THE LINK BETWEEN STATION AREA DESIGN AND TRANSIT USAGE:
THE CASE OF ANKARA

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ABSTRACT

THE LINK BETWEEN STATION AREA DESIGN AND TRANSIT USAGE: THE CASE OF ANKARA

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Investments in rail systems have been increasing throughout the world. This is mainly because public transport is considered to be a sustainable transport mode and the only viable alternative to the car in most urban areas where journeys are too long to be made by non-motorized modes of transport, such as walking and cycling. Amongst public transport modes, urban rail systems are particularly favored by planners since it is believed that rail systems can be effective in attracting car users to public transport. However, an urban rail investment may not be sufficient alone to influence travel behavior and choice of mode. There are many studies that argue that the most powerful tool to change people's travel behavior is by urban planning and urban design. Urban form can make people dependent on car-usage or it can encourage the usage of sustainable modes of transport. Investing in public transit infrastructure is not enough to create a shift towards public transport; such an investment has to be complemented by urban design strategies that create public-transport friendly and walkable urban environments with a view to foster the use of these modes.

Studies that review the performance of urban rail systems also support the above argument. These studies generally result in two propositions: firstly, these investments should be supported by transport policies that restrict car usage in cities while improving public transport; and secondly these investments should be supported with land-use planning and urban design policies in order to reduce car-

dependency and create neighborhood development patterns that support more usage of public transport..

Resting on these two vast areas of research in the literature, this study builds on the argument that certain land-use planning approaches and urban design strategies are required to make the vicinity of transit stations less car-dependent, more walkable and more transit-friendly in order to increase public transport usage. The study aims at understanding the link between station area design and transit usage. The analysis focuses on Ankara and intends to find out the extent to which the built environments around selected Ankara Metro and Ankaray transit stations are “transit encouraging” neighborhoods and whether there is a link between station-area design and the usage of these urban rail stations.

In the literature, density, diversity and connectivity are found to be essential factors in increasing the usage of particular rail transit stations. From this point of view, in the study these parameters have been analyzed in three different scales as macro (Ankara), meso (existing rail transit corridors) and micro (selected rail transit station areas). Principally, the link between station area design and the transit usage is assessed in the study.

It is found that in the context of Ankara, while connectivity seems to have an effect of transit usage for the suburban development corridor that the Ankara Metro serves, overall, spatial parameters are not able to explain the differences in the usage of stations, and that public transport integration is the most important factor that affects the usage of rail transit systems in Ankara. It is also found that context specific results, i.e. the findings for the Metro and Ankaray corridor separately, have been different than the overall analysis results and hence the analysis of each corridor separately would give more insights about the systems and their relation with the urban environment. Nevertheless, the study shows that density is an important factor in newly developing areas to support urban rail usage, as would be expected, and that connectivity parameters such as lighting, interface with parking, ease of pedestrian crossing, landscaping, flat terrain, and sidewalks should be well developed in the

suburban. Above all, integrated transport policies should be well planned and implemented throughout the city.

Keywords: Public transport, Transit station area design, Ridership, Ankara Metro, Ankaray

ÖZ

RAYLI SİSTEM İSTASYON ÇEVRESİ TASARIMI İLE İSTASYON KULLANIMLARI ARASINDAKİ İLİŞKİ: ANKARA KENTİ ÖRNEĞİ

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Dünyada, raylı sistemlere yapılan yatırımlar gün geçtikte artmaktadır. Bunun en büyük nedeni toplu taşın sistemlerinin sürdürülebilir ulaşım modları içerisinde yer alması ve özel araç sahipliğini aza indirecek en iyi alternatifi oluşturmasıdır. Plancılar için raylı sistem yatırımları diğer toplu taşın sistemleri içerisinde en çok tercih edilenidir. Raylı sistemin özel araç sahiplerini toplu ulaşıma çekme gücünün yüksek olduğuna inanılmaktadır.

İnsanların yolculuk davranışlarını değiştirmek için en güçlü aracın kent planlaması ve kentsel tasarım olduğunu tartışan çalışmalar yapılmıştır. Kent formu insanı özel araç kullanımına itebilmekte ya da daha sürdürülebilir modları kullanmayı teşvik edebilmektedir. Ancak, sadece toplu taşın sistemlerine yatırım yapmak yeterli olmamakta, bu yatırımların toplu taşın sistemlerinin kullanımını artıracak kentsel tasarım parametreleriyle beslenmesi gerekmektedir. Bu parametreler, toplu taşın, yaya ve bisiklet dostu kent formları incelenerek ortaya çıkarılabilir.

Bunlara ek olarak, raylı sistem yatırımlarının performanslarını inceleyen çalışmalar da bulunmaktadır. Bu çalışmalar genellikle iki önermede bulunur: Birincisi, bu yatırımlar özel araç kullanımını sınırlayacak politikalarla desteklenmeli, toplu taşın sistemleri geliştirilmelidir. İkinci ise, bu yatırımlar arazi kullanımı ve kentsel tasarım politikaları ile desteklenerek istasyon çevrelerinin kullanımı artırılmalı, toplu taşın

kullanımını teşvik edecek, insanları yürümeye sevk edecek mahalleler tasarlanmalıdır.

Bu çalışmada ikinci argümandan yola çıkılarak istasyon kullanımını artıracak, özel araç sahipliğini azaltacak, toplu taşın ve motorsuz ulaşım modlarını kullanmaya teşvik edecek mekânsal parametreler ortaya çıkarılarak seçilen Ankara Metro ve Ankaray istasyonlarının çevrelerinin bu parametrelere göre "iyi tasarlanmış" mahalleler olup olmadığı araştırılacak, istasyon kullanımı ile ilişkileri ortaya çıkarılacaktır.

Literatürde, yoğunluk, farklı kullanımların bir arada bulunması ve bağlantısallık parametreleri istasyon kullanımını artırıcı temel unsurlar olarak karşımıza çıkmaktadır. Buradan hareketle, söz konusu koşullar üç farklı ölçekte incelenmiştir: makro (Ankara), meso (mevcuttaki raylı system koridorları) ve mikro (seçilmiş olan istasyon çevreleri). Ankara özelinde toplu taşın sistemlerinin entegrasyonu ve altyapının oluşturulması hususunun önemli bir yer teşkil etmesi nedeniyle söz konusu unsur da analizlere dahil edilmiştir. Çalışmada esas olarak söz konusu parametreler ile yolcu sayıları arasındaki ilişki incelenmiştir.

Sonuç olarak, bağlama özgü analizlerin genel analizlerden farklı sonuçlar ortaya çıkardığı (Ankara Metro ve Ankaray için ayrı ayrı analizler yapıldığında) ve sistemler ile yapılı çevreleri arasındaki ilişkiye dair daha anlamlı bilgiler elde edilmesini sağladığı görülmüştür. Ayrıca, yeni gelişen bölgelerde raylı system kullanımlarını etkileyen önemli bir etken yoğunluk olmakla birlikte, aydınlatma, park alanları, yaya geçitleri, peyzaj, eğim, kaldırım gibi bağlantısallığı etkileyici hususların göz önünde bulundurulması gerekmektedir. Esas olarak ise, entegre ulaşım politikalarının tüm kent için oluşturulmasının ve uygulanmasının önemi ortaya çıkmaktadır.

Anahtar kelimeler: Toplu taşıma, Raylı system istasyon çevresi tasarımı, Yolcu sayısı, Ankara Metro, Ankaray

To my baby

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CHAPTER 1

INTRODUCTION

There are many studies that argue that the most powerful tool to change people's travel behavior is by urban planning and urban design. Urban form can make people dependent on car-usage or it can encourage sustainable mobility. Investing on public transit infrastructure may not be sufficient enough to change citizens' travel behavior. It has to be complemented by urban design strategies that would foster the use of these modes. Neighborhood scale (community level and building level) planning and design approaches, such as density, diversity, connectivity, etc., are crucial in creating urban environments that are less dependent on cars. These urban design parameters can be revealed by analyzing public transit, pedestrian and cycle friendly urban forms. Building transit stations does not necessarily create more public-transport-friendly, walkable and bicycle-friendly urban environments; and hence supportive policies of planning and design are needed in order to foster citizens to use these modes.

Investments in rail systems have been increasing throughout the world. This is mainly because public transport is considered to be a sustainable transport mode and the only viable alternative to the car in most urban areas where journeys are too long to be made by non-motorized modes of transport, such as walking and cycling. Amongst public transport modes, urban rail systems are particularly favored by planners since it is believed that rail systems can be more effective in attracting car users to public transport. Rail transit investments have long lasting effects on economic, social and physical life of the cities where the fixed infrastructure result in permanent changes in urban areas.

There are many studies that review the performance of urban rail systems, particularly the factors behind the success of these systems in passenger ridership levels. Such studies generally result in two propositions: firstly, these investments should be supported by transport policies that can restrict car usage in cities while improving public transport; and secondly these investments should be supported with land-use planning and urban design policies in order to make the urban neighborhoods around transit stations more public-transport friendly and more walkable as opposed to the prevailing car-dependent neighborhood development trends. This study focuses mainly on the latter argument, and combines it with the findings of the literature on the effects of built-environment on travel behavior. Hence, it builds on the argument that land-use planning approaches and urban design strategies are required in order to make the vicinity of transit stations less car-dependent, more walkable and more transit-friendly if public transport usage is to be increased. The study aims at understanding the link between station area design and transit usage. The analysis focuses on Ankara and intends to find out the extent to which the built environments around selected Ankara Metro and Ankaray (LRT) transit stations are "transit encouraging" neighborhoods and whether there is a link between station-area design and the usage of these urban rail stations. Consequently, the main research questions are as follows:

- Is there a link between the neighborhood design around transit stations and the usage of that particular transit station?
- Which planning and design parameters are particularly important in fostering people to use the transit system? In other words, with which parameters can we define a "transit encouraging urban environment" that can encourage people to use more public transport?
- Is a frequently used station also a transit station with a "transit encouraging environment"?

Sub-questions are developed regarding the case study area, which is Ankara and its urban rail transit stations. Following questions are asked:

- What are the spatial parameters of the selected transit station areas?
- Is there a clear link between these and the use of the transit stations? In other words, do the urban design characteristics in the vicinity of selected transit stations have any effect on the use of rail systems?

In the rest of the study, first a general overview will be provided regarding the current trends in urban transport, which appear to be car-dependent and extremely unsustainable. Then universally accepted policies for making transport more sustainable will be described, and the role of public transport investments in these policies will be highlighted. Sustainable transport is defined with a particular focus on the strategy to 'shift' urban trips from the automobile to public transport. While public transport investments have become main tools for a less car-dependent urban transport system, their usage can only be increased if they are supported with car-restriction measures and urban planning and design policies that can alter travel behavior. Hence, the next chapter deals with the role of public transport systems for sustainable transport. After this more general review of the topic, specific planning movements, such as New Urbanism, Transit-Oriented Design (TOD) and so on will be presented, and the review will conclude with a list of spatial parameters that can help increase transit usage.

The study will then propose a rationale and method of study that can test these spatial parameters with a view to assess the link between station area design and transit usage. Research proposel is described and the aim of the study is clarified. Methods of analysis and data collection are given.

In the case-study analysis chapters, the research is carried out according to three different scales: macro, meso and micro. In the macro scale analysis, a descriptive analysis is performed. Spatial growth patterns, density, macro-scale diversity and accessibility and connectivity parameters are analyzed for the whole city of Ankara.

Regarding the meso scale, the two urban rail corridors are analyzed. A descriptive analysis is carried out by analyzing density (residential and employment), diversity (variety of uses and dominant use) and accessibility/connectivity (node index). Then the micro scale analysis, which is the fundamental focus of this study, is carried out using three different approaches. Firstly, a land use analysis is made revealing the characteristics of each station area, and certain measures for defining the built environment. Secondly, for each measure (density, diversity and connectivity/accessibility) calculations are made. Finally, qualitative (ranking) and quantitative (single-factor and multivariate regression) analysis are made in order to identify whether there is a link between these station-area design measures and the usage of urban rail systems

In the conclusion chapter, the research is summarized and the main findings are described. The findings of the research provide a better understanding in linking the built-environment characteristics with the usage of rail transit systems. It also reveals context specific results regarding Ankara, which may provide lessons for other cities in Turkey as well as developing country cities that have similar urban characteristics.

CHAPTER 2

ROLE OF PLANNING AND URBAN DESIGN IN CREATING TRANSIT-FRIENDLY URBAN ENVIRONMENTS

2.1. Shift to Sustainable Transport Policies

It is a known fact that there is a strong bond between the physical form and the way the people can have access to the services they need. Changes in the physical form may take a long time, but major changes in certain locations may lead to major travel pattern changes. In this respect, how we deliver urban forms has a contribution to sustainable urban environments (Williams, 2005).

Sustainability deals with the way we live. It recommends new relations of us with the nature. That is why it is a complex phenomenon (Neuman, 2005; Bayramoğlu, 2011). However, there is not a single definition for sustainability. Çalışkan (2004) argued that this vagueness opens the way for this urban planning to create more concrete design and planning principles. He proposed to formulate "key formulations on sustainability" in order to provide "solid-based solutions to actualize the sustainability ideal" (Çalışkan, 2004).

- ✓ In the Brundtland Report (1987), sustainable development is defined for the first time as "development that meets the needs of the present without compromising the needs of future generations to meet their own needs."

- ✓ Sustainable transport is defined as "transportation services that reflect the full social and environmental costs of their provision; that respect carrying capacity; and that balance the needs for mobility and safety with the needs for access, environmental quality, and neighborhood livability (Jabareen, 2006).
- ✓ "European Union Council of Ministers describe sustainable transport system as one that (Williams, 2005, p.4):
    - allows the basic access and development needs of individuals, companies and society to be met safely and in a manner consistent with human and ecosystem health, and promotes equity within and between successive generations.
    - is affordable, operates fairly and efficiently, offers a choice of transport mode, and supports a competitive economy, as well as balanced regional development.
    - limits emissions and waste within the planet's ability to absorb them, uses renewable resources at or below the rates of development of renewable substitutes, while minimizing the impact on the use of land and the generation of noise."

Automobile dependence results in environmental, economic and social problems (Table 1). The external costs from accidents and congestion costs are harmful to the human health. It also affects the quality of life in the city. There is continuous road building in the cities as the new suburbs are emerging. This causes loss of agricultural land and loss of time (because of the sprawl and traffic congestion and continuously increasing distances).

Table 1 Problems of automobile dependence

Environmental	Economic	Social
Oil vulnerability Photochemical smog Lead, benzene High greenhouse gas contributions Urban sprawl Traffic problems	External costs from accidents Pollution, health impacts Congestion costs High infrastructure costs in new sprawl suburbs Loss of productive rural land Loss of urban land to bitumen Loss of time	Loss of street life Loss of community Loss of public safety Isolation in remote suburbs Access problems for the carless and those with disabilities

Source: Newman and Kenworthy, 1996

Automobile dependence also causes environmental problems. It was 2006 that the world's urban population exceeded the rural population for the first time in history. This urban population growth resulted in urban sprawl as well as slum areas in the cities. The sprawl has put pressure on the existing transport networks and made walking and cycling difficult. It also encouraged private car ownership as the distances increased in the city. This resulted in increasing traffic congestion, decreasing road safety and increasing emissions from the cars (UNDP&GEF, 2006).

The sprawl also changes the way we live in the city. The meaning of the street is changing. It becomes more of a transit route rather than a socialization place for the people. The people living in the suburbs are isolated from the rest of the city. The investments for the road infrastructure to these suburbs encourage people to use private cars rather than public transit networks. Public transit services are not frequent, and this causes access problems for the carless and people with disabilities (Newman and Kenworthy, 1996).

In conventional planning, transport is assumed to be linear. This approach puts the stress on the faster modes (Figure 1). The other modes are seen old, slow and unimportant. This inevitably increases automobile dependence and causes problems to the public transit and non-motorized transport users. Under the conventional planning, as described above, streets are defined by the degree in which they serve to the automobiles. This is a functional classification. In this approach, streets for through movements are called the arterials, streets designed for access are called locals and those in between are called the collectors (Tumlin, 2012).

Walk → Bicycle → Train → Bus → Automobile → **Improved automobiles**

Figure 1 Conventional transport planning approach
Source: Adopted from Litman and Burwell, 2006

However, in the sustainable model this linearity disappears (Figure 2). This model assumes each mode useful and emphasizes the balance between these modes and an increase in public transport and non-motorized transport systems (Litman and Burwell, 2006). In the sustainable model, streets are defined with automobiles throughout with pedestrian or cyclist safety and comfort. In this respect, the classification should take into account the land use context and other properties (Tumlin, 2012).

Walk → Improved walking conditions **Bicycle** → Improved cycling conditions **Train/Bus** → Improved public transit service **Automobile** → Reduce the need to travel

Figure 2 Sustainable transport planning approach
Source: Adopted from Litman and Burwell, 2006

Therefore, in the transport planning process it is also important to improve the existing modes (not just avoiding the old ones). It is a similar approach in most of the cities to improve walking; cycling and public transit systems and restrict automobile travel in the congested areas. In this respect, improved transport does not only mean to increase travel; it only means increased comfort and safety, not faster travel or reduce the need to travel (Litman and Burwell, 2006; Litman, 2014).

Transport planning is a challenging issue due to its complex nature especially when environmental challenges need to be tackled. Social, economic and political forces are resolved through management and technology in designing the streets and corridors to supply safe access to people and goods. Therefore, sustainable transportation systems are becoming necessary in the urban areas (Kennedy et al., 2005). The current trends are not encouraging sustainable transport policies. Car ownership rates are increasing rapidly, faster than economic growth (Goldman, Gorham, 2006). Transport consumes energy, human and ecological habitats, individual’s time, and produces emissions. That is why, it is important to analyze “sustainability” in the transportation context. In the following sections, policies for making urban transport more sustainable will be discussed.

As being the second largest source of greenhouse gases after electricity and heat generation, transport sector is responsible for 20% to 30% of the CO_2 emissions (Babalık-Sutcliffe, 2010). Road transport produces 76% of transport CO_2. Air travel produces around 12% of transport CO_2 emissions. According to European Commission Directorate General for Climate Action:

“Transport is responsible for around a quarter of EU greenhouse gas emissions making it the second biggest greenhouse gas emitting sector after energy. Road transport alone contributes about one-fifth of the EU's total emissions of carbon dioxide (CO2), the main greenhouse gas. While emissions from other sectors are generally falling, those from transport have increased 36% since 1990.” (Retrieved from http://ec.europa.eu/clima/policies/transport/index_en.htm on 27.11.2012)

Today, industrialized countries are the main sources of transport emissions. However China, India and Indonesia are rapidly growing and this also increases the CO_2

emissions in those countries. It is projected that the emissions from transport sector would increase by 140% from 2000 to 2050 with the increase of these developing countries and that clearly this cannot be sustained. And hence current state of transport is far from being sustainable (Dalkmann and Brannigan, 2007).

2.2. Policies for making urban transport more sustainable

2.2.1. Clean energies

In the growing pattern of unsustainable transport systems, technology offers new possibilities for changes in the long run (Jolley, 2006). Hybrid and electric cars, biofuels and new technologies help to increase the efficiency of the vehicles and reduce emissions. Hybrid cars use a combination of petrol engine and an electric motor. They do not need to be plugged because their batteries are charged while driving. Electric cars have rechargeable batteries and electric motors providing a sustainable option. They do not release any emissions. Biofuels are produced from wood, staw, wastes and other substances (www.eeca.govt.nz).

Renewable energy technologies are also developing and becoming competitive in the market. Hydroelectric, solar, wind or hydrogen fuel systems are used in transport technologies with almost zero emissions. These technologies are also becoming important in macro policies such as European Union policies. There is a special directive on the issue called the "Directive on the Promotion of Clean and Energy Efficient Road Transport Vehicles". It aims to develop an environment-friendly vehicle market including the public transit sector (Retrieved from http://ec.europa.eu/transport/urban/vehicles/clean_energy_efficient_vehicles_en.htm on 10.10.2011).

To a certain extent new technology would reduce the environmental impacts of transport sector, however there are some areas that solely technology would not be the single solution and that technology is uncertain about. Congestion and traffic reduction is one of these areas. Car-dependent styles lead to urban sprawl and hence over-consumption of agricultural and natural land. Consequently, conversion of natural land to asphalt urges planners to reduce private automobile usage.

There are certain technologies that would be useful in the local scale, but more substantial changes need a longer time that would help the planners to reach the ultimate goal of reducing car usage and making urban transport more sustainable (Geerlings and Gwilliam, 1994). In this respect, car restriction policies also become crucial and these policies will be discussed in the following section.

2.2.2. Restriction of automobiles

Most developed countries are increasingly dependent on cars. Along with that dependence, unsustainable traffic growth patterns come up resulting in both economic, social and environmental problems. Besides, current road schemes are not adequate to solve this problem.

Thus, there has been an interest on the environmental consequences of the unsustainable traffic growth patterns. It is argued that the effective way to improve the transportation system is to reduce the car usage (Banister, D., 2000). According to Goodwin (2001), the new trends give weight to more sustainable patterns emphasizing environmental issues, economic efficiency, and safety and so on. Five developments are listed in his study promoting the reduction in car usage:

1. Town center pedestrianism:

It is becoming popular in most of the European countries to have a "good-quality-pedestrian-space" in the city center[1]. They provide cultural and commercial facilities.

2. Residential area traffic calming:

Speed humps of different sizes, chicanes, culs-de sac, road surfaces, street furniture, signs, trees and plants and so on.

3. National parks and tourist attraction:

Restricted parking availability, restrictions on use of particularly intrusive vehicles, encouragement of access by tourist coaches rather than cars, provision of guided tours and walking.

4. Transport pricing: parking, fuel taxes and road user charges:

Transport pricing approach may be in two forms. The first is to "get the prices right": in cases where travel is currently undercharged, introduction of any form of pricing, i.e. charging, will result in a reduction in traffic". The second is to "decide how much traffic we want, and then use prices to achieve it".

It is also common that pricing policies are combined with parking policies reducing the need to use private cars. Traffic is affected by the increasing fuel prices whether it is aimed to reduce the traffic or it is the side effect of the increased price.

5. Improvements in alternatives:

It is very common to reduce traffic levels by making the alternative transport modes more attractive. New light rail systems, bus priority systems, new cycle lanes, pedestrian lanes, park-and-ride facilities are some examples of these alternatives (Goodwin, 2001).

[1] In some larger districts public transit systems are also provided that could enter into restricted streets or lorries are allowed in determined time periods (mostly in the early mornings). Also in some other cities there are "inner ring roads" providing a pathway for the displaced traffic.

“Carrots” and “carrots and sticks” are the two different groups of these approaches. In the carrots the alternatives are improved whereas the attractiveness of the car usage remains the same. In the carrots and sticks approach, restrictions on the car usage is mixed and supported with public transit or non-motorized transport policies. In the second approach there is usually a reduction in the traffic levels.

Saelens et al. (2003) argued that car dependency can also be reduced by arranging activities in a proximate way. Proximity is defined with two variables in Saelens’ study as density or compactness and land use mix. It is claimed that when the person lives in a denser area with more activities, it would encourage him/her to walk in order to get to work, go shopping or go home. In a more proximate area, there would be good connections between the activities to ease the movement between origins and destinations. However, nowadays most of the modern development has single uses separated from the other parts of the city, encouraging private car usage.

It is also argued that a grid pattern would increase connectivity and offer different route alternatives to the same destination. In contrast, the new modern suburban areas are characterized by low connectivity, few route alternatives and few activity options.

However, all these car restriction policies should be integrated with alternative modes. The two alternatives to private automobiles: non-motorized transport modes (cycling, walking) and public transport modes will be discussed in the following section.

2.2.3. Development and encouragement of non-motorized transport

Land use planning has the leading role in reducing the need to travel and providing better conditions for environment-friendly transport modes. It is assumed that when the activities are separated from each other, travel needs are becoming higher. In order to lower the need of travel, the activities should be close to each other promoting walking and cycling (environment-friendly transport modes). The connected street layout, mixed land use, higher densities are argued in the literature to decrease the private car usage in favor of non-motorized modes and public transport (Jabareen, 2006).

In everyday life, we use any kind of transportation system for going to school, work, shopping or seeing friends. Using the proper mode is essential in people's lives. In a study by Saelens et al. (2003), it is found that approximately 83% of all trips starting from the origin to its destination are short and it is relatively close to home.

Through the centuries, walking has been the major transport mode. It was the beginning of the 19th century that bicycle had developed and it needed 80 years to have a position in the transportation system with its quality and comfort. In the 1950s, cars became dominant in the industrialized countries. At this time, bicycle and walking lost their importance. They became recreational activities, but some exceptions were in the Northern Europe. Also in China and India, the bicycle played an important role in personal travel (Rietveld, 2001).

The growing trend in car usage helped to save time and provide comfort leading to a shift from non-motorized transport modes to private cars. Additionally, urban sprawl and low density urban areas promoted car usage (Rietveld, 2001).

Non-motorized transport modes are usually underestimated in transport statistics. However, they are the essential elements in multi modal transport systems. People walk to or from the parking place, bus stop or the railway station. When the share of bicycles and walking is included to the total trips, the number of trips becomes higher. In Netherlands, average number of trips is 3,7 without including walking and biking. This number rises to 7,5 per person per day when these trips are included (Rietveld, 2001). Bicycle transformed Amsterdam, where it is the most widely used transport mode (Crawford, 2009).

It is also effective to integrate different modes of public transit systems. In Germany, these services are also well integrated with walking and cycling facilities. There are extensive bike parking areas at the rail and metro stations and bus stops. Whereas in

US, most of the metropolitan areas have transit authorities but there is a lack of coordination between them. Most of the rail stations are not in walking or cycling distances either. There are economical weekly, monthly, annual or semester tickets. They provide discounts of 60% for adults and 75% for the high school and university students (Buehler et. al., 2009). It should be noted that fostering the use of public transit systems should be complemented by these policies that would help the public transit systems to become competitive with private cars.

It is important not to forget the positive aspects of walking and cycling although they are low speed, they need physical effort and they are not as comfortable as the other transport modes such as public transit systems or private cars. They provide door-to-door access. While walking or using bicycles, you do not wait at the stops as it is the case in public transport modes where the passengers spend most of their times. They are environment-friendly and healthy activities. Additional properties are given in Table 2.

For certain conditions walking and cycling are reasons for preference such as environmental protection, economical and health benefits, direct access, low energy consumption and so on. On the other hand, for the long distance trips, bad weather conditions, traffic compatibility, change in elevation and so on, other options such as public transport and private cars are preferable (Grava, 2002).

An adult would walk in a speed of 76 m/min which is rational for most purposes. Of course it would vary from person to person and time to time. Crawford (2009) claims that five-minute walk is acceptable in getting to public transit system or meeting daily needs. He suggests a “Reference District” where a district radius of 380 m is accepted providing radial street pattern and metro entrances at different points (Crawford, 2009).

As it is seen from Table 2, although travel time for walking is almost 8 times than private cars, the energy consumption and average cost of using private cars are the highest of all other modes such as public transit systems and non-motorized systems.

Notwithstanding that non-motorized transport modes have economic, social and environmental benefits; these could not compete with private automobiles. Main advantage of private automobiles is that they serve to a larger area in the city. For this reason, urban transport policies aiming at reducing car dependency must also focus on providing an alternative by improving public transit systems which are compatible with private automobiles. The following section argues this issue in details.

Table 2 Comparison of costs of various transport modes (based on average trip length of each mode)

Transport mode	Space used for infrastructure (10^{-2} m^2/km)	Direct+indirect energy use (MJ/km)	Average costs paid by traveller (euros/km)	Travel time
Petrol passenger car	0.55	1.79	0.170	1.34
Train	0.21	0.98	0.075	0.94
Bus, tram, metro	0.51	1.11	0.085	1.92
Bicycle	0.71	0.04	0.045	5.40
Walking	1.7	0.03	0.000	10.77

Source: Rietveld, 2001.

2.2.4. The Form and Design of Urban Areas as an Instrument in Encouraging Public Transport

Developing public transport systems as a tool to decrease private car ownership has been widely used in the world, because both bus rapid transit and rail transit systems provide high quality and fast services in the developed and developing countries.These are also used to reduce the environmental effects of private cars. New patterns produced by new transit systems offer a sustainable urban form. (Retrieved from http://www.urbanicity.org/Site/Articles/Dzurik.aspx on 16.10.2011).

Land use planning can influence mobility patterns of people. In the literature, it has been an interest area where researchers tried to analyze the reductions in the adverse environmental effects of transport by fostering people to live in more sustainable urban forms since this is expected to reduce the need to travel or reduce the distances required to travel. There is a growing need to integrate urban and transport planning and it is well established in the European cities (Stead and Banister, 2001; May, 2013).

The mobility of people has shaped the urban areas and also the urban form reflects the transport technology that has been dominant in the urban areas. Additionally, people tend to live in close distances to major urban centers. This has shaped the cities in three different ways corresponding to three distinct phases of city, as the transport technology and infrastructure have evolved and shaped our environment. As a result of this, the walking city, the transit city and the automobile city have emerged (Newman, Kenworthy, 1996).

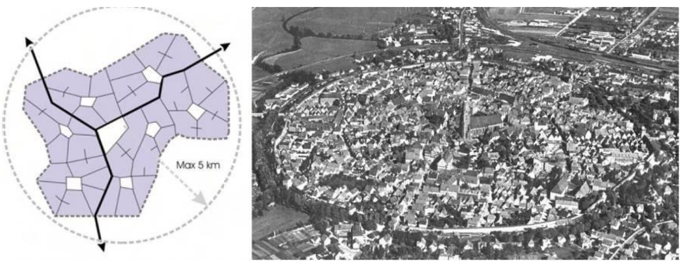


Figure 3 Schematic illustration of traditional walking city
Source: Çalışkan, 2004, p.36

The walking city (Figure 3) has developed around 10 000 years ago. The density is high about at least 100-200 people per ha. The streets are well connected and they are usually narrow. The city has an organic form with mixed land use characteristic. It is easy to reach destinations on foot because the city is not more than 5 km across (Newman, Kenworthy, 1996).

After the developments in the transit technology, trains and trams pushed the city outwards of its territories. In the center, around the train station was a walking city connected by trams creating a linear development across the corridor (Figure 4). The central area was the main focus of the city. The density decreased compared to the walking city and it became medium density (50-100 people per ha, diameter of 20-30 km) (Newman, Kenworthy, 1996).

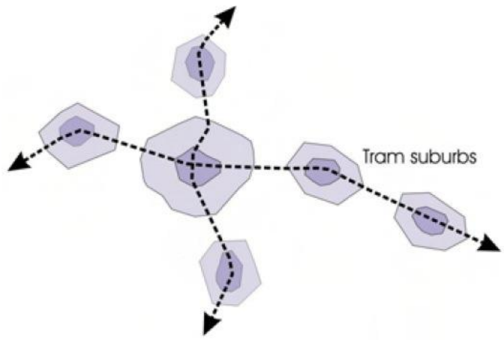


Figure 4 Linear development across the corridors
Source: Çalışkan, 2004, p. 37

After the Second World War, automobile technology started to shape the cities. The buses also made it possible to go to any direction as far as approximately 50 km. New housing areas emerged with low-density (10-20 people per ha) as a reaction to the industrial city. Zoning has become the most useful tool in urban planning in this era. Travel distances increased causing an increase in the automobile dependency (Newman, Kenworthy, 1996).

After the oil crisis in the 1970s, public transport has been recognized once again and most of the metro systems and light rail transit systems have been constructed after 1980s. Additionally, bus rapid transit systems (BRT) were also seen as a cheaper alternative in the developing countries. After the success of these systems, North America and West Europe started to develop bus transit systems together with rail transit systems. Concisely, public transit systems become the main investments in the world.

In brief, in the past walking city was organized according to accessibility and proximity principles. When the automobiles were invented, the city expanded out of its limits without considering the topographical characteristics of the city. Until then, the streetcars could not climb up high hills that the automobiles could. The main determinant feature became the arterial streets and expressways in mobility rather than the transit lines. It increased mobility and created inequities in accessibility regarding different parts of the city. James Flink (cited in Schiller et.al., 2010, p.31) used the term 'car culture' to define "the complex of social factors that buttress and maintain automobile dependence". Another term is also defined in the study as "carchitecture- the ways in which buildings are designed to accomodate automobiles and show their most important features to passing motorists as well as the enshrining of automobile aesthetics (Schiller et.al., 2010, p.31) showing the importance of automobiles in our lives. It is argued that this excessive mobility creates 'time pollution' in which people started to experience with the increased usage of automobiles that steals the quality of time of people.

These features have also been a trend in architecture to accomodate automobiles and designing building s accordingly throughout 20th and into 21st century. The most known examples are Le Corbusier's Radiant City, Peter Hall's Cities of Tomorrow and Frank Lloyd Wright's Broadacre City (Schiller et.al., 2010).

Not all cities in the World faced the same changing pattern as we discussed above. Third World for example, still has more walking and transit oriented urban forms. In

Europe there is also a tendency to return back to the walking city standards. Stockholm, that is a good example, has a transit based corridor development and sub-centers as it is the case in Oslo, Frankfurt and many UK cities where walking and transit systems are encouraged and there is a decrease in the private car usage. In some cities like New York, San Francisco and Melbourne characteristics of all three city types are combined (Newman, Kenworthy, 1996).

As it is seen, the urban form and technology are interlinked together. So, we need to ask where the sustainability lies in this equation. Sustainable mobility strengthens the link between land use and transport. 70-80% of the world's population is living in the cities and empirical researches concluded that a sustainable city has a population of 25,000 with a medium density (over 40 people per ha), with mixed land use and accessible public transit corridors. This would also provide a better connection to the activities in the city. Like in the walking city, the average lengths would be in walking and cycling distances. Public transport priority would also decrease the usage of private cars. Through this combination, quality of life and accessibility to the activities would be increased. As it was mentioned in the previous part, this paradigm would create a better environment by shifting people's travel patterns to a more environment friendly approach (Banister, 2007).

Besides these characteristics, citizens should be encouraged by reducing the fees and promoting policy instruments such as carpooling and so on (Laffel, 2006). Additionally, integration of different modes and electronic fare systems public transit station area design is also crucial in order to encourage the use of public transit systems. Permanent transit facilities such as metro or LRT systems provide high capacity transit services with a fixed track that encourages more intensive land around the vicinity of the stations. Benefits from bus routes are likely to be less than those of rail transit systems. For this reason investors choose to invest on rail transit systems because the bus routes could be changed or eliminated easily, whereas rail lines are permanent.

