrality.

All these facilities mentioned above need good quality pedestrian access: even if the users arrive by the car, they are likely to walk to access these facilities. Livability of the city center which means continuity of these facilities is directly related with good pedestrian access to there. Pedestrianization of certain streets or area-wide pedestrianization is therefore often seen as effective measures to improve pedestrian accessibility and livability and economic viability of city centers.

3.2. Private Car Restriction with Public Transportation Support

Rather than a full–pedestrianization of a city center area or street, it is also possible to designate streets for only public transport vehicles in addition to non-motorized modes of walking cycling. These may be tram-only streets or bus-only streets. The example of Oxford Street in London is also interesting as it allows only buses and taxis to enter this 2 km long shopping street. As a result, this two-directional road only has three lanes and large pedestrian sidewalks (Figure 2). It should be noted that the street is also supported with the underground rail system which has four of its stations along this street.

Figure 2 : Oxford Street in London

Source: Ysangkok (2006)

Such implementations of tram-only or bus-only streets not only restrict motorized traffic in city centers but also encourage public transportation by giving them priority in traffic. Most of the public transportation vehicles like bus and tram are on the traffic with the private cars. To attract people with faster and more reliable public transportation service, these services should have priority in traffic; and bus or tram-only streets can provide this priority and advantage to public transport.

This measure means that a road or area would be closed to private car access by designating the road to public transportation and non-motorized modes. Although it may be claimed that this implementation would create more congestion on the alternative roads and other junctions, in many cities in the world there are examples of this measure working properly. First benefit of this policy is that public transportation vehicles can have faster, reliable and comfortable service due to the elimination of traffic congestion caused by cars. Due to the restriction of the private car entrance to the city center, drivers are forced to use public transportation and private car use in the city center decreases. The other advantage is that; public transportation can be well integrated with pedestrian areas compared with private cars. Public transportation’s negative effect on the movement of pedestrians is less compared with private cars.

3.2. World Examples of Car Access Control Policies and Travel Demand Management

3.2.1. Singapore and Hong Kong

In 1990s both Singapore and Hong Kong had a crowded population and automobile dependency which started to become a vital problem for the cities. In order to prevent problems strategies were created. The strategies were summarized in the table 9.

Table 9 : Singapore and Hong Kong's strategies for overcoming automobile dependence

Traffic Calming	*Favoring Alternate Modes*	*Economic Penalties*	*Non-auto-dependent Land Uses*
Very low levels of road space to start with and limited amount of new road building to cater to private cars. Limited use of pedestrianization and formal traffic-calming schemes. Increasing pedestrian orientation in central area through wide sidewalks, etc.	Heavy investment in mass rapid transit systems. Priority to buses through bus-only lanes, bus-only streets, and bus-only turns. Buses favored as surface access to central city through traffic-restriction zone (Singapore). Heavy parking restrictions. Effective integration between trains and buses. Development of circumferential rail transit services as well as radial services.	High cost of car ownership and use through high taxes on cars and fuel and certificates of entitlement to purchase cars in Singapore. High parking charges.	City-wide planning totally based around the integration of high-density, mixed-use nodes at rail stations on the rapid transit system. Increasing orientation toward pedestrians and cyclists for local access to nodal centers and to transit. Land use planning totally predicated on encouraging nonauto modes.

Source: Newman & Kenworthy (1999), p.193

These both cities have important applications for pedestrian and public transportation. The first and the most important strategy was city-wide planning. "The transit system in both cities is fixed, rapid, and comfortable (electric rail) and is also flexible and local (standard buses and minibuses).This is supplemented in both cities by high levels of nonmotorized transportation (mainly walking) in the dense, mixed-use settings were the main component of many trips is a vertical trip in an elevator." (Newman & Kenworthy 1999)

Other important strategies in city centers are; there are limited amount of new road building to cater to private cars and increasing pedestrians by building wide sidewalks.

Singapore's area licensing scheme (ALS) were applied to reduce the peak commuting in the CBD that means car-owners would bid for the right to buy a vehicle. This scheme was really successful that more than 50 percent of the car owners started to use public transport. According to the success the scheme improved and the main purpose was to prevent car use in the city especially in peak hours.

Hong Kong also used the same model but there were some differences due to its topographical conditions. The supercompact nodes were created and by only a small walk it was easy to reach to all kinds of transport

3.2.2. Curitiba

"The problem for most cities, whether in developing countries or not, is how to minimize the capital cost of transit while providing sufficient investment to make it viable alternative to rapid motorization. Curitiba, Brazil (population of 1894000 in 1990), is a city that has shown how to do this by channeling investment of scarce urban resources into a coherent, city-wide transit service that is closely integrated with land use policy and other social policy in the city" (Rabinovitch,1992). To decrease of the automobile dependency, strategies of Curitiba were summarized in the table 10.

Table 10 : Curitiba's strategies for overcoming automobile dependence

Traffic Calming	*Favoring Alternate Modes*	*Economic Penalties*	*Non-auto-dependent Land Uses*
Pedestrianized central area. Traffic arteries converted to tree-lined boulevards for walking.	Very high priority given to well-organized, three-tiered, integrated bus system providing radial and circumferential travel. Express buses on bus-only lanes and all buses inter-connected through a series of bus terminals. Complete inte-gration of ticketing on all buses. Special floor-level loading tubes to increase operational efficiency.	Heavily subsidized bus fares.	Bus system highly integrated, with high-density, mixed-use nodes along the main express bus axes. Land use planning heavily oriented toward producing minimal in-built auto dependence in new development.

Source: Newman & Kenworthy (1999), p.199

The main transit system of Curitiba began with the buses. Over time busways were developed, express ways were done along the axes radiating from the city center. After time these axes (5 axes were originated) developed and each of them become a 'trinary' road system. Also, central area in Curitiba is totally pedestrianized and traffic arteries converted to tree-lined boulevards for walking.

3.2.3. Zurich, Copenhagen, Stockholm and Freiburg

Zurich, Copenhagen, Stockholm and Freiburg are the examples of European Cities that decreased the dependency on automobile by increasing the quality of life of their citizens.

3.2.3.1. Zurich

Zurich applies different strategies in order to manage the community disturbance, pollution, dispersal related with automobile dependence. Such strategies applied in Zurich are summarized in Table 11.

Table 11 : Zurich's strategies for overcoming automobile dependence

Traffic Calming	*Favoring Alternate Modes*	*Economic Penalties*	*Non-auto-dependent Land Uses*
Regional traffic calming.	Expansion of the light rail and heavy rail systems and bike/pedestrian lanes.	Usual European fuel tax and registration.	Containment of growth.
Extensive thirty-kilometer-per-hour zones.	Carefully timed coordination among all services and modes.	No congestion pricing.	Transit-directed growth.
Development of selected transit malls and pedestrian zones.	Professional marketing and passenger information campaigns.	High parking fees.	New urban villages around the rail system.
Reclamation of traffic lanes for light rail.	No extra road capacity and a cap on parking.		Some mixed use.
Enforcement of car restraint.	Rainbow Pass for transit system.		

Source: Newman & Kenworthy (1999), p.203

In Zurich there are pedestrian zones and some lanes are assigned for light rapid in city center. Also, car restraint is enforced there.

An underground metro could solve the car dependency problem and cars would continue using the streets but instead Zurich chose to improve the old tram systems and upgraded the bus system. The citizens made sacrifices by leaving their cars and using public transport systems.

The main policy of solving the automobile dependency in Zurich claims that a city should always strive to provide something more appealing to its citizens than the options provided by decisions based around automobile.

Husler (1990) summaries Zurich transportation mentality as: "… to point out other, better possibilities of use. That way we can fight a guerrilla war against the car and win."

3.2.3.2. Copenhagen

Copenhagen finds a different solution to the automobile dependency by using innovative social planning. The strategies were summarized in the table 12.

Table 12 : Copenhagen's strategies for overcoming automobile dependence

Traffic Calming	*Favoring Alternate Modes*	*Economic Penalties*	*Non-auto-dependent Land Uses*
Regional traffic calming but extensively pedestrianized in city center. Extensive thirty-kilometer-per-hour zones. Enforcement of car restraint.	Emphasis on bike lanes and pedestrianization No extra road capacity, and reduction of parking by 3 percent per year for fifteen years. Culture of respect for bicyclists.	Usual European fuel tax and very high vehicle registration costs. No congestion pricing. High parking fees.	Corridors of growth. Urban villages around rail lines. Mixed use in centers.

Source: Newman & Kenworthy (1999), p.206

Copenhagen has also extensively pedestrianized city center and enforcement of car restraint.

The urban form of Copenhagen is transit oriented which the shopping center, office complex, community facilities and apartments were built over and around the station. The transit urban form was not enough and in time it had to be resisted. The city chose to pedestrianize the streets and built city housing. Beside these; streets were full of all kinds of attractive facilities, landscape and sculptures were introduced. Other important application is that; bicycle road system is highly developed in the city. All these choices create a pedestrianized, less car dependent city.

The change in Copenhagen is mentioned by Gehl (1992) as; people were isolated from society and everyone was driving, then public realm has been made so attractive and people have started to come back to street by making car accessibility more difficult.

3.2.3.3. Stockholm

Stockholm is one of the richest cities in the world but the car usage started to decrease beginning from the 1980s.The strategies of overcoming the automobile dependency are summarized in the table 13.

Table 13 : Stockholm's strategies for overcoming automobile dependence

Traffic Calming	*Favoring Alternate Modes*	*Economic Penalties*	*Non-auto-dependent Land Uses*
Regional traffic calming, but extensively pedestrian and bicycle-oriented around each rail station.	Strong commitment to transit since the 1950s.	Usual European fuel tax and vehicle registration costs.	Corridors of transit-oriented development ment (TOD) around rail system and no other growth.
Pedestrianized old center-city.	Rail system and feeder buses provide highly coordinated, effective system.	No congestion pricing but tolls on new roads.	Urban villages around new rail stops with high levels of walking and cycling within and between adjacent centers.
Extensive thirty-kilometer-per-hour zones.	Total segregation of pedestrians and bicyclists from road traffic in New Towns.	High parking fees.	Mixed use in centers.
Enforcement of car restraint.	Little extra road capacity and tolled.		
	Transit culture.		

Source: Newman & Kenworthy (1999), p.208

In Stockholm; around of each rail stations and old city center is pedestrianized and bicycle oriented. Also, car restraint is enforced

After 1980s the population began to increase and this caused to create urban villages around rail systems in the inner city. This was one of the pioneers in the world turning from a mono-centric city into a multi-centered metropolis. The main transport system was the rail systems; people start to live and work in different places. This showed the importance of having a good rail-based transit system and closely integrated land use patterns around stations to ensure that travel patterns are sustainable and not automobile- dependent.

3.2.3.4. Freiburg

Freiburg is one of the most important example of reversing the automobile dependence despite the increasing car ownership. The overcoming of automobile dependence strategies were summarized in the table 14.

Table 14 : Freiburg's strategies for overcoming automobile dependence

Traffic Calming	*Favoring Alternate Modes*	*Economic Penalties*	*Non-auto-dependent Land Uses*
Regional traffic calming but extensively pedestrianized in city center.	Strong commitment to light rail transit and bicycle infrastructure.	Usual European fuel tax and vehicle registration.	Corridors and nodes of transit-oriented development (TOD) and no other growth.
Extensive thirty-kilometer-per-hour zones.	Bus feeders strongly support the rail system.	No congestion pricing.	Urban villages around new rail stops.
All new streets in urban villages traffic calmed.	Little extra road capacity.	High parking fees.	Most internal movement within villages on foot and bicycle.
Enforcement of car restraint.	Transit pass similar to Zurich's.		Road penetration into urban village sites strictly limited.
			Mixed use in centers.

Source: Newman & Kenworthy (1999), p.210

Pedestrianization of the streets, area-wide traffic-calming programs and expensive parking in the center were the main enforcements during these policies.

"Overall, Freiburg shows how a coordinated, three pronged approach to overcoming automobile dependence is effective- that is, traffic calming, better transit systems and priorities to pedestrians and cyclists, and compact, mixed land use patterns reinforce one another in providing a city with the conditions necessary to keep automobile dependence at bay and even to reverse it." (Newman & Kenworthy 1999)

3.2.4. Toronto and Vancouver- Canada

3.2.4.1 Toronto

Toronto has also importatnt strartegies to decrease automobile depandency which are shown in the table 15.

Table 15 : Toronto's strategies for overcoming automobile dependence

Traffic Calming	*Favoring Alternate Modes*	*Economic Penalties*	*Non-auto-dependent Land Uses*
Some local traffic calming but no pedestrian core. Efforts to make subcenters pedestrian-friendly. Surface light rail lines act to calm traffic to a degree in inner areas.	Historically strong commitment to effective subway system, plus some new construction. Commuter rail diesel system to distant suburbs being extended and improved. Some new light rail lines being added. Some reasonably well-developed off-road bicycle networks. Strong integration between transit modes to provide good radial and cross-city coverage in Metro Toronto. Generally low road availability compared to U.S. and Australian cities. Limited parking in CBD and in subcenters.	Commercial concentration tax (through parking). Vehicle registration surcharge for air quality initiatives. Feebate on large vehicles.	Strong corridors of transit-oriented development (TOD) within Metro Toronto along subway lines, though suburban development in outer areas is about twice the density of that in the United States and Australia. "Main street" program of densification along light rail/tram lines. Strong mixing of land uses along main streets and at rail station nodes.

Source: Newman & Kenworthy (1999), p.214

Although there is not a pedestrianized core, both city center and sub-centers are designed for pedestrian friendly in Toronto.

In thirty years, Toronto's transportation strategy has changed from increasing car-based policy to transit network policy. 2.3 million people is carried by metro in Toronto and it is very high when compared with the average of the U.S cities.

3.2.4.2. Vancouver

Although all continent has automobile dependent policies; Vancouver has retained sufficient resistance to these policies which are shown in the table 16.

Table 16 : Vancouver's strategies for overcoming automobile dependence

Traffic Calming	*Favoring Alternate Modes*	*Economic Penalties*	*Non-auto-dependent Land Uses*
Selected use in areas such as the West End to create pocket parks in the grid network through street closures.	City of Vancouver has no freeways and the greater region has had few road capacity increases in thirty years.	Gasoline surtax in Vancouver region for BC Transit.	Medium- to high-density development throughout much of the region, especially City of Vancouver.
City of Vancouver characterized by a very dense grid of roads with un-controlled inter-sections that form natural barriers to high speeds.	Extensive bus system (diesel and trolley) in City of Vancouver provides good radial and cross-city services well integrated with Skytrain.		Mixed-use, medium-density strips oriented to transit and pedestrians along main roads.
Frequent pedestrian crossings on all main-road com-mercial strips keep traffic at lower speeds.	New light rail sys-tem a priority in transportation infrastructure.		Transit-oriented, mixed-use subcenters around Skytrain stations with good provision for pedes-trians and cyclists.
No pedestrianized city center but bus transit mall on main street in CBD.	Commuter rail system for suburbs being progressively implemented.		
	Good-quality pedestrian and cycling environ-ment throughout much of the city and prioritized in physical planning, especially around subcenters.		

Source: Newman & Kenworthy (1999), p.218

Although there is no pedestrianization policy in city centers, in main street, bus transit mall is operated and frequent pedestrian crossings decrease the traffic speed and enable flexible movement to the pedestrians.

As Toronto, Vancouver has a significantly sustainable transportation policies when it is compared with the other American cities and car use and road infrastructure provision are both 25 percent below the U.S. city average.

3.2.5. Boulder and Portland

3.2.5.1 Boulder

After the 1990's, Boulder applied a range of strategies to decrease private car use and these strategies are shown in the table 17.

Table 17 : Boulder's strategies for overcoming automobile dependence

Traffic Calming	*Favoring Alternate Modes*	*Economic Penalties*	*Non-auto-dependent Land Uses*
Extensive traffic calming, including pedestrianizing city center.	Strong commitment to bicycle infrastructure.	Congestion pricing for SOVs. Double parking fees and fines.	Growth management and green belt.
Slow zones (thirty kilometers per hour in most residential neighborhoods).	Hop, Skip, and Jump bus system, new rail link, telecommuting, shuttles for kids.	Preferential parking fees for HOVs.	Noise barriers and open land buffers. Urban villages with restricted car ownership.
Enforcement including digital speed displays, double fines in slow areas.	Little extra road capacity allowed, cap on parking with assistance to park on CBD edge.	Mixed use in centers.	
	Ecopass, free bikes, bus passes, computerized carpooling, flextime, four-day week.		

Source: Newman & Kenworthy (1999), p.225

City center of Boulder is pedestrianized and around the city center there is speed restriction which is controlled very strictly. Other than the car access control policies, some other travel demand management policies as congestion pricing for SOV's (single occupancy vehicles), parking fees and noise barriers are applied in the city. As Havlick (1997) mentions; there are a lot of alternative modes like bus, bicycle, walking, carpooling, and shuttle service from outlying parking areas to pedestrian zones.

Boulder has a fairly sustainable transportation strategy by progress of decreasing automobile dependency for the better economy, environment and it is supported by community.

3.2.5.2. Portland

Portland is another U.S. city applys car access control and travel demand management policies which are shown in the table 18.

Table 18 : Portland's strategies for overcoming automobile dependence

Traffic Calming	*Favoring Alternate Modes*	*Economic Penalties*	*Non-auto-dependent Land Uses*
Extensive traffic calming and pedestrianization in city center, particularly traffic lane reduction to accommodate transit. Reclaim Your Street program to institute traffic calming in local areas.	Historic cap on parking in the CBD. Scrapping of some freeways in favor of transit development, especially light rail. Priorities (to both buses and rail) in central city.	Cap on parking in CBD.	Region-wide growth management strategy seeks to limit new urban land development and to focus all new growth in existing areas, especially around the light rail system (MAX). Significant new development appears around MAX stations. Revitalization of public spaces in CBD. Strong program to focus residential development in CBD, where pedestrians, cyclists, and transit are priority modes.

Source: Newman & Kenworthy (1999), p.228

City center of the Portland has an extensive pedestrian area and some lanes in the city center are designated for public transportation. By revitalization of the public spaces in city center, pedestrians, cyclist and public transportation have more priority then private cars. Arrington (1993) considers also this topic and mentions the increase of %50 of downtown jobs with no increase in car commuting in the city center by combined transit priority measures.

The light rail system of the Portland called MAX is a very successful application which enables to extend the public transportation network in the city.

3.2.6. Perth

Although Perth was considered an automobile dependent city in the 1980's; after the strategies shown in the table 19, there is a considerable process to decrease the private car use.

Table 19 : Perth's strategies for overcoming automobile dependence

Traffic Calming	*Favoring Alternate Modes*	*Economic Penalties*	*Non-auto-dependent Land Uses*
Central city area becoming progressively more traffic-calmed and pedestrianized, though much remains to be done.	High investment in upgraded and extended electric rail through the 1980s.	Fuel tax, but used entirely for roads.	Recent extensive new central city housing projects, including revitalization of old industrial land for resident/mixed-use development.
Traffic calming or local area traffic management practiced on ad hoc basis throughout the region.	Commitment to further extend rail system.		Beginnings of urban-village-style development around rail stations through sinking of line at one station and large redevelopment project.
Some good examples in many local centers.	New bus service initiatives to improve cross-city travel (circle route), plus upgraded bus stops and information systems.		A focus on land use planning to discourage automobile dependence in regional centers.
Forty-kilometer-per-hour zones around schools.	A good off-road network of cycleways, especially for recreation, and increasing attention to direct, on-road routes for commuting and other trips.		Development of community code to encourage urban villages in any new urban development.
	Some favoring of pedestrian, cycle, and transit access at regional centers over last five years.		

Source: Newman & Kenworthy (1999), p.235

The main progress in the city about car access control policies is pedestrianization of the city center.

Perth has a support and fund of Australian government to build transit-oriented city which is called “Better Cities” in Australia and this model is very successful and become a model for other cities to decrease the private car use.

CHAPTER 4

METHODOLOGY

4.1. Aims and Objectives

It has been mentioned in previous chapters that meeting the demand of transportation is not a solution of congestion. Furthermore because of increasing private car use, this solution is not sustainable economically, environmentally and socially. New approach is travel demand management. This approach is particularly essential in city centers that suffer most from traffic congestion, resulting in deteriorated access conditions for all users and in economic decline of commercial facilities in city centers. With the good examples in some metropolitan cities, the success of travel demand management applications in city center commercial areas have been described.

Turkey and as the capital of Turkey, Ankara also suffer from an increase in private car use, congestion and pollution. City authorities try to solve this problem by increasing road capacities through road widening or grade-separated junctions. Especially in Ankara, the city center is being used like a transit road, turning into a highway. As described in earlier chapters, city centers are areas where major pedestrian circulation takes place. Therefore; public transportation and pedestrian access must be the main tendency while designing the city centers.

Tunalı Hilmi Street is one of the areas in the city center in Ankara that has major center activities like commerce, working places, entertainment places, recreation places etc. This street is one of the main collector roads of the city center by carrying south part of the city to the city center.

Because of the high pedestrian density and movement, it has always been on the agenda whether this street can be pedestrian or not. On the one hand, Tunalı Hilmi Street is an important collector road for the city center circulation system and city authorities have a tendency to use this road for this main purpose. On the other hand, it is one of the few high-streets of Ankara with intense pedestrian activity, and the fact that it attracts many users for commercial and leisure activities requires a better allocation of road space in favor of the pedestrians.

Therefore, this study assesses the possibilities of traffic restriction in Tunalı Hilmi Street. The study has three main aims:

- To review and highlight effective transport policies and techniques that can help manage travel demand and traffic in city centers;
- To demonstrate traffic count and simulation methods as a decision-making tool that can help evaluate possible consequences of traffic and travel demand management techniques;
- By using these count and simulation methods in Tunalı Hilmi Street, to demonstrate the use of these techniques as well as shed some light to traffic problems, components, and consequently possible solutions for Tunalı Hilmi Street in Ankara.

The previous chapters presented the concepts of travel demand management and traffic management, together with effective tools in city centers and successful implementations in numbers of cases. These contemporary approaches clearly show that some form of car traffic control and restriction should be introduced in city centers. When focusing on a city center street, implementations indicate that car restriction can be attained by a full-pedestrianization of the street or by designating the street for only public transport and non-motorized traffic, hence restricting private car entry and use of the street. The aim of this study is to assess car restriction strategies for Tunalı Hilmi Street in Ankara. Based on car access control policies; four assumptions are studied in this study, as described below.

In the next section therefore, the assumption-based assessment approach is presented: the base case and four main assumptions that are applied in the study are described. Following this the methods of analysis are presented. These include measures, data requirement and simulation tools.

4.2 Assumption-based Assessment Approach

In this study, four main assumptions are defined and assessment is made for them. Also the base case is studied to compare the existing situation with the assumptions.

4.2.1 Base case situation

Simulation of the base case is visualizing of the existing situation. To evaluate the assumptions a simulation program which is described in detail later in this chapter is used. Firstly zones both inside and outside of the area should be defined to the program. In addition to the zones, information, such as the directions of the roads, capacity of the roads and junctions, and street parking on the roads are needed by program. Then an O-D (Origin-Destination) matrix which is obtained from plate tracking method is entered in the program.

Program works after having the required data and shows the video of the simulation of the existing situation. It demonstrates the flow of traffic, congested points, and queuing.

4.2.2. Assumptions based on car access control policy scenario

As it is mentioned in the previous chapter, car access control policies are mainly pedestrianization and allowing only public transportation. Besides them waiting restrictions, pricing and parking regulations in the study area may help the car access control policies by decreasing the demand.

With the base case study, the total demand of the study area is known. When the car access control policies are applied to a road, road segment or area, the demand should be distributed to the alternative routes. In this distribution O-D matrix and minimum path method is used. The O-D matrix already contains information on the tendency of the cars, which means their entry and exit points in the system, or the areas within the system that they aim to reach. Therefore when a street is pedestrianized or only allowed for public transportation, vehicles passing from this street are going to find another route to reach their destination. This route change is made with “minimum path” method.

There are certain complexities in this method. In reality drivers not only choose the minimum path to reach their destination but also they may choose minimum time method with using longer distances or choose a path that is longer and consuming more time but this path may feature recreational or visual quality which attracts the drivers. It is not possible to account for the latter aspect; however, it is possible to overcome the problem regarding the choice of longer distance path that may provide minimum time in travel. For this purpose, capacity-volume analysis is made. If the traffic volume on a road reaches the capacity of the road while the traffic volume on the alternative does not reach the road capacity, then it is accepted that the driver chooses the alternative even if it is a longer path. This process continues until the traffic volume on the alternative path also reaches the capacity of the road.

In the assumptions, effects of designing converting a street to a transit-only pedestrian street are analyzed particularly focusing on the effects on alternative roads. Of course it is expected that this scheme would result in an increase in the volumes of all the other junctions and alternative roads because they would receive the volume of the road which is now a transit- and pedestrian-only corridor. On the other hand, because of the transit drivers and decrease by car access control policies, volume of the other roads may also decrease.

When the car access control policies are applied to Tunalı Hilmi Street, the flow of traffic is impossible to operate without changing the directions of the roads. Most of the roads are operating one way in the system. Therefore to apply the assumptions firstly directions of the roads have to be redesigned.

As base case situation is known; total demand in this area, transit drivers and the drivers whose origin or destination is in the area are also known. On the base of this information and the scenario mentioned above, four assumptions are studied.

Assumption 1: In this assumption, the total demand in the area that is known from the base case is distributed to the alternative roads when Tunalı Hilmi Street is closed for private vehicles.

Assumption 2: Transit drivers mostly use Tunalı Hilmi Street compulsorily. Because their origin or destination is not there and there is not any better alternative. Therefore, in this assumption, transit drivers is assumed to find any other alternative and omitted from total demand when the street is closed to private vehicles.

Assumption 3: When car access control policies are applied, beside the transit drivers, also there will be a decrease in the remaining demand, because the area becomes more accessible for pedestrians, cyclists and the passengers using public transportation. Therefore some passengers using their private cars when travelling to Tunalı Hilmi Street and its surroundings may have a tendency to use public transportation and other modes. In this assumption, besides the omitting of though-travelling transit passengers, it is assumed that number of private cars coming into the area would also decrease to a certain extent due to the fact that the area is now more public-transport-friendly and less car-oriented.

Assumption 4: In Tunalı Hilmi Region Street parking is very common and it decreases the capacity of the streets. Forbidding the street parking all day or only peak hours, can increase the capacity of roads and when Tunalı Hilmi Street is closed to private vehicles, alternative roads can supply more demand. In this assumption a policy for street parking control is tested in the region in addition to the previous assumption's features.

After entering all these routes and demands to the simulation program, it can demonstrate the traffic flow making it possible to assess problematic junctions and routes.

Expected result from such a scheme is not only increasing the pedestrian movement, but also economic and environmental benefits. These effects can also be calculated using the outcomes of the simulation program by using the decrease in private car traffic and basic values such as oil price, oil consumption and emission of vehicles. However the main concern of this study is not environmental and economical, so only traffic effects are analyzed.

4.3. Methods of Analysis

The aim of the analysis carried out in Tunalı Hilmi Street is to assess how traffic in the study area is affected by restricting private vehicle use. Four assumptions are adopted as the main approaches, which are among the basic elements of travel demand management.

The specific objective of the analysis in Tunalı Hilmi Street is therefore to find out, by the help of plate-tracking method, if the street is restricted to private vehicle use, how the alternative roads would be affected, and whether they can supply the demand that comes from Tunalı Hilmi Street.

Following this, the analysis tries to find out:

When the car access control policies are applied to the Tunalı Hilmi Street and direction of the alternative roads changed, can alternative roads and streets accommodate the existing demand; what sections of the area are affected negatively; and whether the possible negative effects of the scheme on side streets may be minimized when one considers a decrease in car-travel in the area due to policies that car usage and car parking in the area less convenient?

As described earlier, the analysis is also to serve the wider research objectives, including a contribution to the ongoing discussions about whether Tunalı Hilmi Street could be pedestrianized; as well as the objective of demonstrating the traffic count and plate-tracking method and simulation in decision-making for transport planning.

4.3.1 Measures

4.3.1.1. Impact of pedestrianization on the alternative routes

As it is mentioned above; if a road is pedestrianized, alternative roads are affected. If this effect makes volume/capacity ratio of the alternative roads more than 1, these roads are congested which means application has some severe negative consequences. This may not necessarily mean that the application should not be adopted, but that it requires a comprehensive approach with other supporting policies in order to minimize such negative effects. If the volume/capacity ratio of the alternative roads is lower than 1 after assigning the traffic of the pedestrianized road to the alternatives, this would mean that the application has a potential to be more easily implemented.

This study is made by “equilibrium method”. This method assigns the traffic according to shortest path. Normally drivers choose the more comfortable routes. Beside the length of the distance they go, arrival time to the destination and quality of the road are also a variable for them. Although drivers do not always choose the minimum distance, in this study, simulation programs own default parameters are used.

4.3.1.2. Impact on the travel times

Travel time of the existing situation is obtained by the plate-tracking method. After assigning the traffic of the pedestrianized road to the alternatives, simulation program gives the result of travel times of all routes. Therefore, it is available to compare the time differences between base situation and the assumption.

4.3.2. Data requirement

When this study was conducted, Ankara Transportation Master Plan has not been completed yet. Therefore there was no data about Tunalı Hilmi Street. Especially intersection counts are very important to compare the counts in the study with the counts made before. All the data used in this study are collected by researcher. Because of the limited time and budget, the study is restricted by Tunalı Hilmi Region. However, this kind of study should be made in whole city to obtain more precise results.

Data collection part was mostly the field study part. To see the result of private car restriction on Tunalı Hilmi Street, plate tracking method was used. This data collection method helped us to see the origins and destinations of all drivers. In addition to that; this survey also enabled an observation of the parking situation in Tunalı Hilmi District.

4.2.2.1. In/out flow plate tracking

Plate-tracking method was used to find for each passenger’s entrance and exit points in the study area. By this method, tendency of the drivers is found. It is also seen whether people use this road as a transit route or whether they stay within the area. This method is generally applied in the weekdays except from Monday and Friday. That is because being the beginning and the end of the weekdays, traffic on these two days are likely to show differences and hence may give fake results. For this study a plate tracking count was made on Wednesday in 02.05.2012 between 08:30 – 09:30 in the morning and 17:30 – 18:30 in the evening which are the peak hours of the study area.

It could increase the reliability of the data if counts were made on other times as well; however, due to limited time and lack of any supporting budget for the study, it was decided to focus the effort on one count. The aim is to demonstrate the usage and suitability of the method; and for further studies, more traffic counts may be made.

Application of this method is quite difficult for large areas. That is because, all entrances and exits should be controlled, and these data should be recorded to have more precise results. After video-recording of all the plate numbers of the vehicles that enter and exit to the study area, matching them by the help of “excel” program is the second step. Finally O-D (origin-destination) matrix is created. In junctions vehicles coming from zone “x” is known and the system also shows that vehicle goes to the zone “y” which means it shows how many travels are originated from zone “x” and over in the zone “y”.

There are two main limitations of this method which are permissions from public institutions and the privacy issue.

For the survey it was necessary to obtain permission from the governorship and the police department. Because of the recording of plates of private cars and using cameras for recording, the permission is needed. It is taken from both public institutions, distributed to the people who have participated in the counting and one copy delivered to the related police department.

Plate recording can be a controversial issue, because, without the permission of the users, recording the plate number means obtaining private information of the owner of the cars. Alternative to this application, a survey method can be used, but then all cars should be stopped in the traffic and asked where their destination is. It is almost impossible to apply this and also getting permission from all drivers whose car’s plate number is recorded is not possible. As long as these plate numbers and records are not used in public, this method can be used.

4.2.2.2. Street parking surveys

Street parking survey was made by recording the plate of the vehicles as plate tracking survey. Plate of parking vehicles in each link (segment) of the road is recorded before and after the peak hours both morning and evening peak hour. Records before the peak hour and after the peak hour are compared and parking situation is obtained. By these analyses it is possible to find how many vehicle stay in the park, how many vehicle leave the park and where they go, how many vehicle come and park and where they come from. Also total numbers of open (on-street and open area) and close parking area values are obtained from this survey.

The limitation of this method is that; only on-street parking is observed. However, there is off-street parking as apartment backyards or garages and car-parks. Because of the difficulty on obtaining data, off-street parking is not considered in this study.

4.2.2.3. Volume capacity ratio

Volume capacity ratio is found to define the efficiency of the existing road/junction capacity and the congestion level of them. There are three kinds of roads in the study area which are collector roads, miner, and major arteries. The capacity of the collector roads are assumed 400 vehicles per lane per hour, for minor and major arteries it is accepted 900 vehicles per lane per hour. Because of the street parking in the collector roads, capacity is decreased from 600 to 400. Beside this implementation, capacities of the links on the signalized intersections are decreased according to green period rate of that links. The volume of the all links in the study area is known after using the simulation program and by dividing volume to the capacity of the road; volume-capacity ratio is obtained.

4.3.3. Use of traffic simulation tools

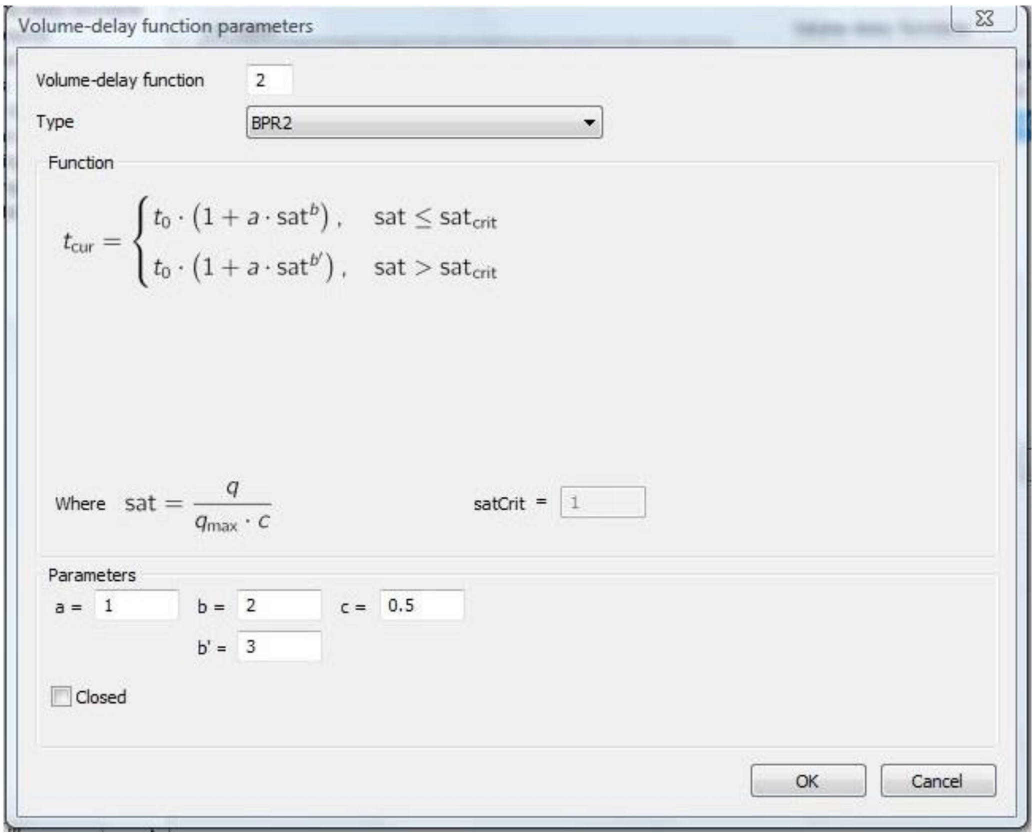
Simulation is creating a model of reality. To see the reality, a model of existing situation and future expectations can be obtained by simulation. For this reason PTV Visum program was used.

PTV Visum is a traffic engineering and transportation planning simulation program. To simulate the existing traffic flow, it requires the O-D matrix, all links and nodes, traffic routes of all study area and traffic signal values such as green and red periods for both pedestrians and cars in each intersection. By entering these values to the program, traffic flow can be seen visually. In addition, congested junctions and road sections and also queuing length can be seen. Moreover, Public transportation routes, stops and frequency, pedestrian routes and quantity can be also added to the simulation program.

The other important feature of the program is making future projections. By entering the required variables, future situation can be easily seen.

In this study, volume delay function (bpr function) is shown in figure 3.

Figure 3: Bpr function parameters of the program



CHAPTER 5

CASE STUDY: PRIVATE CAR ACCESS CONTROL ON TUNALI HİLMİ STREET, ANKARA

5.1. History of Ankara and Tunalı Hilmi Street

In this part of the study; historical background and current transportation situation in Ankara and Tunalı Hilmi Street is briefly discussed.

5.1.1. History of transportation situation in Ankara city center

At the very beginning of the 1900s Ankara settled around the citadel. Population at 1920s was 25.000 and the city was densely populated. The demand for transportation was very limited and it was almost a city of pedestrians. In the 1930s, the population started to increase so that the town started to spread towards Yenişehir and Cebeci. The demand for transportation was also limited but the demand for motorized travel increased. In the 1940s, only %15 of total transportation was made by motorized vehicles due to the compactness of urban space (EGO). Until 1940, there was a little change in both forms of urban space and transportation demands. After 1940, the city came across new demand for and supplies of motorized travel. Second World War caused barriers to the transfer/imports of buses from Switzerland and public transport vehicles became insufficient in the face of increasing travel demands.