Investing in public transit infrastructure is not sufficient to change the travel behavior into a sustainable manner; it also needs 'macro' land use and 'micro' neighborhood design principles. These principles would complement and support the transport network. Major activities should be well connected to each other. People should access to their jobs and to the other activities from their houses with public transit system or by walking or cycling in a convenient way. As Kennedy et al. (2005) states “The devil is in the details, and the details start with the design of streets and neighborhoods”.

Therefore, there is a move to bring back some of the spatial characteristics of traditional neighborhoods; and these movements describe this new approach as neo-traditional neighborhood design.

Most of the researchers have asked if designing pedestrian-friendly neighborhoods foster the citizens to use more sustainable modes. Handy (1993) and Friedman et. al. (1994) found that traditional neighborhoods enable people to walk or cycle and use public transit systems. It is cited from Kennedy et. al. (2005) that other researchers such as Cervero and Radisch (1996) also stressed the influence of traditional neighborhood design on people’s travel mode choice after accounting for other factors. Hereby, the overall urban transit system network should also be considered, because a neo-traditional neighborhood designed as isolated suburban divisions may only have a limited effect on people’s travel behavior. These design principles should also be adapted to other urban areas such as commercial, recreational and business centers besides the residential areas. Friedman et.al (1994) argued that neo-traditional neighborhood design would reduce the need to travel by private cars. It provides dense usage of residential and non-residential areas with a well-defined street network for pedestrians and bicycles. In order to reduce the speed of cars, streets are designed accordingly.

There are more researchers focusing on sustainability, urban form and transport issues. Newman and Kenworthy (1996) focused on New Urbanism; Jabareen (2006) wrote about neo-traditional design approach; Arth (1999) came up with “New Pedestrianism” approach and so on.

It is inspiring for the researchers to make urban areas more accessible and attractive by promoting pedestrian-friendly and public transit friendly environments. It also has an economical vibrancy. (Kennedy et. al., 2005).

2.2.4.1. Recent movements in planning and urban design that emphasize public transport

Recently, urban planners and policy makers put emphasis on creating more compact urban forms with mixed land use characteristics to attain sustainable urban forms. In this respect, it is noteworhty to form different urban design and planning approaches and transport policies. There are increasing arguements on how:

- mixed use brings activities together;
- compact forms shorten travel distances while reducing travel costs and improving quality of life,
- increased connectivity leads people to use public transport modes more frequently (UN Habitat, 2013).

Different approaches of sustainable development and transport policies will be discussed in the following sections. Different design parameters will be revealed that would lead the way for this study to analyze the urban characteristic around transit stations that would foster people to use transit modes.

2.2.4.1.1. New Urbanism

Once, Le Corbusier pioneered urban planning by his modern urban order that replaced the former traditional fabric. He used superhighways; he built tower blocks and has enclosed squares. However today, neo-traditional street patterns, open landscapes, terraces and so on are becoming more favorable in urban planning. That modernist approach has been resisted and with the New Urbanism movement a new approach having a neo-traditional urban planning approach has emerged (Marshall, 2009):

- In the 1960s, Jane Jacobs and Christopher Alexander started to argue the top-down approach in planning and they criticized the modernist way of city planning (Marshall, 2009).
- Traditional Neighborhood Development (TND) concept was formed by Elizabeth Plater-Zyberk and Andrés Duany which focuses on the increased social interactions by designing streets as “outdoor public rooms”.
- On the other hand, the motivation for Peter Calthorpe was the environmental concerns and came up with Transit Oriented Developments (TODs).
- Dan Solomon, Stefanos Polyzoides and Elizabeth Moule executed regionalist architecture. They wrote alternative design principles guiding the new approach, New Urbanism which emerged in the beginning of the 1980s in U.S. to develop policies against the dependency on petroleum and to promote solutions for the climate change. They started to organize their own congresses by the year 1993 with “design matters” as their mantra. From 1993, the scope of the congresses has been widened; there is an on-going work on integrating New Urbanism in comprehensive plans. By the work of New Urbanists’, design manuals have been prepared by CNU (Congress for New Urbanism), the ITE (Institute of Transport Engineers) and the FHWA (Federal Highway Administration). These include urban roadway design manual, street design manual and so on. These guidelines are expected to be used it in municipalities in order to provide pedestrian and transit-friendly environments (Dunham-Jones, 2008).

In the “New Urbanism” movement, transit system is the emphasis of the urban system with a high density and mixed land use. There is less need to travel. It is sustainable, efficient, equitable and livable. As Cervero claims, the density is a major factor in determining the transit system ridership, and with the addition of a mixed land use pattern, it is possible to create better urban areas where residents would prefer using public transit systems (cited in Newman and Kenworthy, 1996).

This approach includes “transit villages”, “smart growth” and “transit oriented developments”. These are compact urban areas and they are integrated with the transit systems.

The common characteristic of these three is the encouragement of walking and public transport systems. The form created by this approach contributes to human health by decreasing the dependency on private cars. Citizens use bicycles or they travel by walking producing denser urban areas as shown in Figure 5.

Schiller et.al (2010) listed the main features of New Urbanism as:

- Compact and mixed development
- Density averaging at least 15 units per ha
- A variety in the built-up area (small-lot family, multi-family, residential over retail and various commercial and institutional structures close together)
- Dwelling within a five minute walk from the center
- An elementary school in 1.6 km radius
- Highly connected street networks
- Minimum parking lots
- Parks and playgrounds not more than 200 m from each dwelling

Figure 5 Neighborhood texture
Source: Retrieved from www.transitorienteddevelopment.org on 06.01.2015.

In a neo-traditional residential area design, there is a wide range of housing types for a wide range of income structure. Houses with front porches, narrow streets, back-alley garages and streets provide a livable neighborhood for the citizens. This helps to controvert urban sprawl and inner-city decline by rebuilding livable neighborhoods rather than building superblocks, suburbs or projects. Neo-traditional design fosters residents to walk, cycle and use public transit system (Jabareen, 2006).

2.2.4.1.2. Urban villages

Urban village is another type of neo-traditional approach. Urban villages were invented by the planners close to Prince Charles in England. This approach then influenced USA and eventually New Urbanism was produced in 1980s (Hall, 2008).

An urban village is “a settlement created on a green field or brownfield site, or out of an existing development. Its features are high density; mixed use; mix of housing tenures, ages, and social groups; high quality; and being based on walking” (Jabareen, 2006).

Kenworthy (1991) argues that urban village trend is supposed to fill the lack of community life and provides convenient and efficient urban areas with a 'larger portion of humanity'. It also reduces traffic congestion, pollution, infrastructure cost and increases the quality of life.

2.2.4.1.3. Transit oriented development (TOD)

There is a growing dependency on private cars in the cities and it also brings a cynicism that the habit of driving cars cannot be controlled. However, with a growing awareness for transit-oriented planning new types of urban areas emerged.

TOD has been used as a tool for promoting smart growth in the US. It is seen as an effective tool in reducing the private car ownership and urban sprawl. They are developments that focus growth around transit station creating walkable, pedestrian-friendly environments with mixed-use with a good street connectivity (Cervero, 2008; Chow, 2014; Knowles, 2012; Niles et.al., 1999).

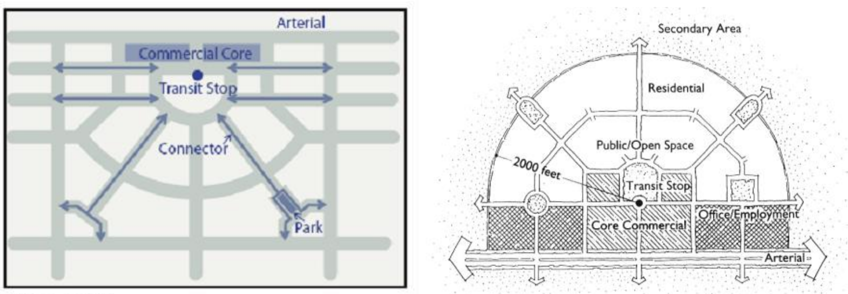


Figure 6 Transit oriented development
Source: Calthorpe P. 1993

Transit-oriented development has some benefits such that it creates more efficient sub-centers and it minimizes sprawl. In a corridor based urban form, it becomes easier to provide infrastructure. It is also economical to invest in transit systems rather than highway systems. As Newman and Kenworthy (1996) argues "a double-track light rail system occupies 50 times less urban space than the highways and parking needed for cars" (Newman and Kenworthy, 1996).

There are basic principles to be addressed in order to create a transit station community. These guidelines would provide a broader direction for planning transit stations that would promote a transit oriented and pedestrian-friendly urban areas.

These guiding principles are as follows:

- Compact, mixed-use development
- Pedestrian-friendly design
- Parking and access management

Compact development is the "relative density or intensity of land use activity" in the given urban area. The variety of land uses that are proximate to each other is a mixed-use development. These two concepts are taken together forming compact, mixed land uses where there are different activities (entertainment, jobs, entertainment and so on) within walking distance. The basic point of this concept is keeping the variety of activities closed together around a transit station.

It is also important to balance the need for private automobile access to the station. These developments are not intended to be auto-free. Private automobiles will be a major transportation mode for the access to the stations. Parking management would help to balance the demand for various travel modes. It should create an area that is both for private automobiles and bicycles. Appropriate parking standards, structured parking facilities and on-street parking issues should be considered (Puget Sound Regional Council, 1999).

Toronto, which is known as the best North American example of a transit-oriented development, faced a large growth of 48% in Metro Toronto's transit use from 1960 to 1980. It had a continued population growth over the years and the density of Metro Toronto has increased by 8%. Having a trend of growth pattern in the city, Toronto has changed dramatically in 20 years to a transit based development from a trend dependent on private cars. With this change, Toronto revitalized its downtown area; new sub-centers were created around the transit stations. New program was developed called 'Main Street' which promoted the life in the inner-city aiming at increasing the inner-city population and revitalizing the light rail system. Around was filled with shop-top housing and residential developments (Newman and Kenworthy, 1996).

Portland, Oregon's largest metropolitan area (US) has also its reputation for its transit-oriented development policies. It is claimed that the areas are benefiting as a result of its planning policies both in the environment and the economy (Song, Knaap, 2004).

"Transit village", "transit-friendly design" and "transit supportive development" are also used to convey the same idea as the transit-oriented development, but commonly TOD is used. It is a mixed-used community within a walking distance of 600 m walking distance. The transit-oriented development approach has its origins in the Ebenezer Howard's Garden city in the late 19th century. It should not be confused with "Urban Villages" which will be discussed in the following that TOD emphasizes the link with the rail-based transport system (Urban Design for Sustainability to the European Union Expert Group, 2004).

Transit villages aim to construct a better living environment. The urban area is concentrated around a transit station and this serves a liveable, safe and regenerated neighborhood for the citizens. The basic urban design criteria for this approach are the five-minute walking time. This would promote walking rather than driving private automobiles. Around the transit station, public buildings are situated and the station is integrated to the residential and working areas (Retrieved from www.transitorienteddevelopment.org on 06.01.2015).

2.2.4.1.4. Pedestrian friendly design

Pedestrian-friendly land use design is created in a way that it fosters travelling on foot rather than travelling by private automobiles. The dimensions of the human body become important. Orientation of the people must be achieved using the circulation networks, this puts emphasize on the importance of placing of buildings. The pedestrian routes should be along the street network. The streets should be narrow, accessible from every point and visible. The routes should be short and direct for pedestrians and cyclists (Puget Sound Regional Council, 1999).

2.2.4.1.5. New Pedestrianism

"New Pedestrianism" was founded in 1999 by Michael E. Arth. It is a variation of "New Urbanism" and it aims to solve social, health, energy, economic, environmental problem. In achieving this goal, its target is to reduce the private car usage. A settlement that is designed in accordance with "New Pedestrianism" is called a "Pedestrian Village" ranging from being solely car-free or having automobile access to the houses having pedestrian lanes in the front. Walking and cycling is encouraged with tree-lined pedestrian lanes of 5 m wide with a smooth side for cycles, skate and others. Automobile circulation is served on a separate network (Retrieved from http://michaelearth.com/introspective.htm).

2.3. Summary

As the current trend in urban transport is becoming more unsustainable there is a need for a fundamental change in the way the people meet their travel needs. There is a need for a more comprehensive analysis of impacts, formulation of broader solutions and more effective planning for urban transport systems (Litman and Burwell, 2006).

Dalkmann and Brannigan (2007) suggested that there are three main ways to formulate a transport planning approach and reduce CO_2 emissions of the transport sector: avoid, shift and improve (Table 3). Firstly, travel or travel by motorized modes could be avoided. Secondly, there might be a shift to more environmental friendly modes. Thirdly, the energy efficiency of transport modes and technology should be improved. This study will focus on the second way of reducing greenhouse gases from transport and explore the environmental attributes that change people's behavior. According to Dalkmann and Brannigan (2007), a variety of sustainable transport instruments can be combined within these strategies.

Shift means change of behavior. As discussed above, public transit systems are effective tools to reduce private car usage and change travel behaviour. However, the effect of these investments might be weak if the urban form does not support walking and public transport. A shift from mobility oriented analysis (that is the evaluation based on quantity and quality of physical travel) to accessibility-based analysis (that considers a variety of impacts and options) has been occurring in transport planning which places people in the center not the automobiles. In mobility-based planning the performance of the system is largely based on traffic speeds favoring automobile usage, but in the latter approach, improvement of non-motorized and public transit modes becomes significant. Urban design principles and accessible land use characteristics are determinant (Litman, 2012).

The concept of sustainable development has given a major stimulus to the question of the contribution that certain urban forms might make to lower energy consumption and lower pollution levels. This challenge has induced scholars, planners, local and international NGOs, civil societies, and governments to propose new frameworks for the redesigning and restructuring of urban places to achieve sustainability. Thus, the role of public transport on the shift of travel behavior is obvious.

In this context, urban planning approaches that focus mainly on transit station and its vicinity were analyzed and parameters correlating the relation between public transport and urban design were revealed.

Table 3 Three main ways to formulate urban transport planning

Avoid	**Shift**	**Improve**
No travel takes place ICT: home offices or working from home at certain days, e-shopping, distant learning, e-banking, e-government...	Use of non-motorized modes: Higher trips made by cycling or walking Use of public transport modes: A shift to buses or rail transit systems. Car and motorcycle usage must be minimized. Higher supply pattern for public transport Higher public transport usage pattern It is important to have legible, permeable, rich, visually appropriate environments to foster citizens' use of these sustainable modes. These design principles would provide better access to the systems. Tax increases that would favor energy-efficient transport modes Improve community design to contain sprawl better, expand transit options, and make efficient use of land within a community. Locate homes for people of all incomes, places of work, schools, businesses, shops and transit in close proximity and in harmony with civic spaces.	Support for new technologies and alternative fuels New urban rail systems, new bus way systems, new ticketing systems Energy efficient vehicles Clean fuels

Source: Adopted from Dalkman and Brannigan (2007), Kenworthy (2006).

Traditional high density and high accessibility patterns of European urban forms provide a good quality of life, cultural and environmental benefits as mentioned in the 1990 Green Paper on the Urban Environment of the European Commission. The compact city approach offers urban settlements with increased densities through infill of existing urban areas or redevelopment (urban intensification). It is seen as the adaptation of 19th century European city (Urban Design for Sustainability to the European Union Expert Group, 2004). With this thinking "New Urbanism", "Smart Growth" and "Sustainable Communities" have emerged as new planning movements.

From the urban palnning approaches mentioned in this section and different studies on the relationship between urban form and transport system parameters that would promote more sustainable patterns in the urban environment were revealed:

- In the studies of Black (1996) and Jabareen (2006) **compactness** is associated with social, environmental and economic characteristics.
- According to Stead and Banister (2001), Jabareen (2006) and Litman (2014), **density** is in a strong relation with the urban character.
- Stead and Banister (2001), Jabareen (2006), Newman and Kenworthy (1996), Jacobs (1961; cited from Jabareen, 2006) and Cervero (2002) stress on the **mixed land use** characteristic of the urban areas. New planning approaches that use mixed land use characteristic will be discussed in the following sections.
- **Diversity** (Jacobs; 1961, cited from Jabareen, 2006) **settlement size** (Stead and Banister, 2001) and **walkability** (Eva Lesliea et.al. 2005; Reid Ewing, et al., 2006; Jabareen, 2006) characteristics were revealed from the authors' studies.

There are many studies, reviewed above; arguing that the most powerful tool to change people's travel behavior is by urban planning and urban design. Urban form can make people dependent on car-usage or it can encourage sustainable mobility. Investing on public transit infrastructure may not be sufficient enough to change the citizens' travel behavior. It has to be complemented by urban design parameters that would foster the use of these modes.

The parameters revealed from literature are not taken for granted in this study. These lead the way for us to analyze the vicinity of rail transit stations which is the main focus of all approaches mentioned above. It is kept in mind that these parameters are not universal, but they should be used in a context dependent way.

CHAPTER 3

DESIGNING TRANSIT STATION AREAS: SPATIAL PARAMETERS THAT HELP TO INCREASE TRANSIT USAGE

As it was mentioned in the previous sections, public transit systems are sustainable transport modes. In order to increase the ridership, these modes should be improved and a shift from other modes should be provided. For a shift from other modes to the public transit modes, sustainable transport policies (integration of modes, restrictions of car usage, land use policies and so on) were discussed in the above chapters. Common parameters from these approaches and movements have been paired together and the main focus is put to the vicinity of transit stations that is analyzed in this study to search out the relationship between transit ridership and neighborhood design.

A railway station has two basic identities: node of networks and place. A node is "a point at which subsidiary parts originate or center. Together with lines or channels, nodes are the basic components of a network -the points where the lines are knotted, secured, interconnected and interrelated-" (Bertolini, Spit, 1998, p. 10). The station provides access to trains and other modes of transport systems and it is a specific part of the city with different kinds of activities (Bertolini, Spit, 1998).

Railway stations are places where people change from trains to subways, buses, cars, and bicycle or to the pavement. They are places for interchange. The word terminal comes from the verb "terminate". Terminate means to end. However, the terminal station is not the final destination. Entire journeys are door-to-door. So, it is crucial to design the transit station area accordingly.

The station serves as a meeting place or a landmark for the residents. They have social, cultural and economic advantages for the people. As Edwards (1997) argues "What gives the railway station particular significance as architecture and essential elements in the life and cultures of cities is precisely this interface between these two worlds - the railway system and the urban back cloth" (cited from Akkelies van Nes, 2011). There is an interaction between the station and its environment. Additionally, it is in relation with the other network parts (Güneş, 2007).

The attractiveness of stations depends on different factors. In a guideline prepared by RTD Transit Access Committee (2009) these factors were divided into two (Figure 7): hard factors (street network, land use and station design) and soft factors (TOD Master Plan, time, comfort and so on).

Hard factors	Soft factors
Street Network:	TOD-friendly Master Plan in place
-Grid pattern	Quality of the pedestrian experience
-Sidewalk connections	Time
-Adequate pedestrian crossing signals	*Comfort:*
Land Use:	-Weather
-Density	-Landscaping and street trees
-Diversity (mix of uses)	-Flat Terrain
Station Design:	-Station condition (maintenance)
-Station served by multiple modes (bus and rail)	-Lighting
-Transit frequencies/headways	-Adequate station and platform cover
-Number of parking spaces	-Lack of crime
-Cost of parking/parking prices	
-Commercial services for transit users	

Figure 7 Variables that influence walking
Source: RTD Transit Access Committee, 2009

Density, mixed land use, connectivity and walkability are factors affecting accessibility. Improved services within the neighborhood and improved transit services have a positive effect on accessibility and it also reduces the travel expenditures (Litman, 2012).

Cervero (2002) defined density, diversity and design as the “core dimensions” of built environment. In his study, Maryland was chosen to assess the influence of these parameters on mode choice. This county was chosen as it provides variety of mode choices. It is found that density at the station area significantly increases the transit usage both in the origin and in the destination. Additionally, design parameter such as the presence of complete sidewalks is found to have a positive influence on the use of transit. He also found that besides design factors, density and diversity appear to explain transit usage levels in the case area. Cervero et.al (1997) also tested density, diversity and design parameters in 50 neighborhoods in San Fransisco Bay Area. They have found that density, diversity and pedestrian-friendly design are signifiant factors influencing the mode choice.

Newman and Kenworthy (1996) shows good examples of different cities where transit usage is high with the help of land use planning policies. Newman et.al (1996) states that in the North American cities, namely Toronto and Detroit, main arguements of transit oriented development such as increasing density, providing mixed uses have been applied and those cities have been transformed from car-oriented cities to cities where transit usage is high.

In conclusion, density, diversity and design which are named as 3D’s by Cervero et.al. (1997) are defined as distinct effects on travel demand appealing compactness. Intensity, pedestrian friendly neighborhoods and walking quality factors are seen as strong indicators for non-motorized transport and use of public transit modes (Cervero et al., 1997). In the following sections, these parameters will be discussed in details.

3.1. Density of development at the vicinity of transit stations

Density is the number of people living in a given area, in other words ratio of people to land area. Population and employment density influence travel demand of the built environment (Chow, 2014). There is a strong relationship between density and the urban character. High density and integrated land use foster social interaction, reduce travel time and energy and produce more livable environments.

In Çalışkan's study (2004) different author's approaches to define density were presented. In Masnavi's study (2000:65) cited in Çalışkan (2004) four elements of the quality of life were related to the compact city paradigm: good accessibility to facilities, reducing need to travel, improving public life, increasing social interaction. For Rogers (1995), compact cities are economically strong, well governed and designed promoting diverse activities (Çalışkan, 2004).

Urban compactness can be shaped horizontally and vertically by means of density. This is a diverse relationship. If the density is low, large amount of area is needed and provided by open spaces and roads. In return, it increases walking distances resulting in urban dispersion. By contrast, high density decreases the area needed involving different activities. Current trend is to stance towards density in favor of medium to high densities.

Density is also an essential factor in the decision making process of transit systems. In high density areas the transit usage also increases. In a research by Transportation Research Board of the National Academy (1996), it is found that the density strongly influences the mode choice. In a low-density area, high-capacity transit systems became unattractive and therefore huge investments are wasted (Gordon, Richardson, 1997). It is also argued by Balcombe and York (1993) that higher densities would provide more space for people rather than cars as the car ownership would decrease by promoting higher densities and efficient public transport systems. As the density increases and the mixed land use being constant, people tend to walk, use bicycles or public transit systems in reference to areas with low density (Jabareen, 2006).

In a study by Stead and Banister (2001), the reasons of promoting sustainability by increasing density are listed as follows:

1. Development takes place in less land area, therefore travel is reduced and energy is used more efficiently.
2. Accessibility to the public transport modes is increased.
3. More local employment is provided; services and facilities are concentrated in nodes or corridors reducing the private car ownership.
4. Walking and cycling is promoted
5. Stead and Banister (2001) also suggest that the density should be 40 dwellings per hectare similar to London.

Transit station area provides higher intensity uses such as residential, office, retail and so on. The mixed land use would increase the attractiveness of the area and attract more transit users (Transit Station Area Principles, 2011). Transit creates places of different activities and services bringing people together. A neighborhood with a transit station becomes more accessible to the outside (Palm Tran Transit Design Manual, 2004). It is found that high concentration of people living and working around 800 m of a station increase the ridership levels. It is recommended in RTD Transit Access Guidelines of Denver (US) that, household densities should be 3 to 5 dwelling units per m^2 (10 to 20 dwelling units per gross acre); employment densities should be approximately 6 jobs per m^2 (25 jobs per gross acre) close to a transit station. It would support frequent and high capacity transit service (RTD Transit Access Committee, 2009).

In the same study completed for nine stations in Chicago region, the relationship between the ratio of dwelling units per acre and the percentage of commuters walking or using bicycles to the station were revealed. A strong grid pattern, sideway connectivity, presence of commercial services and high residential density has been found as the key walkability factors in the area. It is also found that if it is easy to cross streets or there are different street amenities people tend to walk (RTD Transit Access Committee, 2009).

Plans for transit station areas should provide opportunities to increase the density over time. Vacant lots, existing low density uses or parking lots would be in-filled over time. It would be achieved by phasing plans with flexible strategies that would meet the community needs in the future (Transit Oriented Development Best Practices Handbook, 2004).

It is argued that there is a direct relationship between transit use and urban compactness. In Cervero (1998; cited in Çalışkan, 2004) a statistical comparison was made between different cities. It was found that every 10% increase in population and employment densities results in an increase in transit use by between 5 and 8% (factors such as income, parking supply and so on are controlled). In the same manner, in a study by Pushkarev and Zupan (cited in Çalışkan 2004) it was concluded that an average of 30 dwelling units per hectare is required by sufficient rail transit demand in downtown. Residential density between 18 and 45 units per hectare is stated as necessary to sustain transit ridership (Çalışkan, 2004).

As stated in UN Habitat Gobal Report (2013), there has been efforts to define urban densities that would influence the usage of public transport systems. It is found in the studies that in order to support public transport investments average of 3000 p/km2 is needed. On the other hand, for more car-oriented countries as US, UK, Canada or Australia, this threshold rises up to 3500 p/km2 in order to attain adequare ridership (UN Habitat, 2013).

Litman (2012) argued that density and clustering tend to increase accessibility. However, it should be kept in mind that low-density areas can have higher degree of clustering so density (the number of people or jobs per ha) and clustering (people and activities locating together) are different concepts. In a neighborhood with housing, retail, officies and transit serices located together would provide high accessibility as seen in Figure 8 and 9 (Litman, 2012).

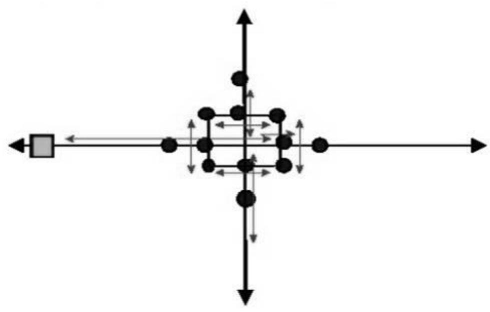


Figure 8 Accessibility with clustering of destinations
Source: Litman, 2012, p.15

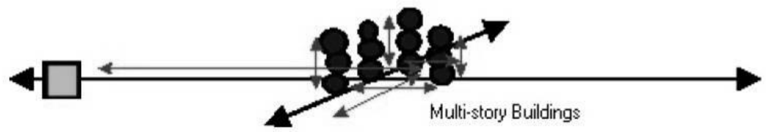


Figure 9 Accessibility with vertical clustering

Source: Litman, 2012, p.16

The relationship between density and accessibility might become complex due to the fact that they might result in increase in traffic congestion. This problem should be overcomed by promoting walking, cycling and transit with the above mentioned design principles.

3.2. Diversity of land uses: availability of services and amenities around stations

Diversity is as important as density around the transit stations. It is found that a greater mix use would increase the percentage of walking trips. A mixed use environment provides different types of opportunities such as residential, retail or office use in proximity which affect walkability (Chow, 2014). People tend to walk farther between the station and residential or employment than retail services (RTD Transit Access Committee, 2009).

Mixed land use is defined as "integration of land use by increasing the proximity of urban activities. In Çalışkan's study (2004), mixed-use is defined as the balance of residential and non-residential land uses and categorized in three aspects: number and ratio of the facilities provided, horizontal mix of land uses and vertical mix of uses. While the first indicator entails the degree of the variation in supply of services and facilities, horizontal mix of uses implies the individual developments of different uses sit side by side within urban area. Additionally, vertical mix of uses refers the urban characteristic of 'living over the shop'" (Çalışkan, 2004, p.18).

As the city grows through the accumulation of buildings and areas, a street network emerges which links it all together, and through its structure the emergent street network shapes a patterns of "natural movement" making some spaces higher in co-presence than others (Hillier, 2008).

Mixed land use provides many services within an area reducing the need to travel and the private car trips for commuting, shopping or leisure trips. It is assumed that all facilities and amenities are to locate together: housing, jobs, services, facilities, recreational areas and so on (Jabareen, 2006).

The presence of shops in locations that are already movement rich attract more movement, so there is a multiplier effect on the movement already there. This then attracts more-and more diverse- land uses, which seek to take advantage of enriched co-presence of the location (Hillier, 2008).

In the comprehensive work of Cervero and Ewing, they concluded that transit ridership levels are dependent on local densities and land use mix. In his earlier studies Cervero used data of 15,000 households and found out that the presence of retail shops within approximately 100 m (300 feet) around the residential area increases the probability to use transit (on average by 3%). In a recent study in Montgomery County, Maryland (US), mixed use at the origin and destination fosters travel for all purposes (elasticity between transit use and diversity ranging from 0.45 to 0.62) (Cervero, 2004).

Jane Jacobs (1961) claims that in dense and diversified areas, people tend to walk. As the urban area gets intensely diversified and becomes high density, walking increases, even if they have used their private car or public transportation system to come to that settlement. She argues that to have a diversified urban area the buildings in that area should be in different ages, accommodating different people and different businesses. The district should serve in different functions to provide different activities for the people in different times. There should be path options enhancing social relations resulting in economic development. The density should be high. These characteristics would provide diversity that would end dullness and homogeneity in the area (cited from Jabareen, 2006).

Greater mix of uses facilitates the use of non-motorized transport and public transit modes. In a study by Song and Knaap (2004), two measures for land use mix are proposed: the actual mix of nonresidential land uses in the neighborhood and the mix of zoned nonresidential land uses.

In the first measure, acres of commercial, industrial, and public land uses in the neighborhood are divided by the number of housing units. With this approach they found a ratio that indicates the land use mix. The second measure also reveals a ratio which is found by dividing acres of land zoned for central commercial, general commercial, neighborhood commercial, office commercial, industrial, and mixed land uses by the number of housing units. The higher ratio represents the greater land use mix (Song, Knaap, 2004). Places of different activities and services can be also calculated from maps.

MIX-OF-USES variables

- Provision of facilities
  - number of key facilities for every 1000 residents.
  - ratio of residential to non-residential urban land.
- Horizontal mix of uses
  - percentage of sectors containing four or more key facilities.
  - percentage of sectors containing four or more key facilities.
  - percentage of sectors containing all key facilities.

  overall spread of key facilities.
- Vertical mix of uses
  - living over the shop: area of retail space that includes accommodation (as a percentage of total retail space).
  - mixed residential and commercial uses: number of flats in commercial buildings (as a percentage of all built flats).

Figure 10 Indicators of mixed land use
Source: Çalışkan, 2004, p. 19

Besides the different types of mixed uses it is also necessary to have an analysis covering different scales such as micro, meso and macro to get more comprehensive results (Choi, Sayyar, 2012). Stemming from this idea, in the study each parameter will be analyzed in three different scales.

3.3. Street network around transit station

One of the hard factors that would increase the use of the transit mode is the connectivity of the street network. High connectivity of the network provides high level of accessibility.

'Great streets', 'liveable streets' and 'complete streets' are different concepts in the US which provide streets accomodating both non-motorized and motorized modes serving places for social life and active living (Schiller et.al., 2010). Changing the nature of the streets and making them 'liveable', 'complete' or 'great' would attract people to the transit station areas. It is a common belief that railway stations attract people because of having different activities in its facilities such as shops, restaurants and offices. Railway stations are public places with a human scale and complex functions inside. However, the connectivity of the streets in the surrounding areas of the station also affects the access of the people to the stations which is almost forgotten by the designers. Some stations are considerably more accessible by foot or by public transit system than the other which is only accessible by private cars (van Nes, 2011).

Connectivity is also determined by the presence of sidewalks, pedestrian paths and their continuity. It becomes important to avoid barriers in the pedestrian movement (Southworth, 2005).

Location of the transit station becomes a key element in the determination of its accessibility. The distance from and to the station is the second key element which derives from connectivity.

It is little appreciated that the placing and shaping of blocks can have critical effects on the length of trips from all points in the system to all others, a property we call metric integration. The grid with small central blocks has a shorter trip length, and is therefore more trip efficient than the regular grid; this is a pervasive phenomenon in center formation in cities.

Connectivity being the fundamental measure of accessibility may differ due to different spatial structures of a place; even two different locations at the same place may have different accessibilities (Rodrigue et. al 2006).

Researches mainly focused on road network design, street connectivity, block size and density in evaluating effect of built environment on the travel choice. It has been found that communities with neighborhood accessibility with high street intersections would promote walking (Ozbil et al., 2009; Chow, 2014; Dill, 2004). The streets should also serve for pedestrians not only for the private cars.

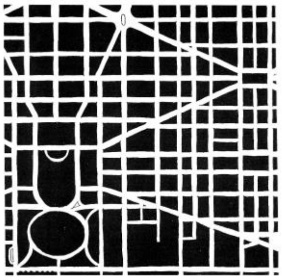
A grid network provides the simplest street pattern and is often emphasized as the preferred model in neo-traditional neighborhood design (Figure 11). It increases walkability by providing a better sense of direction. Street connectivity indicates how densely the streets are connected with each other. Block length is measured in a grid form, where shortest blocks provide more direct travel (APTA Sustainability and Urban Design Program, 2011).

When the streets are interconnected in a system of small blocks, it becomes possible to reduce car travels by between 10-40%. In a research by the Puget Sound Regional Council (PSRC) in Washington State, transit riders were found to prefer walking to station where the sidewalk networks were complete (RTD Transit Access Committee, 2009).

Figure 11 Grid pattern
Source: APTA Sustainability and Urban Design Program, 2011

The following figure (Figure 12) also highlights variations within a grid system that provides both high connectivity and different measures of attractiveness for pedestrians and other users (Jacobs, 1993).

San Francisco **Philadelphia**



Washington, D.C. **Barcelona**

Savannah

Figure 12 Street connectivity

Source: Jacobs, A.B. 1993

Litman (2012) gives the example of accessibility on grid network. As seen in Figure 13, it is shown that with short and connected roads multiple routes are created which results in direct connections between destinations. This helps transit ridership to increase encouraging pedestrians and cyclist through these routes (Litman, 2012).