EGO, an institution of public transportation established in 1930, had a significant role in transport planning and management. It has played a role as public transport provider; however, because of the difficulty in increasing the number of buses in public transport fleet, from 1950s onwards, the share of public agencies on public transportation dropped from 70% to 50%. While the rate of municipality buses in public transportation decreased, that of small entrepreneurs (namely minibus) increased. Municipality of Ankara has increased the quota of minibuses since 1968.

1960s is the milestone of private car ownership. In 1967, Turkey's first domestic mass -production car, “Anadol” was started to be produced and in 1970 two addition Anadol factories were added in car production. According to EGO, UPRSD, in 1969 the number of trips which was made by private cars was 134.400; this equaled to 10% of total trips.

Between 1967- 1975 there was a rapid increase in private car ownership. In addition to Anadol, Renault and Fiat started to produce private cars. End of 1975, the number of passengers who traveled by privately owned vehicles was almost equal to those who traveled by EGO buses (Ankara Urban Transportation Study, 1986).

Ankara has experienced a transformation from a city of 90,000 populations with motorized trips comprising only %10 of the total urban trips to a city of 2.3 million populations in 1985. 70% of the trips were made by motorized modes in 1985. While the population of Ankara increased, motorized trips demand increased more compared to rate of population. Between 1970-1985 traffic management plan has been realized by the public based on the framework of a master plan. During this period, the main purpose of transportation planning studies were development scenarios and land use decisions, which was revealed during the upper scale urban planning studies, was examined in terms of transport aspect. Ankara Urban Rail Transit Project 1980, SOFRETU Transportation survey of Ankara, Rail Mass Transit System Feasibility Study in 1983 was made in that time period. Also Transportation Master Plan Study was made in 1985. (Özalp & Öcalır, 2008)

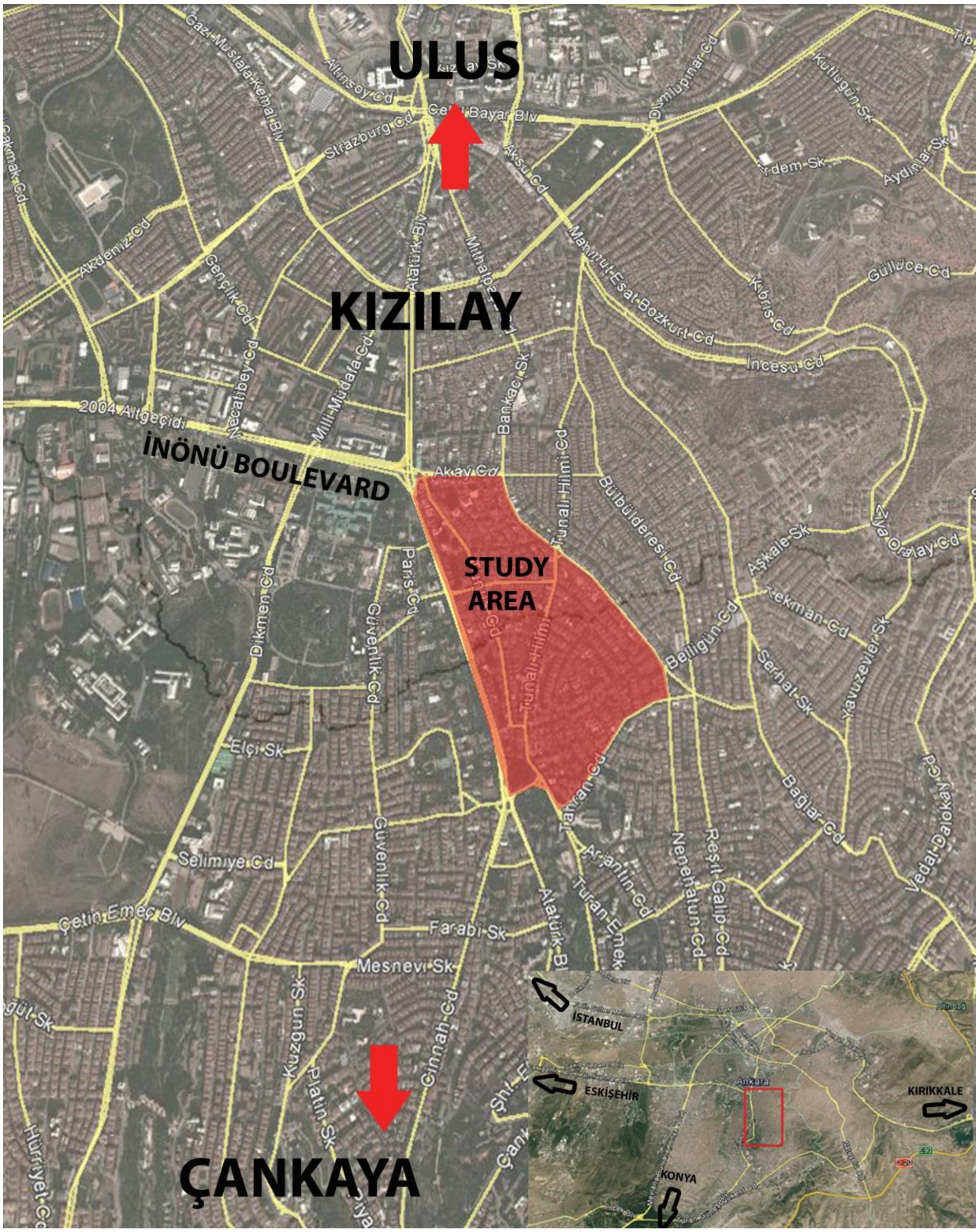
One of the most important applications of this study was the metro and the LRT (Ankaray) system that opened to service in the second half of the 1990s. With the construction of Ankaray and the Metro, a reduction of traffic congestion in the city was estimated; however, on the contrary, traffic congestion has continued to increase. Grade separated crossings, construction of intersections, eliminating pedestrian at-grade crossing in order to provide non-stop vehicular traffic all increased the speed level of private cars and encouraged motorized traffic. Today, 17 pedestrian overpasses are located in Kızılay Zone (Atatürk Boulevard, Meşrutiyet and Mithatpaşa Streets) (Babalık-Sutcliffe 2005, 296) resulting in inconvenient accessibility conditions for pedestrians. These policies not only increased congestion in the city center, but also pedestrians became more disadvantages in the city center. According to EGO (1998), rail network was insufficient and the use of the existing rail system was also not enough to decrease the private car use. This situation has continued throughout the 2000s and until today, since the city has been subjected to extremely car oriented transport policies. As a result of grade-separated junction investments, road widening schemes, elimination of traffic lights for pedestrian at-grades all created a very car-oriented transport infrastructure. Share of car usage in total motorized trips was around 20% in the late 1990s; and it reached as high as 35% in the early 2010s.

In spite of this recent car-oriented approach in transport planning in Ankara, there was a pedestrianization study in the 1980s made by EGO (1982). According to this study Yüksel, Karanfil, Sakarya Streets and surroundings, İzmir Street and its surroundings have been proposed as a pedestrian zone. However, only small part of the Sakarya Street and İzmir Street was pedestrianized. Pedestrianization of other streets had been postponed. (TMMOB Şehir Plancıları Odası Ankara Şubesi, 2004). Today although there are pedestrianized areas in the city center, it does not satisfy the need. Pedestrian access is often interrupted, do not work with an integrated transport network and movement of pedestrians is not seen as part of the transportation system. Moreover pedestrians are mostly seen as just an obstacle for private cars. Also there are not any bike paths in the city.

5.1.2. History of transportation in Tunalı Hilmi Street

Tunalı Hilmi Region starts from Kuğulu Park reaching to Akay Street and ending on the intersection of Esat Street. Today, Tunalı Hilmi Street is one of the most used Streets in Ankara for both pedestrians and motorized trips. Popularity of Tunalı Hilmi Street began in the 1980s. "Tunalı Hilmi Street is located in the southern area of Kızılay and functions as a city center, an extension of Kızılay" (Ünsal, 2010). Land use on the Street proves the city center characteristics of the region. Generally, the ground floors are being used for cafes/restaurants, hotels and shopping activities; upper floors are being used for offices.

Figure 4 : Location of the study area in the city center



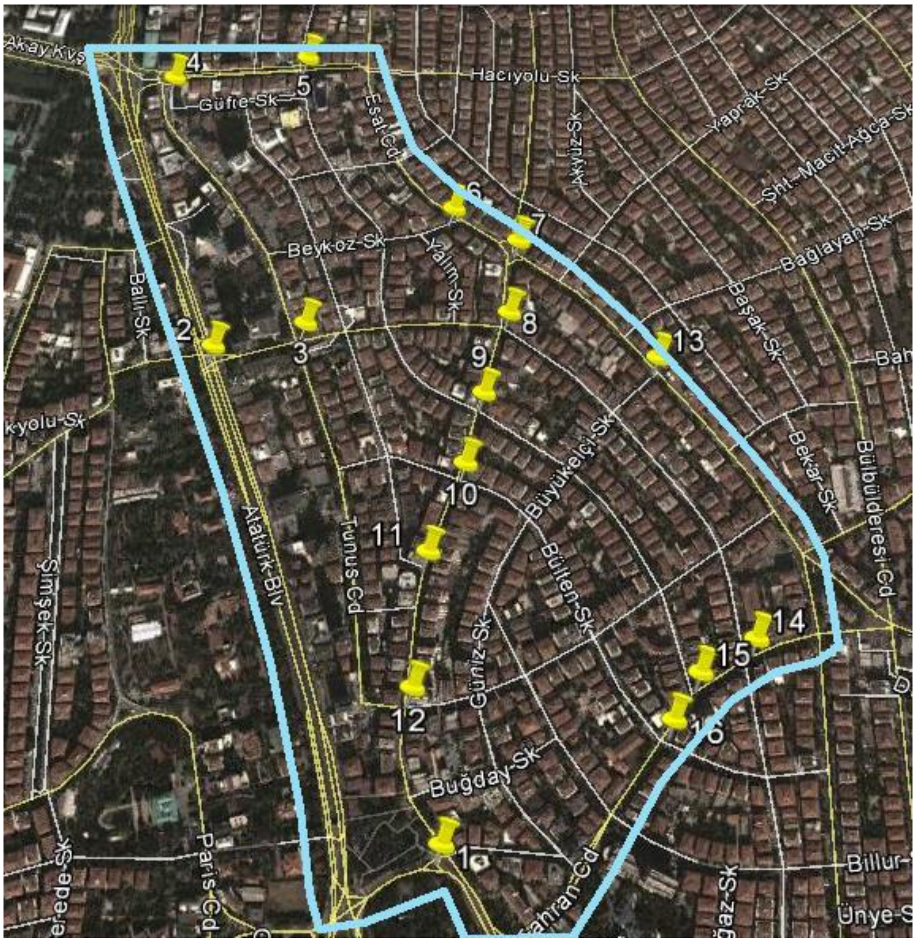
A pedestrianization implementation project was made by Ankara Metropolitan Municipality in the late 1990s in order to strengthen the character of the street. On weekend days in the afternoon Tunalı Hilmi Street is closed to motorized traffic from Kuğulu Park intersection to the Bülten Sokak intersection However, this implementation did not last too long.

5.2. Data Process and Travel Demand in Tunalı Hilmi District

5.2.1. Nodes, links and counting points

In the study area there are a total of 14 entry and exit gates. 10 of these gates are controlled and analyzed in this study. The volumes of the other 4 gates are relatively low. Beside the 10 gates, 6 controlling points inside of the area are also analyzed. 5 of them are on the Tunalı Hilmi Street which enables to see all movement on this street. The counting points and study area are shown in the figure 5.

Figure 5 : Study area and counting points



29 people attended the counts, 14 of whom were with video recorder. While nodes with high volumes were controlled by cameras, nodes with low volumes were recorded manually.

Inside of the area is divided into 65 links and all the street parking on these links were controlled before and after the counts. 2658 plate numbers were recorded in this analysis. Link number, location and number of parking on each link are shown in the table 20.

Table 20 : Link locations and number of street parking

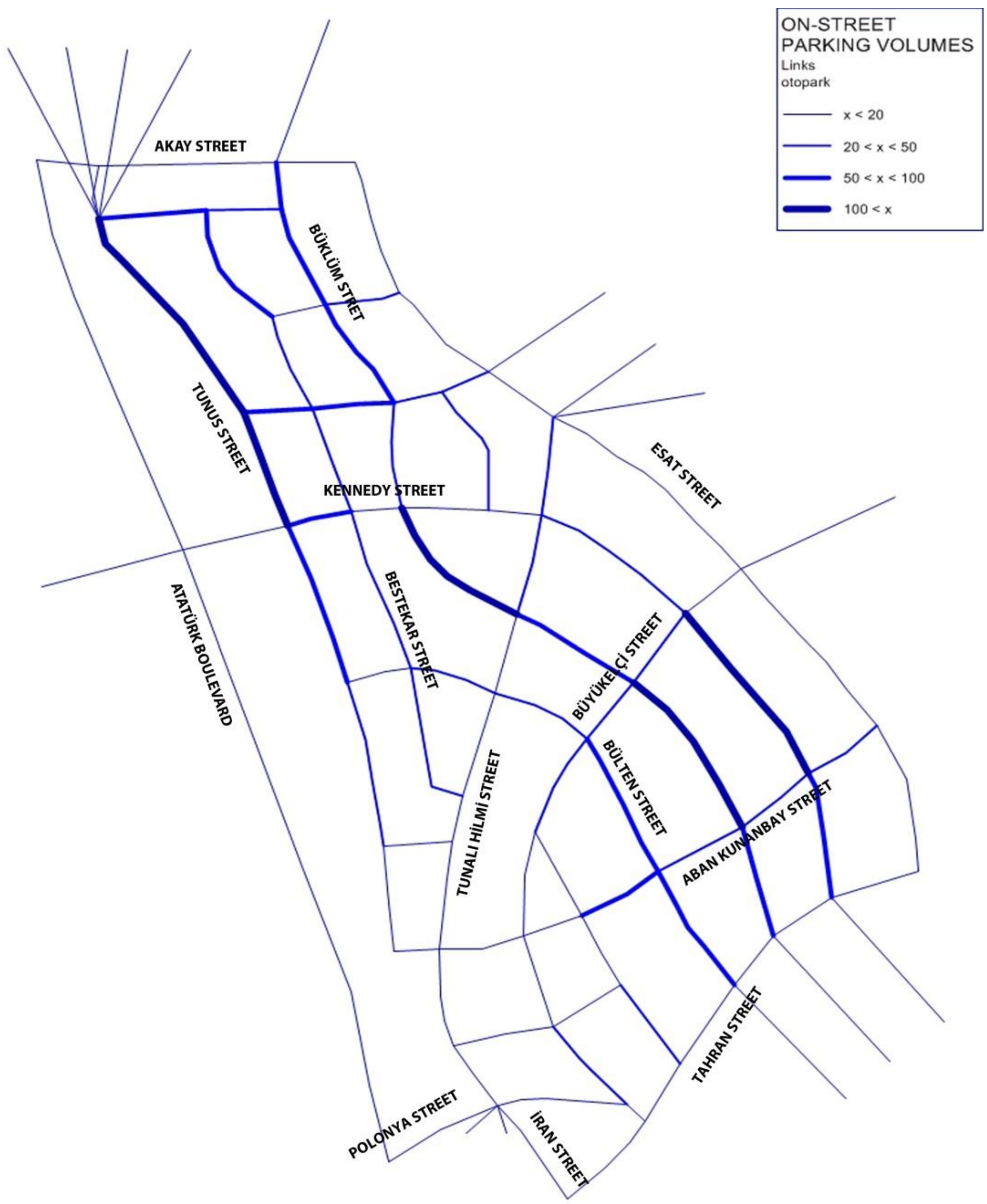
LINK ID	LINK LOCATION	NUMBER OF ON STREET PARKINGS
1	John F. Kennedy -Tunus X Tunus-Beykoz	259
2	Tunus- Beykoz X Tunus- Güfte	
3	John F. Kennedy- Bestekar X Bestekar- Beykoz	33
4	Bestekar- Bilezik X Bestekar- Güfte	95
5	Tunus- Güfte X Güfte- Bestekar	89
6	Güfte- Bestekar X Güfte- Büklüm	26
7	Bestekar- Bilezik X Bilezik- Büklüm	0
8	Tunus- Beykoz X Bestekar- Beykoz	159
9	Bestekar- Beykoz X Beykoz- Büklüm	
10	Büklüm- Beykoz X Büklüm- John F. Kennedy	23
11	Büküm- Beykoz x Büklüm- Bilezik	68
12	Büklüm- Bilezik X Bilezik- Esat	27
13	Büklüm- Bilezik X Büklüm- Güfte	63
14	Büklüm- Güfte X Büklüm- Akay	78
15	Büklüm- Beykoz X Beykoz- Yalım	43
16	Beykoz- Yalım X Yalım- Esat	41
17	Beykoz- Yalım X Yalım- John F. Kennedy	47
18	John F. Kennedy- Tunalı Hilmi X Tunalı Hilmi- Esat	24
19	Atatürk- John F. Kennedy X John F. Kennedy- Tunus	65
20	John F. Kennedy- Tunus X Tunus- Bülten	55
21	John F. Kennedy- Tunus X John F. Kennedy- Bestekar	0
22	John F. Kennedy- Bestekar X Bestekar- Bülten	22
23	Tunus- Bülten X Bülten- Bestekar	4
24	Bestekar- Bülten X Bestekar- Tunalı Hilmi	36
25	Tunus- Bülten X Tunus- Çığır	29
26	Tunus- Çığır X Tunus- Tunalı Hilmi	12
27	Tunus- Çığır X Çığır- Tunalı Hilmi	7
28	Tunalı Hilmi- Bestekar X Tunalı Hilmi- Çığır	26
29	Tunalı Hilmi- Çığır X Tunalı Hilmi- Tunus	
30	Tunalı Hilmi- Tunus X İran- Polonya	8
31	Tunalı Hilmi- Buğday X Buğday- Güniz	12
32	Buğday- Güniz X Güniz- Abay Kunanbay	0
33	Buğday- Güniz X Buğday- Billur	13
34	Buğday- Billur X Billur- Abay Kunanbay	13
35	İran- Polonya X Binnaz- Güniz	14
36	Güniz- Tahran X Güniz- Buğday	40

Table 21 (continued): Link locations and number of street parking

37	Tahran- Billur X Billur- Abay Kunanbay	21
38	Tunalı Hilmi- Abay Kunanbay X Abay Kunanbay- Güniz	
39	Abay Kunanbay- Güniz X Güniz- Billur	19
40	Abay Kunanbay- Güniz X Abay Kunanbay- Billur	35
41	Abay Kunanbay- Billur X Güniz- Billur	11
42	Güniz- Billur X Güniz- Bülten	40
43	Güniz- Bülten X Bülten- Abay Kunanbay	60
44	Abay Kunanbay- Billur X Abay Kunanbay- Bülten	54
45	Abay Kunanbay- Bülten X Bülten- Tahran	54
46	Bülten- Abay Kunanbay X Abay Kunanbay- Büklüm	35
47	Abay Kunanbay- Büklüm X Büklüm- Tahran	63
48	Abay Kunanbay- Büklüm X Büklüm- Güniz	112
49	Büklüm- Güniz X Büklüm- Tunalı Hilmi	86
50	Abay Kunanbay- Büklüm X Abay Kunanbay- John F. Kennedy	31
51	Abay Kunanbay- John F. Kennedy X John F. Kennedy- Tahran	58
52	Abay Kunanbay- John F. Kennedy X Abay Kunanbay- Esat	21
53	Abay Kunanbay- John F. Kennedy X John F. Kennedy- Büyükelçi	138
54	John F. Kennedy- Büyükelçi X Büyükelçi- Esat	14
55	John F. Kennedy- Büyükelçi X Büyükelçi- Büklüm	22
56	Büyükelçi- Büklüm X Bülten- Güniz	21
57	Güniz- Bülten X Bülten- Tunalı Hilmi	33
58	Bülten- Tunalı Hilmi X Tunalı Hilmi- Bestekar	0
59	Bülten- Tunalı Hilmi X Bülten- Bestekar	23
60	Bülten- Tunalı Hilmi X Tunalı Hilmi- Büklüm	14
61	Tunalı Hilmi- Büklüm X Tunalı Hilmi- John F. Kennedy	21
62	Tunalı Hilmi- Büklüm X Büklüm- John F. Kennedy	137
63	Tunalı Hilmi- John F. Kennedy X John F. Kennedy- Büyükelçi	39
64	Akay- Tunus X Tunus- Güfte	15
65	Bestekar- Bilezik X Bestekar-Beykoz	50
	TOTAL	**2658**

Density of the parking situation varies in the study area. Density of the street parking according to links is shown in the graphic 2.

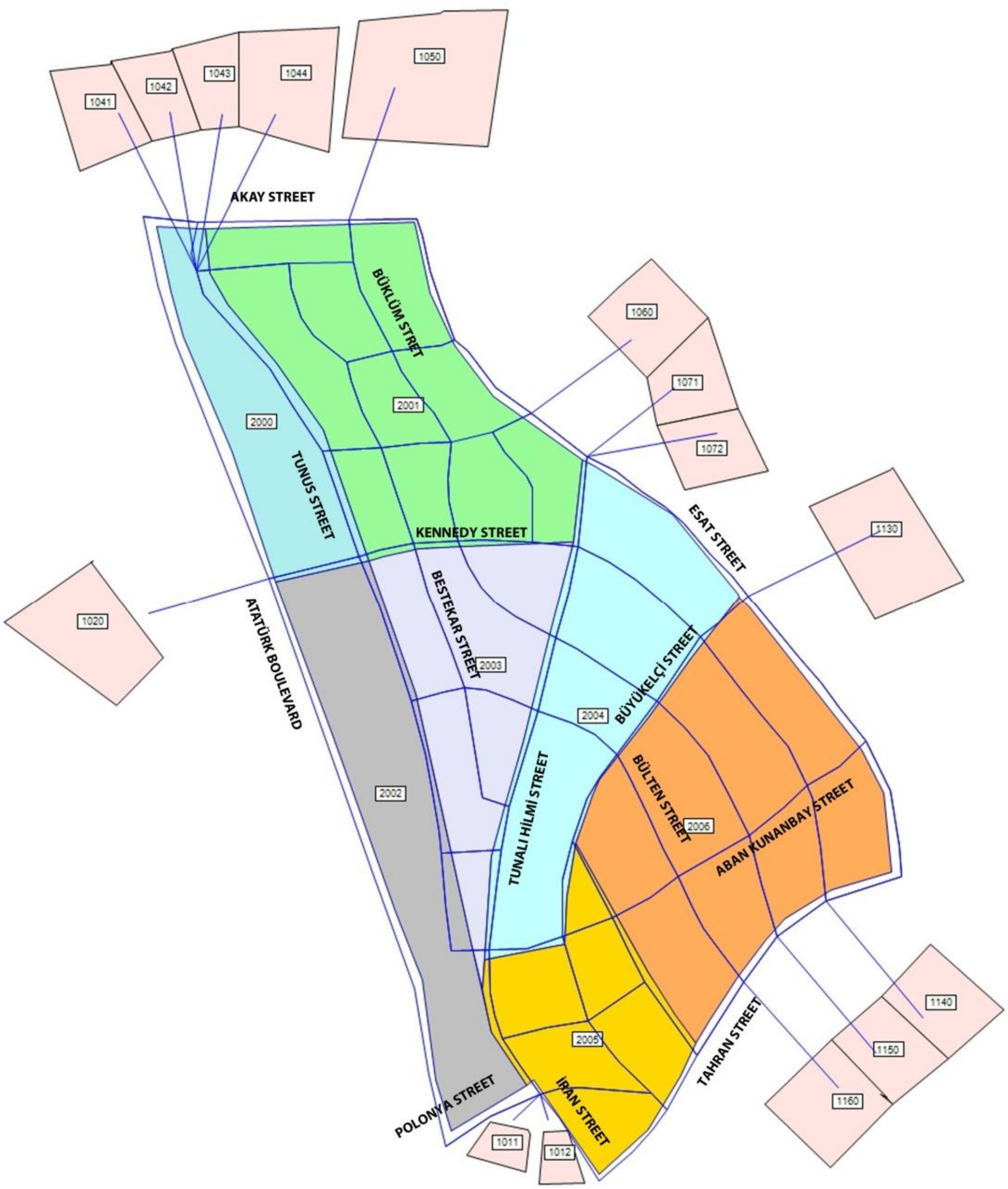
Graphic 2 : Parking volumes in Tunalı Hilmi Area



5.2.2. Traffic zones in Tunalı Hilmi District

Zoning was the second step in the study. It is made by considering parking situation of the area and function of usage. In parking survey, total number of the cars parking in all streets is known. These links are also generator and attractor like the zones outside of the area. Because cars parking in the street may leave the area (moves from its zone to another one) or cars coming from a zone may park to these links. Besides parking situation, functions of usage are other criteria in identifying zones as there are commercial, office or residential regions in the study area.

Graphic 3 : Traffic zones in Tunalı Hilmi Area



The main aim of the zoning is to find O-D (origin-destination) matrix of existing situation. Inside of the study area is divided into 7 zones. Outside of the study area is also divided into zones. Totally 22 zones are created in the study area and analyses are made by them. The code and the location of the zones are shown in the table 21.

Table 22 : Zone locations

ZONE ID	ZONE LOCATION
1011	Western zones that connect to Tunalı Hilmi Street via Polonya Street entrance.
1012	Southern zones that connect to Tunalı Hilmi Street via İran Street entrance.
1020	Western zones that connect to Kennedy Street via Atatürk Boulevard exit.
1041	Western zones that connect to Tunus Street via İnönü Boulevard entrance by tunnel.
1042	Western zones that connect to Tunus Street via Atatürk Boulevard entrance.
1043	Northern zones that connect to Tunus Street via Akay Street entrance.
1044	Northern zones that connect to Tunus Street via Akay Street exit.
1050	Northern zones that connect to Büklüm Street via Akay Street entrance.
1060	Eastern zones that connect to Beykoz Street via Esat Street entrance.
1071	Northern and Eastern zones that connect to Tunalı Hilmi Street via Esat Street exit. (to the west)
1072	Southern and Eastern zones that connect to Tunalı Hilmi Street via Esat Street exit. (to the west)
1130	Eastern zones that connect to Büyükelçi Street via Esat Street entrance.
1140	Southern and Eastern zones that connect to Kennedy Street via Tahran Street entrance.
1150	Southern and Eastern zones that connect to Büklüm Street via Tahran Street entrance.

Table 23 (continued): Zone locations

1160	Southern zones that connect to Bülten Street via Tahran Street exit.
2000	Border: Atatürk boulevard, Akay Street, Tunus Street, and Kennedy Street
2001	Border: Akay Street, Tunus Street, Kennedy Street, Tunalı Hilmi Street and Esat Street
2002	Border: Atatürk boulevard, Kennedy Street, Tunus Street, Tunalı Hilmi Street and Polonya Street
2003	Border: Kennedy Street, Tunus Street and Tunalı Hilmi Street
2004	Border: Tunalı Hilmi Street, Abay Kunanbay Street, Büyükelçi Street and Esat Street
2005	Border: Tunalı Hilmi Street, Abay Kunanbay Street, Güniz Street, Billur Street, Tahran Street and İran Street
2006	Border: Billur Street, Tahran Street, Esat Street and Büyükelçi Street

In zoning there are some limitations. In this study, zoning is made roughly which means there must be more zones to find more precise O-D matrix, for example by dividing the commercial and residential areas sharply. However this division creates a fairly high workload. Because of limitation of time, zoning is made with relatively larger zones instead of using higher number of zones.

The other limitation for the outside of the study area with regards to zoning is considering commercial and residential areas together in the same zones. For example in the north-west of the study area, there are many different kinds of usage in one zone. Bahçelievler, Emek, Söğütözü, universities and Çayyolu are all in this zone as they indicate a direction of traffic flow and for the purpose of this study it is not crucial to know exactly which destination the vehicles go to in that large area.

The study area has an open network. Therefore it is almost impossible to control all the enter-exit gates and inside-outside zones without an error rate.

Although there are some limitations in zoning, it can be applicable because main focus of the thesis is not zoning and this study can be maintained regardless of a small error rate that these generalizations may create.

5.2.3. Data process

After zoning, the data obtained from plate tracking survey and parking survey are entered into the Excel program. By the help of the some coding process, plates of the cars are matched.

In the morning plate tracking survey data; 12003 vehicles has been recorded, and 7318 different plate number were recorded. Among these 2765 plates could be matched (recorded at least at two points) and the rate of the matches was %38.8. Also in parking survey 2658 plates were read.

Table 24 : Plate tracking analysis

TOTAL NUMBER OF RECORDS	TOTAL NUMBER OF CARS	NUMBER OF PLATES RECORDED AT LEAST AT TWO POINTES	RATE OF MATCHES AMOUNG TOTAL CARS (%)	NUMBER OF CARS OBSERVED AT ON-STREET PARKING
12003	7318	2765	38.8	2658

In this study, the number of total vehicles in system is considered as 5073 according to the number of the vehicles that enter the area. However total number of identified plate is 7318. This difference is because of omitting of all in zone movements from the O-D matrix. Especially street parks that is not moved in the period of counting process is considered as in zone movement which means, a car parking in the zone “x” before counting is accepted to enter the system before counting process. If the same car realizes in the zone “x” again after the counting process, it is considered as a movement from zone “x” to zone “x” which is in-zone movement. These movements are not affecting the traffic flow in the system. Therefore they are omitted.

The limitation of these surveys is that all the plate numbers in the surveys are not readable. Some of the links are operating in 4 lanes and it is very difficult to catch the plate number of all the vehicles in these sections. However all the vehicle counts in all nodes are known. Therefore assumptions and calibrations are made with minimum error rate to obtain the study data.

In the meantime, existing data are entered to the simulation program. The map of the region; all nodes, links and zones are drawn. Also existing and operational capacities and direction of the links are entered into the program. The last required data was O-D matrix which is obtained from surveys.

5.2.4. O-D estimation in Tunalı Hilmi District

After analyzing the data of plate tracking and parking surveys, O-D matrix is needed to observe tendencies of all vehicles in the study area. As it is mentioned above, there are 22 zones in and out of the area and movement between them is shown in O-D matrix.

In the first step, 2765 cars that correspond to the matched plates are entered to the system; then according to the identification rate of the plate numbers in the entrance gate, calibration is made and total of 5073 vehicles are distributed. According to the check points (counts inside of the study area) only 2 intersections error rate is below 10%. All the other intersections have close values with the existing situation. This error rate is mostly because of the difference between driver behaviors and simulation program’s assignment approach. Equilibrium model is used in simulation program; however, drivers in reality may not choose the shortest path.

After entering the required data; O-D matrix is obtained and showed in the table 23.

Table 25 : O-D matrix of existing situation

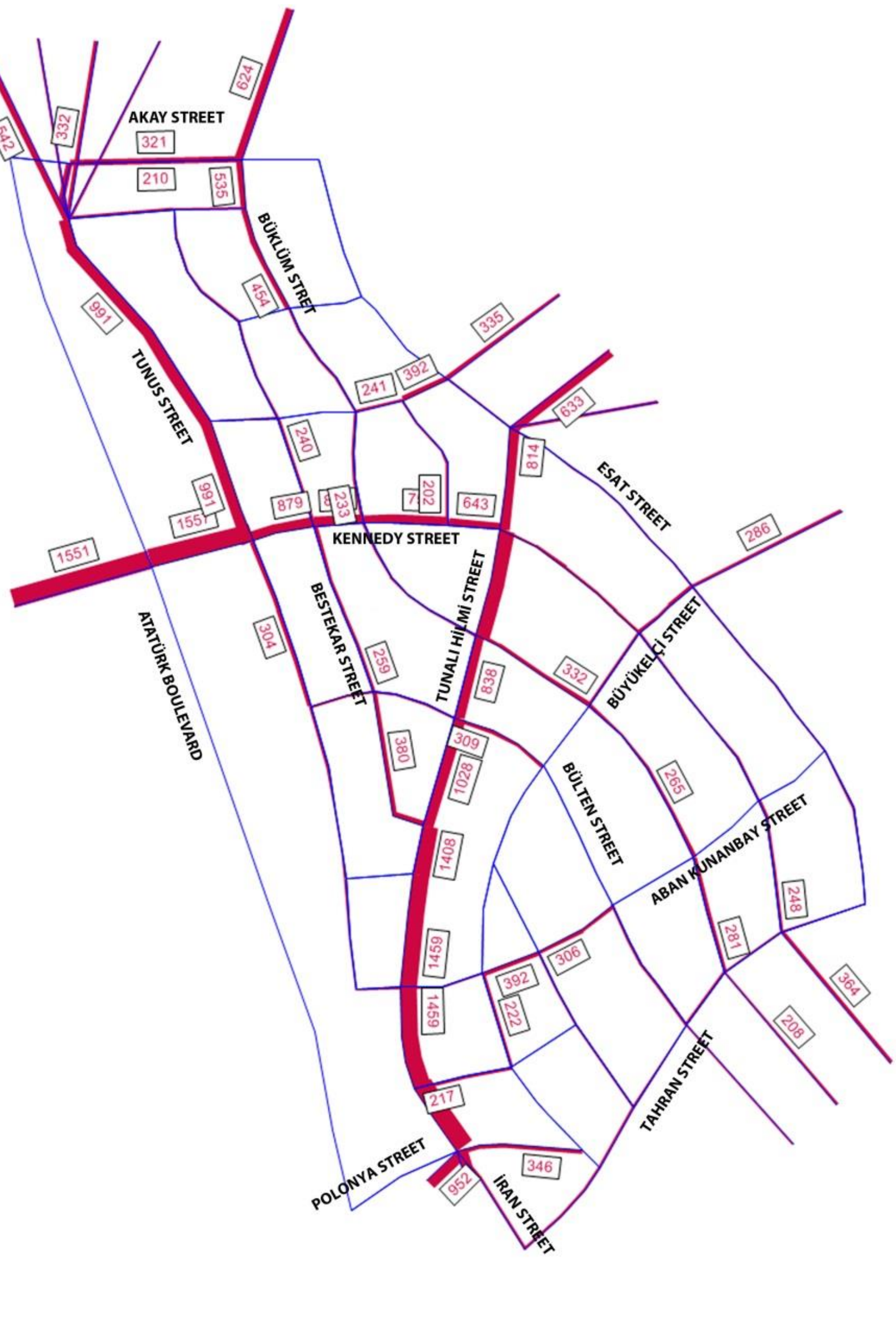
0	1011	1012	1020	1041	1042	1043	1044	1050	1060	1071	1072	1130	1140	1150	1160	2000	2001	2002	2003	2004	2005	2006	
1011	0	15	165	10	0	0	42	0	0	178	52	0	0	0	71	30	30	24	50	73	147	65	952
1012	3	0	202	5	6	0	19	0	0	212	50	0	0	0	48	15	49	13	75	163	71	4	935
1020	6	6	5	8	0	0	0	0	0	0	0	0	0	0	0	26	11	2	5	8	13	0	90
1041	0	6	240	0	5	0	28	0	0	33	13	0	0	0	3	54	69	1	2	29	27	32	542
1042	0	0	67	0	0	0	0	0	0	5	1	0	0	0	0	24	6	1	1	1	1	1	108
1043	0	6	178	0	2	0	6	0	0	12	6	0	0	0	4	8	49	5	5	32	17	2	332
1044	0	0	5	2	0	0	0	0	0	0	0	0	0	0	1	9	8	4	4	1	2	1	37
1050	3	2	221	0	0	5	25	0	0	28	13	0	0	0	12	50	153	0	50	21	18	23	624
1060	3	0	195	7	3	0	3	0	0	11	2	0	0	0	0	9	60	0	25	7	5	5	335
1071	0	0	4	5	0	2	2	0	0	0	0	0	0	0	3	10	20	0	0	11	9	4	70
1072	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	18	13	0	0	20	5	15	76
1130	2	4	67	0	0	1	0	0	0	31	23	0	0	0	22	1	7	1	1	87	13	26	286
1140	2	3	121	0	0	2	4	0	0	52	6	0	0	0	10	10	10	9	11	13	4	107	364
1150	0	0	65	0	0	0	0	0	0	39	4	0	0	0	4	3	4	3	3	24	8	51	208
1160	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1	0	0	0	0	6
2000	0	0	0	2	2	1	0	0	0	4	2	0	0	0	0	1	2	1	1	0	0	0	17
2001	0	0	7	0	0	0	2	0	0	6	1	0	0	0	0	0	6	0	1	1	1	0	26
2002	0	1	1	3	0	0	0	0	0	3	1	0	0	0	0	0	0	0	0	0	0	0	8
2003	1	0	1	0	0	0	0	0	0	7	3	0	0	0	0	0	0	0	0	1	0	0	13
2004	0	1	4	1	0	0	0	0	0	9	1	0	0	0	1	0	0	1	1	2	2	2	24
2005	0	0	1	0	0	0	0	0	0	1	2	0	0	0	0	0	0	0	0	1	1	0	6
2006	0	1	2	1	0	0	0	0	0	2	1	0	0	0	2	0	0	0	1	1	3	1	15
	20	46	1555	43	18	11	131	0	0	633	181	0	0	0	181	268	500	66	236	496	347	339	**5073**

5.2.5. Traffic flows in Tunalı Hilmi District

The main aim to obtain O-D matrix is to see main flow in the system. To obtain flow, a simulation program is used. Nodes, links, zones and O-D matrix are drawn and entered to the program and existing traffic flow is visualized.