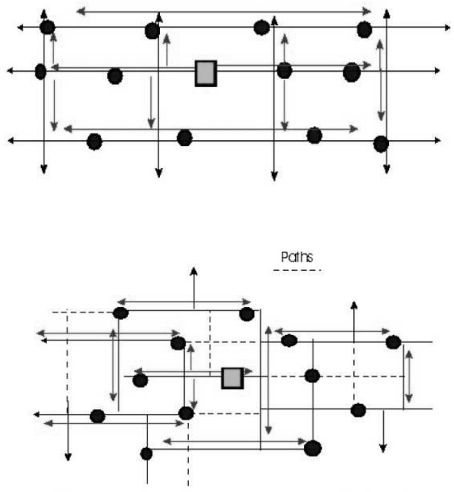


Figure 13 Grid road network

Source: Litman, 2012, p.17

As it is seen from Figure 14, as the origin is located in the center of roadways, and the destinations are located together, results in an increase in accessibility. These destinations can be reached by walking (Litman, 2012).

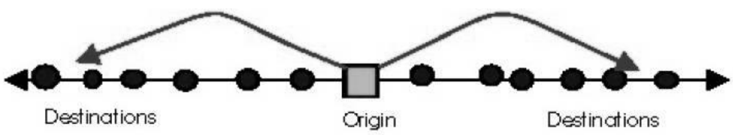


Figure 14 Accessibility from a location in the center of a roadway
Source: Litman, 2012

Accessibility also increases when the connectivity increases as shown Figure 15. A connected loop and location at the crossroads increases accessibility. Allowing more direct travel between nodes is another example for increased accessibility.

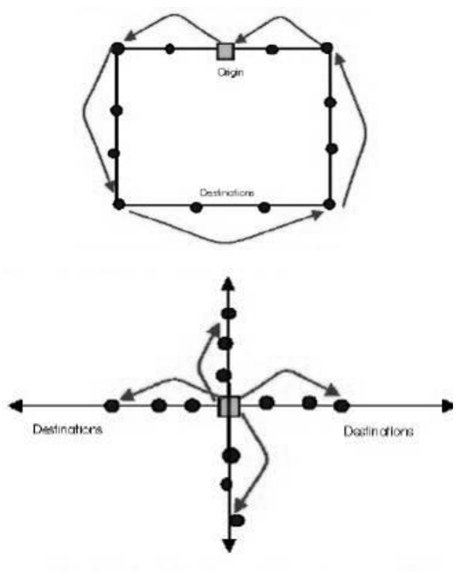


Figure 15 Increased connectivity increases accessibility
Source: Litman, 2012, p.14

On the other hand, circuitous routes, cul-de-sacs and dead ends decrease walkability, ending up with a decreased ridership number of transit modes. In less regular forms, connectivity is represented by intersections per square mile. When the intersections increase, connectivity increases (Figure 16) (APTA Sustainability and Urban Design Program, 2011).

Figure 16 Less regular pattern
Source: APTA Sustainability and Urban Design Program, 2011

As it was mentioned previously, every trip starts and ends with walking. Therefore, creation of pedestrian-friendly environments is important in the success of transit modes. Pedestrian routes should be short, continuous, direct and convenient (Transit Oriented development Best Practices Handbook, City of Calgary, 2004). It is also important to compare travel based on time rather than miles while comparing different modes with walking or cycling (Litman, 2008).

Walking distance is usually 400 to 600 meter radius of the station. Bertolini and Spit (1998) defines 500 (10 minutes walk) as the minimum walking distance. It is important to avoid circuitous routes. Accessibility for all should be considered with minimum number of stairs and grade changes. Sidewalks should be connected directly to the entrances of station buildings providing safe environments. Number of crossings should be limited. It is also important to integrate other transport modes such as bus transit systems/non-motorized systems and place the bus stops/bicycle parks in a walking distance to the station. This distance should be shorter than the distance of parking spaces that would encourage the use of bus transit systems (Transit Oriented development Best Practices Handbook, 2004).

In a study by Akkelies van Nes (2011), the relation between the street network integration and the value of railway station is tried to be revealed by using space syntax method and Node Place value model.

Luca Bertolini (1999) developed the **Node Place** value model to correlate the degree of functionality and local place qualities for nodes. As a node and a place, the station and its surroundings are places where different people come and also can do many activities: "it is an accessible node, but also an accessible place" (Bertolini, 1999, p.201). Accordingly, a station functions well when these two values correspond to each other. The parameters used in the model are the variation in mobility type, the frequency of the public transport system, the accessibility of the network connected to the node and the mobility means reaching the hub. The parameters for the place value are also dependent on the function available in the node (shops, offices, dwellings and so on). If a place has one function, the place value is lower than a node having two different functions such as a dwelling and an office. This model shows the optimal relation between place value and node value. If there is a balance, this node and place are defined to be successful (van Nes, 2011).

The model is a simple xy diagram as shown in Figure 17. The y value is the node-content of an area (accessibility of the node) and the x value is the place-content of the area (intensity and diversity of activities). The y value provides data about the potential human interactions thus "the more people can get there, the more the interaction takes place". With the x value, the degree of actual realization of the potential human interaction can be found out (Bertolini, 1999).

There are four ideal situations for this relation:

- The middle diagonal line area is where the node and place are equally strong.
- The top of the line areas are "under stress". Intensity and diversity of urban activities are at the maximum level. There is a strong human interaction and it has been realized. This indicates that this is a strong node and a strong place. This might also reflect extensive activities on a limited space.

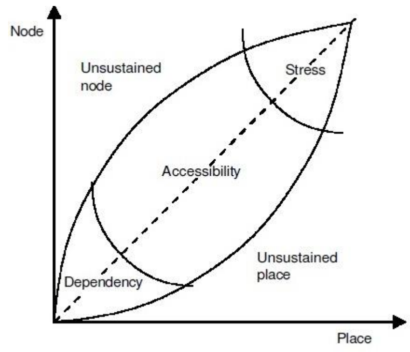


Figure 17 Node place model
Source: Bertolini, 1999

- The bottom of the middle line is second ideal situation which is represented by “dependent” areas. In this areas, demand for transport services and urban activities is low.
- At last, two unbalanced situations are shown in the figure. These are the “unsustained nodes” identified on the top left where transportation facilities are much more developed by urban activities and bottom right where urban activities are more than transport facilities.

This model was used by researchers by means of multi-criteria analysis (MCA) and a node-index was produced as a measure for the accessibility of a node. This index uses the key criteria of intensity and diversity and unites accessibility by:

- train (number of directions served, daily frequency of services, amount of stations within 45 minutes of travel),
- bus,
- tram
- underground (number of directions, daily frequency), by car (distance from the closest motorway access, parking capacity)
- bicycle (number of freestanding bicycle paths, parking capacity) (Bertolini, 1999).

The place-index on the other hand, is the measure for intensity and diversity of activities in the surroundings of the transit station. This is defined within a walkable distance of 800 meters from the main pedestrian entrance to the transit station. The variables are: the number of residents in the area, the number of workers per each of four economic clusters (retail/hotel and catering, education/health/culture, administration and services, industry and distribution) and the degree of functional mix. In this context, the node-place model identifies the differentiation and intensification of activities around the transit station (Bertolini, 1999).

It is stated by Bertolini (1999) that suburban developments mostly contain cul-de-sacs creating big blocks and lacking of connectivity. In this respect, the measures in the study of Bertolini (1999) the number of nodes and intersections, the distance between points of access into the neighborhood, the number and lengths of blocks, and the lengths of cul-de-sacs are involved. All of them measure connectivity within neighborhood and the second one measures connectivity between neighborhoods (Bertolini, 1999).

Another model is the **space syntax method** which illustrates how the spatial structure of the street and the road network affects human activities. It was developed by Bill Hillier et. al. at the University College London. Software using this model – Depthmap software- calculates the integration of streets in relation to all others in terms of direction change, angular relationship between them and also the metrical distance. It also visualizes the spatial inequalities and simulates movement routes of people (van Nes, 2011).

The "syntactic space-led approach to the city" shows a link between the form and its functions. It proves the effects of space network in shaping the movement patterns of people (Hillier, 2008).

In most engineering-based models, the mass of a location attracts movement such as the shopping floor area. Herein, the "space network" is just the means of arriving to destination. This model is in analogy to the Newtonian physical system where attraction is directly proportional to mass and indirectly to distance. This model has been used for many years; however it lacks the patterns of movement. In the space network, by shaping network pattern of attractors are also shaped because the patterns are created by the network. Accordingly, the starting should not be the distribution of attraction but the network pattern due to emergent characteristic of movement. The shift to space syntax method is a paradigm shift in which the city is put into a different order (Hillier, 2008).

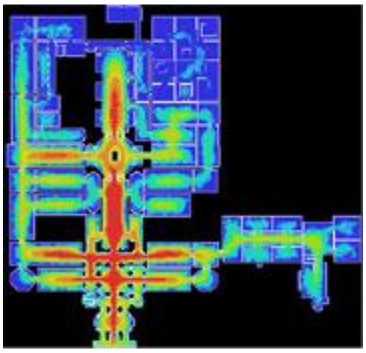


Figure 18 "Most integrate" represented with hot colors
Source: Retrieved from http://www.spacesyntax.net/ on 04.06.2012.

In a network that can be presented by a graph it is simplistic to calculate the closeness of each activity (accessibility to the activity) and the degree to which these activities are aligned. In the syntax model, the closeness of each element to the others is called the “integration value”, and it is colored from dark to light according to high to low integration. The “betweenness value” which is called the “choice value” determines how each space is chosen on the network from all the others. It is also colored from dark to light to see the pattern (Figure 18) (Hillier, 2008).

Yet, the perception of distance and its calculation differs from person to person. In the study of Hillier (2008) it was assumed that the least number of lines were indicative not the distance. They named it as the “fewest turns distance”. These “least line” maps have been the basis for different projects. It is also claimed in the study that not only the least number of lines matter; the angle of turns also affects our notion of distance. This problem was solved with small changes in the space syntax technique. Hillier (2008) divided each line into its segments starting from the least line map. Then these segments were represented as nodes of a graph (the intersections as links). Integration and choice measures were assigned to different definitions of space: “shortest path (metric)”, “least angle change (geometric)”, “fewest turns (topological)” and “weightings to relations between each segment and all others”. These measures were applied to different radii from each segment defining “radii for the shortest paths”, “least angle change paths” and “fewest turn paths”. A matrix is created showing people’s actual movement through the urban fabric (Hillier, 2008).

By using Node Place and space syntax models Akkelies van Nes (2011) found out that main railway stations in larger towns and cities have higher inter-accessibility whereas railway stations in smaller towns and cities have higher local accessibility. These two station types have vital streets around its surroundings. It is also revealed that stations with high accessibility patterns also are transfer stations or an intersection of two or more railway lines. Mostly street network are provided for private cars and these areas are not pedestrian friendly. The stations with lower accessibility patterns are in remote areas and have low-frequency train departures. The researcher also made relations between the timetables and the accessibility of the station. Regional and local stations have higher frequency timetables and good road networks (van Nes, 2011).

Paksukcharern (2003) used space syntax analysis and studied both the inner space of the station and its surrounding. He used two methods referred as “all line axial analysis (Spacebox analysis) and “convex shape analysis (Pesh analysis) which were developed by Nick Dalton. These methods help to predict the movement and position of people in a defined space in one dimensional organization and two-dimensional organization respectively. He argued that:

“Despite Bertolini and Spit’s (1998) clear conclusion that the key concept in most current projects was to develop railway stations as a node and place in the city, the missing link between spatial design and its effects on space uses has created an ambiguous and vague task for architects and urban designers. This thesis has employed a combination of configurational analyses of increasing precision, urban condition surveys, and detailed observations to examine London's eleven mainline railway terminus areas. So far, it has revealed that it is possible to analyze the relationship between morphological patterns and space uses within the areas” (Paksukcharern, 2003, p.354)

Paksukcharem (2003) concluded that the inner space of the terminus must be well integrated to the outer space to become a part of the system.

In a study by Litman (2012), “**connectivity index**” was introduced which is used to evaluate the network connection of destinations. It is found by dividing the number of roadway links by the number of roadway nodes. This index can also be used for non-motorized transport modes. High index stands for increased choice of travel and more direct connections. Litman (2012) evaluated the connectivity index of a simple box, a four-squared grid and a nine-square grid. The results are 1.0, 1.33 and 1.5 respectively. It has been mentioned above that the cul-de-sacs and dead ends reduce the index value. It is found that a minimum of 1.4 is needed for a walkable urban environment (Litman, 2012).

Litman (2012) also pointed out that different people and groups have different accessibility needs so that planning should reflect every group’s needs. In Table 4, Litman (2012) showed different groups’ tendencies to use certain modes rating from 3 (most important) to 0 (unimportant). Different locations and activities have different accessibilities: some areas might be automobile-oriented with low pedestrian access; some might be transit-oriented having good walkability conditions and high quality transit services. He argued that it is appropriate to analyze the accessibility of a particular destination taking into consideration of different groups (Litman, 2012).

Table 4 Importance of Transportation Modes

Groups	Walking	Cycling	Driving	Public Transit	Taxi	Air Travel
Adult commuters	2	1	3	2	1	1
Business travelers	2	0	3	2	3	3
College students	3	3	2	2	0	1
Tourists	3	2	3	2	2	3
Low-income people	3	2	2	3	2	0
Children	3	3	2	1	0	1
People with disabilities	3	2	1	3	2	2
Freight delivery	0	1	3	0	1	1

Source: Litman, 2012

In a study by Song and Knaap (2004) connectivity is calculated with five different approaches:

- **Intersection_Connectivity**: It is the number of street intersections divided by sum of the number of intersections and the number of cul-de-sacs. The higher the ratio, the greater the internal connectivity.
- **Blocks_Perimeter:** It is the median perimeter of blocks. The smaller the perimeter, the greater the internal connectivity.
- **Blocks:** It is the number of blocks divided by number of housing units. The fewer the blocks the greater the internal connectivity.
- **Length_Cul-De-Sac:** It is the median length of cul-de-sacs. The shorter the cul-de-sacs, the greater the internal connectivity.
- **Ext_Connectivity:** It is the median distance between access points in feet. The shorter the distance, the greater the external connectivity" (Song, Knaap, 2004, p.214).

Three measures of accessibility are also recommended by Song and Knaap (2004): distance to commercial uses, distance to a bus stop, and distance to a public park. Each is measured as the median distance from the centroid of every single-family parcel in the neighborhood to the centroid of the nearest commercial use, bus stop, or public park.

Pedestrian access is determinant in defining walkable and transit-friendly environments. Therefore, it is measured by the percentage of single family homes that are within walking distance (0,402336 km=1/4 mile) in the study.

- **Pedestrian_Commercial:** It is the percentage of single family dwelling units within 1/4 mile of all existing commercial uses. Higher the percentage, greater the pedestrian access.
- **Pedestrian_Transit:** It is the percentage of single family dwelling units within 1/4 mile of all existing bus stops. Higher the percentage, greater the pedestrian access" (Song, Knaap, 2004, p.215).

In a study by Kim (2007), New Urbanism examples were examined in order to reveal their connectivity schemes and they were compared to each other. The researcher has investigated different measures of street connectivity in the literature and has developed a table consisting of different measures (Table 5). In the study, Kim (2007) used several measures from the literature as Reach and Directional Distance (Peponis et al., 2006), street density (total street length in a given area), block density (total number of blocks in a given area) and connected intersection (total number of connected intersections in a given area). Reach is the "total street length that can be reached as we walked in all possible directions from a given origin up to a certain distance threshold" (Kim, 2007, 092-02). It is argued that if the street network is denser, then there are plenty of destinations that a person can reach resulting in an increase of non-motorized transport in the area. "Directional distance is measured in direction changes" (Kim, 2007, 092-03).

Table 5 Street connectivity measures in planning literature

Block length (mean)	Cervero and Kockelman (1997)
Block density	Cervero and Kockelman (1997), Cervero and Radisch (1995), Frank et.al. (200)
Connected intersection ratio	Allen (1997), Song (2003)
Street density	Handy (1996), Mately et.al. (2001)
Pedestrian route directedness	Hess (1997), Randall and Baetz (2001)
Walking distance	Aultman-Hall et.al. (1997) (mean, maximum, percent of homes meeting minimum standard)

Source: Kim, 2007.

Rodrigue et. al (2006) analyzed different indexes to measure network connectivity. In Table 6 these indexes are given. **Detour** index is used to measure the efficiency of the networks. The closer the detour index gets to 1, the more the network is spatially efficient. **Network density** is calculated by dividing kilometer of links by square kilometer of the surfaces. The higher the value, the more the network is developed. **Beta index** measures the level of connectivity- number of links divided by number of nodes. **Gamma index** shows the connectivity that considers the relationship between the number of observed links and the number of possible links.

It is observed in the study that different types of station areas would require different strategies for promoting sustainable means of mobility in transport planning and urban design processes. These methods and models would serve to make a priority list of urban tasks to provide better and more sustainable urban areas.

Table 6 Indexes to measure network connectivity

Index	**Symbol /formula**	**Definition**	**Explanation**
Detour index	DI= DT/DD	a measure of the efficiency of a transport network in terms of how well it overcomes distance or the friction of space. "For instance, the straight distance (DD) between two nodes may be 40 km but the transport distance (DT; real distance is 50 km. The detour index is thus 0.8 (40/50). The complexity of the topography is often a good indicator of the level of detour."(Rodrigue, 2006, p.64)	The closer the detour index gets to 1, the more the network is spatially efficient. Networks with a detour index of 1 are rarely, if ever, seen and most networks would fit on an asymptotic curve getting close to 1, but never reaching it.
Network density		the territorial handhold of a transport network in terms of km of links (L) per square kilometer of surface (S).	The higher it is, the more a network is developed.
Beta index		measures the level of connectivity in a graph and is expressed by the relationship between number of links € over number of nodes (v).	Trees and simple networks have beta index values less than 1. More complex networks have a value greter than 1. Complex networks have a high beta index.
Gamma index		a measure of connectivity that considers the relationship between the number of observed links and the number of possible links	The value of gamma is between 0 and 1, where a value of 1 indicates a completely connected network and is extremely unlikely in reality.

Source: Derived from Jean-Paul Rodrigue et. al (2006) and Dill (2004)

3.4. Design and architecture of the transit station

For Rossi (1983; cited in van Nes, 2011) a railway station is an artifact promoting further development in the cities. The station area became as important as the piazza or the market place in many cities in the history. As Betjeman claims "Railway terminals in the last century are the cathedrals of the railways". However, last decade has faced a tendency in investing in highway infrastructure and neglecting the railway infrastructure. It is nowadays that climate change issues are becoming important and private cars are blamed to be the major source for CO_2 emissions. With the ecological movement there is a growing interest in public transit systems and especially on rail (Akkelies van Nes, 2011).

Station design is the third hard factor influencing people to use transit stations (RTD Transit Access Committee, 2009). As Tumlin (2012, p.217) argued:

"In the vocabulary of a city, transportation is the verbs: walk, ride, access, travel. Transit station areas……are different. They are the nouns: places and things, anchoring transportation services with locations. Planning for station areas is therefore different from planning for transportation systems and it requires a different mindset about both access and acitivity."

He defined six pedestrian conditions that should be considered planning the transit station area:

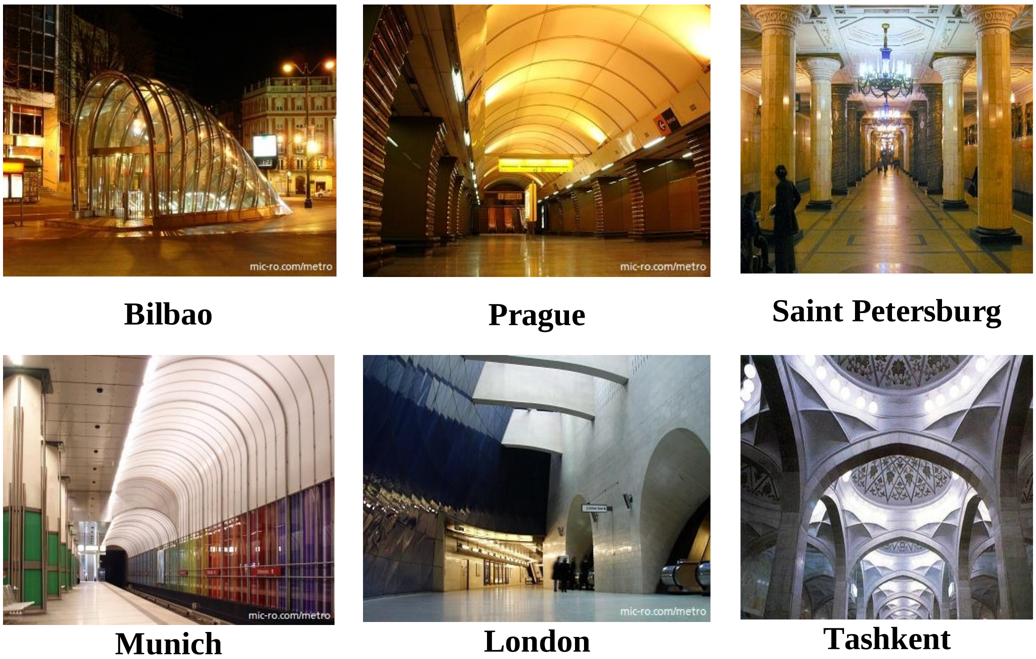
- Safety
- Security
- Directness-Pedestrians do not prefer to increase their travel time. An overpass may add more than 30 seconds to his/her travel time. For this reason, generally a crossing at street level is mostly used than an overpass.
- Ease of entry
- Comfort
- Aesthetics (Tumlin, 2012)

Stations integrating different modes such as bus transit systems and rail transit system are found to attract greater percentage of walk trips. Transit service frequencies also play a key role in the decision to walk or drive. It is found in the study that people would walk farther to transit stations that provide high level of service such as light rail systems; however they would tend to walk shorter distances (less than 150 m or 500 feet) to transfer. Parking areas, platforms and the facilities affect the decision to walk or drive. Parking should be separated into lots, or it must be shared with other office parking lots to encourage people walk to the stations rather than using their cars (RTD Transit Access Committee, 2009).

Munich Municipality (Germany) acquires an important character to metro stations. According to the municipality, metro stations are “lebensraum (living room)” where thousands of people spend much of their time every day. Therefore, the design of the transit stations should be humanistic. The aim should not be just to help people to reach their destinations quickly, comfortably or safely, it should be also to provide a “positive feel” (Güneş, 2007).

The transit stations below (Figure 19) are examples of good architecture and they are the stations that foster arts in subways:

The stations should be well-lit providing legible sign to orient the visitors. Transit station would become a landmark that would make the area attractive and memorable with a unique design (Transit Oriented development Best Practices Handbook, 2004). Different color schemes and works of art are attractions for daily visitors (Retrieved from http://mic-ro.com/metro/metroart.html on 17.10.2011).



Bilbao | Prague | Saint Petersburg

Munich | London | Tashkent

Figure 19 Examples of transit stations with good architecture and work of art
Source: Retrieved from http://mic-ro.com/metro/metroart.html on 17.10.2011

Transit stations and terminals are also the contact points of rail transit systems with other modes such as walking, private cars or other transit. It affects the passenger convenience, comfort and safety. Rail systems with positive images are seen as an effective tool in providing accessibility (Özgür, 2009). The accessibility of railway stations affects the travel choice of people. Often train is not chosen because of people facing problems while getting to and from the railway stations. Since, walking and cycling are important entry and exit modes to train; they are underestimated while designing the transit station area. In order to get to the stations people make detours than direct trips producing more emissions. When the entry and exit modes are taken into account, emissions per train increase due to the fact that they are made with motorized modes. Bad connections to the station and low speeds of entry results in reduced number of trips made by train than private automobiles. It becomes feasible to use train when the origin and destination of trips are close to the transit station area by walking or cycling (Rietveld, 2000).

3.5. Summary

Boarnet et al. (2001, p.3) claimed that “travel is not a simple story”. Every travel choice reflects the choice of living, working and commuting. The built environment, availability of sidewalks, transit system services and so on affects the travel choice. It is also argued in the study that travel behavior is a complex phenomenon and due to its complex nature very little is known about the relationship between the built environment and travel behavior (Boarnet et al., 2001).

Land use planning can influence mobility patterns of people. In the literature, researchers tried to analyze the reductions in the adverse environmental effects of transport by fostering people to live in more sustainable urban forms since this is expected to reduce the need to travel or reduce the distances required to travel.

Public transit systems are sustainable transport modes. In order to increase the ridership, these modes should be improved and a shift from other modes should be provided. For a shift from other modes to the public transit modes, sustainable transport policies (integration of modes, restrictions of car usage, land use policies and so on) were discussed in the above sections. Common parameters from these approaches and movements have been paired together.

In this respect, investing in public transit infrastructure is not sufficient to change the travel behavior into a sustainable manner; it also needs ‘macro’ land use and ‘micro’ neighborhood design principles. These principles would complement and support the transport network. Major activities should be well connected to each other. People should access to their jobs and to the other activities from their houses with public transit system or by walking or cycling in a convenient way. In different parts of the world, cities are transforming into more sustainable urban forms having denser neighborhoods, connected streets and mixed land use characteristics (UN Habitat, 2013).

In the light of literature on urban form and public transport, compactness, density, mixed-land use, diversity, settlement size and walkability are determined as land use characteristics that play a crucial role in promoting more sustainable travel patterns in the urban environment.

Compact cities are high density and mixed use. This fosters people to live close to their work in principle. Travel demand is reduced encouraging people to walk or cycle**.**

There is a strong relationship between density and the urban character. High density and integrated land use fosters social interaction, reduces travel time and energy, producing more liveable environments. Mixed land use provides many services within an area reducing the need to travel and the private car trips for commuting, shopping or leisure trips. Jane Jacobs (1961) claims that in dense and diversified areas, people tend to walk. It is important to bear in mind that settlement size is important in developing non-motorized patterns of movements in the urban areas. Station design is also argued to be an important factor in influencing people to use transit stations (cited from Jabareen, 2006).

In the following chapter, the rationale of the study will be discussed accordingly to the literature reviewed above. Additionally, discussion on the methodology of the study will be provided.

CHAPTER 4

RESEARCH METHODOLOGY

4.1. Context and research questions

There are many studies that review the urban transit systems. These generally result in two propositions: firstly, these investments should be supported by transport policies that can restrict car usage in cities while improving public transport; and secondly these investments should be supported with land-use planning and urban design policies in order to make the urban neighborhoods around transit stations more public-transport friendly and more walkable as opposed to the prevailing car-dependent neighborhood development trends.

This study focuses mainly on the latter argument, that land-use planning and urban design policies are required to make the vicinity of transit stations less car-dependent, more walkable and more transit-friendly. Additionally, the study does not present an analysis on socio-economic context, car ownership rates and travel behavour. The study aims at understanding the link between station area design and transit usage. Analysis focuses on whether the surroundings of selected Ankara Metro and Ankaray transit stations are “transit encouraging” neighborhoods (from the point of view of increased transit usage). Therefore, these questions are asked:

- Is there a link between the neighborhood design around transit stations and the usage of that particular transit station?
- Which planning and design parameters are particularly important in fostering people to use the transit system? In other words, with which parameters can we define a “transit encouraging urban environment” that can encourage people to use more public transport?
- Is a frequently used station also a transit station with a “transit encouraging environment”?

In the literature, there are studies arguing that density, diversity and connectivity/accessibility has an influence on the use of transit systems. Also in the US, Australia and Hong Kong, neighborhoods are designed using such parameters. As stated in Akkar Ercan’s study (2011) designing neighborhoods is not a straightforward process. These measures might change from one location to the other. In this respect, in the study these parameters will lead a way to analyze the relationship between existing neighborhoods and ridership levels of each transit station and it is also expected to reveal different characteristics (if they exist).

Sub-questions are developed regarding the case area (rail transit stations). Following questions are asked:

- Do the urban design characteristics in the vicinity of selected transit stations have any effect on the use of rail systems?
- What are the spatial parameters of the selected transit station areas? Is there a clear link between these and the use of the transit stations?

4.2. Case study selection

There are different studies regarding Ankara urban transport system, especially rail systems. In a study by Akar (2004), TDM (traffic demand management) and TSM (traffic safety management) strategies were recommended such as congestion pricing, restrictions in the taxi quotas in the city center, parking management and so on. She also stresses the need of a shift from private cars to urban public transit systems.

Doğru (1999) analyzed the different aspects of mode choice process and modal split models. She found out that after the opening of Ankaray system, people shifted from the other modes and started to walk longer distances, spend longer times to use the system. This was because of the fact that the system has reduced total travel time and travel cost and provided comfort.

Demir (2007) argued that metro stations are dinamic spots transforming city spatially, socially and functionally and built her work accordingly on Ankara Kızılay-Batıkent Metro line.

In a study by Okulu (2007), Tunalı Hilmi Street was analyzed to figure out if the street is suitable for pedestrianization. The thesis makes an emphasis on pedestrianism and non-motorized transport systems; however the importance of transit system is not emphasized. She argues the necessity of urban design arrangements that would prevent car-oriented policies to revitalize the city center.

Kırsakal (2002) showed how the individual's perception of urban environment changes by considering the transport mode that she/he uses. She argued that people perceive the environment less while they are travelling underground. Aside from this negative characteristic of metro systems she claimed that metro influences the physical structure of the city and changes the accessibility of people. Terminals attract commercial uses. Additionally, the central station brings people into pedestrian areas and shopping streets.

Özgür (2009) analyzed the expectations from the rail transit investments in Turkey and compared the outcomes. She found that planners' expectations of rail transit system performances are barely met. The main reason for this failure is that many policies and measures such as integration, combined tickets, pedestrian areas are lacking although they were proposed during the planning of the systems. There have been many investments in rail transit systems. Usually these investments were built by extreme political support and high expectations. Attaining high ridership has often been the primary objective. The previous research showed that overoptimistic expectations regarding the performance and positive impacts of rail investments resulted in low number of passengers using these modes because of the lack of complementary or supportive policies and urban design (Özgür, 2009).

In the study by Kaçıral (2007), Ankara Metro is analyzed regarding social principles of sustainability. The results of the study showed that gender, income and distance to the station has an influence on the travel behavior and quality of life.

Güneş (2007) studied underground use and identity of metro stations (Batıkent Metro station). He found out that design of metro stations play an important role in eliminating psychological and physiological problems in underground and also related to the local identity. Therefore, metro station design process should be a participatory one both with the stakeholders. Ankara Metro is limited in architectural variations. Most of the stations are similar; there is no differentiation between the stations and lines. The rail stations are just a product of civil engineering. Most of the stations have tile combinations and glazed ceramics lacking in art objects. Especially in the Kızılay station, that is transfer station between Ankaray and Ankara Metro, there are commercial shops, a small mosque and box offices of municipality service. The centrality of the station is only read from its size, not from its architecture or its integration with its vicinity. Güneş (2007) examined the general perception of Ankara Metro by its users and listed the answers as "unidentical, complex, small, low, uniform, clean, desolate, close, passive, colored, plain, inconsistent, green, chaotic, spacious, disharmonic, crisp, luxury, new, depressing and freaky". He concludes that Ankara misses the opportunity to use positive design aspects in its transit systems (Güneş, 2007).

While there are many studies in the world that aim at studying the link between transit station area design and transit usage, such a study is limited in Turkey and in fact such studies are limited in developing country context with the exception of some studies made in Chinese cities. This may be due to the fact that transit usage is still relatively high in most developing country cities and the strategies of such transit-friendly design may have not yet become crucial planning policies. However, the case of Turkey and Ankara is different in that transit usage is decreasing in the face of rapidly increasing automobile usage. As a result, Ankara case has been selected as the case study.

While the main focus of the study is to assess the link between transit station area design and transit usage, it was crucial to provide a comprehensive picture of transport and land use in Ankara and therefore the analysis was not carried out only on station area design, but included larger scales of analysis as well. Then the city has been divided into three scales as macro, meso and micro:

- Macro scale: Whole city→Ankara
- Meso scale: Existing rail transit systems (before the extension of the systems)→Ankara Metro (Corridor I) and Ankaray (Corridor II)
- Micro scale: Vicinity of transit station→defined by the walking distance (min.500 m, max. 800 m)

This study has started on 8 November 2011. At that time, there were two existing rail transit lines in the city: Ankara Metro and Ankaray (LRT). The extensions of Ankara Metro line and an additional line (Çayyolu Metro) have started operating in 2014. Due to the recent opening of the systems, only two existing rail transit line stations have been selected in the scope of the analysis. Additionally, selection criteria have been defined for the stations that will be analyzed in micro scale:

<u>Distance to CBD:</u> The stations that are close to/at the central business district namely Kızılay, Ulus, Sıhhiye, Kültür Merkezi (Ankara Metro), Maltepe, Demirtepe and Kolej (Ankaray) will not be analyzed due to their potential to attract more ridership and this would misguide the study.

Attraction points: Akköprü station area would distort the analysis because Ankamall shopping center which is located next to the station is on its own is an attraction point of the city composed of different uses such as entertainment, shopping, catering and so on. The stations are classified into two groups (Table 7) according to the land use around their vicinity:

Table 7 Stations used in the study

	Group 1: Residential	Group 2: Industrial
Ankara Metro	Batıkent Hastane Demetevler Yenimahalle İvedik	Ostim Macunköy
Ankaray	Aşti Emek Bahçelievler Beşevler Tandoğan Kurtuluş Dikimevi	

4.3. Method of analysis

Analysis of sustainable urban planning approaches and new paradigms have been presented in the previous sections. It is found that density, diversity, design and accessibility/connectivity have influence on the use of transit stations. In the following chapters, only design of transit station will not be analyzed due to Güneş's analysis that Ankara misses the opportunity to use positive design aspects in its transit systems (Güneş, 2007). All the stations are almost identical.