When the traffic flow of the existing situation is analyzed; it is observed that the highest volume in the system is western part of the Kennedy Street which is between Tunus Street and Atatürk Boulevard. Also Tunalı Hilmi Street has a high volume of the traffic. Although Tunus Street has relatively lower volume compared with the other two streets, its volume is also high.

Graphic 4 : Traffic flow and volume of existing situation



Speed analysis is also made in existing situation. In this analysis, in the main arterials initial speed is considered as 50 km/h and in the collector Roads it is considered as 20 km/h because of the on street parking.

5.3. Car Access Control Policies Scenario Adopted for Tunalı Hilmi Street and Related Assumptions

There are four assumptions in this study to test the condition of car access control policies scenario in Tunalı Hilmi Street.

First of all, road directions have been rearranged. Without changing the existing road directions, Tunalı Hilmi Street cannot be closed to private vehicles. That is because there are some links on the Tunalı Hilmi Street that has no alternative and when these links are closed there will be no path between some zones.

When rearranging the street directions, it was seen that beside Tunalı Hilmi Street, Bestekar Street also had to be closed to private vehicle access. That is because this street has no direct and strong link or effect to the main flow and keeping it as a vehicular link did not contribute at all to the system. In addition, pedestrian density of this street is also known to be high. Therefore, since it does not play any significant role in carrying traffic flow in the case of closing Tunalı Hilmi Street to vehicular traffic, it was seen that such a scheme for Tunalı Hilmi Street should be considered to include Bestekar Street too, and hence this street was also closed to private vehicle traffic in the model.

When the policies that mentioned above are applied, passengers need to find another route. These routes are mostly peripheral roads and they have their existing volumes. To find a more precise value capacity of the peripheral roads are decreased according to their usage.

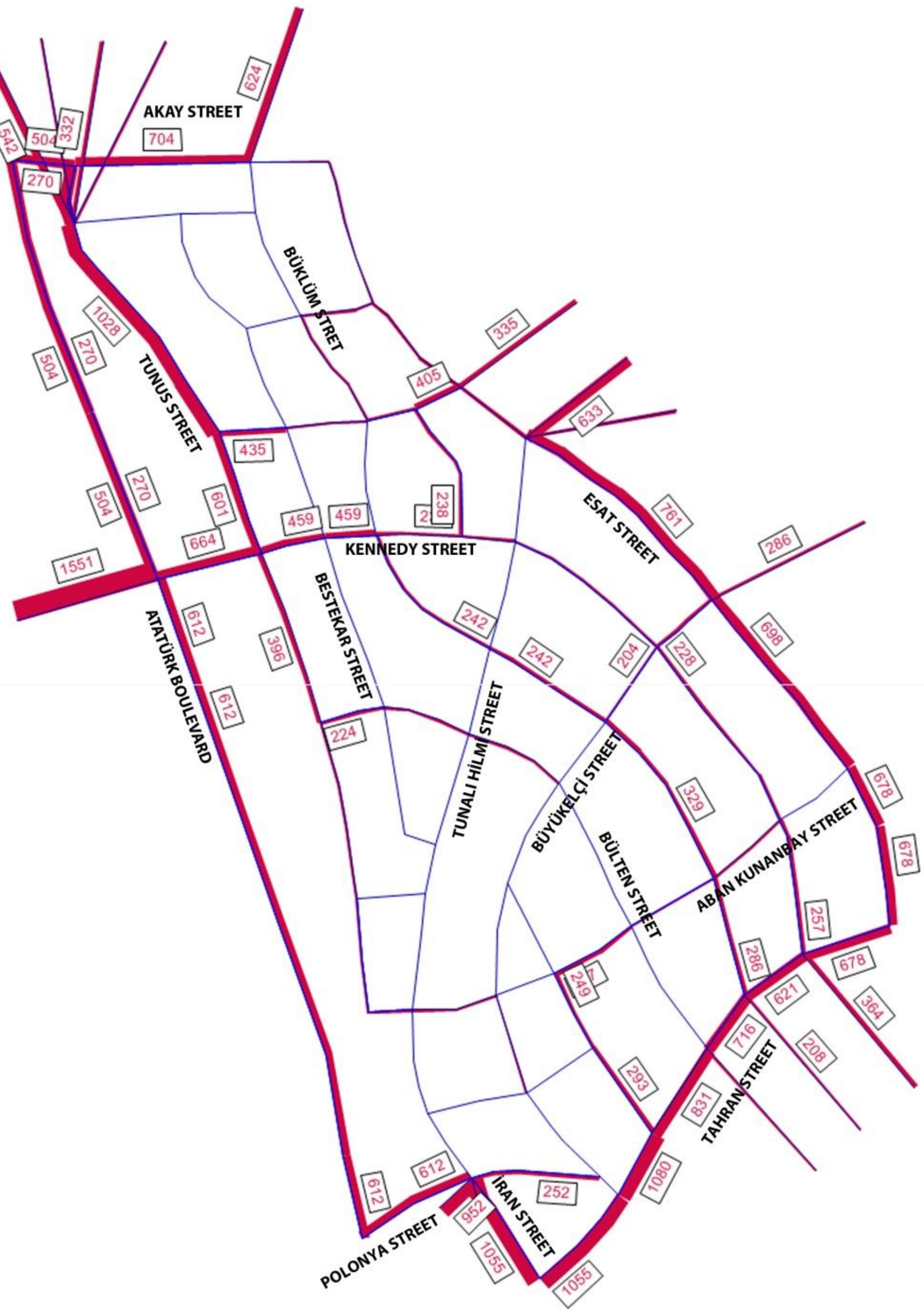
Figure 6 : Change in traffic directions, pedestrianized and car access control policies applied streets

5.3.1 Assumption 1: The current demand would remain the same in spite of the car access control scheme

The first assumption in this study is sending all the demand in Tunalı Hilmi Street to the system while car access control policies applied. The traffic demand, i.e. number of vehicles, on the roads that car access control policies are applied, are distributed to the alternative roads. Flow result is shown in the graph below. The volume and flow results of this assumption are;

- The volume of the Tunus Street is almost the same when compared to its existing situation.
- Almost 700 vehicle/hour adds to the existing volume of Esat Street.
- Tahran Street is another one that has an excessive increase.
- As Tahran and Esat Streets, Atatürk Boulevard has also additional volume between 500 and 600.
- The volume of the Kennedy Street decreases by more than 50% in general, also in some links the decrease is more than %65.
- The volume of the Abay Kunanbay Street decreases almost %50.
- The volume of the Büklüm Street changes in different links but in average volume of this street is almost the same with the existing situation.

Graphic 5 : Traffic flow and volume of first assumption

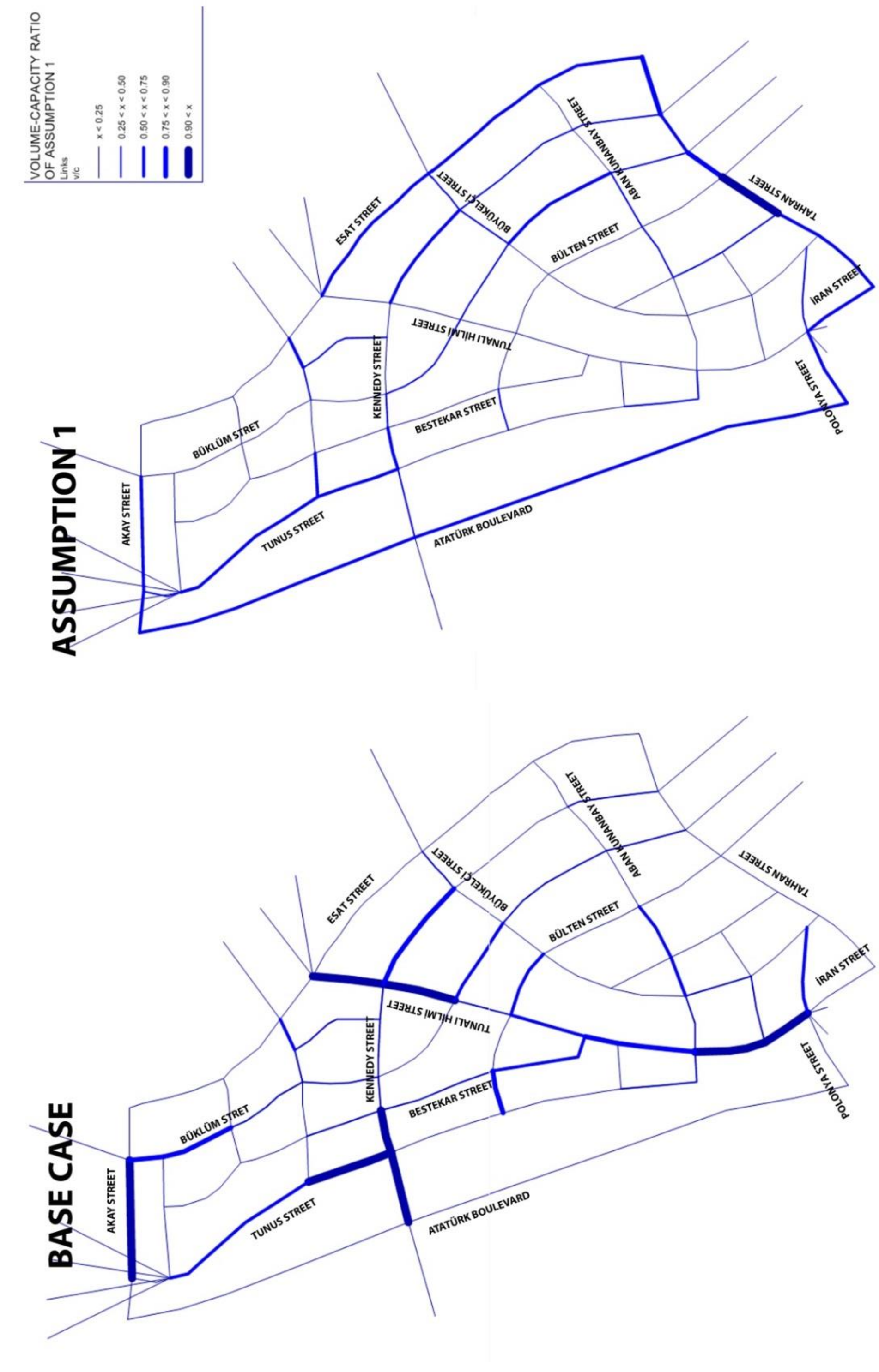


5.3.1.1. Change in congestion levels

To calculate the congestion level, volume-capacity ratio is used. When all existing demand is send to the system while the first assumption's features are applied; there are some important changes. Of course volume-capacity ratio of the streets, which are subjected to car access control policies, have the value of zero or very close to zero. Because, although they have capacity, traffic volume of these streets are zero or very few (carrying only public transport buses). The graph below is a comparison of volume-capacity ratio of the existing situation and assumption 1.

- The volume-capacity ratio of the Akay Street decreases in this assumption when it is compared with the existing situation.
- Tunus Street shows different results in each links. While a remarkable decrease is observed close to Kennedy Street, there is a very few increase in the links that are close to Akay Street.
- Büklüm Street shows different attitude on its northern and southern part. While in northern part, volume-capacity ratio of the base case is more; in southern part it has both smaller and bigger values.
- Esat Street has very big increase in volume-capacity ratio due to the increase of the volume.
- South-eastern part of the Kennedy Street has also an increase in volume, when compared with capacity. On the other hand, western part has remarkable decrease.
- Like Esat Street, Tahran Street has an extensive increase in volume-capacity ratio.

Graphic 6 : Volume-Capacity ratio comparison between existing situation and first assumption

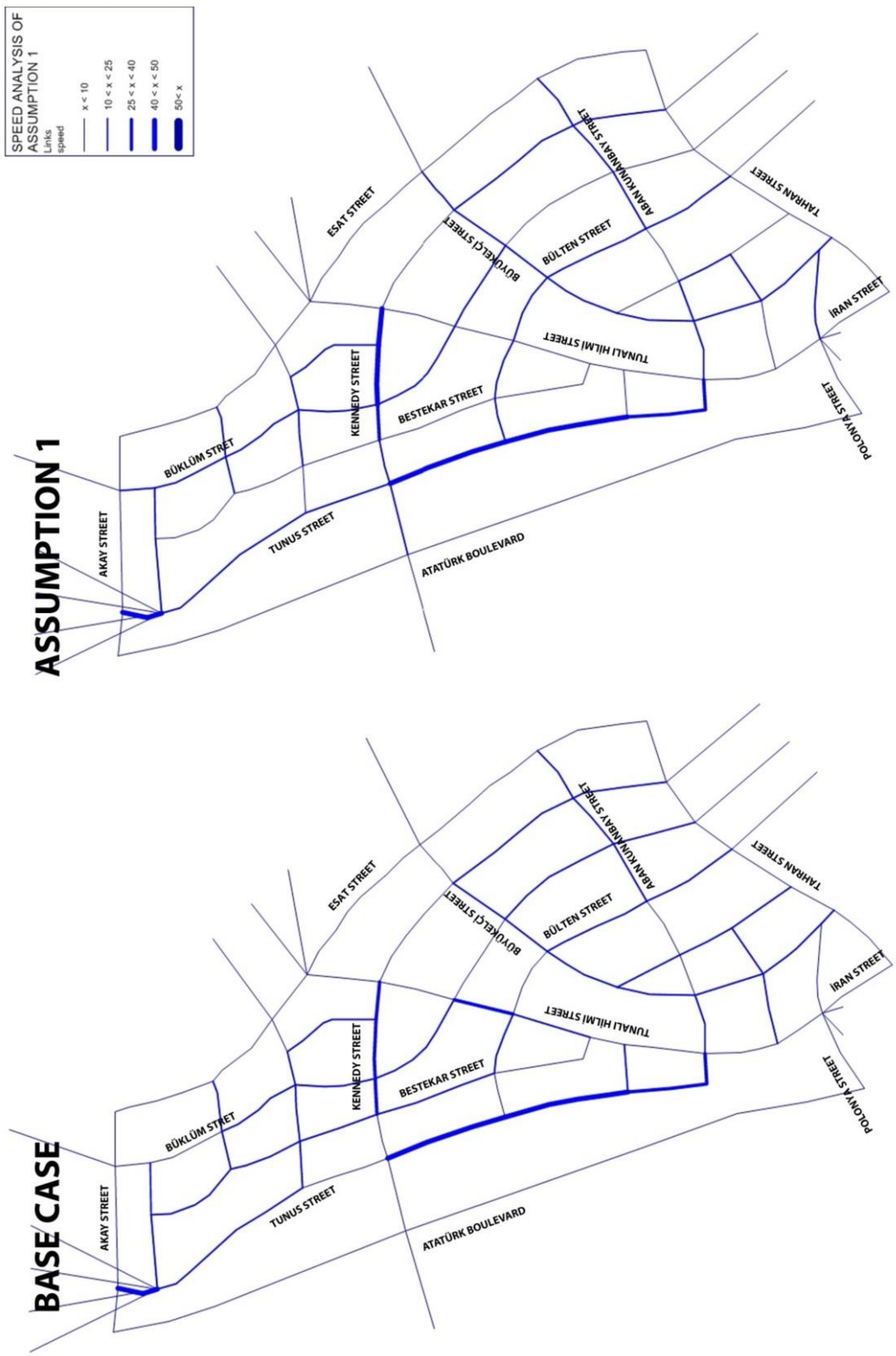


5.3.1.2. Change in speed

Speed analysis is important to observe the traffic flow. Decrease of the speed shows more congestion while increase of speed shows better traffic flow conditions. When all existing demand is send to the system while the first assumption’s features are applied; there are some changes. Of course speed of the streets, which are subjected to car access control policies, have the value of zero or very close to zero. The graph below is a comparison of speed of the existing situation and assumption 1.

- Speed difference between existing situation and first assumption in Tunus Street is almost zero except from the link of north of the Kennedy Street. In this link because of the decrease of the volume, speed is increased.
- Bülten Street is the other Street that speed is increased.
- Southern part of the Büklüm Street shows differences in each links. While in some links speed is increased, others have low values.
- Speed of both western and south-eastern part of the Kennedy Street is increased.

Graphic 7 : Speed comparison between existing situation and first assumption

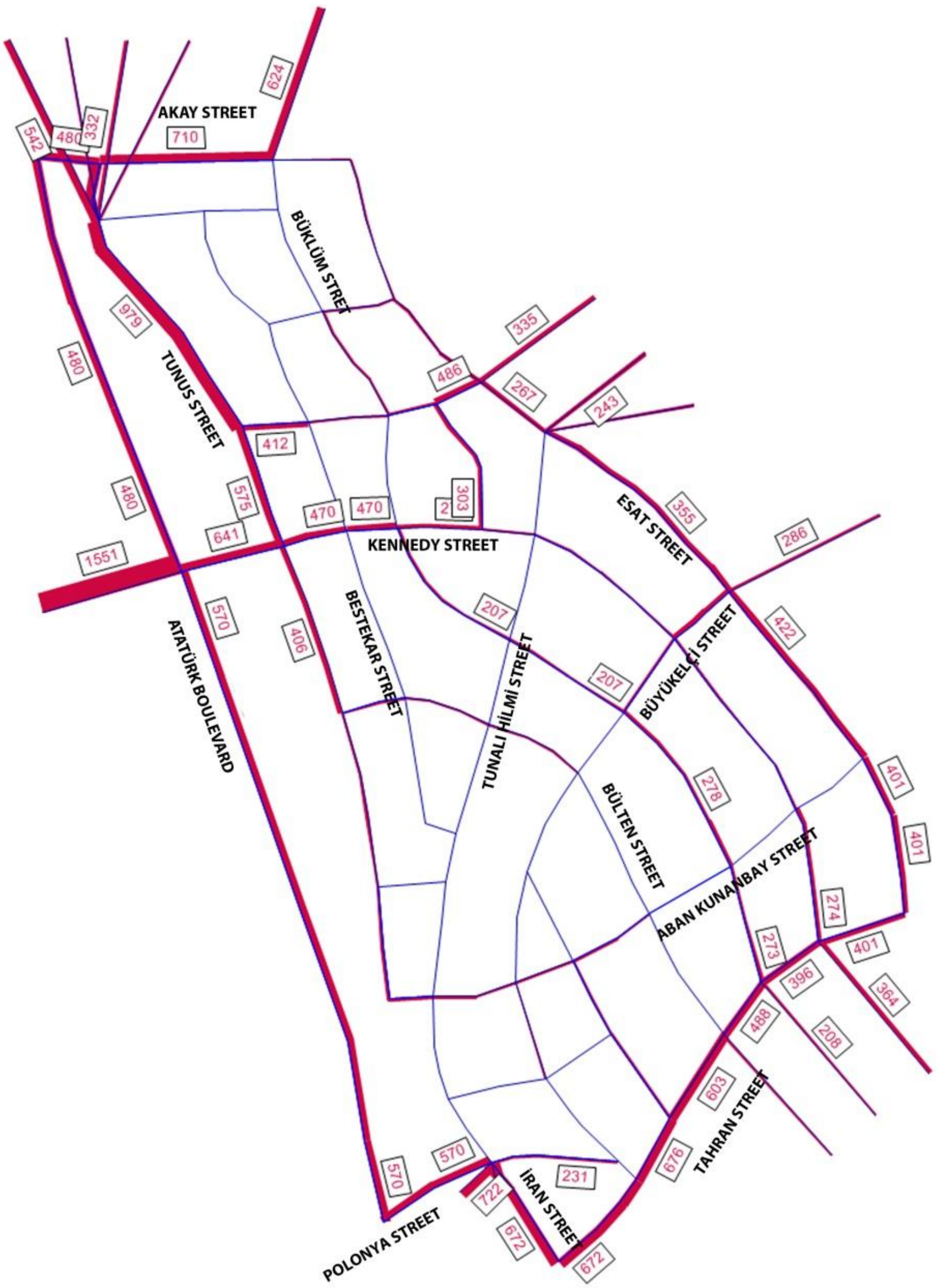


5.3.2. Assumption 2: Eliminating through traffic

In this assumption, passengers who use Tunalı Street as a transit path are omitted. That means vehicles enter the system from Kuğulu Intersection (intersection of İran Street and Polonya Street) and exits the system from “Esat Dörtyol” (intersection of Tunalı Hilmi Street and Esat Street) without stopping in the system are omitted. Flow result is shown in the graph below. The volume and flow results of this assumption are;

- The volume of the Tunus Street on the northern links has the same value, but southern links and links close the Kennedy Streets has significant decrease.
- Although Esat Street has an average increase of 400 vehicles per hour compared to the base case, this increase is half of the previous assumption.
- As Esat Street, Tahran Street has an excessively increase.
- Although there is a some decrease, Atatürk Boulevard has still an additional volume around 500.
- The volume of the Kennedy Street decreases the same with the first assumption which is more than %50 in general, also in some links decrease is more than %65.
- There is also a decrease of the volume of the Abay Kunanbay Street.
- The volume of the Büklüm Street also decreases.