In the previous chapter, different methodologies that have been used in measuring density, diversity and accessibility and connectivity were given. Amongst them following approaches will be used in this study. As different users, modes and scales require different methodologies in the analysis, parameters revealed from the literature are analyzed within three different scales as described previously (Table 8).

a. Macro scale analysis

Macro scale is defined as the whole city. In the study this case is the capital city of Turkey, Ankara. In the macro scale, a descriptive analysis is made by discussing spatial form and growth patterns of the city and land use-transport integration policies.

b. Meso scale analysis

In meso scale, existing rail transit lines Ankara Metro (Corridor I) and Ankaray (Corridor II) are analyzed. A descriptive analysis is carried out by analysing the following parameters:

- Density (Descriptive analysis of the corridor): Number of residents per hectare, number of workers per hectare
- Diversity (Descriptive analysis of the corridor): Variety of uses and dominant uses
- Accessibility and connectivity: Station served by multiple modes, number of bus lines feeding into the station, availability of parking facilities (car and bicycle) and kiss-and-ride

Table 8 Parameters in different scales

MACRO The city		MESO Rail system corridors		MICRO Walkable radius from rail stations (500 m and 800 m)	
Parameter	Measurement/ Anaysis/Index	Parameter	Measurement/Anaysis/ Index	Parameter	Measurement/Anaysis/Index
Spatial Form of city Spatial growth patterns	Compactness vs. Sprawl Change in density	Density	Number of workers per hectare Number of residents per hectare	Density	No of living/working units per hectare
Macro-scale diversity	Variety of uses	Diversity	Descriptive analysis of the corridor Variety of uses Dominant uses	Diversity	Place value (Bertolini, 1999) Degree of functional mix (percentage of units regarding its function)
Accessibility and connectivity	Land use-transport integration Modal split Fares of different transport modes	Accessibility and connectivity	Station served by multiple modes Number of bus lines feeding into the station Availability of parking facilities (car and bicycle) and Kiss-and-ride	Accessibility and connectivity	<u>Direct and short routes:</u> Beta index (Rodrigue, 2006) or Connecitivty index (Litman, 2012 <u>Node Value (Bertolini, 1999):</u> Station served by multiple modes Number of bus lines feeding into the station Availability of parking facilities (car and bicycle) and Kiss-and-ride

c. Micro scale analysis

Walkable radius around the selected transit stations defines the micro scale. The minimum distance is 500 m around the station and the maximum distance is 800 m.

Firstly, a land use analysis is performed regarding micro scale analysis. Land use maps are created in the field survey. Additionally, a descriptive analysis is made in order to provide a broad picture. It also helped to reveal insight data regarding the selected areas.

Secondly, for density, diversity and connectivity/accessibility calculations are made as follows:

- For the density parameter residential and employment populations are calculated:

  Residential density: (Number of residential units × number of storeys × household size) / total area

  Employment density: Number of employees / total area

- For the diversity parameter:

  Firstly, distribution of different land use types is analysed using land use maps created by the researcher as an outcome of the field survey.

  Secondly, the percentage of each land-use type (residential, office, commerce, others such as school and hospitals) is calculated. Total built up area (m^2) is divided by the total area to show the variety of each use.

  Then, a ranking system is created to analyze the mixed use characteristic of the area. In order to have a mixed use characteristic, the area must embody residential, commercial and other uses (education, health services areas and so on). Accordingly, a calculation is made assuming that an ideal transit station would have 33,33% residential, 33,33% commercial and 33,33% other uses (Table 9). From this point of view, proximity to this ideal is assessed:

Table 9 Proof

	Residential	Commercial	Other
Percentage of use	33,33%	33,33%	33,33%
Proximity to 33,33% (in absolute values)	0	0	0

Total of "0" is the ideal situation.

- For the connectivity/accessibility parameter, "Connectivity index" (Litman, 2012) or "Beta index" (Rodrigue, 2006) is calculated and the ridership of selected stations are collected. Connectivity is found by dividing the number of links by the nodes. It reveals walkability and directness. Beta index measures the level of connectivity in a graph and is expressed by the relationship between number of links € over number of nodes (v). Accessibility changes according to different people and groups, therefore the analysis might be used to define different groups' accessibility needs.

Furthermore, a check list which will give additional information about each station and its vicinity is provided (Table 10).

Table 10 An example of a check list

Measures (name of station)	Presence	Poor	Average	Good	Total
Lighting					
Interface with parking (on street parking)					
Ease of pedestrian crossing					
Landscaping and tree-lined streets					
Flat terrain					
Availability of sidewalks					

As a result, in order to keep the analysis simple, it was decided that presence of each measure has a score of 2, where lack of the measure gets 0. If one part of the neighborhood has the measure but the other part is lacking of it, then a score of 1 is given. Quality of each measure has also been graded (Good: 1, Average: 0, Poor:-1). At the end, all the grades are added up.

- For the assessment of the link between built environment characteristics and rail transit usage, an attempt was made to identify the measures or indices that seem to explain the ridership levels of the stations in the most effective way. In other words, each measure (density, diversity, accessibility, connectivity and integration with public transport) analysed here are separately compared with the ridership figures to see whether those stations that perform the best in terms of that measure are also the stations that have a higher ridership. For instance, from the point of view of the density measure, stations with the highest population density in their vicinity would be expected to be those that have the highest ridership. It is intended to find out the relations between the indicators analysed and the ridership. For this reason, two different approach of analysis is used: Qualitative (Ranking Analysis) and Quantitative.

  In the Qualitative (Ranking Analysis), all the values are listed for each station (Table 11). Accordingly, the stations are given a rank from 1 to 14 (1 being the first, 14 being the last). These ranks are added up to find the total score of each station.

Table 11 Ranking table

Ridership	Name of station	Density	Diversity	C_ score	C_ index	Daily_f_ bus	Daily_f_ dolmuş	Integ.	Total

For the Quantitative Analysis, influence of factors such as density, diversity, and accessibility/connectivity on ridership levels is analyzed using collinearity analysis, principal factor analysis and single factor regression analysis. Additionally, in order to reveal the different aspects and magnitude of each element, multivariate regression analysis is carried out to understand the planning and design parameters influencing the use of the transit systems.

4.4. Data collection

In Turkey, traffic data is rarely collected regarding the whole city or its parts. Local governments do not leave budget for travel surveys or household surveys. However, recently a study was made by Ankara Greater Municipality in order to prepare Ankara 2023 Master Plan in 2007. In this study, for macro and meso scales, mostly the recent data from Ankara 2023 study is used. Additionally, in-depth interviews are conducted with the experts in the Ankara Greater Municipality, Çankaya Mınicipality and Yenimahalle Municipality (Figure 20).

Figure 20 Data collection

However, for the micro scale, there was a lack of data for the neighborhoods around the stations. For this reason, a land use analysis is made from June 2013 to April 2014 for the selected 14 transit station areas with a team of two persons. Base maps have been provided from Ankara Greater Municipality, Çankaya Municipality and Yenimahalle Municipality. The field survey has been the most important task of the study. Then a field analysis is made for each station area by experiencing the area and for each parameter, data has been collected accordingly.

- <u>For the density parameter:</u>

  Building units were counted. Then a calculation is made as follows to find both residential density ((Number of residential units×number of storeys×household size)/total area) and employment density (Number of employees/total area) around selected transit station.

- <u>For the diversity parameter:</u>

  For each station area, a list has been made including all commercial, administrative, social, military, health services areas and so on. In order to find the number of employees regarding each use:

- For small businesses like hairdressers, real estate firms, markets, furniture shops and so on: An average of 5 is used in the calculations. For Ostim industrial site an average of 10 employees has been used.
- For the others:
  - Requests for acquisition of knowledge have been sent to administrative units (State Archive, MKE, Ankara University, Gazi University and so on)
  - Request via telephone

- For the connectivity parameter:

A check list which comprises the presence and quality of lighting, ease of pedestrian activity, parking, landscaping, flat terrain and sidewalks has been filled during the field survey while experiencing the site.

CHAPTER 5

MACRO-SCALE ANALYSIS:

URBAN FORM, MOBILITY PATTERNS AND TRANSPORT INFRASTRUCTURE AND POLICIES IN ANKARA

5. Macro scale analysis

In macro scale, the analysis will be descriptive, urban form and transport tendencies and trends will be argued. An idea will be given regarding the whole city.

As it is seen from Table 12, this section will cover three main issues: spatial form and spatial growth patterns, macro-scale diversity and accessibility and connectivity.

Table 12 Parameters in macro scale analysis

MACRO The city	
Parameter	Measurement/Anaysis/Index
Spatial form of city Spatial growth patterns	Compactness vs. Sprawl
Macro-scale diversity	Variety of uses
Accessibility and connectivity	Land use-transport integration Modal split Fares of different transport modes

5.1. Spatial form of the city and spatial growth patterns

5.1.1. Background information on Ankara's spatial history and existing form

Centrally located in Anatolia, Ankara is the capital city of Turkey with a population of 4,338,620 (2012). It is historically a high density city with a compact form. Mostly government buildings, commercial and industrial sites, residential areas and embassies are located in the city. Located in the center of highways and railroads, Ankara is also the cross roads of trade.

Ankara has been facing a rapid population growth since the 1970s. This has put pressure on the city center which has been holding business, service, finance and administrative facilities. The city started to expand to the fringes continuously. Over-crowding in the city center continued despite the urban growth. It became difficult to manage urban transport system. Nevertheless the low car ownership rates, traffic congestion became an important problem causing severe air pollution.

Since 1970s, there has been planning studies to transform compact urban form into controlled decentralization along two main corridors, western and southwestern (Figure 21). It aimed to create a mix of use of different land uses such as residential areas, commercial, industrial and working places. These corridors have faced different decentralization process which will be explained in the following section (Babalık-Sutcliffe, 2013).

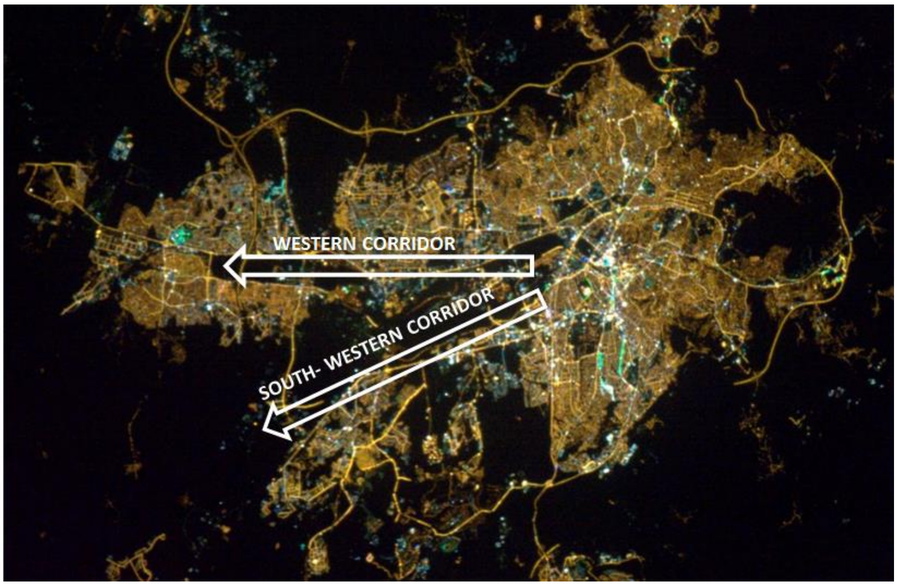


Figure 21 Corridors (Satellite photo)

Traditionally, for a long time there was no public transit service in Ankara. It was the first time in 1929 that the commuter train started to operate. Before that, urban transportation was mostly operated by privately owned motor vehicles. In 1935, municipality bought 100 buses operating only in the peak hours. It was an attempt to increase the usage of public transportation by establishing "Ankara Bus Management" in 1944 and EGO in 1950, however the shortages in the public transit services lead in increase in private sector investments in transportation as “dolmuş” and “taxi dolmuş”. After the 1970s, government agencies started to provide services for their employees. Local car factories started producing cars creating an increase in the car ownership rates (EGO, 2007).

Within these developments in the urban form, car usage has been increasing over the years. While, private car ownership rates are 613 cars/1000 people in Europe and 328 cars/1000 people in East Europe, it is 151 cars/1000 people in Turkey (KPMG 2013 Report). It is lower than the car ownership levels in Europe. However, it should be kept in mind that this rate was lower in the recent past. With the developments in the car industry and the local policies regarding car-oriented investments, this rate is increasing rapidly. It is assumed that this rate will increase to 253 cars/1000 people in 2015.

5.1.2. Compactness vs. Sprawl

Being located in a topographical crock shapened the urban form of Ankara. The main factor of Ankara being compact is its geographical characteristic. Its form which is named as ‘oil-drop’ in Turkish planning literature, “absorbed fragmented open spaces into built up area and produced an inflexible urban tissue with respect to the density pattern and solid-void relationship” (Çalışkan, 2004, p. 191).

Throughout the years, planning efforts have shapened Ankara. Starting from Lörcher and Jansen plans, Ankara was planned to be developed through north and south axis compressing it into the topographical crock. Consequently, opportunities for urban development have failed inducing transport and pollution problems that the city is facing today. Within that period, the structure of the city center could not be built.

In 1950s, road transport system became dominant in Turkey strengthening ring road constructions and outskirt connections of the city. İstanbul Road, Samsun Road, Konya Road and Eskişehir Road which are the four main roads connecting Ankara to the other cities were constructed in that period. The city outreached its boundaries, so new plans had to be prepared. In 1955, Raşit Uybadin and Nihat Yücel won the planning competition and started a new plan for Ankara. This plan could not solve the city center problem and there were no policies regarding the continuious development of the city.

After 1965, areas which were planned to be low density areas were tear down. Central business district areas were transformed into higher density areas. Additionally, improvement plans for squatter housing areas were prepared causing an increase in the topographical crock. Sprawl was an inevitable outcome of this process. Upper income class moved to sourthwestern part of the city to the fringes. This process was supported by constructing shopping centers in different centers through the corridor (Günay, 2005).

Change in the macroform throughout the years can be observed from Figure 23 below. Throughout the years, efforts to change urban form of Ankara from compact to controlled decentralized form continued. Two corridors were planned as mixed use residential areas having new centers and workplaces. Ankara also expanded along north-south axis. In the northern parts, manufacturing industry, construction and retail trade facilities were developed and new residential areas were planned in the squatter neighborhoods along that corridor. In the southern parts, financing and community services were developed and low density residential areas have emerged.

These two corridors had differences regarding the land use and residential characteristics. The western corridor was planned for decentralisation of industry, while the south-western corridor was planned for the decentralization of government offices and also for the university campuses.

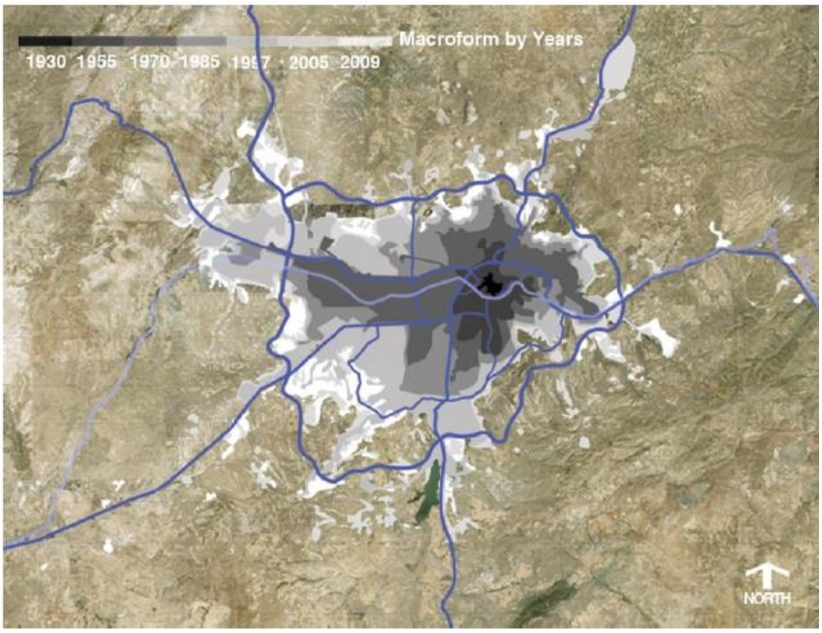


Figure 22 Change in the macroform of Ankara by years
Source: Yaşar, 2010, p.56

In the western corridor large scale mass housing projects were funded by the government, whereas the south-western corridor was planned as market-led residential development (Figure 23-24).

Western corridor (Batıkent) was the first priority metro line and south-western corridor (Çayyolu) was the second. Batıkent metro line was opened in 1997. On the other hand construction studies of Çayyolu Metro has started in 2002 and it finally started operating on 13 March 2014.

Figure 23 Western corridor- Yenimahalle (left), Hastane (right)
Source: Personal archive

Figure 24 South-western corridor- Alacaatlı (left), Çayyolu (right)
Source: Çalışkan (2004)

Two corridors faced different decentralization processes. In 1990, 40% of the population living in the western corridor were living 10 km away from the city center. This ratio was 76% in 2000. In the south-western corridor, 92% of the population were living in the first 10 km in 1990, this rate fell to 60% in 2000 (EGO, 2007). As it is observed from the figures, decentralization was faster in the south-western corridor. Additionally, this corridor was limited in the number of working places and public transit services. In the western corridor, despite the fact that the metro was operating, private car usage levels did not diminish as it was expected.

5.2. Macro-scale diversity

Central business district functions are mainly located in Ulus and Kızılay with high density levels. Moving to the south, mainly shopping malls and residential areas and to the south-western part (Eskişehir Road axis, Konya road axis and so on) government offices have been located supported by road infrastructures. There are also partial areas such as Bahçelievler, Mebusevleri, Çukurambar, Öveçler and Balgat holding central functions within themselves (EGO, 2007) (Figure 25).

There are more non-residential functions than residential in the central planning zone. Commercial service levels are high. Also residential areas are mostly observed. To the northern parts towards Ulus, the ratio of residential areas decreases, whereas towards the southern and south-western parts residential areas become dominant with high quality prestigious houses. In the transition area from Kızılay to Ulus, which is called Sıhhiye, small scale textile production shops have been located (EGO, 2007).

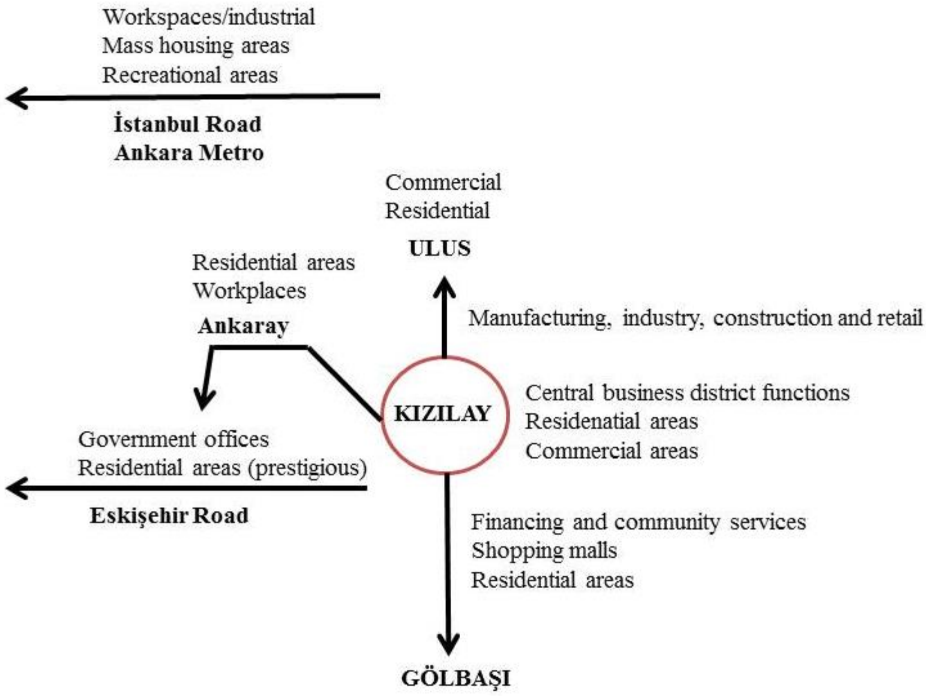


Figure 25 Schematic analysis

In the northern part of the central planning zone, manufacturing industry, construction and retail trade generates employment. This trend is different in the southern part with a high level of financing and community services. This opposite trend differentiates the socio-demographic characteristics of the area. Half of the people working in the central planning zone are employed in community services and 13,7% are in finance sector and financial institutions (EGO, 2007).

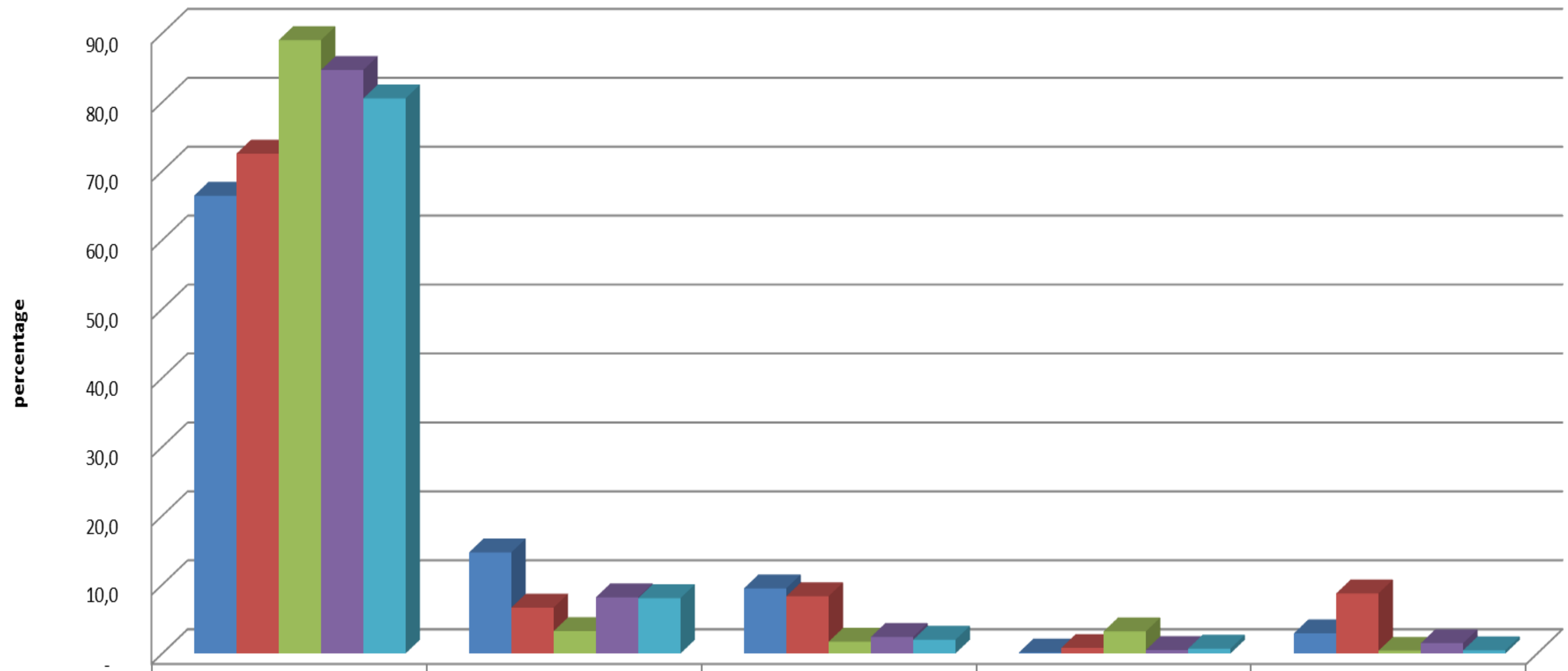
In summary, there is a certain level of diversity of land-uses throughout the city although the city centre remains to be the main Central Business District. Residential areas have been moving out of the city centre so it must be said that the city centre does not have much diversity in terms of bringing homes and workplaces.

Nevertheless, there is still housing at the periphery of the city centre in close proximity. Planning zones are mostly composed of residential buildings.

Predominantly, central and western planning zones accomodate commercial buildings.

Industrial sites have been decentralising along the western development corridor since the 1970s, and together with the residential area development at this corridor, this creates a certain degree of diversity, which will be further explained in detail for this corridor in the meso-scale analysis below.

The northern part of the city also accommodates many industrial areas, creating a good mix and diversity of residential areas and working areas, as well as commercial sub-centers. The southern Ankara, together with the soutwestern development corridor, however, has experienced residential growth mostly, lacking in working places (Figure 26).



	Residential	Residential+non-residential	Commercial	Education+culture+health+social+sports	Industry
Central	66,4	14,7	9,4	0,1	2,9
Western	72,5	6,7	8,3	0,8	8,7
South-western	89,0	3,2	1,7	3,2	0,4
North	84,7	8,2	2,4	0,5	1,5
South	80,5	8,0	2,0	0,7	0,5

Figure 26 Variety in the built-up area
Source: EGO, 2007

5.3. Accessibility and connectivity

5.3.1. Transport policies

Historically, in Ankara there is high usage of public transport. There has been efforts in integrating land use plans with transport policies. However, developments in the land use of Ankara accompanied urban sprawl and this has been fed by car-oriented policies increasing the share of private cars in the city.

The need for a metro system in Ankara has been proposed in Ankara Transportation Study (1972) which was prepared by Ankara Greater Municipality EGO General Management and a French firm SOFRETU. The system was planned to operate in two corridors (Özgür, 2009).

In 1985, Ankara Urban Transportation Study was prepared composing of four elements: Transportation Study, Transportation Master Plan, Feasibility Study for Rail Transit Investment and Documents, Description of the System, Bid Documents and First Draft. In the plan, main transport corridors and a rail transit system of 55 km long and a busway was proposed. A decentralized development was planned along two corridors supported by metro systems. This study was an integrated approach of land-use and transport. However, it did not become legally approved (Özgür, 2009)

Throughout the years, private car ownership rates continued to increase. growing interest on road transport investments and traffic congestion problems resulted in air pollution and transport problems. In consequence of these problems 2015 Ankara Transport Plan study was carried out. It suggested rail transit corridors and a ring road. However, the plan has not been implemented. Ankara Metro and Ankaray (LRT) which were proposed in the plan started to operate, but the construction studies of Çayyolu Metro took 12 years. Çayyolu Metro and extensions of Ankara

Metro to Sincan have started operating in 2014, however the work is ongoing regarding the Keçiören metro line (EGO, 2007).

Since 1990s, with an increased number of private cars in traffic, Ankara Gretaer Municipality solved the traffic congestion by constructing grade-seperated junctions and adding new lanes to the existing roads (Figure 27) (EGO, 2007).

Figure 27 Grade-seperated junctions in Ankara

The study by EGO (2007) was prepared to propose different alternatives for a compact macroform for Ankara. In the recent past, an urban sprawl trend was observed in the city rather than controlled decentralized policies proposed in the former plans. In the study, the need for a transport plan is also emphasized. However, lacking of a transport plan, this study proposes 10 additional rail transit lines with a length of approximetely 50 km (EGO, 2007). Thereof, it can be claimed that the study has not been prepered in an integrated approach.

In summary, from the 1970s to 1990s, there has been an effort to integrate transport and land-use planning policies however this has changed from the 1990s facing urban spatial growth and urban sprawl in the city. Private car usage has been increased; on the other hand extensions to the existing metro systems or proposed rail transit systems have not been actualized. In the recent years, the efforts in land-use transport integration seem to be put on the shelf.

Ankara is not a city having major pedestrian areas or transit encouraging neighborhoods. Most of the developments are road-oriented rather than transit-oriented. However, it would be fruitful to analyze the parameters set out in the literature review to see whether these parameters are present in the current urban areas, or whether they are applicable to Ankara and can be planned in the ongoing transit station areas.

5.3.2. Modal split

Minibus, bus, private bus and rail transit systems are different public transit systems in the city. Additionally, there are service vehicles for the schools and government offices which have a high percentage in the total motorized transport system. It is seen from Table 13 and Figure 28 that share of public transit in daily travel is 48,94% and private transport is 22,69%. These shares were 76,78% for public transit and 17,24% for private transport in 2000. Share of public transit is advantegous and it is higher than of Europe, however average car usage levels has been growing rapidly. This increase is important and also prejudicial. According to TÜİK data, 1,028,915 private cars were registered in traffic in 2012 and 1 out 3 person owns a private car in Ankara. Increasing demand for service vehicles also shows the inadequacy of public transport services in the city (EGO, 2007).

Analyzing different public transit modes, it is seen that minibus-dolmuş (9,99%) and EGO buses (21,67%) are commonly used public transit modes. In 1993, EGO buses were carrying 845.500 passenger corresponding to 26,2% of total system. This ratio had eventually decreased due to increased number of private cars and new rail transit systems in the city. Decreased number of new buses also affected this process.

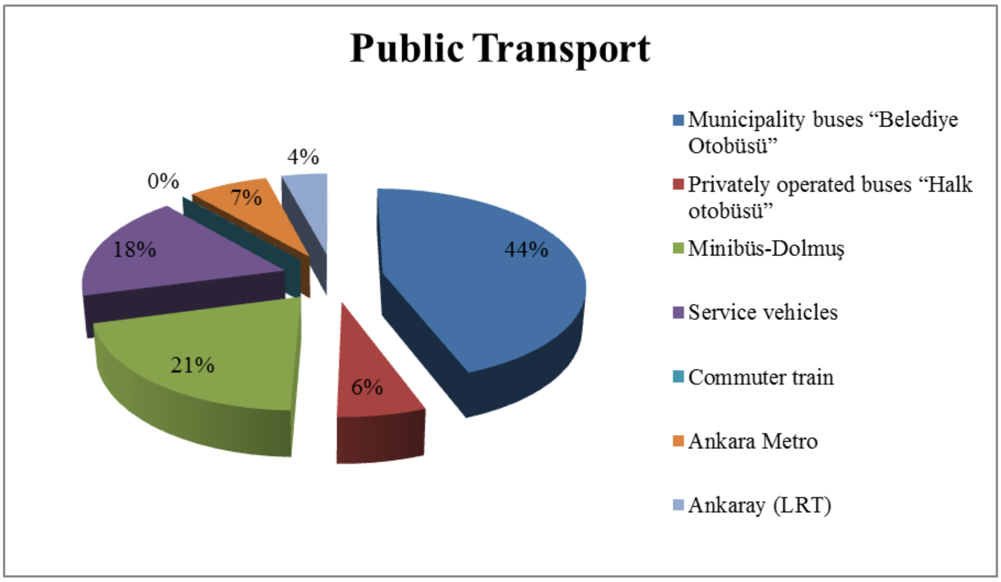
Considering public transport modes, rubber-wheeled vehicles are used more than rail transport systems. Rail transport only correspond to 5,6% (Ankara Metro 3,56% and Ankaray 2,04%) of total travels.

Table 13 Modal split in Ankara

Mode	Total %
Municipality buses “Belediye Otobüsü”	21,67
Privately operated buses “Halk otobüsü”	3,00
Minibüs-Dolmuş	9,99
Service vehicles	8,66
Commuter train	0,02
Ankara Metro	3,56
Ankaray (LRT)	2,04
Public transport total	48,94
Taxi	1,0
Private cars	21,69
Motorcycle	0,07
Private transport total	22,69
Bicycle	0,08
Walking	27,91
Non-motorized transport	27,99
Other	0,31
Total	100,0

Source: Ankara Metropoliten Alanı ve Yakın Çevresi Ulaşım Ana Planı, 2014

Regarding private car ownership rates, average car usage levels in Ankara were 21% in 2000. However, it increased rapidly and in 2013 private car ownership ratio reached to 184‰.



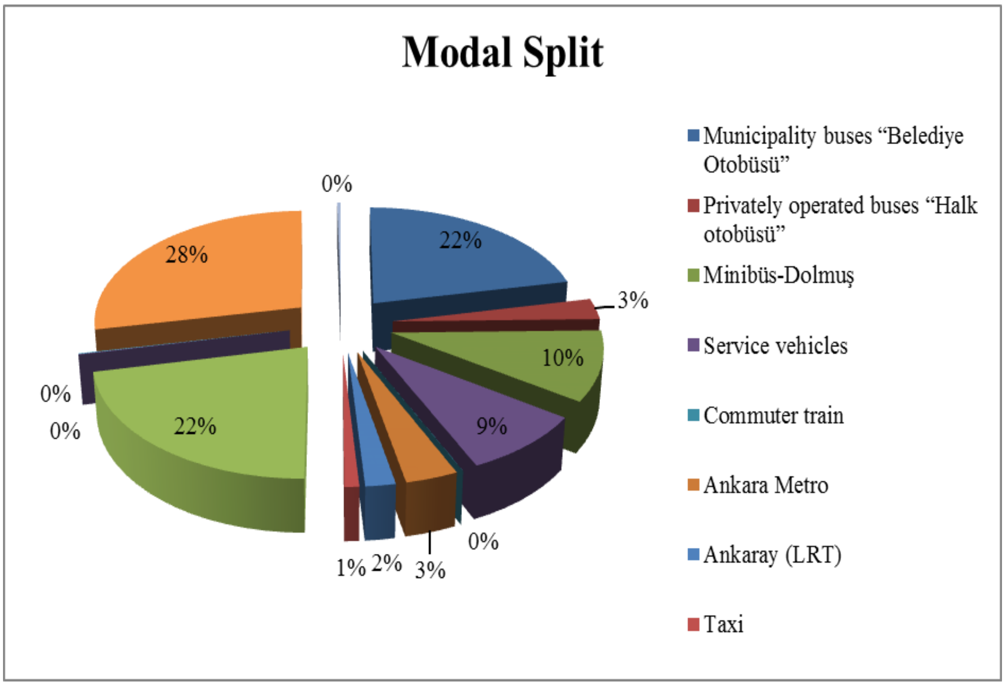


Figure 28 Modal split
Source: Ankara Metropoliten Alanı ve Yakın Çevresi Ulaşım Ana Planı, 2014

There are two rail transit systems operating in the city, Ankara Metro and Ankaray (LRT) and a commuter train travelling from Sincan to Kayaş. Çayyolu Metro and extension of Ankara Metro to Sincan have started operating in 2014. Due to the recent opening of these systems, only two existing rail transit line stations have been selected in the scope of the analysis. Ankara Metro was opened in the late 1997 operating between Kızılay and Batıkent. It connects the city center to the new residential and industrial areas that were proposed in the urban development plan under the decentralization strategy. The system was proposed to have a total length of 44.5 km in the year 2015 composed of four different lines: Kızılay-Batıkent, Kızılay-Çayyolu, Ulus–Keçiören and TBMM-Dikmen. In the plan Kızılay, İskitler, Atatürk Culture Center (AKM) and Balgat were proposed to be transfer stations from Ankara Metro to Ankaray rail transit system which is the second operating system in Ankara operating between AŞTİ and Dikimevi (Özgür, 2009).