Graphic 8 : Traffic flow and volume of second assumption

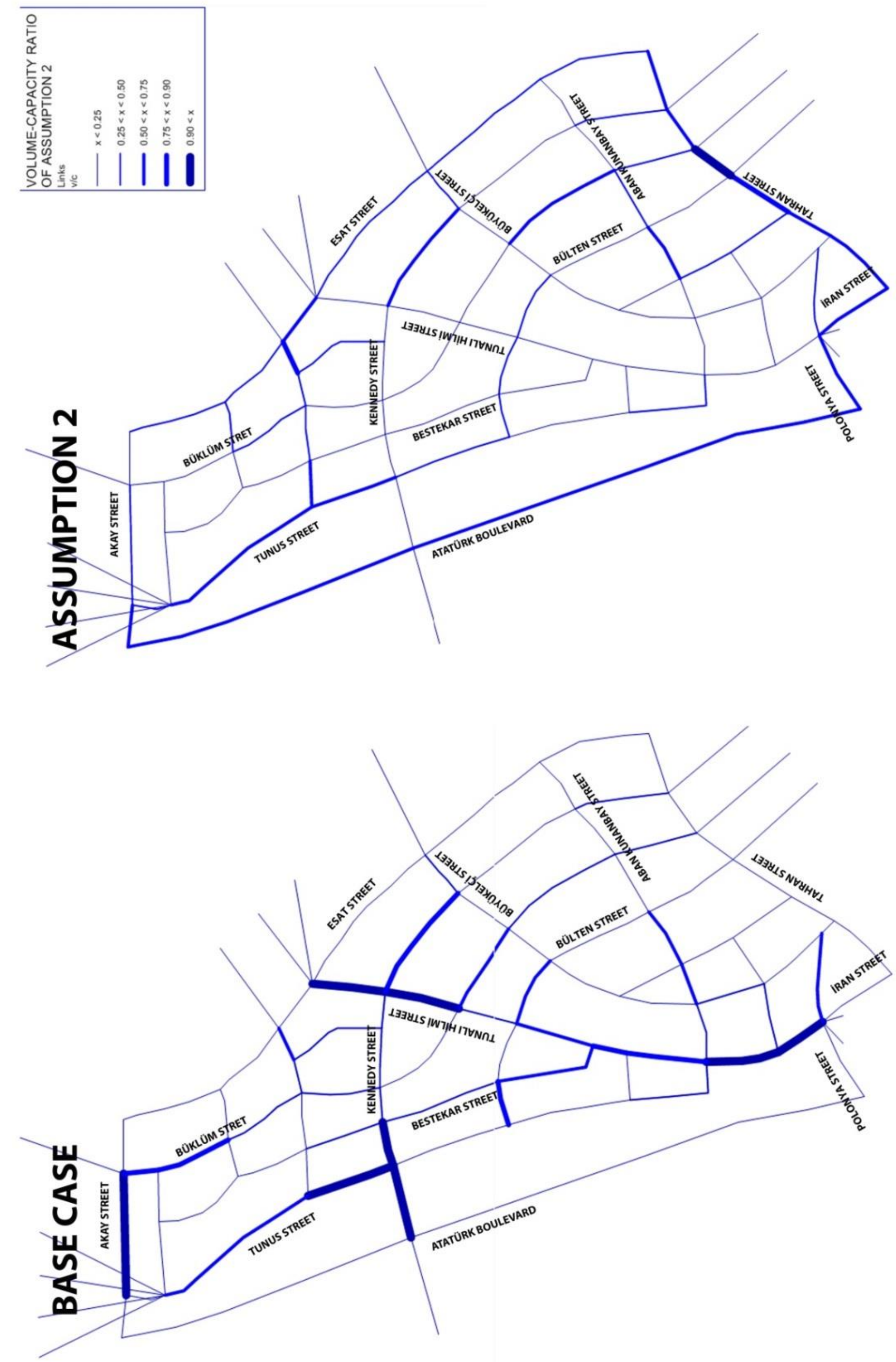


5.3.2.1. Change in congestion levels

When though traffic is omitted and the remaining demand is sent to the system, there are some important changes as the first assumption. Of course volume-capacity ratio of the streets, which are subjected to car access control policies, have the value of zero or very close to zero. The graph below is a comparison of volume-capacity ratio of the existing situation of the assumption 2. According to the graph, the outcomes are;

- As the first assumption, in this assumption Akay Street has lower volume-capacity ratio when it is compared to the existing situation.
- Tunus Street is also the same with first assumption and has a decrease in south links.
- Büklüm Street shows different attitude. Except from one link in the south part, all the links have lower volume-capacity.
- Esat Street has also an increase in this assumption but it is lower than the first one.
- All links of the Kennedy Street has the same or lower value. Especially western part of the Kennedy Street, which is normally the most congested part, has significant decrease. This also shows that this part of Kennedy Street becomes congested due to through-traffic and once they are diverted to main arterials, the traffic conditions improve.
- There is a decrease in volume-capacity ratio in Abay Kunanbay Street when it is compared with existing situation.
- Polonya Street has an extensive increase in volume-capacity ratio.

Graphic 9 : Volume-Capacity ratio comparison between existing situation and second assumption

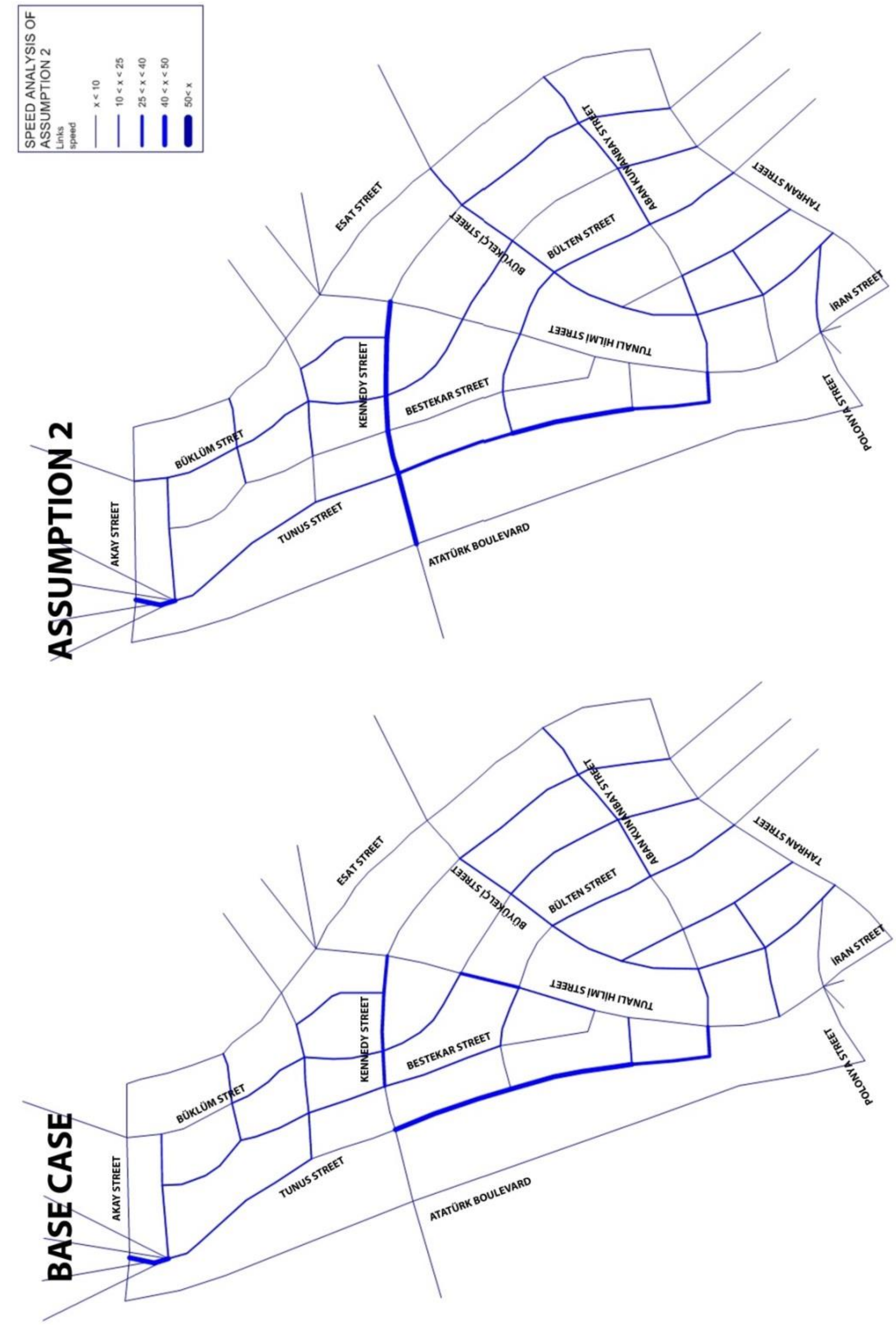


5.3.2.2. Change in speed

When through traffic is omitted and remaining demand is sent to the system and the car access control policies are applied as first assumption; there are also some changes. The graph below is a comparison of speed of the existing situation and assumption 2.

- Speed difference between existing situation and second assumption in Tunus Street is almost zero except from the link of north of the Kennedy Street. In this link because of the decrease of the volume, speed is increased.
- Bülten Street is the other Street that speed is increased.
- Southern part of the Büklüm Street shows differences in each links. While in some links speed is increased, others have low values.
- Speed of western part of the Kennedy Street is increased.
- Some links of Abay Kunanbay Street have increase of the speed.

Graphic 10 : Speed comparison between existing situation and second assumption

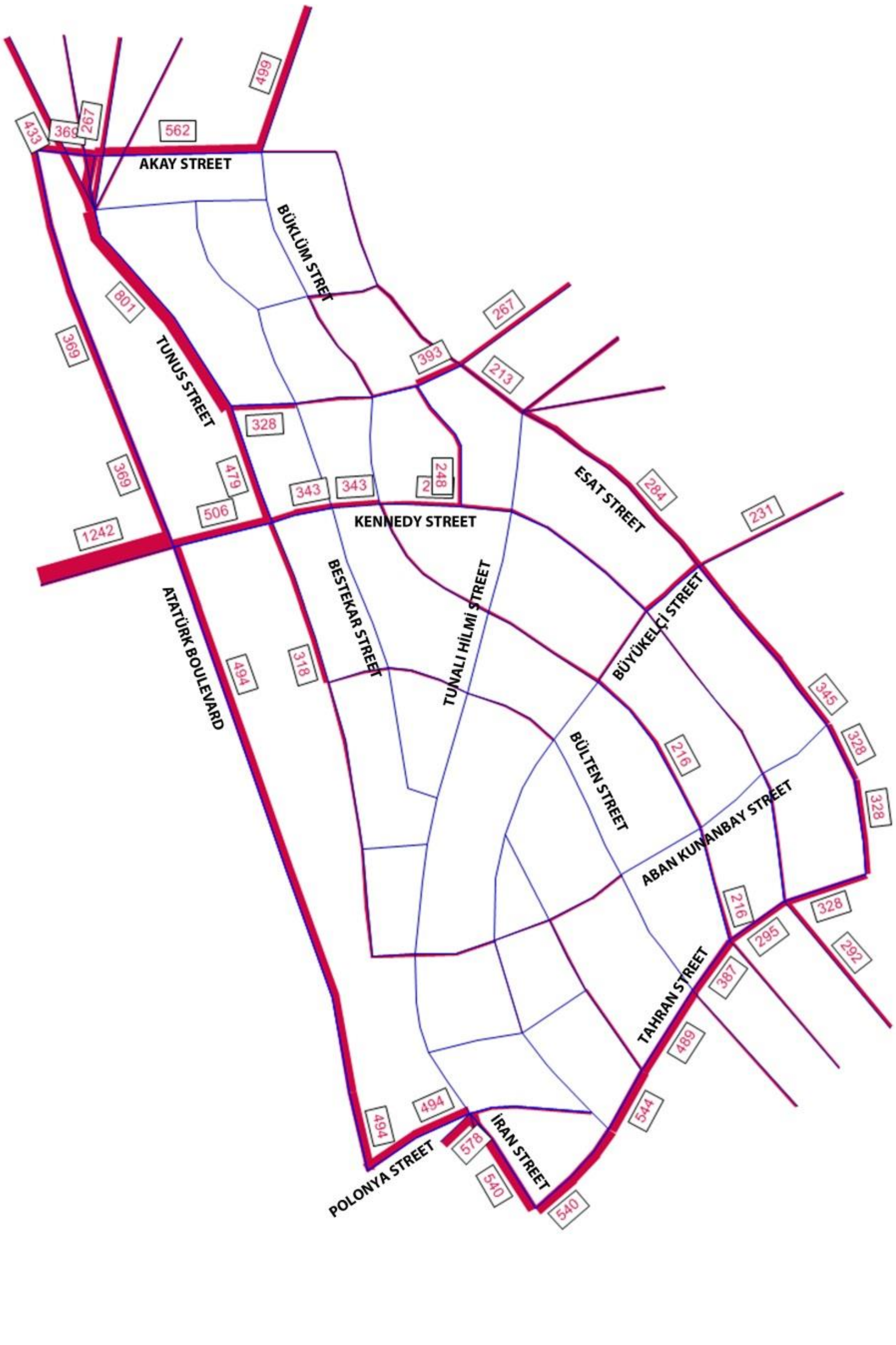


5.3.3. Assumption 3: Eliminating through traffic and reduction in private vehicle traffic due to car access control policies

In this assumption; in addition to the previous one, a decrease is assumed in the number of private car users because of the car access control policies implemented. Converting a street into a transit-only corridor, and converting another side street (Bestekar Street) into a pedestrian area result in changes to users' perceptions of relative convenience of transport modes. That change in perception is the key to Travel Demand Management as the users travel behavior may be changed this way: Creating a transit- and pedestrian-priority system generally works as a disincentive to use private cars when accessing such transit- and pedestrian-friendly areas. Hence when such schemes are implemented, decision makers must be aware that such a reallocation of road space from the private vehicles to public transport and pedestrians would discourage car users from driving to this area – they may either access this site by using public transport and walking, or decide not to visit this site. In any case, a reduction must be assumed in the private vehicle traffic. This reduction is assumed as 20% in this study. Flow result is shown in the graph below. The volume and flow results of this assumption are;

- The volume of the Tunus Street is lower than the base case. Especially southern links have less than half of the volume of the existing situation.
- Esat Street has also 300 vehicle/hour increase in this assumption. However the increase is fewer than the first two assumptions.
- Tahran Street has more increase when it is compared with the increase of the Esat Street.
- Atatürk Boulevard has around 400 additional vehicles.
- The decrease of the volume of Kennedy Street is more than 50%, moreover in some links it is very close to %70.
- The decrease of the volume of the Abay Kunanbay Street is more than the %50.
- Büklüm Street has an increase, but this increase is lower than the first two assumptions.