Today, Ankara Metro starts from Kızılay to Ulus, Yenimahalle, Demetevler, Ostim and Batıkent having a total length of 14.6 km and it has 12 stations (7 underground, 3 at-grades, 2 elevated). Tandoğan-Keçiören (M4) (10,582 km, 11 stations) system's construction work is ongoing. There is another line which is in the planning phase that connects the airport to Kızılay. In "2023 Capital Ankara Master Plan", it was found that since 2006, there is a continuous increase in the ridership levels. This increase was related to the Eryaman bus system that was integrated to the Batıkent station. However, in total the ridership levels are low compared to the estimated ridership levels of the system (2023 Başkent Ankara Nazım İmar Planı, 2006). Ankaray (LRT) runs between Dikimevi and AŞTİ with a system length of 8,745 km (6.6. km underground and Emek station above ground). It has 11 stations and the system is a fully segregated system. The ridership has been increasing since 1996. It was 14.240.834 in 1996, and it increased to 42.395.463 in the year of 2006. It was found in "2023 Capital Ankara Master Plan" that mostly used station of Ankaray is the Kızılay station which is located in the central business district (CBD) and this station was followed by Dikimevi, Beşevler and Aşti respectively. Beşevler, Dikimevi and Maltepe stations were mostly used for school trips, whereas Kızılay station was used for working trips (2023 Başkent Ankara Nazım İmar Planı, 2006).

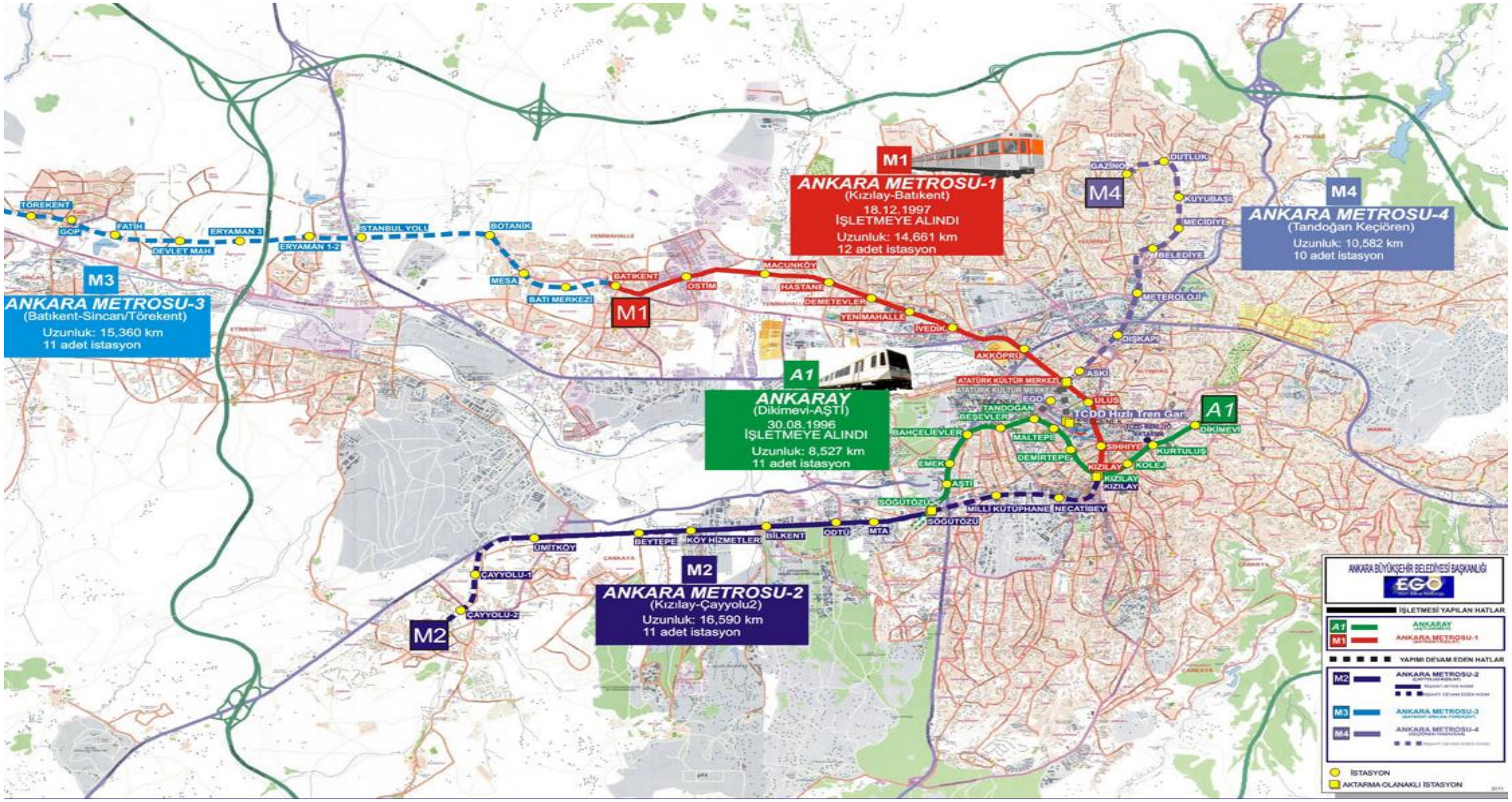


Figure 29 Rail transit systems in Ankara
Source: EGO Genel Müdürlüğü

5.3.3. Fare policy

There are two kinds of buses serving the whole city. One is run by municipality, “Belediye Otobüsü”, which requires electronic tickets. The second type of bus is privately operated bus which is called “Halk Otobüsü”. In those buses only cash is accepted (Table 14).

Table 14 Fares of different modes

Mode	Full fare (TL)	Discount ticket (TL)	Short distance (TL)	Long distance (TL)
Municipality buses “Belediye Otobüsü”	2	1,5 0	NA	2,60 to 5,90
Privately operated buses “Halk Otobüsü”	2,40	1,50	NA	1,30 to 9,75
Privately operated midibus	2,40 (inner city)	1,50 (inner city)	NA	NA
Minibüs-Dolmuş (intracity)	NA	NA	2,40	2,75
Commuter train	Within the scope of Başkentray project, commuter train service has been cancelled since 01.08.2011.			
Ankara Metro	2	1,50	NA	NA
Ankaray (LRT)	2	1,50	NA	NA

Source: UKOME General Assembly Resolutions, 06.06.2014

*With the Ankarakart there are at most 2 transfer opportunities within 75 minutes with an additive cost of 0,67 TL for each transfer. For the cut-price tickets the transfer cost is not taken.

Fares for municipality buses operating to the districts differs from 2 TL to 5,90 TL (full fare) and 1,50 TL for discount ticket; privately operating public transport vehicles from 1,30 TL to 9,75 TL (full fare) and 1,50 for discount ticket. Fare for rail transit system is as the same as "Belediye Otobüsü" and the same electronic ticket (Ankarakart) can be used.

Dolmuş-minibüs is a small vehicle with a capacity of approximately 14 passengers with a flexible schedule and special routes. It takes off when the vehicle is fully occupied. It has no fixed stops. Each passenger pays according to the distance travelled differing from 2,10 TL (short distance) to 2,40 TL (long distance) in the city.

There are also yellow taxis. These are for 4 people. The fare is calculated in the meter. Initial price is 2,4 TL, this rises 0,24 TL per 100 meters.

Existing fare system in Ankara is not transit-encouraging. There is no fare integration system, however with the introduction of Ankarakart system from August 2014 a change is envisaged in the use of transit systems. In İstanbul, there is a reduced price system within 75 minutes. In İzmir, the ticket can be unlimitedly used within 90 minutes. In İstanbul, fare integration system covers both public and private urban transit systems. However, in Ankara there is a transfer price since 2011 (second journey was free before 2011) and only fare integration is between EGO buses and Ankara Metro and Ankaray.

5.3.4. Parking policy

In Ankara, there are no consistent parking policies regarding the whole city. In some areas there are multi-storey parking areas, privately operated parking areas and on-street parking areas. There are no regulations on fare systems for the purpose of transit use.

5.4. Summary

In this section, spatial growth patterns, density, macro-scale diversity and accessibility and connectivity parameters have been analyzed in macro scale. The findings will be presented by each parameter:

Spatial form of the city/Spatial growth patterns:

- Although there are advantages due to compactness, Ankara has faced a rapid sprawl which changed the form of the city. Urban form of Ankara has gone through a process of controlled decentralization through two proposed corridors to southwest and west. It also expanded along north and south axis.

Macro-scale diversity

- Main acitivities in the city are community services, financial services and insurance, social and personal services, transportation, communication and storage, industry, retail and construction.

Accessibility and connectivity

- Daily travel is made mostly by private cars (33,2%), minibus-dolmuş (22,5%) and EGO buses (13,9). Considering public transport modes, rubber-wheeled vehicles are used more than rail transport systems. Rail transport only correspond to 5,4% (Ankara Metro 3,3% and Ankaray 2,1%) of total travels. Notwithstanding that the metro does not play a significant role in transport terms, it only covers 3,3% of all motorized trips in 2012. Actual metro ridership level in the western corridor has achieved only 27% of the forecasted value (Özgür, 2011).
- There is no fare integration system and parking policy in the city. Existing fare system in Ankara is not transit-encouraging. There are no regulations on the integration of parking areas and transit system. The city is a car-oriented city.

In the following section, these parameters will be extended and an in-depth analysis will be given regarding two rail transit corridors in Ankara.

CHAPTER 6

MESO-SCALE ANALYSIS:

DENSITY, DIVERSITY, ACCESSIBILITY AND CONNECTIVITY ALONG THE URBAN RAIL CORRIDORS IN ANKARA

6. Meso scale analysis

In the study, meso scale is defined as the rail transit corridors in Ankara, Corridor I: Ankara Metro and Corridor: II Ankaray (Table 15).

The neighborhoods around Ankara Metro and Ankaray routes define the corridors (Figure 30). Density, diversity and accessibility and connectivity will be analyzed according to the literature review. Number of workers per hectare and number of residents per hectare will be presented. This will show the density differences around the corridors. After a descriptive diversity analysis variety of uses and dominant uses will be given to reveal the neighborhood characteristics. For the two corridors, station served by multiple modes, number of bus lines feeding into the station, availability of parking facilities (car and bicycle) and kiss-and-ride opportunities will be analyzed.

Table 15 Parameters in meso scale analysis

MESO Rail system corridors	
Parameter	**Measurement/Anaysis/Index**
Density	Number of workers per hectare Number of residents per hectare
Diversity	Descriptive analysis of the corridor Variety of uses Dominant uses
Accessibility and connectivity	Station served by multiple modes Number of bus lines feeding into the station Availability of parking facilities (car and bicycle) and kiss-and-ride

Mostly data from the study by Ankara Greater Municipality (2007) will be used. Within five zones defined in the study, central and western planning zones are composed of neighborhoods surrounding the two corridors in the study. Central planning zone accomodates the central business district and its surrondings, including Altındağ and Çankaya districts and some parts of Yenimahalle district. Western planning zone is located on the “western corridor” of Ankara which includes Yenimahalle, Etimesgut and Sincan districts.

6.1. Density

Over the years, the metropolitan area has quadrupled and the densities has been diminished. After the 1990s, the western and soutwestern corridors have started to develop attracting more population out from the city center and this changed the overall density pattern of the city.

Regarding population density, it differs in the neighborhoods varying from 17 p/ha to 400 p/ha. In spite of the fact that there is urban sprawl, generally the city is denser than the cities in Western Europe.

In the following figures, built-up densities of different neighborhoods are divided into 5 groups: lower than 50 p/ha; 50-100 p/ha; 100-200 p/ha; 200-300 p/ha and 300-higher p/ha. Neighborhood which has the lowest density is Cumhuriyet (17 p/ha) and the highest density is Demetlale (770 p/ha) (Figure 31).

Densities are higher in the “main crock” of Ankara. Regarding Corridor I, multi-storey buildings (14-15 storeys) are dominant in Yenimahalle and Demetevler districts. Especially in Demet, where the density levels reach to 448 p/ha, there are unauthorized multi-storey buildings including empty lots. In this sub-district, when Demet, Demetgül and Demetlale neighborhoods are analyzed, it is found that density levels rise up to 770 p/ha. As for Yenimahalle, there has been a dramatic transformation from 2-storey houses with gardens to multi-storey buildings have led to an increase in density levels up to 332 p/ha. Besides these developments, planned and relatively organized developments in Batıkent (158p/ha) sub-district are observed (EGO, 2007). Regarding Corridor II, neighborhoods around the central business district are mainly residential with high density levels. Since 1980s, with major structural and transportation changes in the city, Ulus and its surrounding faced urban decay. In Kültür, Devlet and Ulus sub-districts the density is very high whereas there are areas having 31 p/ha density in the same territory showing the outcomes of this process. It is observed that Kültür and Devlet sub-districts have very low densities (Figure 31) (EGO, 2007).

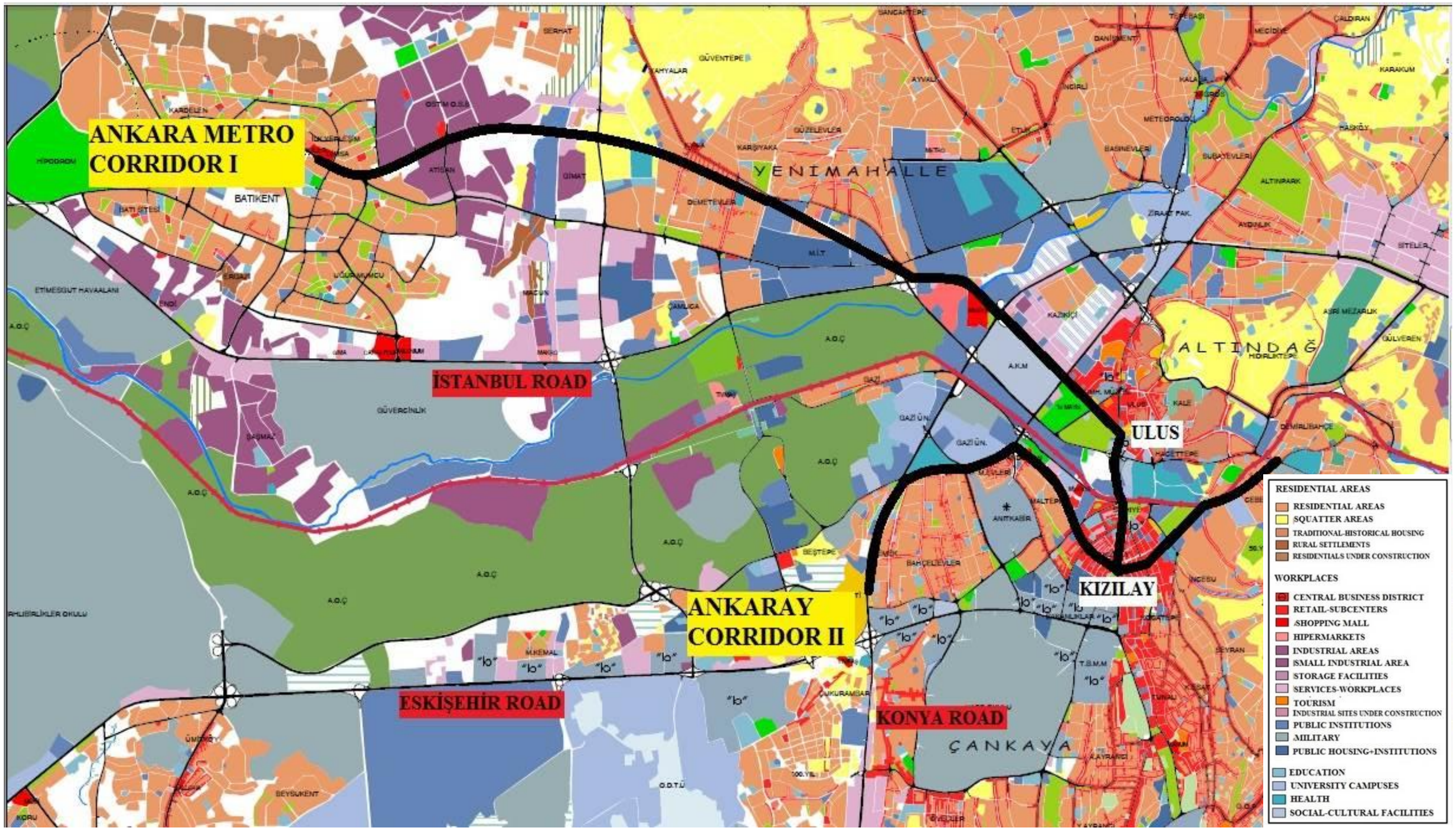


Figure 30 Land use map around the corridors (2005)
Source: EGO, 2007

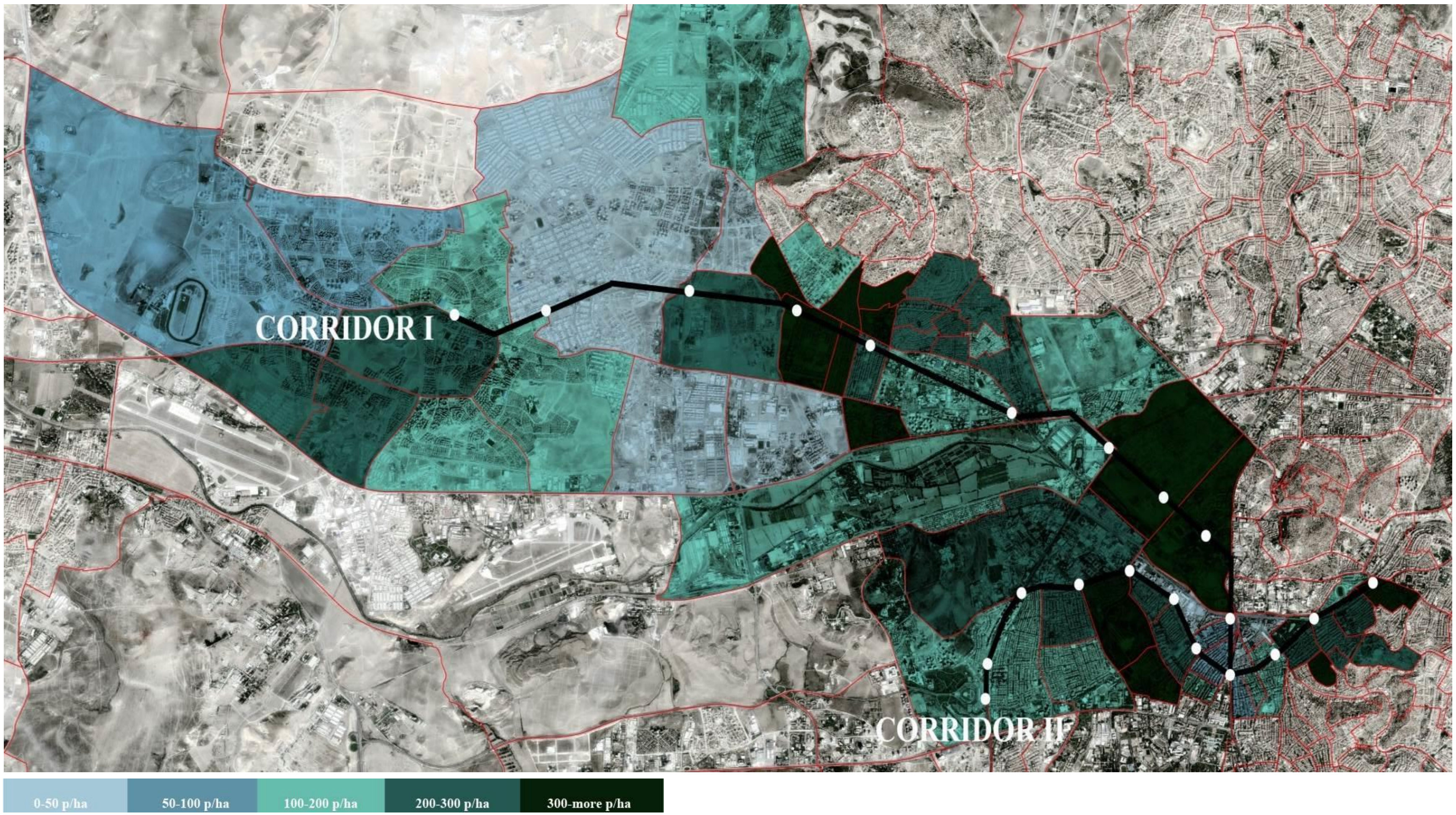


Figure 31 Residential Population Densities along Corridor I and Corridor II (See Appendix I)

Employment densities are also calculated (Table 16). For Corridor I, it is found that Yenimahalle, Demet, Karşıyaka and Batıkent hold relatively high employment density levels in the corridor. For Corridor II, Bahçelievler, Maltepe, Kızılay and Devlet hold relatively high employment density levels in the corridor.

Table 16 Employment densities of sub-districts in Corridor I and Corridor II

Name of sub-district	Area (ha)	Employment population	Employment density (p/ha)	Name of sub-district	Area (ha)	Employment population	Employment density (p/ha)
Y.mahalle	500,49	24.993	49,94	B.evler	304,91	21.134	69,31
Demet	778,75	34.749	44,62	Maltepe	260,50	12.992	49,87
Karşıyaka	829,48	23.024	27,76	Kızılay	108,67	3.001	27,62
Batıkent	2236	53.173	23,78	Ulus	152,25	2.127	13,97
Fatih	1363,16	21.309	15,63	Varlık	247,96	1.669	6,73
Sincan	5130,25	55.331	10,79	Kültür	66,33	515	7,76
Eryaman	2475,56	20.495	8,28	Devlet	491,59	12.535	25,50

Source: EGO, 2007

Both corridors have higher densities that are higher than of North American and many Western European cities. In literature (Newman and Kenworhty, 2006) 35-40 persons per hectare (residential and employment) were defined as the level that would reduce automobile dependence and encourage public transit. These levels differ in Ankara as as being located in a developing country. In Ankara, density levels are higher than 35-40 p/ha.

In Corridor I, the existence of metro line would have resulted in high density areas. It might also be the result of mass housing projects along the same corridor. Babalik-Sutcliffe (2013) argued that the metro investment in the western corridor also supported residential development and increased density. Corridor II was already developed area before Ankaray was constructed. High density would have an affect on the transit ridership. However, only the density parameter is not enough to create environments which would encourage people to use transit systems. In the following sections, diversity and accessibility will be analyzed and a table of analysis will be made accordingly to the parameters.

6.2. Diversity

Main functions in Ankara have been located along Ankara Metro route: Macunköy, Ostim and İvedik stations are located next to main industrial areas in Ankara. Ankara Oncology Hospital is located next to Hastane station. Akköprü station mostly serves to Ankamall Shopping Center and Youth Park, Opera House and Courthouse are next to Ulus station.

Across Corridor I, there are mainly mass housing areas (28%) such as Eryaman, Batıkent, Fatih, Etimesgut and Sincan (Table 17). This corridor also has recreational areas and workspaces. Especially Sincan Organized Industrial Site, OSTİM, İvedik Organized Industrial Site and İstanbul Road may be defined as the largest workspace of the planning zone (EGO, 2007).

Table 17 Location of the stations in Corridor I

Name of the station	Location of the station (place value)
Kızılay	Central Business District, Residentials
Sıhhiye	Courthouse, Officer's club, Commercial areas, Cafes
Ulus	Youth Park, Theatre, Opera House, Hotels, Youth Sports Center, Administrative buildings
Kültür merkezi	Smal size industrial areas, Ataturk Cultural Center, Hotels, Transit station construction
Akköprü	Auto mechanic, Ankamall, Hotel, Police headquarters
İvedik	Residentials, Hasan Doğan Stadium, Provincial Agriculture Directorate, Peynirci Market, Butcher, Coiffeur
Yenimahall e	Residentials, Mosque, Department of Finance Education Center, Polyclinic, School
Demetevler	High Schools, Residentials, Commercial areas (mixed use)
Hastane	Residentials, Commercial areas (mixed use), Oncology Hospital
Macunköy	Residentials, Vacant lots, Aselsan, EGO Bus Garage,
Ostim	Industrial areas
Batıkent	Gimsa Shopping Center, Metro Cente, Marketplace, Residentials, Park

This corridor employs half of the industrial workforce. However, creating commercial cores as mentioned in the plan have not been materialized; instead large shopping malls and hypermarkets have been opened.

Table 18 Home-work travel pattern in Corridor I

	Corridor I
Those working along the same corrdior	51%
Those working in the city center	40%
Increase in traffic levels in 1985-2005	12 times

Source: Babalık-Sutcliffe, 2013

As seen in the Table 18, half of the population living in this corridor also works in the same corridor. This results in a decrease in the need to travel to the city. However, the traffic level has been increasing in the corridor which is due to the increasing population and urban growth rates (Babalik-Sutcliffe, 2013).

As a result, Babalik-Sutcliffe (2013) argued that in the western corridor (Corridor I), creating diversity is accomplished holding both residential and industrial functions(Figure 32). In a survey made by Middle East Technical University (METU) in 2002 showed that 51% of people living in the western corridor also work in the same corrdior. This ratio shows the high rate of mixed land use characteristic of the corridor.

Corridor II (Ankaray) is composed of neighborhoods which have socio-cultural activities with financial services, production services, residential areas and government offices. This corridor holds mostly residential and commercial areas. The residential areas through the axis of Tandoğan Bahçelievler and around Cebeci were planned for working class in the former plans of Ankara. Along Ankaray route, there are university campuses (Gazi University and Ankara University), hospitals, hotels, residential areas, parks and cafes and so on (Table 19, Figure 33).

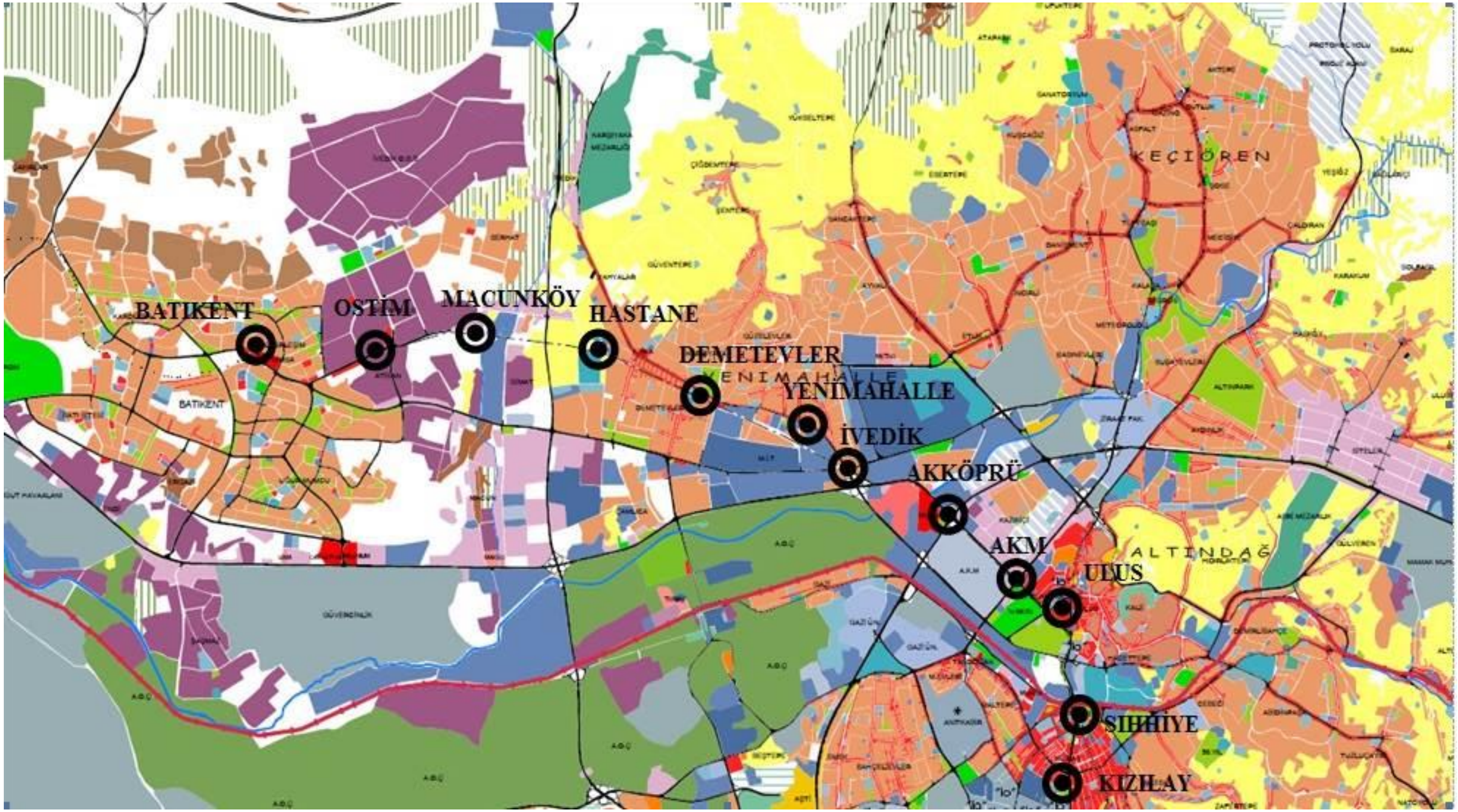


Figure 32 Land use map around Corridor I (2005)
Source: EGO, 2007

Table 19 Location of the stations in Corridor II

Name of the station	Location of the station (place value)
Aşti	Ankara Law School, Residential areas, Underpass under Konya Road
Emek	Underpass under Konya Road, Automotive stores, Directorate General of Mining Affairs, Steep stairs connecting residentials to the station, Poor lighting
Bahçelievler	Gazi University Hospital, Pharmacies, Teacher's lodge, Atatürk Anatolian High School, Riding Center, Türkeş's grave, Residential areas
Beşevler	Commerce, Conservatoire, Cafes, Residential areas, Vocational High School, Petrol station, Mosque inside the station, Elevator
Tandoğan	TSK Eğitim Vakfı, Altınel Hotel, Ziraat Bank, Officer's Club, Mechanical Chemistry Industry, Ankara University, Çelikler market, Long waiting time at lights for the pedestrians
Maltepe	Commerce, Anatolian Agency, Railway station, Gazi University, Hotels, Residential areas, Workplaces
Demirtepe	Commerce, Maltepe Mosque, Cafes, Workplaces, Residential areas
Kızılay	Central Business District, Commerce, Residentials
Kolej	Commerce, TED University, Hotels, Ministry of Çankaya, Kurtuluş Park, Marriage office
Kurtuluş	Commerce, Faculty of Political Sciences, Kurtuluş Park, Hamamönü, Hospitals, Workplaces, Residential areas, Dormitories,
Dikimevi	Commerce, Residential areas, Workplaces, War veterans association, Military, Ankara Medicine School

In summary, with the strategy to decentralize along the western corridor, major mass housing projects took place with three organized industrial areas and working places in the corridor. The employment as percent of total city employment is 39,41% (metropolitan area). When analysing the employment as percent of total city employment in Corridor I, it is observed that this ratio is 41,86% showing the high participation in economic life (EGO, 2007).

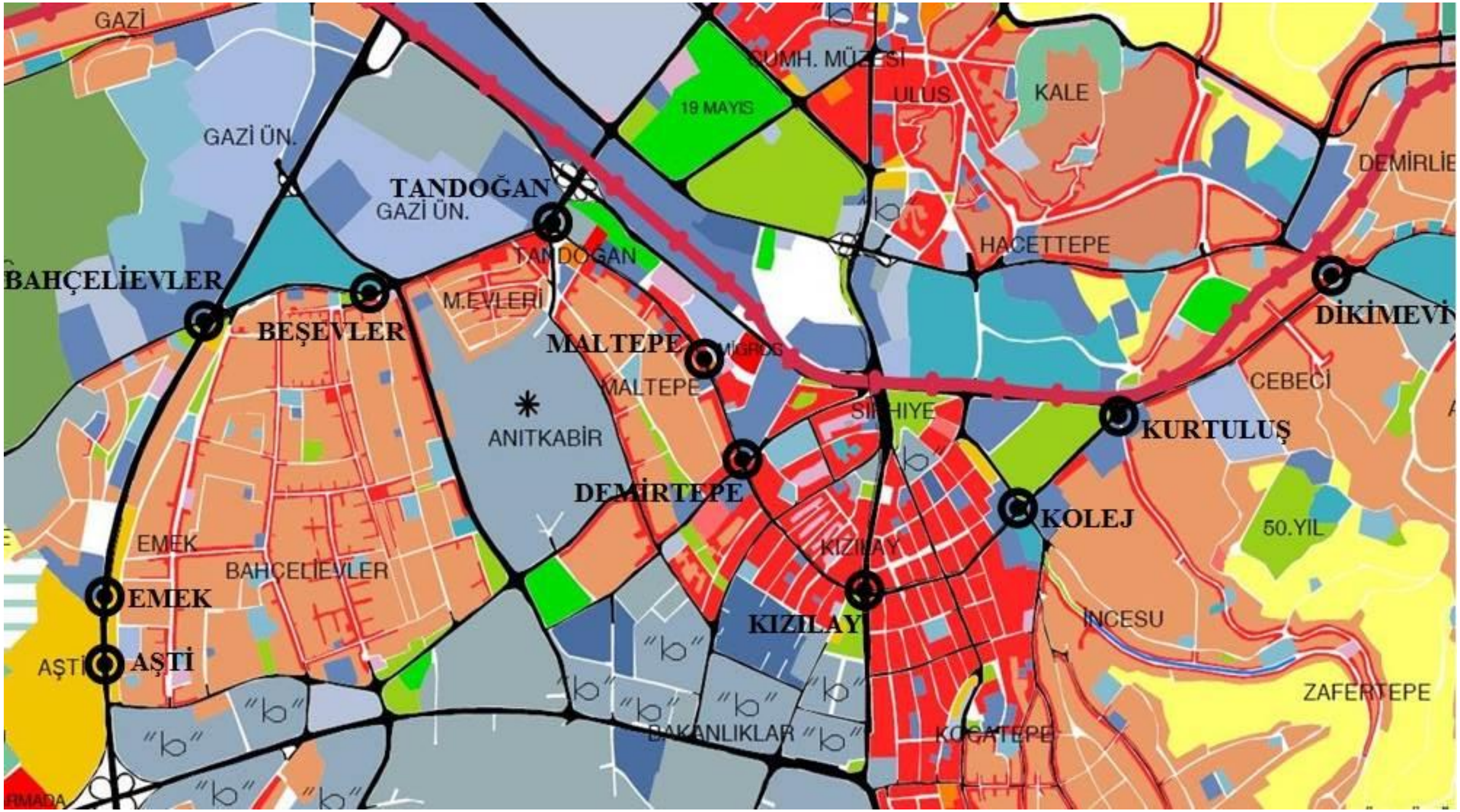


Figure 33 Land use map around Corridor II (2005)
Source: EGO, 2007

6.3. Accessibility and connectivity

In this section, the following properties will be revealed:

- Station served by multiple modes
- Number of bus lines feeding into the station
- Availability of parking facilities (car and bicycle) and kiss-and-ride

Dolmuş operates parallel to most parts of Ankara Metro and Ankaray system. There are also privately operated bus lines along the same corridors especially along Ankaray corridor.

For Corridor I, there is cable-car system which is integrated to this station and its construction has started at the time of the study and it has started operating on 17 June 2014. It is planned as the first public transit cable car system in Turkey. It has a capacity of 2400 passengers/hour/direction. The system have four stations and 48 cabins (it is planned to have 106 cabins when the system operates fully) having a capacity of 10 passengers each. There is an integrated fare system between metro and cable car. Passengers will not buy extra tickets for the cable car system. However, it should be noted that the system has not started operating when the study began. For this reason, the effect of the system to the ridership levels of Yenimahalle station is neglected in the study.

The following Figure 34 shows how Ankaray is integrated with other modes. It is seen that Kurtuluş and Maltepe stations are integrated to the commuter rail, Kızılay serves as a transit station and AŞTİ station is integrated with the Bus Terminal.

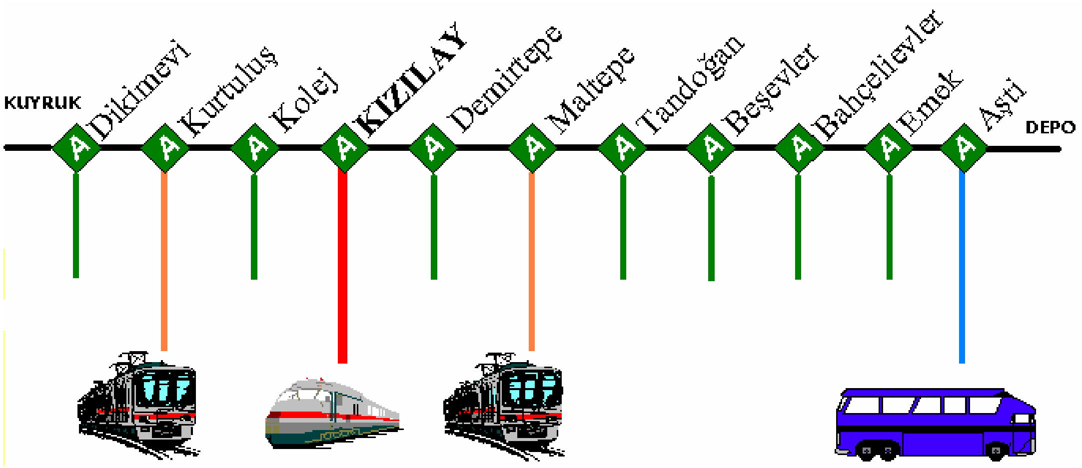


Figure 34 Ankaray

In the following figure (Figure 35) number of bus lines passing by each station in Corridor I and Corridor II are given. These numbers are found by using EGO Bus Application, which shows the bus routes, time schedules and online movement of each bus. Bus lines shown in the table have bus stops near each station. It is analyzed that Sıhhiye (183), Kızılay (106) and Ulus (84) stations are accessible by more than 80 bus lines. Bus lines shown in the tables cover both the feeder bus systems (A1 and A2 for Ankaray, M1 and M2 for Ankara Metro) and the others. When the feeder systems are analyzed in Corridor I, bus feeder systems are available at Batıkent, Ostim, Macunköy, Hastane, Demetevler and İvedik stations. There are 27 different bus lines feeding into Batıkent station, from which 6 of them are ring systems from Eryaman resulting in an increase in the transit ridership levels of Batıkent station. Kültür Merkezi station is under construction to become a transit station. In the long term, feeder bus system might be planned for this station.

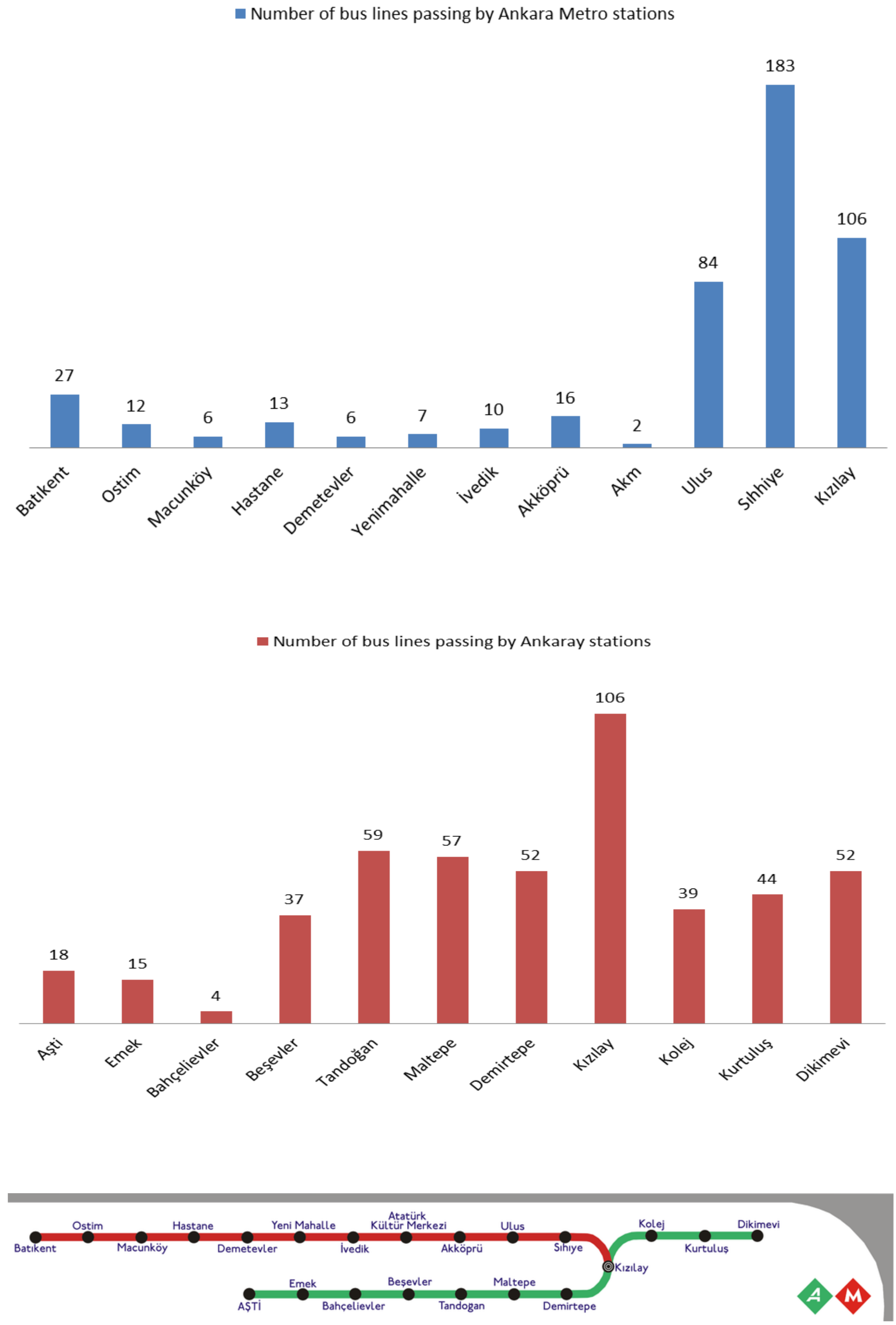


Figure 35 Number of bus lines passing through Corridor I and Corridor II

Source: EGO website, 2013

In Corridor II, there are two feeder bus lines operating along the rail transit route starting from Aşti and Dikimevi stations. Additionally, two lines departing from Beşevler serves the system.

AŞTİ, Emek, Kolej, Akköprü, İvedik, Yenimahalle, Demetevler and Hastane stations have parking areas. Especially for Macunköy station, kiss-and-ride is mostly used due to the fact that the station has poor access by walking (Figure 36). There are some residential developments around the station, however it is located next to the highway and there are vacant lots. For this reason, people do not prefer to walk to the station; park-and-ride or kiss-and-ride is observed. Most of the stations are lacking of bicycle parks. Only AŞTİ station has two car bicycle parks with a capacity of 100 bicycles.

Figure 36 Macunköy station parking area and kiss-and ride (up), AŞTİ station parking area and bicycle parks (down)

Rail transit system service frequency is 3 to 5 minutes in the peak hours and 8 to 9 minutes in off-peak hours operating between 6 am and midnight.

6.4. Summary

In this section, Corridor I: Ankara Metro and Corridor: II Ankaray were analyzed. Findings will be given according to each corridor and parameter:

Corridor I:

<u>Density</u>

- Along Corridor I there are high density neighborhoods. The density levels are between 105 p/ha (Namık Kemal) and 770 p/ha (Demet).

<u>Diversity</u>

- Along the corridor there are mainly mass housing areas. Sincan Organized Industrial Site, OSTİM, İvedik Organized Industrial Site and İstanbul Road may be defined as the largest workspace of the planning zone. Main characteristic of this corridor is that 51% of people are working living in the same corridor.

<u>Accessibility and connectivity</u>

- Corridor I is accessible by bus systems, dolmuş and cable car system. Along the corridor, there are feeder bus systems M1 and M2 besides large amount of other buses. Kiss-and-ride is mostly observed in Macunköy station which is located in an industrial area along the corridor.

Corridor II:

Density

- Along Corridor II, density levels are between 31 p/ha and 635 p/ha. There are financial services, production services, residential areas and government offices. This corridor holds mostly residential and commercial areas.

Diversity

- Corridor II is composed of neighborhoods which have socio-cultural activities with financial services, production services and residential areas, government offices. This corridor holds mostly residential and commercial areas.

Accessibility and connectivity

- This corridor is accessible by bus systems, dolmuş and commuter rail system. The feeder bus systems A1 and A2 operate along the corridor. Near AŞTİ, Emek and Kolej stations there are parking opportunities. Additionally, AŞTİ is the only station that has bicycle parks. It should be noted that getting on train with a bicycle is not permitted, but the studuis are on-going to integrate bicycle with rail transit.

In the following chapter, selected stations will be analyzed according to the parameters in micro scale.

CHAPTER 7

MICRO-SCALE ANALYSIS:

BUILT ENVIRONMENT CHARACTERISTICS, ACCESSIBILITY AND CONNECTIVITY AT RAIL TRANSIT STATION AREAS IN ANKARA

7. Micro scale analysis

In the study, micro scale is defined by the vicinity of transit station with its circular radius It is argued in the literature that the optimum walking distance is 500 m and the maximum walking distance is often accepted as 800 m. In this respect, two circles are determined around the case-study stations, one with 500 m and one with 800 m radius, and the analysis is made accordingly.

As described before, the micro-scale analysis of the vicinity of transit stations aims at observing the built environment around the stations with the underlying objective of finding out whether the built environment is supporting transit usage and whether the qualities of the built environment have an effect on the usage of a given station. The literature clearly indicates density and diversity as major factors in creating transit-friendly built environments. In addition, the walkability of the station-area can have an important effect on the usage of transit. In the transportation literature the term “walkability” is often used to define walkable environments where walking is more readily performed. These urban areas are dense residential areas that have a mixed land use and highly connected streets (Gauvin, 2005). In this respect, vicinity of the transit station will be analyzed under density, diversity and accessibility and connectivity parameters (Table 20).

Density is measured by finding the number of people per hectare. This can be calculated by using residential population per hectare or working population per hectare. In the study, both residential and employment population will be calculated and used to determine the characteristic of the area.

Table 20 Micro scale parameters

MICRO Walkable radius from rail stations **(**500 m and 800 m)	
Parameter	**Measurement/Analysis/Index**
Density (800 m radius)	Number of residents per hectare and number of working per hectare
Diversity (800 m radius)	Place value (Bertolini, 1999) Degree of functional mix (percentage of units regarding its function)
Accessibility and connectivity	Beta index (Rodrigue, 2006) or Connectivity index (Litman, 2012) (number of links over number of nodes) Grid pattern vs. cul-de-sacs (descriptive analysis) Availability of sidewalks Lighting Ease of pedestrian crossings Street width Landscaping and tree-lined streets Interface with parking (on street parking) Flat terrain (grade changes, stairs etc.) <u>Node Value (Bertolini, 1999):</u> Station served by multiple modes Number of bus lines feeding into the station Availability of parking facilities (car and bicycle) and Kiss-and-ride Service frequency

Diversity will be analyzed by calculating the degree of functional mix, assessing vertical and horizontal mixed use and presenting the variety in the built-up area. Accessibility and connectivity measures will be used in order to show the pattern around the transit station. In the following sections, each parameter will be analyzed by each transit station.

7.1. Ankara Metro

7.1.1. Density

For the density analysis firstly, the number of people living and working within 800 m radius around the stations (vicinity of station) was calculated and secondly these numbers were divided by the area of the analysis. The residential population was found by multiplying number of buildings within the area, number of storeys, number of apartments at each storey and the household size. Household size is taken as 4 as this is the same value used by the Greater Municipality of Ankara in its 2007 Master Development Plan. A plot-basis analysis has not been made, because this would not give an overall picture in the vicinity of the station. In other words, it is useful to include vacant plots and undeveloped areas within the vicinity of the station in the calculation of the total area, because the existence of such empty plots (or very large roads) results in reduced number of people within walking distance to the station. Therefore, gross densities are calculated by including the whole area within the circle of 800 m radius, as opposed to net densities. The starting point of the analysis is the assumption that high density characteristic would have a positive effect on the ridership levels of the stations. This is going to be tested in the following sections.

When the residential and employment densities were calculated within the 800 m radius around the transit stations (Table 21), it is found that Demetevler station area with a residential density of 1846 p/ha is the densest area among the stations analyzed in the study. It is followed by Hastane (1086 p/ha), Yenimahalle (703 p/ha), İvedik (277 p/ha) and Batıkent (193 p/ha) station areas.

It was observed in the meso scale analysis that the neighborhoods in which Demetevler station is located hold the highest density levels. This is also the fact when analyzing the vicinity of the station. There are mostly 6-9 storey buildings closely placed on the southern part, and 3-5 storey buildings on the northern part. The patterns will be analyzed, which will also give a clue of the high density characteristic.

Table 21 Density

Name of station	Density (p/ha)	Residential density (p/ha)	Employment density (p/ha)
Batıkent station area	193	190	3
Ostim station area	81	3	77
Macunköy station area	53	33	20
Hastane station area	1086	1067	19
Demetevler station area	1868	1846	23
Yenimahalle station area	709	689	21
İvedik station area	277	271	7

Number of employees in big companies (Aselsan), government offices (Yenimahalle Municipality, Devlet Arşivleri) and hospital (Oncology Hospital) were collected. For other employees which are working in markets, hair salons, manufacturers, industrial area an average[2] has been used in the calculations.

[2] For markets, hair salons, manufacturers an average of 5 employees were given. For Ostim industrial site an average of 10 employees has been used.

Considering employment density, it is analyzed that Ostim station area which is characterized as an industrial area has 77 p/ha density which is the highest employment density among the stations in the study, where İvedik and Batıkent station areas have the lowest densities, the latter one due to its highly residential characteristic.

7.1.2. Diversity

7.1.2.1. Variety in the built-up area

Batıkent station

Batıkent station is the last station of Ankara Metro. It serves residential, commercial and industrial areas. In Figure 37, land use around Batıkent station is shown on the map.

It is found that commercial buildings around the station are mostly located within 500 m. GİMSA Shopping Center, Metro Center, market place, Post office are located near the station along the road. There are also vertically mixed used buildings (ground floor commercial, upper floors residential) around the station. Batıkent Sports Hall and a school are located next to the station. In the 800 m radius around the station, there are mostly residential areas. There is also an increase in the number of parks and green areas. There is a fire station, school areas and two mosques in the area. Industrial areas cover the northeastern part of the station area and it is out of the micro study borders.

In the northern part of Batıkent station, there are single family houses with 2-storeys. In the southern and southeastern parts there are mostly multi-storey buildings (3 to 11 storeys). Figure 37, shows the setting of different building types in the area.

Ostim

Ostim station area has an industrial characteristic. It is located next to Batıkent. There are mostly auxiliary equipment, furniture and white appliances shops. There are cafeterias on each corner serving to the employees and they do not serve on Sundays. There is a hotel and business center which is the tallest building in the area located next to the station. Residential areas are composed in the southern and south-western parts which is a part of Batıkent development area. These residential areas are mostly single family houses and few multi-storey buildings (Figure 38).

The vicinity of Ostim station is not complex when the different types of buildings are analyzed which can be easily observed from Figure 38. Most of the buildings are similar to each other in terms of number of storeys.

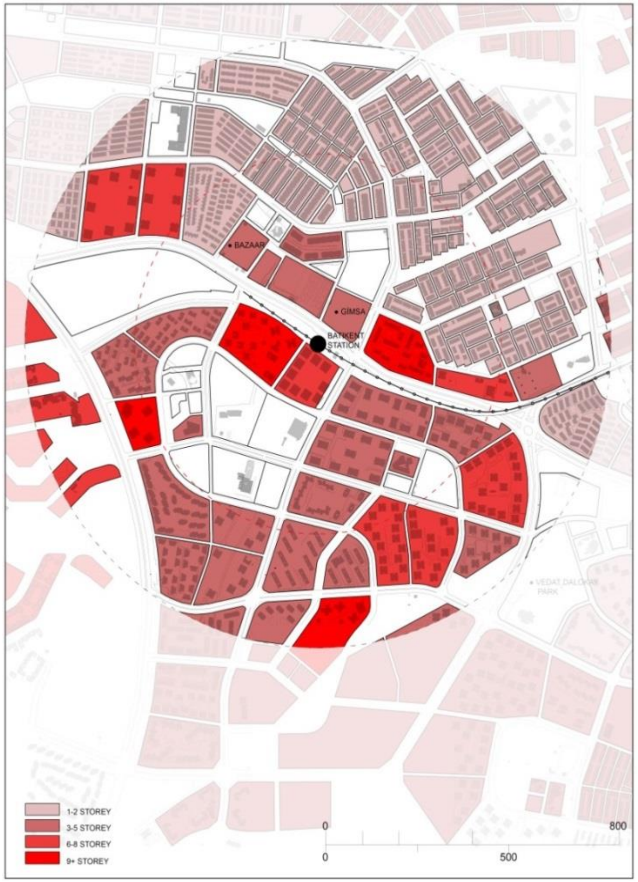
Macunköy

Macunköy station serves industrial sites and residential areas. In the vicinity of the station, there are mostly construction sites and few residential buildings. It is located next to EGO Bus and Metro Depot and Atelier, Aselsan (a company of Turkish Armed Forces Foundation), concrete and stone ateliers and auxiliary equipment stores (Figure 39).

It is observed from the land use map that there used to be small houses which formed the Macunköy village. Today, Macunköy has not been developed yet. There is limited number of commercial and social facilities around the station owing to the neighborhood characteristic of the station.

Figure 37

Land use around Batıkent station



Variety in the built up area

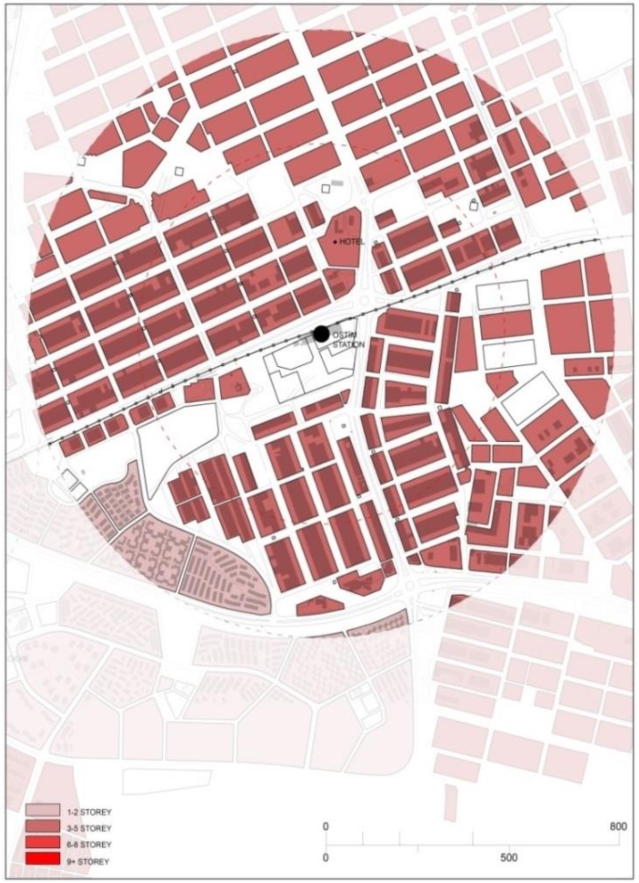


Figure 38 **Land use around Ostim transit station** **Variety in the built up area**

It is seen from Figure 39 that the built-up area is the smallest portion of the area. Property development has been started in the southeastern parts of the station. Small houses seen from the map has been demolished and up to 15 storey buildings started to be constructed. A new shopping mall project is underway. This would affect and change the whole neighborhood and transit usage in the future.

Hastane station

Hastane station takes the name of Oncology Hospital which is located 300 m away from the station. Hastane station is located in a neighborhood composed of residential buildings where mostly the ground floor is used for commercial purposes. Within 500 m radius around the transit station, there are coffee shops, markets, florists, restaurants, furniture shops and so on.

The neighborhood is mixed of old and new buildings; housing estates and single buildings; single family houses as well as multi-storey buildings ranging from 4 storeys to 15 storeys. In some parts, 1-2 storey houses are observed; however, these are negligible in number. Residential buildings have 3-4 apartments on each floor (Figure 40).



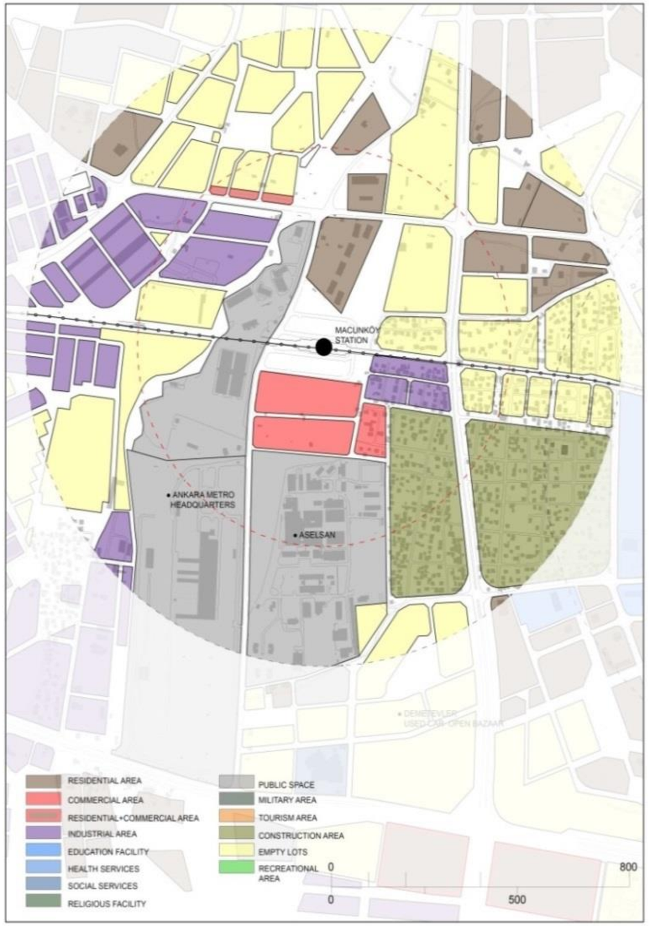
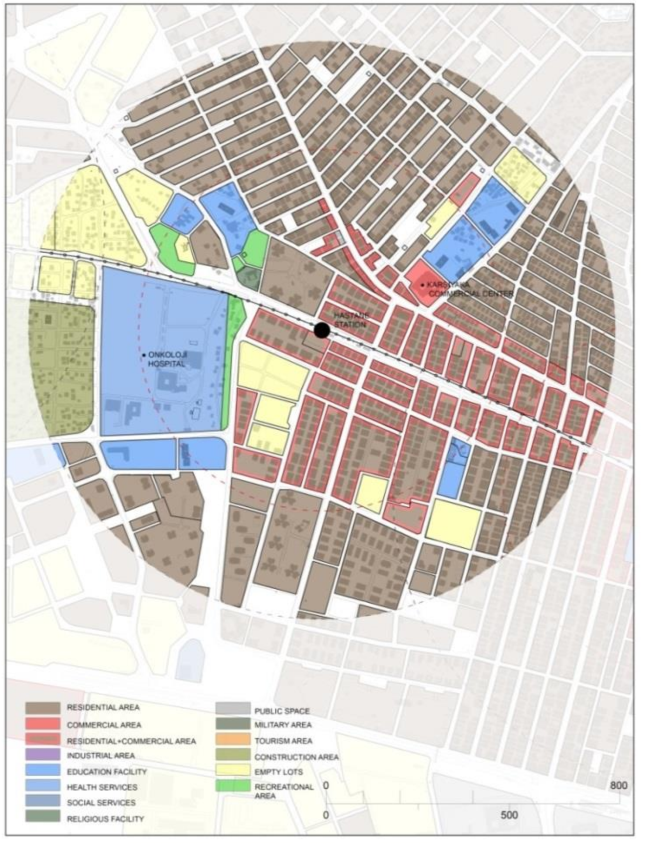



Figure 39 **Land use around Macunköy transit station** **Variety in the built up area**



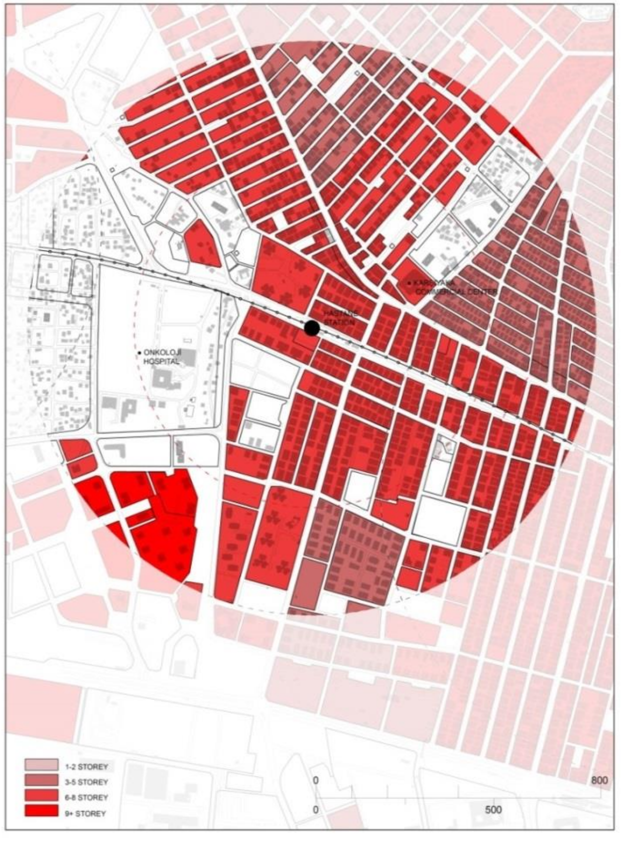


Figure 40 **Land use around Hastane transit station** **Variety in the built up area**

Demetevler station

Demetevler station area is composed of originally unauthorized multi-storey buildings. Building heights, road widths, storey heights were structured without the control of the municipality. After the rail system was constructed, additional functions developed such as commercial areas, hospitals, business centers, sports centers and so on. Simultaneously with the operation of the system, unauthorized buildings got permission from the municipality (Demir, 2007).

Within 500 m radius around the transit station, ground floor is used for commercial purpose. There are coffee shops, markets, florists, restaurants, coiffures, sport centres, electrician and so on (Figure 41).

The nighborhood is a mix of old and new buildings with a height ranging from 4 storeys to 20 storeys (Figure 41). Residential buildings have 3-4 apartments on each floor.

Yenimahalle station

Yenimahalle station serves public buildings, government uses and residential areas. It is located behind Yenimahalle Municipality reaching to Demetevler along State Archive Building Complex. Almost 1/3 of the vicinity of the station is covered by public buildings and military area. Yenimahalle Municipality is located 600 m walking distance from the station. The rest is composed of residential buildings.

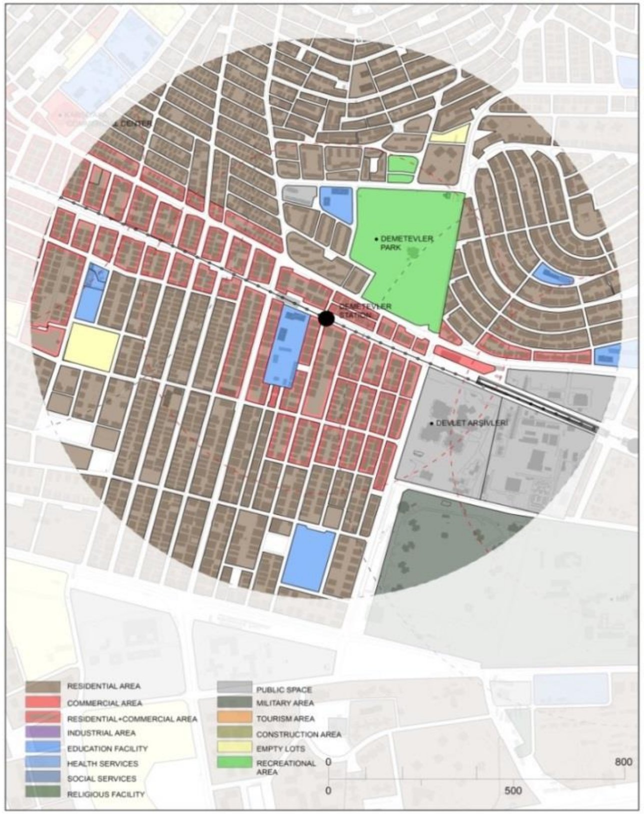
In the northern part there are mostly 4-storey buildings which are vertically mixed use (ground floor commercial, upper floors residential) along the main streets and in the southern part there are mostly multi-storey buildings (12 storeys maximum) (Figure 42). Halide Edip High School is located 300 m away from the station.

İvedik Street acts like an invisible border in classifying the variety of residential buildings in the area. In the southern part of the street there are mostly old buildings and building complexes. There are both 4-storey buildings and multi-storey building (up to 12 storeys). In the northern part of the station, there are single buildings with 4 storeys. In some parts, 1-2 storey houses are observed; however, they are negligible in number (Figure 42).

İvedik

İvedik is mostly composed of residential buildings and public buildings. Buildings facing the main streets are vertically mixed-use buildings (ground floor commercial, upper floors residential). The other parts are mostly residential. There are schools, a football field, public buildings, some vacant lots and a large grade-separated junction in the area.

Residential buildings range from 4-storey buildings to 12-storey buildings (Figure 43). In the southern part of the station there are mostly old buildings and in the northern part there are mostly new buildings with 4 or 5 storeys.