Graphic 11 : Traffic flow and volume of third assumption

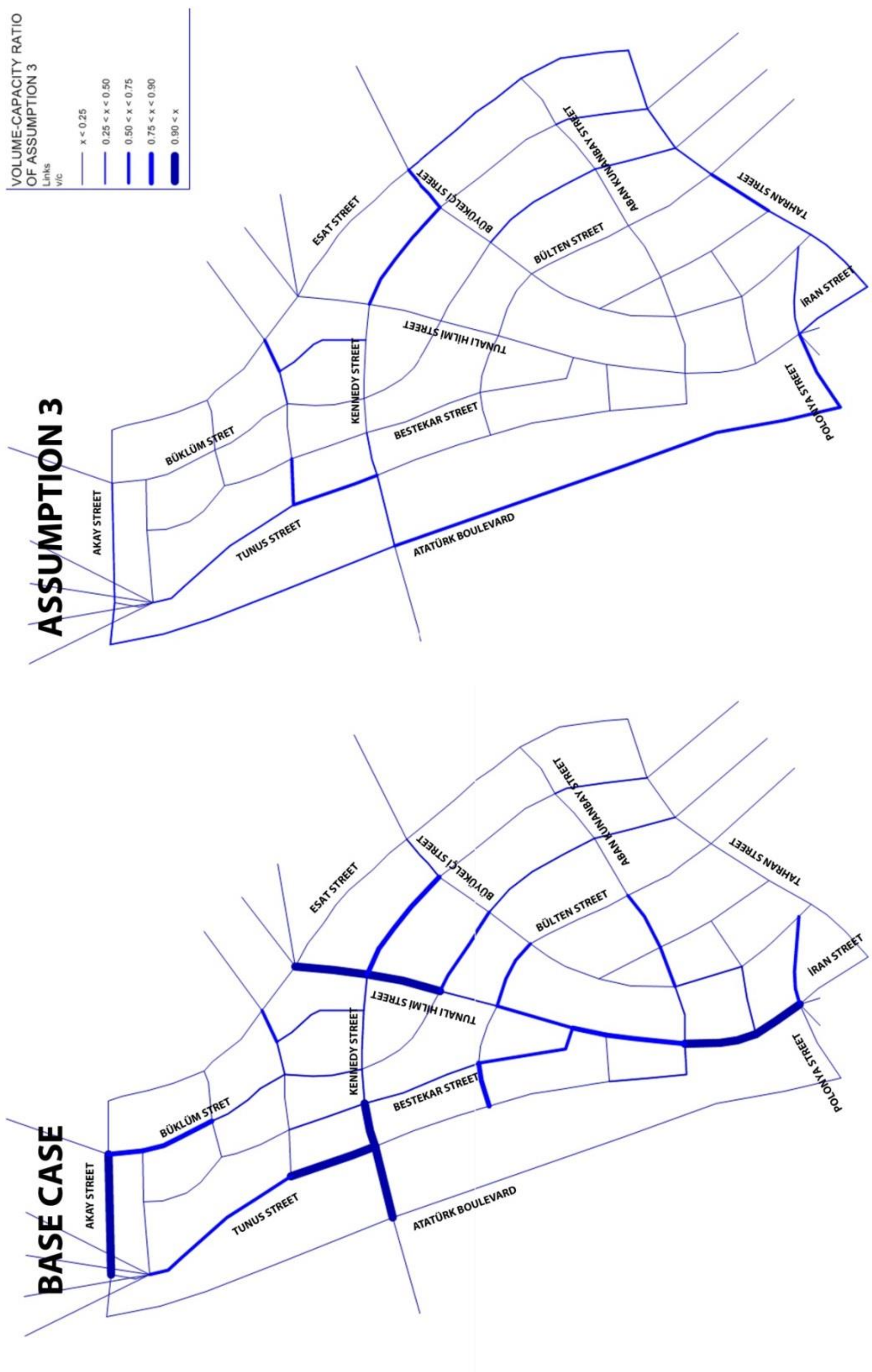


5.3.3.1. Change in congestion levels

When a 20% decrease is assumed in the demand in addition to the previous assumption; the volume-capacity ratio of almost all links decreases. The first graph below is a comparison of volume-capacity ratio of the existing situation and assumption 3. According to the graph, the outcomes are;

- The volume-capacity ratio of Akay Street is far more lower than that of the existing situation
- All links of the Tunus Street have lower values compared with the existing situation.
- Büklüm Street also has lower volume-capacity ratio.
- In this assumption Esat Street has few increase compared with the existing situation.
- Kennedy Street also has a sharp decrease when compared to the previous assumptions.
- There is also a decrease in Abay Kunanbay Street when it is compared with existing situation.

Graphic 12 : Volume-Capacity ratio comparison between existing situation and third assumption

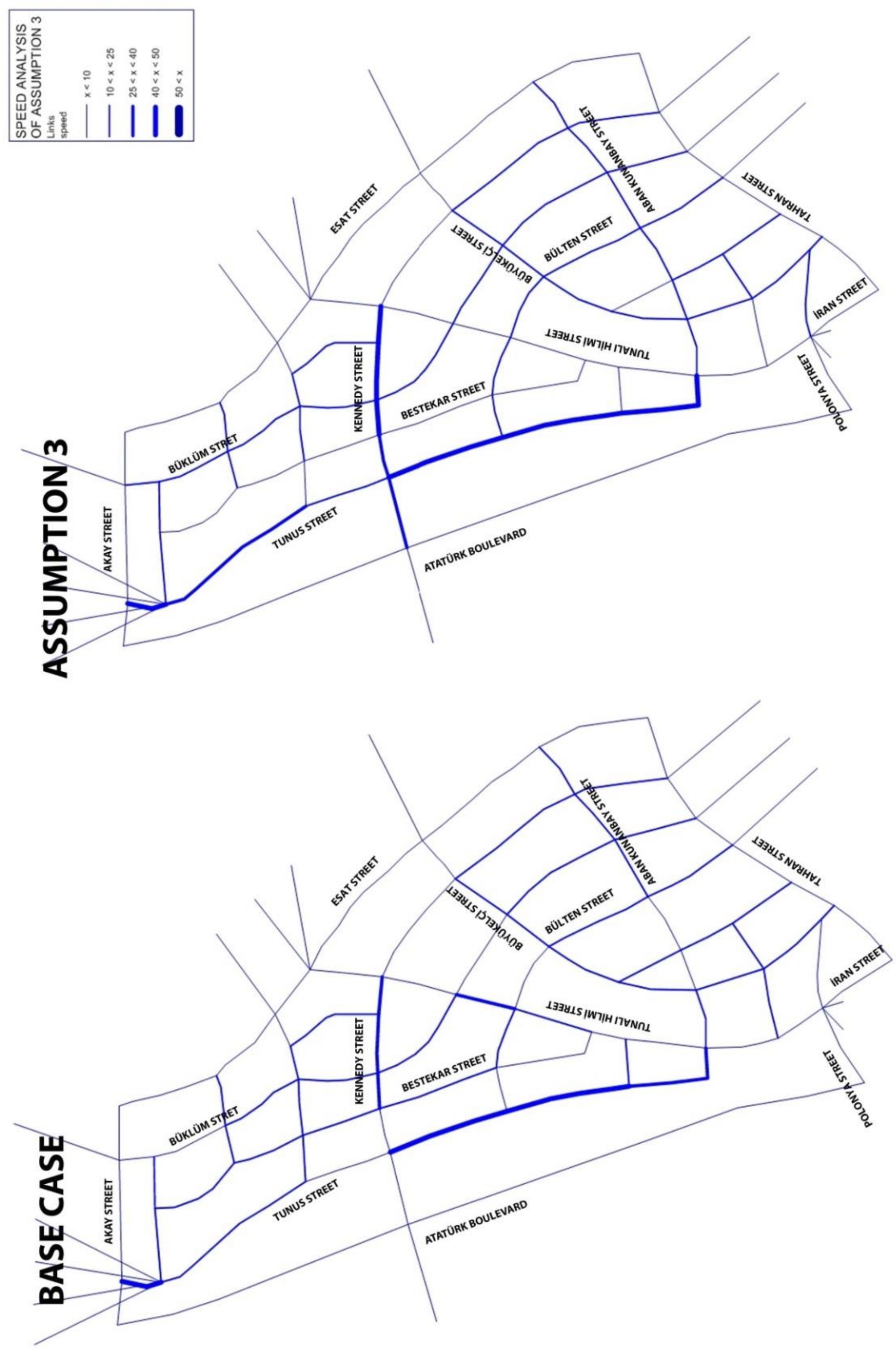


5.3.3.2. Change in speed

When a 20% decrease is assumed in the demand in addition to the previous assumption; there are also some changes. The graph below is a comparison of speed of the existing situation and assumption 3.

- In Tunus Street speed of all links are increased.
- Bülten Street is the other Street that speed is increased as Tunus Street.
- Both southern and northern part of the Büklüm Street have higher speed than existing situation
- Speed of western part of the Kennedy Street is increased.
- Some links of Abay Kunanbay Street have increase of the speed.

Graphic 13 : Speed comparison between existing situation and third assumption

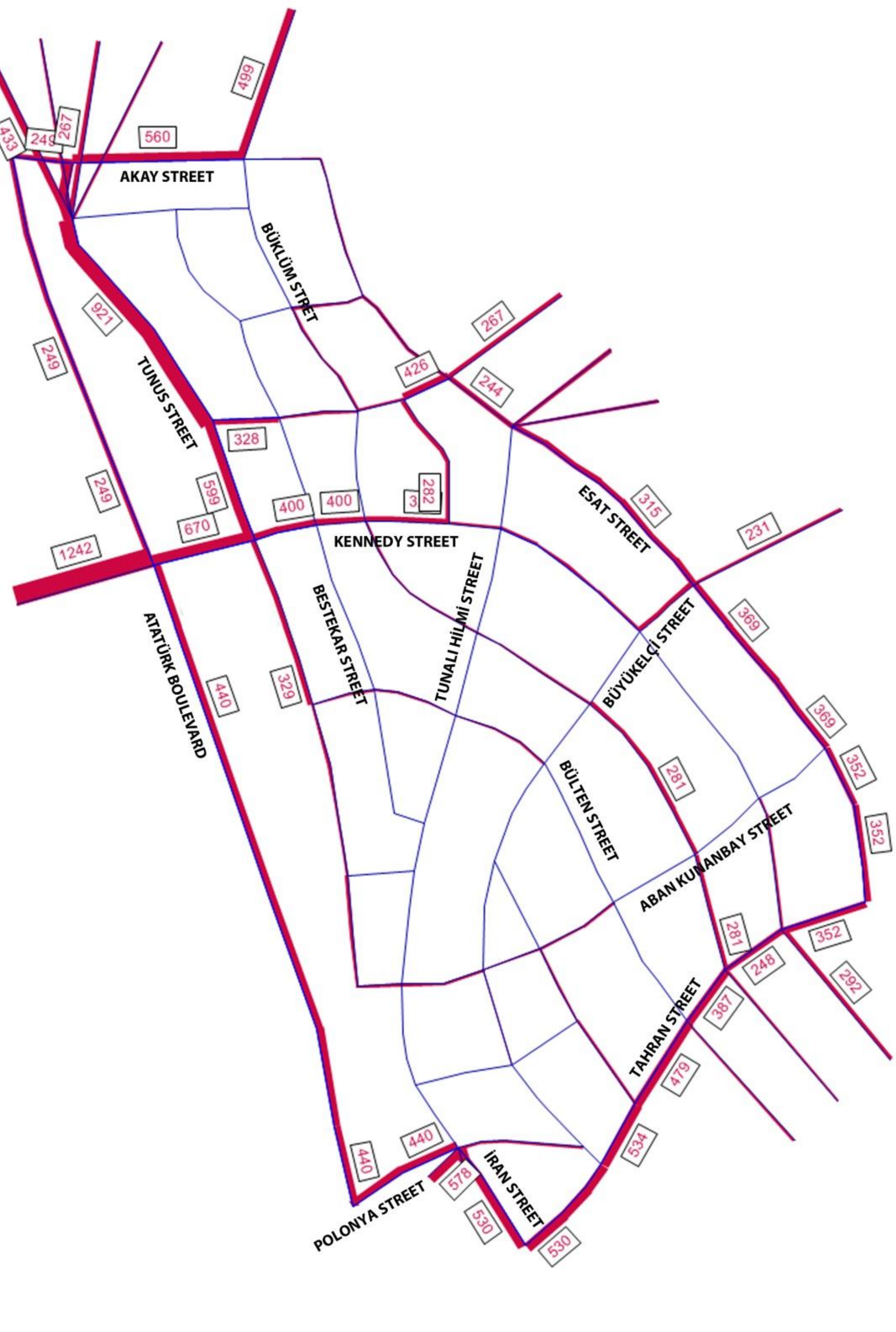


5.3.4. Assumption 4: Parking restriction in the area in addition to the previous assumptions' features

In this assumption, in addition to the previous one, it was attempted to test whether a major improvement is to be attained if on-street parking is controlled and banned especially in peak hour. As a result, the capacities of the streets are increased. On the other hand, it must be remembered that the Tunalı Hilmi Region also has residential areas besides commercial and office areas. Therefore there is a need of on-street parking in the region. Back yards of the buildings are sometimes not sufficient for even residents. Although eliminating street parking increases the capacity of roads, it creates parking problems for the residents. Therefore, this assumption cannot be fully implemented; however, in this study, it was decided to test this possibility too, in order to see whether substantial improvements are to be gained from a strict resident-parking permit and control in the area.

Flow result is shown in the graph below. The volumes, i.e. the flows on the links, are almost the same with the third assumption. However, because of the increase of the capacities, volume-capacity ratios are different.

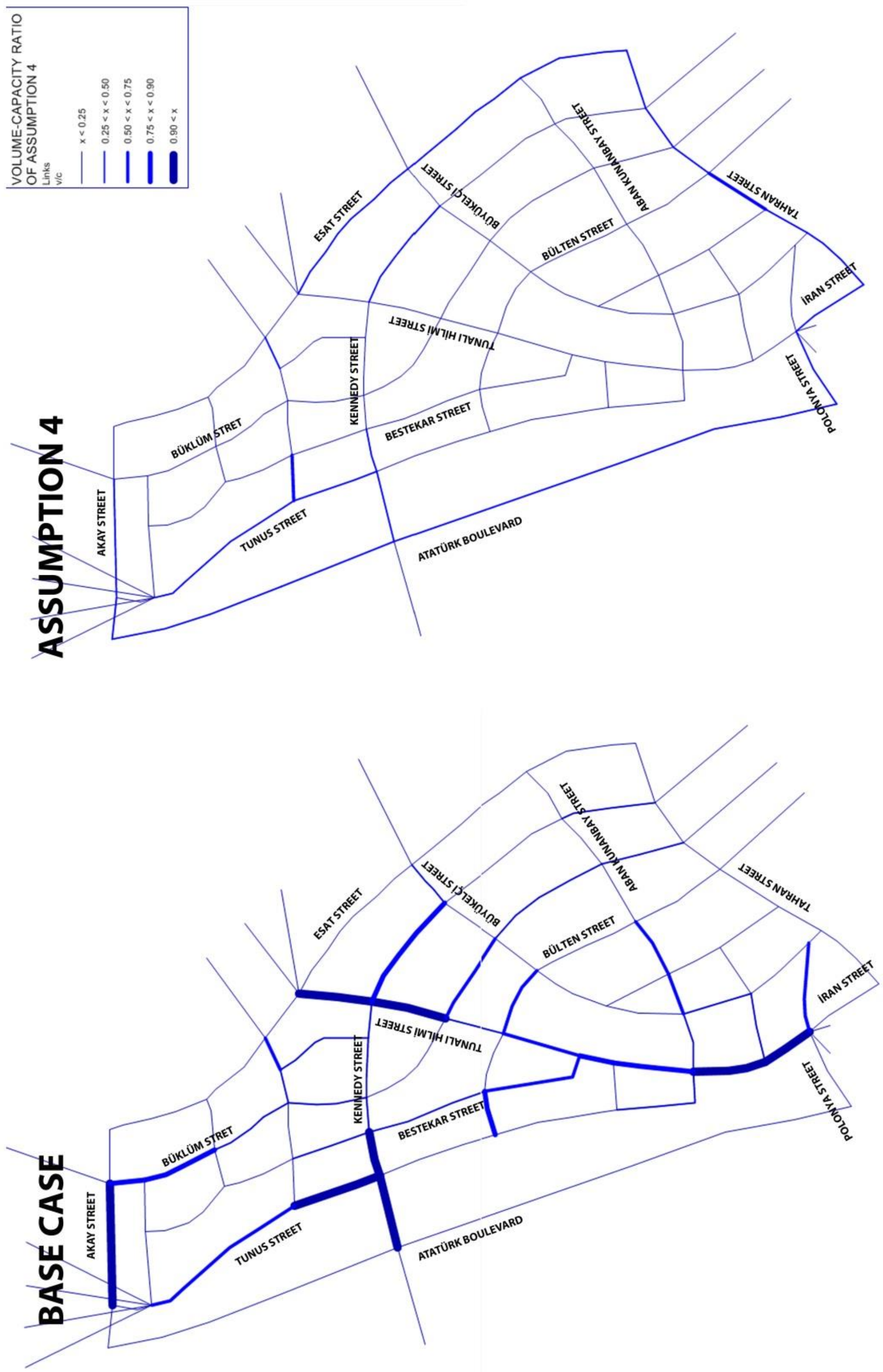
Graphic 14 : Traffic flow and volume of fourth assumption



5.3.4.1. Change in congestion levels

When street parking is forbidden in the study area in peak hours in addition to the previous assumptions' attributes; the volume-capacity ratios of almost all links are lower than 0.50. Only two links' values are more than 0.5 which are Tahran and Beykoz Streets. Moreover very few links are between 0.25 and 0.50. Of course volume-capacity ratio of the streets, which are pedestrianized or car access control policies are applied, have the value of zero or very close to zero. The graph below is a comparison of volume-capacity ratio of the existing situation and assumption 4.

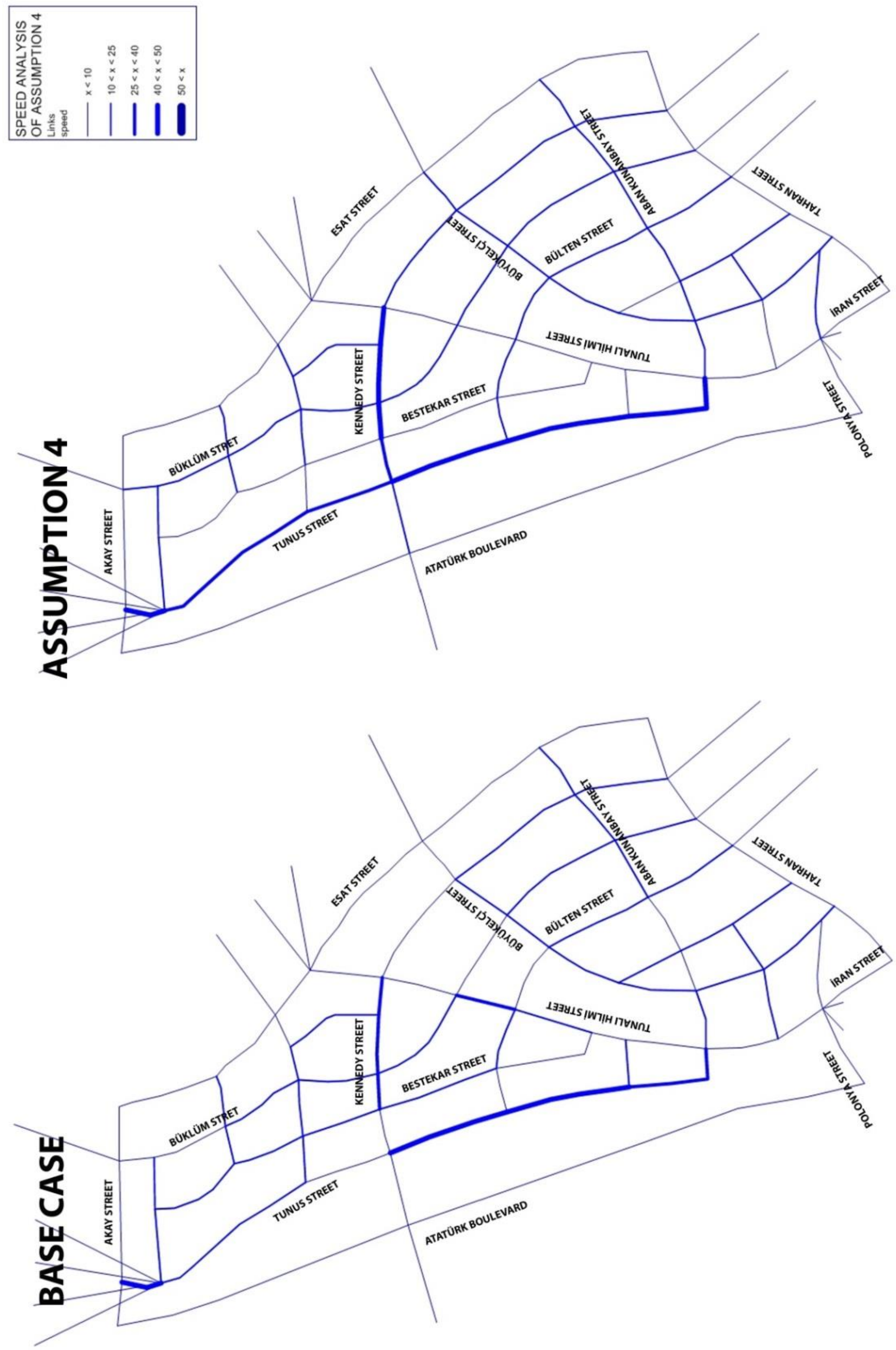
Graphic 15 : Volume-Capacity ratio comparison between existing situation and fourth assumption



5.3.4.2. Change in speed

When street parking is forbidden in addition to the previous assumption, speed of almost all links is increased. The graph below is a comparison of speed of the existing situation and assumption 3.