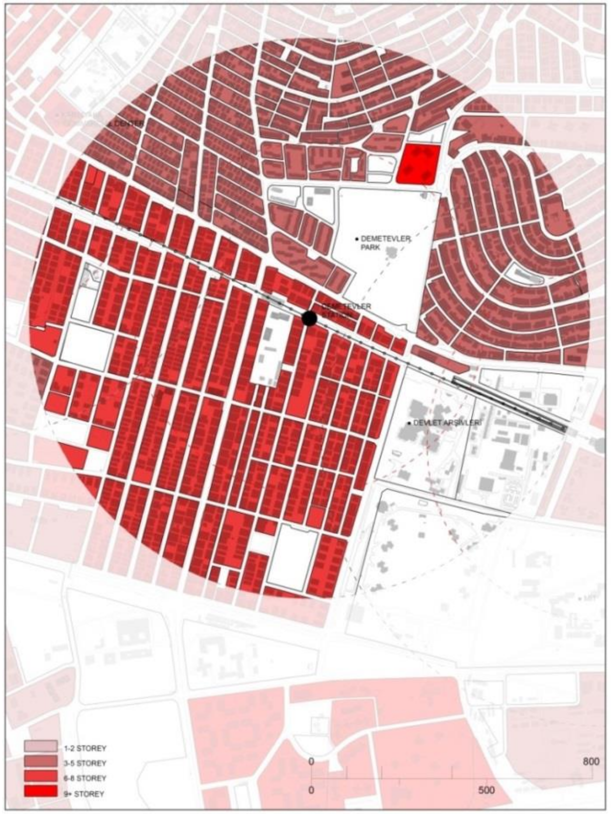
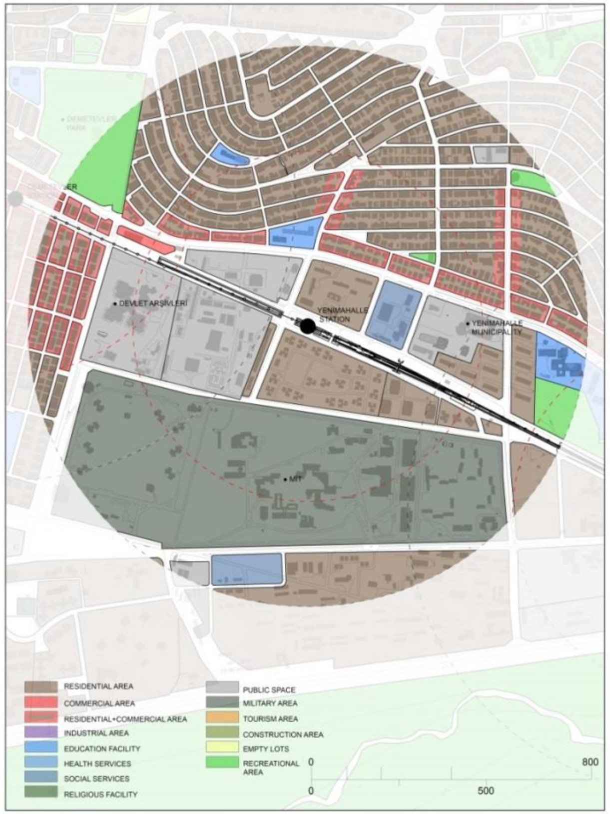


Figure 41 **Land use around Demetevler transit station** **Variety in the built up area**



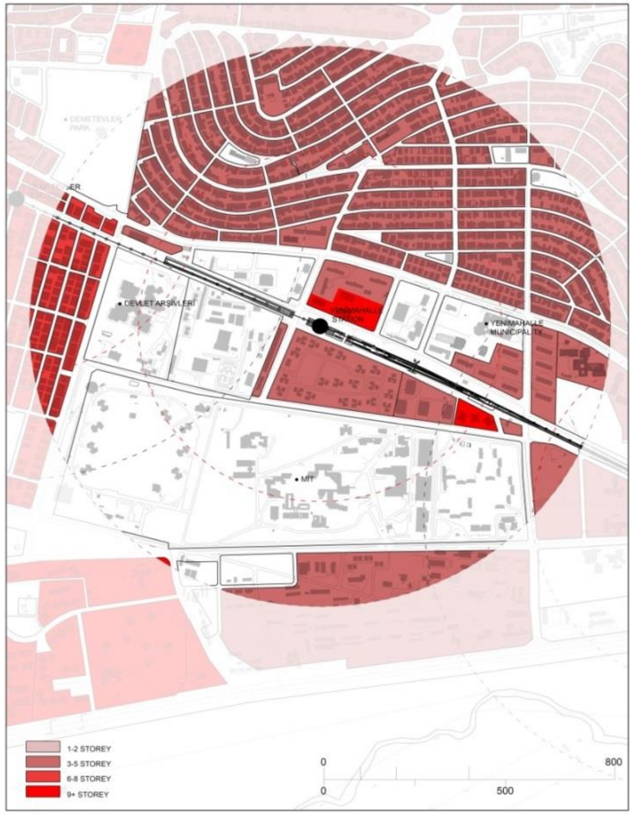


Figure 42 **Land use around Yenimahalle transit station** **Variety in the built up area**

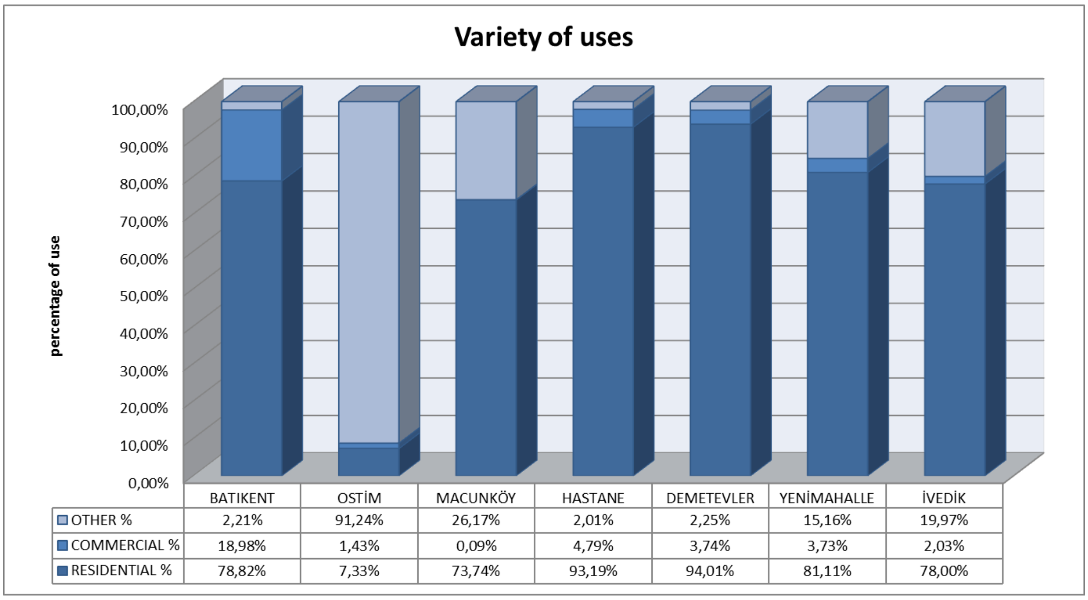
Figure 43 **Land use around İvedik transit station** **Variety in the built up area**

7.1.2.2. Degree of functional mix

For each use (residential, commercial, residential+commercial, other), a percentage has been found showing the variety of uses within the area ((built up area / total area) × 100).

Then, a ranking system is created to analyzed the mixed use characteristic of the area. In order to have a mixed use characteristic, the area must embody residential, commercial and other uses (education, health services areas and so on).

When the built up environment is taken into consideration (Figure 44), with the exception of Ostim area, residential uses are the main uses around the transit stations. Vicinity of Batıkent (78,82%), Demetevler (94,01%), Hastane (93,19%), Yenimahalle (81,11%), İvedik (78%) and Macunköy (73,74%) stations are mostly composed of residential areas (Figure 44). Additionally, Demetevler, Hastane and Yenimahalle are located in neighborhoods in which the buildings are vertically mixed use (ground floor for commercial purposes, upper floors residential).



	BATIKENT	OSTİM	MACUNKÖY	HASTANE	DEMETEVLER	YENİMAHALLE	İVEDİK
OTHER %	2,21%	91,24%	26,17%	2,01%	2,25%	15,16%	19,97%
COMMERCIAL %	18,98%	1,43%	0,09%	4,79%	3,74%	3,73%	2,03%
RESIDENTIAL %	78,82%	7,33%	73,74%	93,19%	94,01%	81,11%	78,00%

Figure 44 Percentage of different functions in the built environment around the stations

Around Batıkent station, there are buildings used for only commercial purposes that may have a positive effect on the use of the station.

Ostim station is characterized as an industrial area. It is seen from the figure that residential areas only cover 7,33% of the land-use in the vicinity of the station.

In the vicinity of Macunköy station, working places and empty lots cover most of the area. After the property development, this rate would change towards residentials being the most common use in the area.

Table 22 Ranking of stations according to the mixed used around the station

Name of station	Rank
Macunköy	**1**
İvedik	**2**
Batıkent	**3**
Yenimahalle	**4**
Ostim	**5**
Hastane	**6**
Demetevler	**7**

When the built environment is taken into account, it is found that Macunköy, İvedik and Batıkent station areas have the highest mixed use characteristics, whereas in the vicinity of Ostim (industrial), Hastane and Demetevler (residential) stations, residential areas are the dominant uses (Table 22).

7.1.3. Accessibility and connectivity

In the literature review chapter, it was mentioned that road network design and street connectivity have an effect on the travel choice. Researchers found out that the neighborhoods having high street intersections would promote walking (Ozbil et al., 2009).

It is argued that a grid network provides the simplest pattern and it is the mostly preferred pattern in neo-traditional neighborhood design. It has a positive effect on walkability and provides a better sense of direction. On the other hand, circuitous routes, cul-de-sacs and dead ends decrease walkability, ending up with a decreased ridership number of transit modes. In Figure 45, it is seen that in the vicinity of each station there is a different pattern. Batıkent has developed partially by cooperatives resulting in disintegration of sub-centers with the center and public transit with pedestrian activity. It is seen from the figure that each residential complex is separated from each other.

Ostim station area has a grid network. Owing to its homogeneous characteristic, there are no different patterns in the neighborhood except from the residential area in the sourthwestern part.

Demetevler transit station area is composed of both a grid network and a less regular pattern. In the northern part of the station, less regular pattern is observed which might be the reason of terrain change in that part of the neighborhood.

Around Yenimahalle and İvedik stations, less regular patterns are observed. The vicinity of Macunköy station has no pattern as the area is rather underdeveloped.

In a study by Litman (2012), "**connectivity index**" was introduced which is used to evaluate the network connection of destinations. It is found by dividing the number of roadway links by the number of roadway nodes. This index can also be used for non-motorized transport modes. Street connectivity indicates how densely the streets are connected with each other.

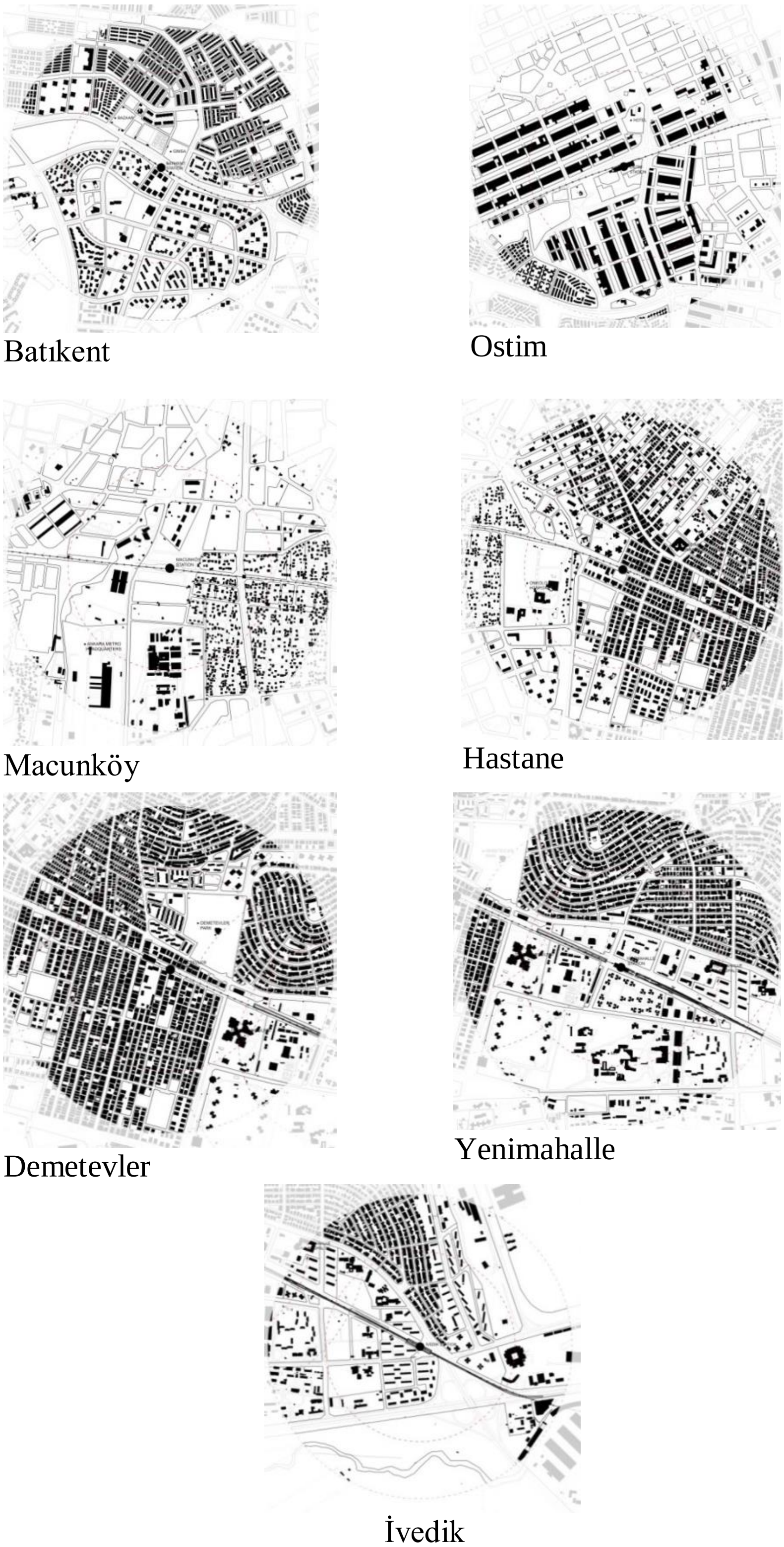


Figure 45 Pattern analysis

In this study this index has been calculated regarding each station (Table 23).

Table 23 Connectivity index of each station (500 m)

Name of station	Node	Link	Index (Node/Link)
Hastane	66	90	1,363636364
Ostim	61	83	1,360655738
Yenimahalle	32	43	1,34375
Demetevler	73	97	1,328767123
Batıkent	35	43	1,228571429
İvedik	27	33	1,222222222
Macunköy	7	6	0,857142857

Litman (2012) argued that high index stands for increased choice of travel and more direct connections. Litman (2012) evaluated the connectivity index of a simple box, a four-squared grid and a nine-square grid. The results are 1.0, 1.33 and 1.5 respectively. Cul-de-sacs and dead ends reduce the index value. It is found that a minimum of 1.4 is needed for a walkable urban environment.

In Table 23, it is seen that Ostim and Hastane station areas have the highest value for a walkable environment (approximately 1,4). Demetevler and Yenimahalle station areas also have high levels for this connectivity index (1,3). These values are the result of grid patterns in these neighborhoods. However, in the southern part of Yenimahalle and the northern part of Demetevler, this pattern changes. Dead ends reduce the index value.

Batıkent station area is composed of mostly residential areas which are composed of cooperatives. Also, the transit line makes interruption at different parts of the neighborhoods which creates dead ends. This reduces its connectivity index value

(1,2). The vicinity of Macunköy station has not been developed yet. There is no pattern in the neighborhood. In result, it has the lowest connectivity index level amongst the stations analyzed in the study (approximately 0,9).

In the following sections, measures of connectivity and accessibility which were revealed from literature will be analyzed regarding each station. This analysis will give more detailed information regarding the vicinity of each station from accessibility and connectivity point of view.

Batıkent station

- Integration with other modes

Non-residential activities in the area are surrounded by main arterial roads. Vicinitiy of the station has a car-oriented characteristic. Due to the parking cars, pedestrian access conditions are poor (Figure 46).

In the western part, there is a highway which almost draws the boundaries of 800 m radius area (Figure 46). Pedestrian access is limited. Besides this highway, there are new high rise buildings and shopping malls.

In the east, Batıkent is connected to Ostim, a major industrial area with a significant size of employment, with a junction where the metro line operates above ground. This junction interrupts pedestrian movement (Figure 46).

Main road, highwayand junction | **Pedestrian roads, landscaping and fence** | **Integration with other modes** | **Parking** | **Stairs and ramps**

Figure 46 Batıkent

Station has been strongly integrated to other transport modes such as dolmuş, public transport buses and taxi. There are bus stops both in front of the station and across the street. Along the street dolmuş and taxis operate. Private cars are also used to access the station in the form of both parking and dropping and picking up of passengers. Dolmuş routes which are parallel to the rail transit route might have a negative effect on the ridership levels of the rail transit system attracting passengers from rail to dolmuş. In the area, there are feeder bus systems, but passengers usually choose to travel by only one mode not using both feeder system and the metro (Figure 46).

- Parking

There is a parking area behind GİMSA Shopping Center which has not been originally planned as a parking area serving the station. In the former plans, the area which is nowadays covered by GİMSA was designed to be a parking area for the station. However, there have been changes in the development plans in the period of 1994-1999 and in 2004 GİMSA Shopping Center has been opened. The area behind GİMSA, which is marked as General Directorate of Security Affairs Service Area in the development plan has been organized by GİMSA and changed into a parking area. This area serves for the shopping mall as well as for the transit station (park-and-ride purposes, approximately 350 vehicles).

It is also observed that streets around the station and the market place (approximately 130 vehicles except for Sundays on which the neighborhood market place is set) are also used for on-street parking purposes (Figure 47). In Figure 47, purple areas are the parking areas, where blue lines show the on-street parking. Also the slope changes in the area are shown by red arrows.

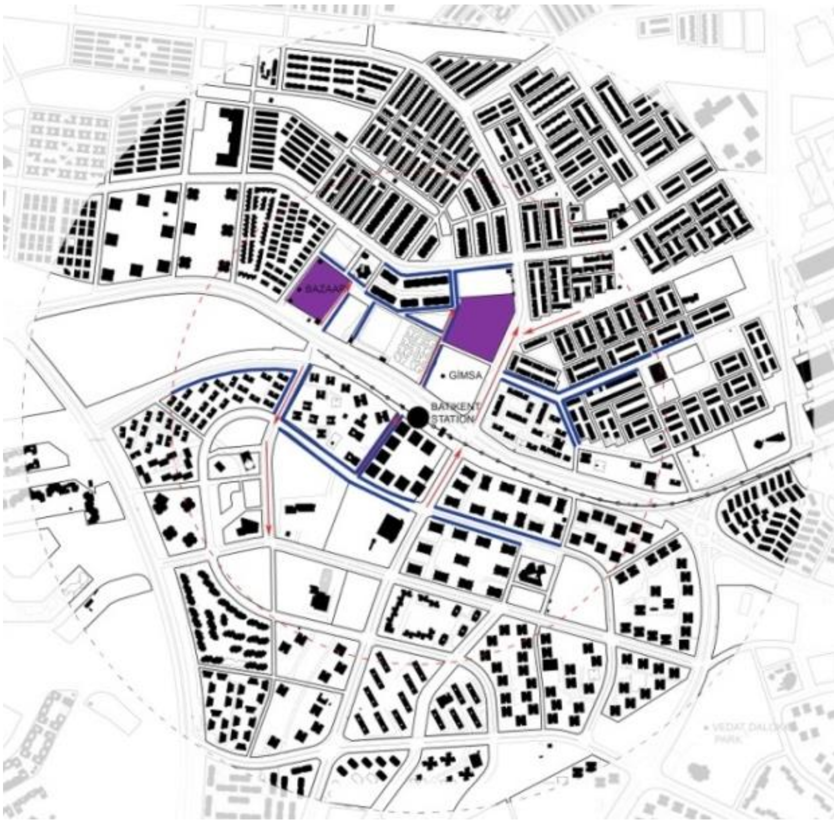


Figure 47 Parking areas

- Pedestrian activity

There are six entrances four of which are located on the one side of the road and 2 of which are located in front of GİMSA. There are no underground pass or overpass around the station. Adequate pedestrian crossing signals provide an environment accommodating pedestrian needs and movements. However, residential areas and the area around the station building are separated by fences which interrupt pedestrian activity and orient people to different routes. As it is seen from Figure 46, there is no direct passage between the exit of the station and the residential buildings behind the station.

There are stairs, ramps and slope changes around the station. It is observed that main streets directing pedestrians to the station are located on inclined land which might cause problems in the winter time. It might also get hard to walk with heavy carriage along those streets (Figure 46).

In designing streets, tree-lined streets and well-lit environment show high quality for walkability. Observing the vicinity of the station, it is found that lighting and landscaping is on an average level in the area. Most of the streets are well-lit. It is observed that in the 2-storey building areas there are more tree-lined streets whereas in some parts of high-storey building these kinds of streets are also observable. There is Ethem Sarısülük Park and Seyranı Park in the area, a pedestrian street and a pedestrian route along the road, which is poorly designed and finished with the walls of grade-separated railway in the boundaries of 500 m (Figure 46)

- To sum up:

Hereby, regarding the walkability measures, a check-list is given below (Table 24). The sign (+) shows the presence of the measure in the area and (-) means that this measure is not present.

Table 24 Accessibility and connectivity measures in the vicinity of the station

Measures (Batıkent)	Presence	Poor	Average	Good
Lighting	+		√	
Interface with parking (on street parking)	+			√
Ease of pedestrian crossing	-	N/A		
Landscaping and tree-lined streets	+		√	
Flat terrain	+-	N/A		
Availability of sidewalks	+			√

As a result, strengths and weaknesses of Batıkent station area are revealed. It is observed that integration with other modes, on-street parking opportunities and availability of sidewalks are the strengths of the vicinity of the station. On-street parking opportunities are observed in most of the streets which might have an effect on ridership levels attracting private car owners for using park-and-ride options.

Landscaping and tree-lined streets and lighting are on an average level in the area. Grade changes and up slopes affect walking in some parts of the area as mentioned before on the map which is the weakness of the area.

Having a car-oriented characteristic, the streets are designed for private cars and as a result there are two-lane divided roads. In the junctions, traffic signals are provided; however, in the rest of the area there is no adequate number of pedestrian crossings.

Ostim station

- Integration with other modes

The station has been strongly integrated to other transport modes such as dolmuş, public buses and taxi. There are bus stops in front of the station. Mostly feeder bus systems are used by the transit users. Along the street dolmuş and taxis operate. Dolmuş connects Ostim to Keçiören, Demet, Batıkent, Mamak, Kızılay and Cebeci (Figure 48).

- Parking

Transit station is accessible by motorized vehicles, but there are no parking areas serving the station. Employees use the station and walk to their workplaces. However, the customers use their own cars and park them in front of each store interrupting the pedestrian movement. Additionally, there is a highway forming a boundary between the residential areas and the industrial part of Ostim. This also affects the pedestrian movement.

- Pedestrian activity

The area is not a pedestrian-friendly neighborhood. Lighting and landscaping is average in the area. The streets have 2 or 3 lanes in each direction. There are few pedestrian crossings. This causes difficulties for crossing the street. On the other hand, there are some aspects, which might positively affect pedestrian movement. The area is located on a flat terrain and there are no underground pass or overpass around the station.

- To sum up:

Hereby, regarding the walkability measures, a checklist is given below (Table 25), where (+) sign shows the presence of the measure in the area and (-) sign means that this measure is not present.

Table 25 Accessibility and connectivity measures in the vicinity of the station

Measure (Ostim)	Presence	Poor	Average	Good
Lighting	+	√		
Interface with parking (on street parking)	+	√		
Ease of pedestrian crossing	-	N/A		
Landscaping and tree-lined streets	+		√	
Flat terrain	+	N/A		
Availability of sidewalks	+	√		

Considering the car-oriented design of the area, it is observed that street widths are extensive creating difficulties for the pedestrians. There are inadequate pedestrian crossing signals and landscaping in the area. Even though there are opportunities for on-street parking, sidewalks are also used for parking purposes interrupting pedestrian activity.

The only strenght of the area is the flat terrain which eases walking. However, overall, it is observed that vicinity of Ostim station was not designed for pedestrians and private car accessibility has been a priority.

Integration with other modes | **Pedestrian roads and crossings** | **Parking**

Figure 48 Ostim

Macunköy station

- Integration with other modes

Employees of EGO and Aselsan are the main groups of people using the station. However, most of the employees of Aselsan use employee services which has a negative effect on the use of transit system.

Another group uses the station to take feeder bus system. There are bus stops in front of the station. Mostly feeder bus systems are used by the rail transit users. Next to the station taxis operate. Kiss-and-ride is mostly used due to the fact that the station has poor access by walking.

- Parking

There are two parking areas located on both sides of the station with a capacity of 150-200 vehicles each (Figure 49). However, parking areas are mostly vacant due to the fact that this station is mostly used by the workers in the industrial site.

- Pedestrian activity

After getting off the car, access to the other facilities around the station is limited. As it is seen from the figure, there are fences interrupting the pedestrian activity around the station. The only path for the pedestrians is the stabilized sidewalk along the road (Figure 49).

There are some residential developments around the station, however it is located next to the highway and there are vacant lots. Lighting and landscaping is poor in the area. There are no parks and pedestrian streets. For this reason, people do not prefer to walk to the station; park-and-ride or kiss-and-ride is observed. On the other side of the highway, there are construction sites which are surrounded with partitions (Figure 49).

Highway	Parking	Pedestrian ciculation interrupted by various barriers

Figure 49 Macunköy

- To sum up:

Hereby, regarding the walkability measures, a check-list is given below (Table 26). The sign (+) shows the presence of the measure in the area and (-) sign means that this measure is not present.

Table 26 Accessibility and connectivity measures in the vicinity of the station

Measure (Macunköy)	Presence	Poor	Average	Good
Lighting	-	N/A		
Interface with parking (on street parking)	+	√		
Ease of pedestrian crossing	-	N/A		
Landscaping and tree-lined streets	+	√		
Flat terrain	+	N/A		
Availability of sidewalks	-	N/A		

As seen from the table, when analyzing accessibility and connectivity measures, the strength of the vicinity of Macunköy station is only the flat terrain, which has a positive effect on walking. Pedestrian crossing opportunities are weak. Lighting and landscaping is poor in the area. There are no parks and pedestrian streets. However, it is observed that when the construction projects in the area are completed, there might be changes regarding pedestrian activity in order to connect the station to the residential areas and the shopping center that are under construction.

Hastane station

- Integration with other modes

The station has been strongly integrated to other transport modes such as dolmuş, municipality buses and taxi. There are bus stops both in front of the station and across the street. Along the street dolmuş and taxis operate. Vatan Street and İvedik Street are the main streets connecting Demetevler and Yenimahalle to Hastane causing severe traffic congestion problems. As mentioned in the Batıkent case, dolmuş is also a competing mode in the area. Employee services are also used by the Oncology Hospital, which has a negative effect on the use of transit system.

- Parking

Along most streets on-street parking on each side of the street is observed. There is a parking area with a capacity of 50 vehicles next to the station. There is also on-street parking with a capacity of approximately 80 vehicles along Vatan Street (Figure 50). However, it is observed that mostly these parking areas are used for other purposes than using the metro.

- Pedestrian activity

There are 2 entrances to the station. One side of the station is a narrow street where on-street parking is observed and the other side is a one-way street. Getting off the station, one should cross the street by inadequate traffic signals.

Lighting and landscaping is poor in the area. Buildings cast shadow on streets, which helps the pedestrians to walk easily, even on the hottest day.

There are few parks and no pedestrian streets. However, the sidewalk along the street, which is next to the station, has been enlarged and used as a small park and pedestrian route along the street. The park between Vatan Street and the hospital is the biggest one in the area, but is rarely used owing to its location. On the other hand, another park which is located within the residential areas, is used by both children and women (Figure 50).

One could easily get lost finding the Oncology Hospital from the station. It is 300 m away from the station building and there is a steep incline change along the way. The entrance when approaching from the station is not legible. Hospital area is enclosed with fences disintegrating the park and the residential areas (Figure 50).

Parking **Pedestrian areas** **Hospital area**

Figure 50 Hastane

There are also ramps and slope changes around the station. Below is the map of these changes. Red arrows show the direction of the slope changes (Figure 51). It is observed that along the main street leading to the hospital there is a steep ramp. In the northern part of the station, there are also ramps which make walking difficult and it might be harder in the winter time and with heavy carriage.

Figure 51 Slope change

- To sum up:

Hereby, regarding the walkability measures, a check-list has been given below (Table 27). The (+) sign shows the presence of the measure in the area and (-) sign means that this measure is not present.

Table 27 Accessibility and connectivity measures in the vicinity of the station

Measures (Hastane)	Presence	Poor	Average	Good
Lighting	+		√	
Interface with parking (on street parking)	+			√
Ease of pedestrian crossing	-	N/A		
Landscaping and tree-lined streets	+		√	
Flat terrain	-	N/A		
Availability of sidewalks	+	√		

In conclusion, strengths and weaknesses of Hastane station area are revealed. It is observed that integration with other modes and availability of on-street parking which might affect the usage of the rail transit system are the strengths of the vicinity of the station.

There are mostly two-lane streets around the neighborhood. There are two main one-way roads connecting the neighborhood to Batıkent and Demetevler which are highly congested which has a negative effect on the pedestrian movement. There are inadequate pedestrian crossing signals.

Availability of sidewalks changes from street to street. In some of the streets there is a sidewalk, however the conditions are poor; some of them do not have a sidewalk and some streets have good conditioned sidewalks.

Landscaping and lighting are on an average level. Mostly tall buildings cast shadow on the street.

There are steep ramps in the area make walking difficult and it might be harder in the winter time and with heavy carriage.

Demetevler station

- Integration with other modes

Bus stops are located next to the station. Along the street there are two taxi ranks. Vatan Street and İvedik Street are the main streets connecting Hastane and Yenimahalle to Demetevler. As mentioned in the Batıkent and Hastane cases, dolmuş is also a competing mode in the area. Employee services are also used by State Archives which has a negative effect on the use of transit system.

Integration with other modes	Parking	Pedestrian activity	Street lights and landscaping	Ramps, stairs and slope changes

Figure 52 Demetevler

- Parking

Along most streets, on-street parking on each side of the street is observed. There is a parking area with a capacity of 100 vehicles next to the station. There is also on-street parking along Vatan Street and the streets around Vatan Street. However, it is observed that mostly these parking areas are used for other purposes than using the metro as it is the same in the Hastane station area.

- Pedestrian activity

There are 2 entrances to the station. Getting off the station, there are no pedestrian crossings or traffic signals (Figure 52).

Lighting and landscaping is poor in the area. Buildings cast shadow on streets which helps the pedestrians to walk easily even on the hottest day.

There is a big park located 100 m north to the station which has an area of approximately 10 ha. There is an amusement park inside the park. There are picnic tables, tennis courts and a wedding salon within the park. However, the park is not integrated to the pedestrian activity pattern and it is surrounded by high fences. It has entrances facing the four streets; other than these entrances it is not possible to cross the park (Figure 53).

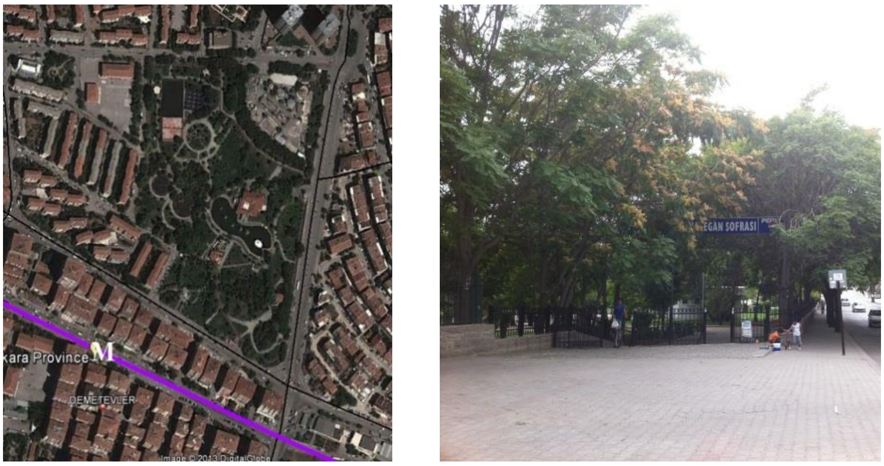


Figure 53 The park

There are mostly two-lane streets around the neighborhood (Figure 52). There are two main one-way roads connecting the neighborhood to Hastane and Yenimahalle which are highly congested and have a negative effect on the pedestrian movement. There are inadequate pedestrian crossing signals.

All the streets have sidewalks. In some of the streets their quality is poor; while some streets have good conditioned sidewalks. Pedestrian activity is interrupted by trees or waste containers on the street (Figure 52). However, mostly in the northern part of the station there has been pavement maintenance work (Figure 52).

It is observed that along the street leading to Şentepe there are steep ramps In the northern part of the station, there are also stairs which make walking difficult and it might be harder in the winter time and with heavy carriage (Figure 52).

- To sum up:

Hereby, regarding the walkability measures, a check-list is given below (Table 28). The (+) sign shows the presence of the measure in the area and (-) sign means that this measure is not present.

Table 28 Accessibility and connectivity measures in the vicinity of the station

Measure (Demetevler)	Presence	Poor	Average	Good
Lighting	+		√	
Interface with parking (on street parking)	+			√
Ease of pedestrian crossing	-	N/A		
Landscaping and tree-lined streets	+		√	
Flat terrain	+ -	N/A		
Availability of sidewalks	+		√	

The vicinity of the station is seperated into two parts: one is located on a flat terrain and the other one is located on an inclined land. As seen from the table, high slopes in the northern part of the station makes walking difficult especially in the winter and with heavy load. As the traffic passes along the two main streets in the area, pedestrian activity is obstructed. With the addition of inadequate pedestrian crossings, it becomes difficult to walk within the area. Lightings, tree-lined streets and sidewalks are provided, but the conditions are poor. It is observed that with the on-street parking opportunities and the express traffic, the area is mostly designed for the vehicles not for the people.

Yenimahalle station

- Integration with other modes

Station has been strongly integrated to other transport modes such as dolmuş, municipality buses and taxi. There are bus stops in front of the station (Figure 54). Along the street taxis operate. There is cable-car system which is integrated to this station and its construction has started at the time of the study and it has started operating on 17 June 2014. It is planned as the first public transit cable car system in Turkey. It has a capacity of 2400 passengers/hour/direction. The system have four stations and 48 cabins (it is planned to have 106 cabins when the system operates fully) having a capacity of 10 passengers each. There is an integrated fare system between metro and cable car. Passengers will not buy extra tickets for the cable car system. However, it should be noted that the system has not started operating when the study began. For this reason, the effect of the system to the ridership levels of Yenimahalle station is neglected in the study.

Vatan Street is the main street connecting Demetevler and İvedik to Yenimahalle, and it experiences severe traffic congestion problems. As mentioned in the Batıkent, Hastane and Demetevler cases, dolmuş is also a competing mode in the area (Figure 54).

- Parking

Along most streets, on-street parking is observed on each side of the street. There is a parking area with a capacity of 30 vehicles next to the station. There is also on-street parking with a capacity of approximately 300 vehicles along the streets (Figure 54). However, it is observed that mostly these parking areas are used by the residents not for the transit purpose.

- Pedestrian activity

There are two entrances to the station. One side of the station is a narrow street where on Sundays market place is set up and the other side leads to the residential areas by a 2-lane street (Figure 54).

Lighting and landscaping is on an average level in the area. Most of the streets are well-lit. It is observed that in the 4-storey building areas there are more tree-lined streets whereas in some parts of high-storey building these kinds of streets are also observable. There are small parks between the residential areas which provides playing environment for the children (Figure 54).