Graphic 16 : Speed comparison between existing situation and forth assumption



5.4. Discussion of the Results

After car access control policies are applied to Tunalı Hilmi Street and four assumptions are tried, positive and negative outcomes are observed.

By applying car access control policies scenario to Tunalı Hilmi Street, pedestrianizing Bestekar Street and redesigning the road directions; the flow system of the study area is totally changed. As discussed before in this study, the benefits of pedestrianization and car-access control in city centers cannot be discussed by observing traffic effects only. There are many benefits as commercial activities defiantly increase and these areas become more attractive for both people and shop/office owners. Moreover, there may be benefits in terms of traffic safety, and a reduction of environmental and noise pollution etc. However, this study focused on traffic impacts with a view to test whether the implementation of car access control in the case study area would have severe negative consequences on traffic on residential side streets, and whether different assumptions can be tested to see those with the least negative traffic consequences on residential side streets.

In the existing situation, traffic volume of the region is mostly concentrated on Tunalı Hilmi Street, Tunus Street and western part of the Kennedy Street. These Streets suffer from congestion in peak hours and traffic is stuck. Especially Tunalı Hilmi Street and western part of the Kennedy Street have almost equal volume to the capacity.

In the first assumption, after applying car access control policies, all the demand obtained from existing situation is send to the system. The system mostly distributes the transit users on Tunalı to Tahran, Esat Street and Atatürk Boulevard. Between 1100 and 600 additional volume are added to the existing volume of these streets. Especially Tahran Street cannot supply this demand.

In contrast to Tahran and Esat Streets, the volume of the Kennedy Street decreases significantly. More than 50% decrease is important when existing situation of Kennedy Street is considered.

The other positive effect of the first assumption is the decrease in the volume of Akay Street. While volume -capacity ratio was very high in existing situation; in this assumption, it decreases a lot.

When the collector roads are analyzed, some links in the eastern part of the region has an increase of the volume.

In the second assumption, through-traffic is omitted from the existing demand. Esat and Tahran Street have an increase between 400 and 600.

Tunus Street shows no difference with the first assumption and southern part of it has a significant decrease.

There is also more than %50 decrease on western part of the Kennedy Street.

The situation of Akay Street and collector roads inside of the area are the same with the first assumption.

In the third assumption, in addition to the elimination of through traffic, a certain amount of decrease is assumed in private vehicle traffic due to car access control policies and travel demand management policies. Therefore, volumes of all streets experience a decrease.

Traffic volume of Tunus Street is better when it is compared with the first two assumptions. Especially southern links have less than %50 of the existing situation.

Tahran and Esat Streets also have improvement. Their volumes are lower when compared with the first two assumptions.

Volumes of all other streets are lower than existing situation.

Forth assumption includes parking restriction to the previous assumption. Although implementation of this assumption is arguable because of the parking requirement of residential areas here, this assumption was also tested.

The volume is the same with the previous assumption, because demand is not changed. The difference is in the volume-capacity ratio because of the increase of capacities.

By this application, almost all links in the study area has a volume-capacity ratio that is lower than 0.50, which means there are no congested links.

System travel time shows the total time that all vehicles spend in the study area in 1 hour. The values are shown in the table below. According to the data, 536 hours are spent in 1 hour in the existing situation (6.34 minutes per vehicles). In first assumption because of using the Atatürk Boulevard and peripheral Streets, system travel time decreased to the 344 (4.07 minutes per vehicles). When it is assumed that through traffic would not enter this area anymore due to the closing of Tunalı Hilmi Street to private vehicles that is assumption 2, the total time spent decreases to 295 hours which is 49 hours less than the previous assumption. This is a significant finding, showing that travel conditions in Tunalı Hilmi Street, which is an important shopping and leisure street of Ankara city center, can be improved if this street is not used a transit path for accessing from the south-eastern part of the city to the city center.

Furthermore, a 20% percent decrease in the demand also directly affects the total time spent in the system and a striking decrease is seen to 160 hours. Restriction of on-street parking does not have a big impact on system travel time. The differences between assumptions three and four is approximately 20 hours.

Table 26 : System travel times of base case and all assumptions

	base case	assumption 1	assumption 2	assumption 3	assumption 4
system travel time (h)	536	344	295	160	140
per vehicle (m)	6.34	4.07	3.50	1.90	1.65

The analyses reveal the following findings:

If decision makers consider converting Tunalı Hilmi Street into a pedestrian and transit-only corridor, the initial traffic simulations (described here as Assumption 1) show that many side streets would be heavily loaded, some side streets would have very high volume-capacity ratios would be experienced by all vehicles in the system Assumption 1 however excludes basic consequences of car restriction in Tunalı Hilmi Street: beside the decrease of the time spent in the system, with the closing of this street to private vehicle traffic, the street stops being a transit path for through traffic. This is an unavoidable side effect of closing Tunalı Hilmi Street to private vehicle traffic. In fact, this is also one of the arguments for restricting car traffic in Tunalı Hilmi Street since such a high street with commercial and leisure activities in the city center should not be used by through traffic as a transit route.

The second assumption therefore includes the possible consequence of car access control in Tunalı Hilmi Street and omits all the through traffic that use Tunalı Hilmi Street as a transit route. This assumption shows that actually travel time spent in the system would become less than the previous one. However, there is still high volume on some of the streets that can cause congestion in both inside and outside of the area. But it should also be noted that apart from the Büklüm Sokak case, the residential side streets are not as loaded as would be expected. The streets that have high volume-capacity ratio, i.e. congested are Esat and Tahran Streets, all of which have more connector street characteristics, rather than being residential local streets. This is also an interesting outcome, showing that although the area comprises of many residential local streets, due to the limited continuity and directness of these local streets, diverted traffic is not likely to end up in these small side streets.

Although the Second assumption provides some advantages and improvements due to the elimination of through traffic from the area, a third assumption was developed in order to see the effects of creating a pro-pedestrian and transit-friendly environment of travel behavior and car usage. As described before, it was assumed that the overall vehicular traffic that arrives here (excluding the through traffic) would fall by 20 % since car drivers would decide to come here by public transport or walking as the area is not very convenient to come by private cars any more. Obviously, this assumption is the best when all advantages and disadvantages are considered. First of all system travel time is almost half of the previous assumption. Inside of the study area, almost all links have lower volume than existing situation. The only problem still existing in spite of the car traffic reduction in this assumption is Tahran Street. The street still has to accommodate additional vehicles.

In the fourth assumption, which incorporates parking restrictions on all streets and therefore eliminates on-street parking, there are both advantages and disadvantages. Although it has the lowest value of volume-capacity ratio and it is absolutely certain that traffic is fluent, application of this assumption is arguable. Tunalı Hilmi Street has a high density residential area with limited parking space. Therefore restriction of street parking may negatively affect residents living there. Considering that the time gain from this assumption is not significant, it is ideal to consider this option cautiously, and perhaps implement a resident-only parking scheme that may eliminate parking in some streets or sections only.

To summarize, it seems to be possible to implement a car access control policy in Tunalı Hilmi Street without having negative traffic consequences, such as diverted traffic, in local residential side streets. A policy that allows only public transport buses along Tunalı Hilmi Street would result in the elimination of through traffic here and even on its own this results in a slight relief of congestion in most links, although there are some connector streets that continue suffering from congestion, but most of them are not higher than the base case assumption, i.e. the existing situation. Furthermore, if one considers that the reallocation of space away from the cars to public transport would result in a reduction in car trips to this area, the traffic effects of this car access control policy in Tunalı Hilmi Street become almost negligible. Further schemes of travel demand management, such as parking control or parking price increases may result in further reductions in car traffic and may also be considered, although it is important to ensure that as a result of these the area does not become an unattractive and inconvenient place to visit. Hence further schemes to improve public transport service levels, pedestrian conditions, etc. may help more people use these modes and hence result in further reductions in car usage.

CHAPTER 6

CONCLUSION

6.1. Summary of research

The focus of this study has been the implementation of Travel Demand Management policies in city centers in general, and car access control measures in particular. It has been described and illustrated through case studies instead of increasing road capacities to meet the ever-increasing demand for car usage in cities, local authorities in the world that now opt for solutions that restrict car movements in city centers with a view to make public transport, walking and biking more viable options when travelling to city centers. There are many examples in the world, where cities implement pedestrianization projects or convert their main boulevards to pedestrian and transit-only corridors. In Turkey in Ankara too, a possible pedestrianization of a city center street, Tunalı Hilmi Street, has been on the agenda for decades. In 1990, a temporary implementation was carried out but was not continued. Since then, pedestrianization of this street has been defended by some since it is a high street with many shopping and leisure activities creating dense pedestrian activity. On the other hand, possible negative effects of such pedestrianization on residential local side streets have been a major concern preventing any action for car access control schemes at this area.

Therefore, the analyses carried out in this study aimed at exploring possible effects of transforming the Tunalı Hilmi Street in Ankara into a pedestrian and transit-only street. This meant that only public transport buses would be allowed into the street while the entry of other motorized vehicles into the street restricted. Amongst the main aims of the study, it was intended to use and demonstrate traffic count and simulation methods as a decision-making tool that can help evaluate possible consequences of traffic and travel demand management techniques. Therefore, firstly the current situation in Tunalı Hilmi Street was analyzed through traffic counts focusing on through traffic as well as the traffic that originate from within the neighborhood and the traffic that has its final destination within the neighborhood. By identifying the components of different traffic, a simulation was made to try and test possible effects of converting the street into a transit-only corridor. Various assumptions were made and each one was tried with this simulation technique in order to provide policy alternatives that can support this transit-only corridor scheme in Tunalı Hilmi Street.

When car access control policies were implemented in the case of Tunalı Hilmi Street, the main question was whether the alternative roads would be capable of supplying for the demand after the closure of Tunalı Hilmi Street to private vehicles, and whether local residential side streets would be negatively affected to the diverted traffic.

In order to answer these questions and to test the traffic effects of car access control policy in Tunalı Hilmi Street, four assumptions were identified.

Assumption 1: In this assumption, it was assumed that the existing demand, i.e. the existing level of traffic would not change at all in spite of the closing of Tunalı Hilmi Street to vehicular traffic (except for public transport buses) and so the simulation was made by distributing all the existing demand to the alternative.

Assumption 2: It was discussed that in fact the above assumption 1 was not realistic because the closure of Tunalı Hilmi Street for private vehicles would mean that this street is not a transit route for through traffic any more. Therefore, in assumption 2 it was assumed that through traffic (those who only pass through) using Tunalı Hilmi Street as a transit road would have to choose an alternative route since this area does not offer them a direct through route any more and therefore the through traffic was eliminated in the assumption and the remaining demand was distributed.

Assumption 3: As discussed in earlier chapters of the study, car access control policies, including pedestrianization and creation of a transit-only corridor are also likely to discourage more people to use their private cars. Therefore in assumption 3, beside the elimination of through traffic, a further 20% reduction was assumed in private vehicle numbers as a result of the new character of the area, which is transit-friendly and not car-oriented any more. The remaining demand was distributed with the simulation tool.

Assumption 4: In this assumption a further step was assumed: It was discussed that a better car parking control and enforcement in the side streets can help eliminate the usage of two lanes (on both sides) of streets for parking and hence side streets' capacity may be slightly improved while car access is restricted in Tunalı Hilmi Street. Although the implementation of this assumption is arguable because of the parking requirement of residential areas here, this assumption was also tested to observe whether a strict parking ban and enforcement would make significant improvement in traffic conditions.

In order to set up the simulation model, first of all the existing situation was analyzed. By vehicle plate number tracking method and parking surveys, all the behavior of vehicles that enter, exit or stay in the area were observed. With this information, and Origin-Destination (O-D) matrix was obtained. This data was entered into simulation program and the existing volume and volume-capacity ratio of all links were seen. Car access policy scenario and related assumptions were then tested by closing Tunalı Hilmi Street to vehicle traffic. However the testing of the assumption could not be made without making certain changes to existing street directions. As a result, the street directions were studies and redesigned.

6.2. Research findings

In all the assumptions Tunalı Hilmi Street was closed to private vehicle traffic. With this action, it became necessary to change some street directions as well, as mentioned above. In addition, it was found that Bestekar Street would also have to be pedestrianized within this scheme because the street functions almost only with vehicular traffic that it takes from Tunalı Hilmi Street. When Tunalı Hilmi Street is closed private vehicle traffic, Bestekar Street may also be closed to traffic since it stops carrying traffic. This street was also pedestrianized in all of the assumptions as a result.

The simulations showed that if decision makers consider converting Tunalı Hilmi Street into a pedestrian and transit-only corridor, the initial traffic simulations (described here as assumption 1) indicate that many side streets would be heavily loaded, some side streets would have high volumes. However, besides decreasing the total system travel time, as described before, assumption 1 excludes the basic consequences of car restriction in Tunalı Hilmi Street: with the closing of this street to private vehicle traffic, the street stops being a transit path for through traffic. This is an unavoidable side effect of closing Tunalı Hilmi Street to private vehicle traffic. In fact, this is also one of the arguments for restricting car traffic in Tunalı Hilmi Street since such a high street with commercial and leisure activities in the city center should not be used by through traffic as a transit route.

The second assumption, which omitted all the through traffic that use Tunalı Hilmi Street as a transit route, showed that travel time spent in the system would in fact become 49 hours less than the first assumption. This is a significant finding, showing that travel conditions in Tunalı Hilmi Street, which is an important shopping and leisure street of Ankara city center, can be improved if this street is not used as a transit path for accessing from the south-eastern part of the city to the city center.

In spite of the time savings, there was still high volume on some of the streets under assumption 2, which can cause congestion in outside of the area. It is interesting to note however, that apart from one side street, the local residential side streets were not as loaded as would be expected. The streets that have high volume-capacity ratio, i.e. congested, were those that have connector street characteristics, rather than being residential local streets. This is an interesting and positive outcome, showing that although the area comprises of many residential local streets, due to the limited continuity and directness of these local streets, diverted traffic is not likely to end up in these small side streets.

The Third assumption, which was developed to see the effects of creating a pro-pedestrian and transit-friendly environment on travel behavior and car usage, showed that if overall vehicular traffic in this area fell by 20 % (due to inconvenience of using a car in this pedestrian and transit-only corridor and its surroundings), total system travel time would be decrease to the 160 hours. This would certainly be a very significant improvement. In addition, inside of the study area, almost all links had lower volumes than the existing situation, with only a few exceptions.

In the fourth assumption, which incorporated parking restrictions on all streets and therefore eliminated on-street parking, there were both advantages and disadvantages. Although it had the lowest value of volume-capacity ratio and it was certain that traffic is fluent, application of this assumption is arguable. Tunalı Hilmi Street has a high density residential area with limited parking space. Therefore restriction of street parking may negatively affect residents living there. Another important aspect is that the time gain in this assumption was not as significant: Only an additional 20 hours was gained on top of the time savings of assumption 3. Considering that the time gain from this assumption is not as significant, it is ideal to consider this option cautiously, and perhaps implement a scheme that may eliminate parking only in some streets or sections while keeping resident-only parking opportunities on other streets and sections.

6.3. Concluding remarks

The simulation program showed that it is possible to implement a car access control policy in Tunalı Hilmi Street without having negative traffic consequences, such as diverted traffic, in local residential side streets. A policy that allows only public transport buses along Tunalı Hilmi Street would result in the elimination of through traffic here and even on its own this results in a slight relief of congestion in most links, although there are some connector streets that continue suffering from congestion, but not higher than the base case assumption, i.e. the existing situation. Furthermore, if one considers that the reallocation of space away from the cars to public transport would result in a reduction in car trips to this area, the traffic effects of this car access control policy in Tunalı Hilmi Street become almost negligible. Further schemes of travel demand management, such as parking control or parking price increases may result in further reductions in car traffic and may also be considered, although it is important to ensure that as a result of these the area does not become an unattractive and inconvenient place to visit. Hence further schemes to improve public transport service levels, pedestrian conditions, etc. may help more people use these modes and hence result in further reductions in car usage.

Apart from the assumptions that were developed and tested here, there can be many other alternatives. First of all, the quality of public transportation service can affect the demand significantly. Light rail, such as tram systems, may be offered or bus service may be more frequent in the area. The price and integrated ticketing on public transportation is also important.

Beside public transportation, bike roads may be offered as a transportation mode. A connection to the city center with bike roads and pedestrian continuity encourage people to leave their private cars and accordingly demand in this area may decrease.

Parking policy is also one of the most important applications in demand management, and this also true for Tunalı Hilmi Area, because street parking in this area decreases the capacity of the streets. Therefore, some streets may be restricted to parking; street parking may be charged for the vehicles not belonging to the residents in the area or car-parks may be built outside the central city at public transport stations while parking in the city center is made significantly more expensive. The literature also showed that congestion charging could be an option, but only after public transport alternatives are significantly improved and access by public transport is comfortable and convenient. All these policies may be considered for further studies; and it should be noted that for an accurate estimation of the effects of pricing policies, such as public transport ticket prices, parking prices and congestion charging, a comprehensive study would have to be made to identify price elasticity.

A more general outcome of this research is to do with the use of traffic simulation models and program in planning. It has been demonstrated that these models can become effective decision making tools as they can illustrate the effects of any planning decision on traffic and transport system. With the use of simulation approach, the effects and relative gains (such as time savings) of each scheme can be analyzed and calculated, which can help formulate effective and appropriate policies in transport and urban planning.

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