The main street (Vatan Street) divides the area into two. In the northern part, the streets are narrow which allows pedestrians to walk safely. However, along the main street and the streets in the southern part of the station, number of lanes and the speed of traffic increases, which affects the pedestrian crossing (Figure 54).

All the streets have sidewalks. Most of the streets have good conditioned sidewalks (Figure 54). There are stairs, ramps and slope changes at northern part of the station towards Şentepe. It is observed that main streets directing pedestrians to the station are located on flat terrain in the southern parts, which might ease walking. However in the northern parts, it might also get hard to walk with heavy carriage along the streets (Figure 54). Three pedestrian crossings are provided in order to get to the other side of the railway. Two of them are over-passes and the other one passes under the viaduct. They both are well-lit, but the overpasses are not appropriate for disabled people.

- To sum up:

Hereby, regarding the walkability measures, a check-list is given below (Table 29). The (+) sign shows the presence of the measure in the area and (-) sing means that this measure is not present.

Table 29 Accessibility and connectivity measures in the vicinity of the station

Measure (Yenimahalle)	Presence	Poor	Average	Good
Lighting	+		√	
Interface with parking (on street parking)	+			√
Ease of pedestrian crossing	+	√		
Landscaping and tree-lined streets	+		√	
Flat terrain	+-	N/A		
Availability of sidewalks	+			√

It is observed that integration with other modes and availability of on-street parking which might affect the usage of the rail transit system are the strengths of the vicinity of the station. Weaknesses are the inadequate pedestrian crossings and the high slopes in the northern part of the station. Besides these measures, vicinity of Yenimahalle station provides a pedestrian-friendly environment.

Integration with other modes | **Parking** | **Landscaping and parks** | **Pedestrian activity** | **Stairs and ramps**

Figure 54 Yenimahalle

Ivedik station

- Integration with other modes

Access to the station by private car is complicated. From İvedik Street, there is access to the station and the empty lot next to the station might be used for parking purposes. However, from other directions there is no direct access to the station. There are grand junctions around the station leading to other parts of the neighborhood.

Dolmuş operate on İvedik Street. It connects İvedik to Ankamall Shopping Center and Yenimahalle, Demetevler, Keçiören. Next to the station, there is EGO Bus Parking Area which is also used by private cars. Apart from the parking area there is also a bus stop integrated to the station. Along the street, next to the station there is a taxi rank (Figure 55).

- Parking

Transit station is not easily accessible by private car. There is no parking area serving the station. However, the bus park and the sidewalks around the station are used for parking purposes.

- Pedestrian activity

High speed roads surround the station. There is a clover leaf junction and crossover road next to the station which has a negative effect on pedestrian activity (Figure 55). As seen from the figure, İvedik Street is separated with a fence to prevent pedestrian crossing and the pedestrians are forced to use the underpass to cross the street (Figure 55). However, the underpass is not well-lit, and the escalator was not working at the time of the study. There is no sign indicating that the underpass leads to the station. Transit passengers who do not know the neighborhood might easily get lost in the area. Mostly, overpasses are provided in the area in order to maintain pedestrian crossing (Figure 55). Traffic signals are adjusted just for the vehicle movement; there is lack of pedestrian signals. Behind the station, there is the football field of Yenimahalle Municipality. The street leading to the field is not properly designed for pedestrians (Figure 55). Sidewalks are poorly designed; there is no lighting and landscaping along the street. In the evenings, this street becomes desolated.

- To sum up:

Hereby, regarding the walkability measures, a check-list has been given below (Table 30). The (+) sign shows the presence of the measure in the area and (-) means that this measure is not present.

Table 30 Accessibility and connectivity measures in the vicinity of the station

Measure (İvedik)	Presence	Poor	Average	Good
Lighting	+	√		
Interface with parking (on street parking)	+	√		
Ease of pedestrian crossing	-	N/A		
Landscaping and tree-lined streets	+	√		
Flat terrain	+/-	N/A		
Availability of sidewalks	+		√	

In conclusion, considering the car-oriented design of the area, it is observed that street widths are extensive creating difficulties for the pedestrians. There are inadequate pedestrian crossing signals and landscaping in the area. Lighting and landscaping is poor in the area. There are no parks and pedestrian streets. There is a recent sidewalk construction work in the area. However, it only covers the main streets; some of the streets still do not have any sidewalks.

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Integration with other modes	High speed roads around the station	Underpasses and overpasses	The street leading to the stadium

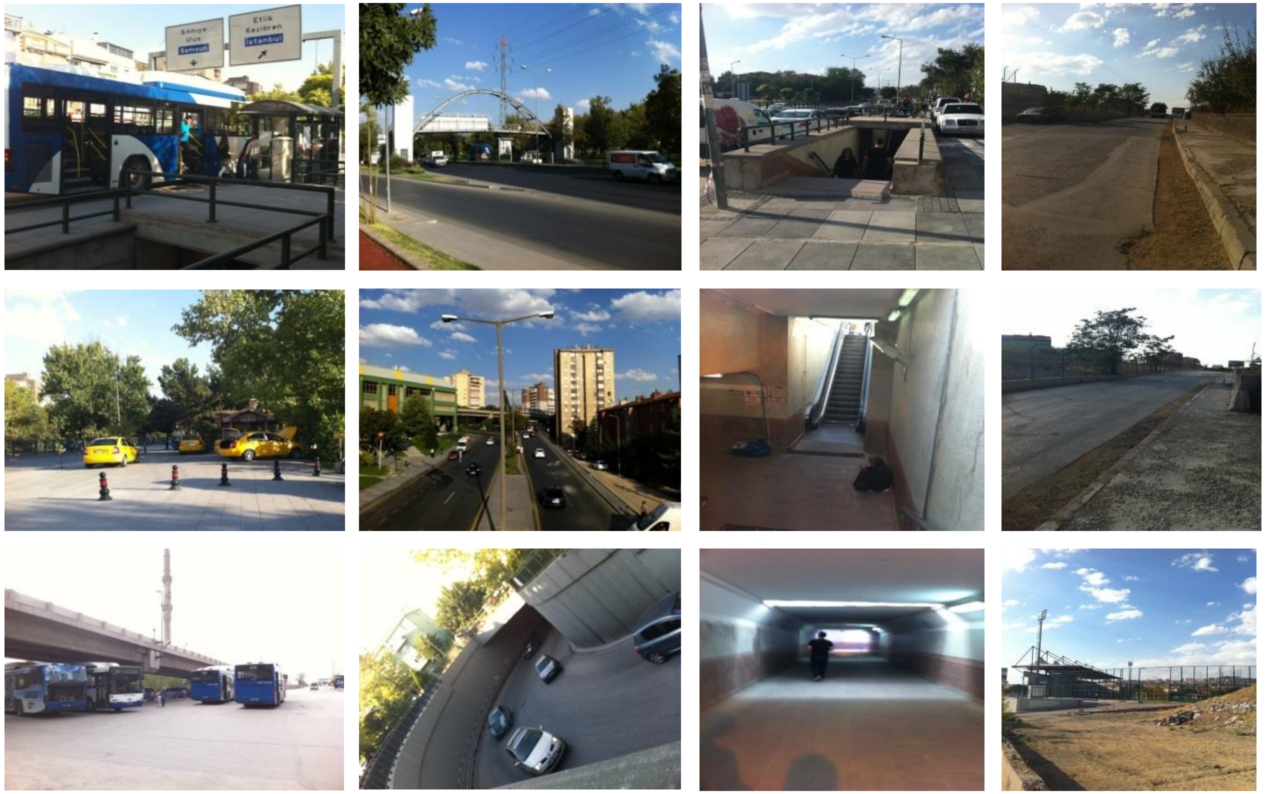


Figure 55 İvedik

7.1.4. Summary

It should be kept in mind that this study aims at understanding the link between station area design and transit usage. Analysis focuses on whether the surroundings of selected Ankara Metro and Ankaray transit stations are "transit encouraging" neighborhoods (from the point of view of increased transit usage). In the previous sections these parameters are revealed and each station has been analyzed accordingly. Findings will be given according to each parameter below:

Density

- It is found that densities around all the stations analyzed are higher than the densities that are defined as the level that would reduce automobile dependence and encourage public transit in the literature.
- Considering the built-up area and residential density, **Demetevler** station area with a density of 1846 p/ha is the densest area among the stations analyzed in the study.
- It is followed by **Hastane** (1086 p/ha), **Yenimahalle** (703 p/ha), **İvedik** (277 p/ha) and **Batıkent** (193 p/ha) station areas.
- **Ostim** has the lowest residential density whereas it is the highest ranking station area when the employment density is analyzed.

Diversity

- Considering the built-up area, Demetevler (94,01%), Hastane (93,19%), Yenimahalle (81,11%), İvedik (78%) and Macunköy (73,74%) stations are composed of residential areas. Additionally, Demetevler, Hastane and Yenimahalle are located in neighborhoods in which the buildings are vertically mixed use (ground floor for commercial purposes, upper floors residential).

- By looking at **the mix use**, it is found that Macunköy, İvedik and Batıkent station areas have the highest mixed use characteristics, whereas Hastane and Demetevler stations have the lowest (they are highly residential areas).
- **Ostim** station area has mostly industrial facilities (91,24%), only 7,33% of the area serves residential purposes.

Accessibility and connectivity

In the previous section, a wide range of measures have been analyzed for each station. Regarding the connectivity/beta index, it was found that Ostim and Hastane station areas have the minimum value for a walkable environment (1,4). Where Demetevler and Yenimahalle have the closest value to the optimum level (1,3). The vicinity of Macunköy station has not been developed yet. There is no pattern in the neighborhood. In result, it has the lowest connectivity index level amongst the stations analyzed in the study (0,9).

Analysis of each station was followed by a table that incorporated all the measures together in order to reveal the better performing transit stations. It should be noted that every measure may not have the same effect on transit usage; in other words each measure may have a different weight; for instance presence of the sidewalk might affect walking to the station more strongly than the landscape and tree-lined streets. However, it is not a straightforward task to assign weight to each measure. Understanding the relative values of each measure require an analysis that focuses on user's preferences and perceptions; and therefore cannot be made solely by the researcher. Proposing such a value system within this study would be subjective and arbitrary. In other words, to assign relative values to the measures requires a major research and cannot be carried out within the scope of this study. As a result, in order to keep the analysis simple, it was decided that presence of each measure has a score of 2, where lack of the measure gets 0. If one part of the neighborhood has the measure but the other part is lacking of it, then a score of 1 is given. Quality of each measure has also been graded (Good: 1, Average: 0, Poor:-1). At the end, all the grades are added up. Below, a table (Table 31) which shows the ranking of the stations according to accessibility and connectivity attributes is given.

It is found that amongst the stations along Ankara Metro analyzed in the study:

- The vicinity of **Yenimahalle** (12) and **Batıkent** (11) stations have the highest scores. On the other hand, the vicinity of **Macunköy** (4) station is the lowest ranking station when analyzing the presence of accessibility and connectivity parameters followed by **İvedik** (6) station.
- Additionally, when the conditions of each measure are compared, it is also observed that **Batıkent** and **Yenimahalle** station areas are found to be the most walkable environments amongst the stations analyzed in the study.
- In **Ivedik** and **Ostim** station areas, more than half of the parameters indicate poor conditions.

Table 31 Summary of accessibility/ connectivity measures of selected Ankara Metro stations

Measures (Batıkent)	**Presence**	**Poor**	**Average**	**Good**	**Score**
Lighting	2		0		11
Interface with parking (on street parking)	2			1	
Ease of pedestrian crossing	0	N/A			
Landscaping and tree-lined streets	2		0		
Flat terrain	1	N/A			
Availability of sidewalks	2			1	
Measure (Ostim)	**Presence**	**Poor**	**Average**	**Good**	**Score**
Lighting	2	-1			7
Interface with parking (on street parking)	2	-1			
Ease of pedestrian crossing	0	N/A			
Landscaping and tree-lined streets	2		0		
Flat terrain	2	N/A			
Availability of sidewalks	2	-1			

Table 31 (Continued)

Measure (Macunköy)	Presence	Poor	Average	Good	Score
Lighting	0	N/A			4
Interface with parking (on street parking)	2	-1			
Ease of pedestrian crossing	0	N/A			
Landscaping and tree-lined streets	2	-1			
Flat terrain	2	N/A			
Availability of sidewalks	0	N/A			
Measures (Hastane)	**Presence**	**Poor**	**Average**	**Good**	**Score**
Lighting	2		0		8
Interface with parking (on street parking)	2			1	
Ease of pedestrian crossing	0	N/A			
Landscaping and tree-lined streets	2		0		
Flat terrain	0	N/A			
Availability of sidewalks	2	-1			
Measure (Demetevler)	**Presence**	**Poor**	**Average**	**Good**	**Score**
Lighting	2		0		10
Interface with parking (on street parking)	2			1	
Ease of pedestrian crossing	0	N/A			
Landscaping and tree-lined streets	2		0		
Flat terrain	1	N/A			
Availability of sidewalks	2		0		
Measure (Yenimahalle)	**Presence**	**Poor**	**Average**	**Good**	**Score**
Lighting	2		0		12
Interface with parking (on street parking)	2			1	
Ease of pedestrian crossing	2	-1			
Landscaping and tree-lined streets	2		0		
Flat terrain	1	N/A			
Availability of sidewalks	2			1	
Measure (İvedik)	Presence	Poor	Average	Good	**Score**
Lighting	2	-1			6
Interface with parking (on street parking)	2	-1			
Ease of pedestrian crossing	0	N/A			
Landscaping and tree-lined streets	2	-1			
Flat terrain	1	N/A			
Availability of sidewalks	2		0		

7.2. Ankaray

7.2.1. Density

For the density analysis, firstly the number of people living and working within 800 m radius around the stations (vicinity of station) was calculated and secondly these numbers were divided by the area of the analysis. The residential population was found by multiplying number of buildings within the area, number of storeys, number of apartments at each storey and the household size. Household size is taken as 4 as this is the same value used by the Greater Municipality of Ankara in its 2007 Master Development Plan. A plot-basis analysis has not been made, because this would not give an overall picture in the vicinity of the station. In other words, it is useful to include vacant plots and undeveloped areas within the vicinity of the station in the calculation of the total area, because the existence of such empty plots (or very large roads) results in reduced number of people within walking distance to the station. Therefore, gross densities are calculated by including the whole area within the circle of 800 m radius, as opposed to net densities. The starting point of the analysis is the assumption that high density characteristic would have a positive effect on the ridership levels of the stations. This is going to be tested in the following sections.

When the residential and employment densities were calculated within the 800 m radius around the transit stations (Table 32), it is found that Emek station area with a residential density of 544 p/ha is the densest area among the stations analyzed in the study. It is followed by Dikimevi (453 p/ha), Bahçelievler (446 p/ha) and Kurtuluş (395 p/ha) station areas.

Table 32 Density around Ankaray stations selected in the study

Name of station	Density (p/ha)	Residential density (p/ha)	Employment density (p/ha)
Aşti station area	313	292	21
Emek station area	544	529	15
Bahçelievler station area	446	411	35
Beşevler station area	250	223	27
Tandoğan station area	338	291	47
Kurtuluş station area	395	361	34
Dikimevi station area	453	425	28

Regarding employment density, Tandoğan (47 p/ha) is followed by Bahçelievler (35 p/ha) and Kurtuluş (34 p/ha) station areas.

7.2.2. Diversity

7.2.2.1. Variety in the built-up area

In the Ankaray corridor, vicinity of stations which are determined as the 800 m radius around the stations (maximum) overlaps at Aşti, Emek, Bahçelievler, Beşevler and Tandoğan stations.

Aşti station

Aşti station takes the name of Intercity Bus Terminal which is located next to the station. Konya Road divides the vicinity of the station into two parts (Figure 56). Almost ¾ of the station area is covered by government offices and bus station. The rest is composed of residential areas, where mostly the ground floor is used for commercial purposes.

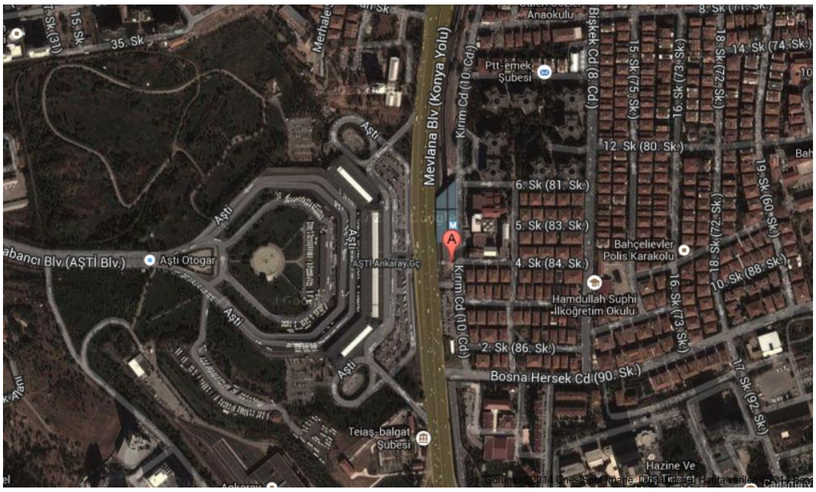


Figure 56 Konya Road and Intercity Bus Terminal

The neighborhood is mixed of old and new buildings which are multi-storey buildings ranging from 4 storeys to 11 storeys. In some parts, 2 storey houses are observed; however, these are negligible in number. Residential buildings have 4 apartments on each floor.

There are also Ankara University and Gazi University Faculties and Ministries within the boundary of 800 m radius around the station as seen in Figure 57.

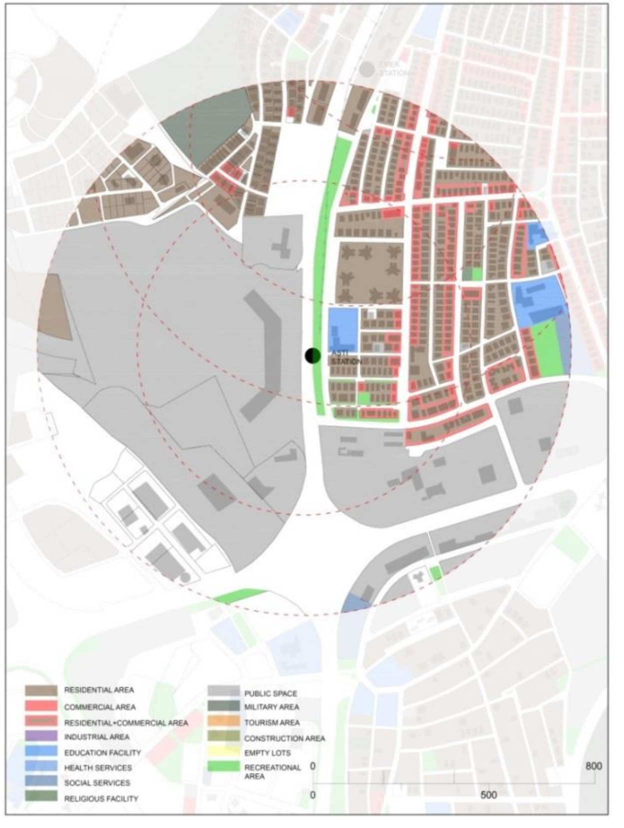


Figure 57 **Land use aroundAşti transit station** **Variety in the buildings**

Figure 58 **Land use around Emek transit station** **Variety in the buildings**

Emek station

Emek station serves residential areas. It is located next to Konya Road. Along Konya Road, there are mostly 15-storey buildings which have auto galleries on the ground floors and residential on the upper floors.

On the west side of Konya road, there are mostly 4-storey residential buildings and on the east side of the road there are 4 or 5-storey buildings which are vertically mixed use (ground floor commercial, upper floors residential). Ground floors are mostly used by markets, hair salons, tailors, real estate and auto galleries (Figure 58).

Bahçelievler station

Bahçelievler station is located next to a grand junction connecting Konya Road, Alparslan Türkeş Street and Bahriye Üçok Street. Vicinity of the station is surrounded by Gazi Medicine Faculty and Hospital, Teacher's Lodge, Atatürk Anatolian High School, Riding Center, Dormitories and residential areas.

Along Konya Road, there are mostly 15-storey buildings which have auto galleries on the ground floors and residential on the upper floors. On the west side of Konya road, there are mostly 4-storey residential buildings.

The neighborhood is mixed of old and new buildings which are mostly 4-storey buildings. Ground floors are mostly used by cafes, pharmacies, boutiques, markets, hair salons, real estate and auto galleries (Figure 59).

Beşevler station

Beşevler station serves both residential areas and campuses of Ankara University, Gazi University and Hacettepe State Conservatory. Due to its location next to big school campuses it is an attraction point of the city.

There are mostly 3 or 4-storey residential buildings. In some parts, 1-2 storey houses are observed; however, these are negligible in number. Residential buildings have 3-4 apartments on each floor. Buildings facing the main streets are vertically mixed-use buildings (ground floor commercial, upper floors residential) (Figure 60).

Tandoğan station

Altınel Hotel, Ziraat Bank, Machinery and Chemical Industry Corporation (MKE), Officer's Club, Turkish Armed Forces Education Foundation and Ankara University Campus are located around the station.

There are mostly 3- 4 storey and 6-8 storey residential buildings. Residential buildings have 3-4 apartments on each floor. Buildings facing the main streets are vertically mixed-use buildings (ground floor commercial, upper floors residential) (Figure 61).

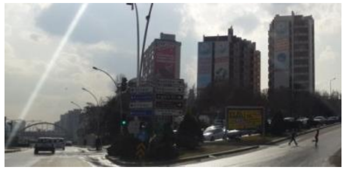


Figure 59 **Land use around Bahçelievler transit station** **Variety in the built up area**

Figure 60 **Land use around Beşevler transit station** **Variety in the buildings**

Figure 61

Land use around Tandoğan transit station

Variety in the built up area

Kurtuluş station

Kurtuluş station is located in a neighborhood that is composed of Ankara University Campus, Hacettepe University Hospital, Hamamönü, Fire Station, Kurtuluş Park, Cebeci Stadium, residential areas and dormitories. Due to its location next to school campuses, it is an attraction point of the city (Figure 62).

Figure 62 Variety in the buildings

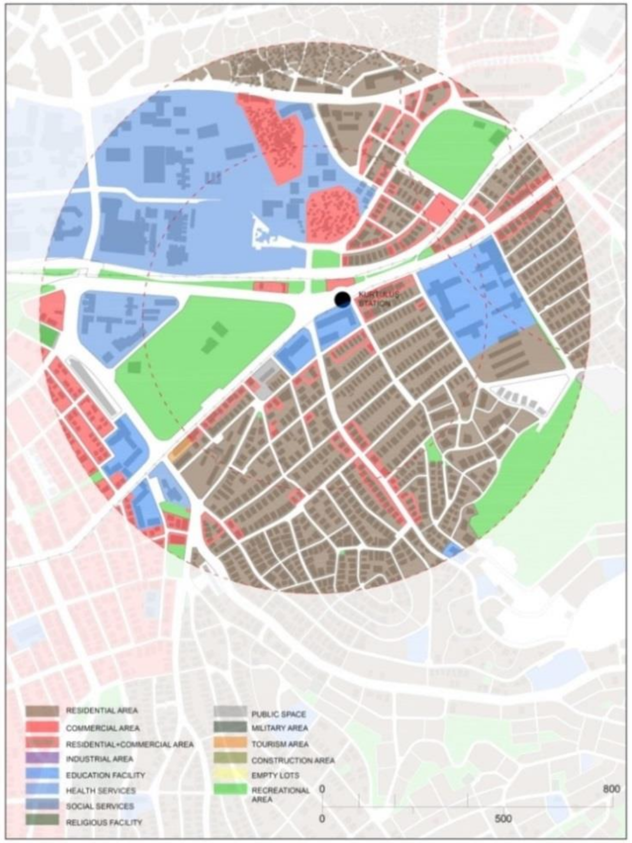
There are mostly 5 to 7 storey residential buildings. Residential buildings have 3-4 apartments on each floor. Buildings facing the main streets are vertically mixed-use buildings (ground floor commercial, upper floors residential). In the southern part of the station, up to the hills, there are squatter areas (Figure 64). Along the main street (Cemal Gürsel Street), there are mostly tall buildings up to 11 storeys which are used for office purposes (Figure 63).

Figure 63 Tall buildings along the main road

Dikimevi station

Dikimevi station is located in a neighborhood that is composed of Ankara University Campus, Ankara Medicine Hospital, Military Area, Mamak Municipality, residential areas, shops and dormitories.

Along Cemal Gürsel Street (Main Street), there are mostly 7-9 storey buildings which have commercial purposes on the ground floor and the upper floors are used for residential purposes. In the other parts, there are mostly old buildings having 5-storeys. There are also new housing developments within the area (Figure 65).



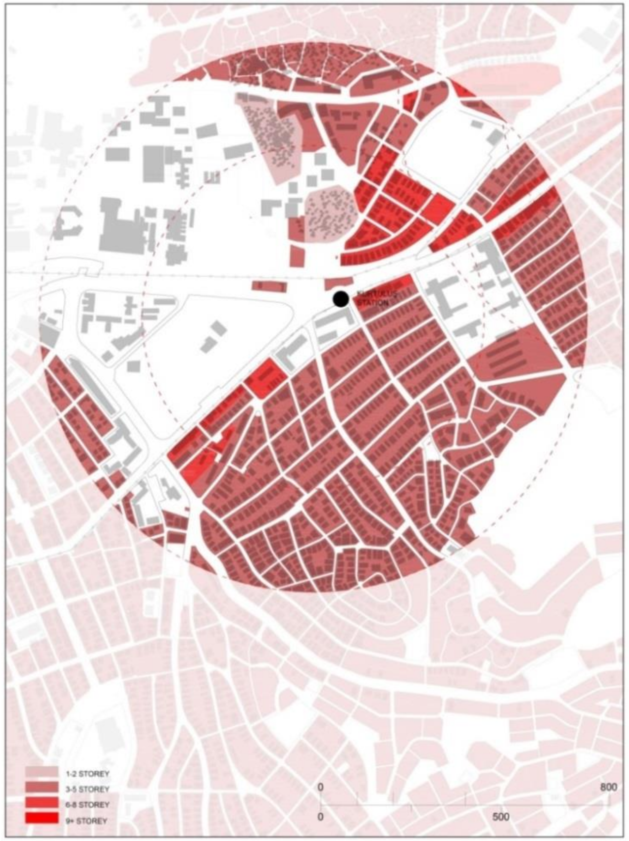
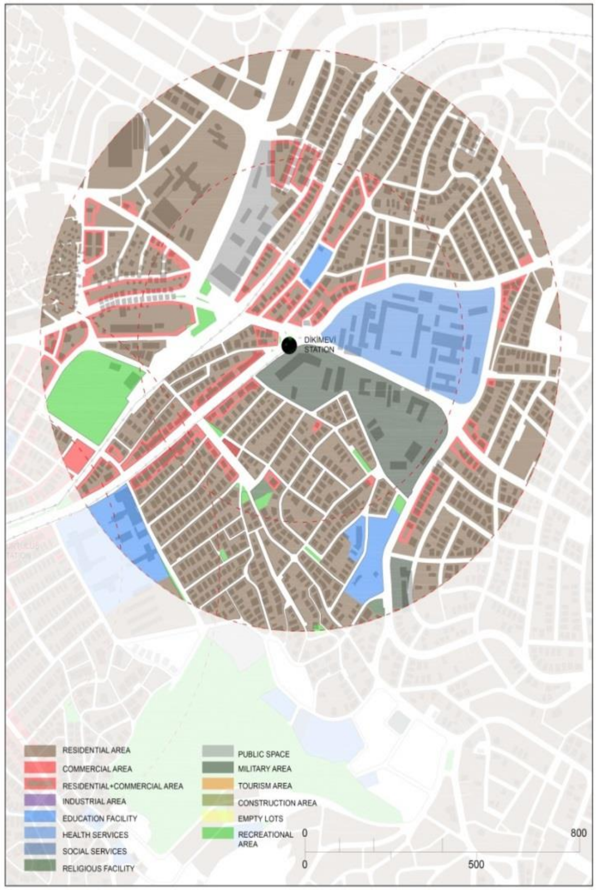


Figure 64 **Land use around Kurtuluş transit station** **Variety in the built up area**



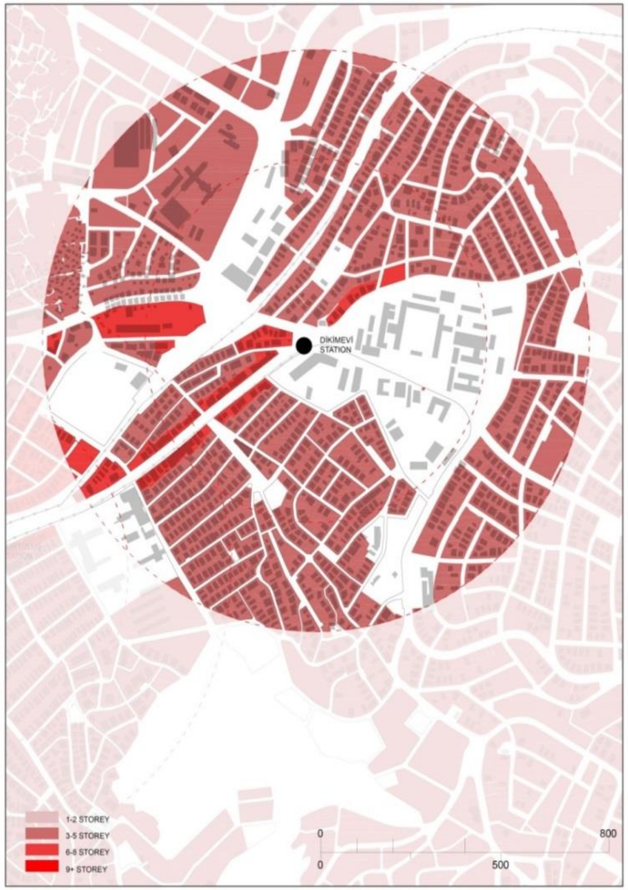


Figure 65 **Land use around Dikimevi transit station** **Variety in the buildings**

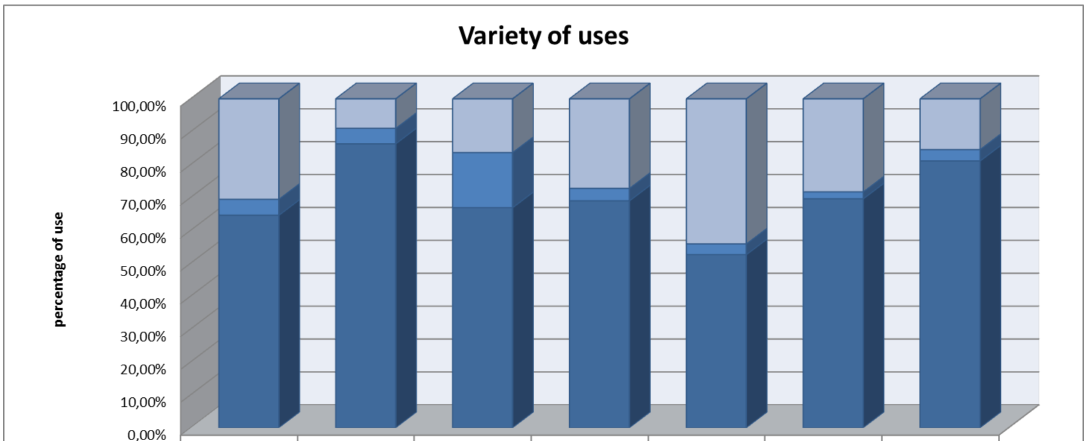
7.2.2.2. Degree of functional mix

For each use (residential, commercial, residential+commercial, other), a percentage has been found showing the variety of uses within the area ((built up area / total area) × 100).

Then, a ranking system is created to analyzed the mixed use characteristic of the area. In order to have a mixed use characteristic, the area must embody residential, commercial and other uses (education, health services areas and so on).

When the built up environment is taken into consideration, residential uses are the main uses around the transit stations. Vicinity of Emek (86,35%) and Dikimevi (81,12%) stations are mostly composed of residential areas (Figure 66).

Beşevler staton is located in a neighborhood in which the buildings are mostly vertically mixed use (ground floor for commercial purposes, upper floors residential).



	AŞTİ	EMEK	BAHÇELİEVLER	BEŞEVLER	TANDOĞAN	KURTULUŞ	DİKİMEVİ
OTHER %	30,55%	8,98%	16,33%	27,21%	44,11%	28,30%	15,42%
COMMERCIAL %	4,84%	4,67%	16,75%	3,79%	3,26%	2,08%	3,46%
RESIDENTIAL %	64,61%	86,35%	66,93%	69,00%	52,64%	69,62%	81,12%

Figure 66 Percentage of different functions in the built environment around the stations

It is found that Bahçelievler, Tandoğan and Aşti station areas have the highest mixed use characteristics, whereas Emek and Dikimevi stations have the lowest. As mentioned before, Emek and Dikimevi station areas are mostly residential (Table 33).

Table 33 Ranking of Ankaray stations regarding the mixed use around the stations

Name of station	**Rank**
Tandoğan	**1**
Aşti	**2**
Bahçelievler	**3**
Beşevler	**4**
Kurtuluş	**5**
Dikimevi	**6**
Emek	**7**

7.2.3. Accessibility and connectivity

In the literature review chapter, it was mentioned that road network design and street connectivity have an effect on the travel choice. Researchers found out that the neighborhoods having high street intersections would promote walking (Ozbil et al., 2009).

It is argued that a grid network provides the simplest pattern and it is the mostly preferred pattern in neo-traditional neighborhood design. It has a positive effect on walkability and provides a better sense of direction. On the other hand, circuitous routes, cul-de-sacs and dead ends decrease walkability, ending up with a decreased ridership number of transit modes.

Aşti

Emek

Bahçelievler

Beşevler

Tandoğan

Kurtuluş

Dikimevi

Figure 67 Pattern analysis

In Figure 67, it is seen that in the vicinity of each station there is a different pattern. Due to university campuses, Konya Road and road junctions, neighborhoods around Aşti, Emek, Bahçelievler, Beşevler and Tandoğan stations are separated into two different parts. One part which has grid pattern is almost the same in each station area.

Kurtuluş transit station area is mostly composed of grid network and there are also parts which have circular pattern. In the southern part of the station, circular pattern is observed which might be the reason of terrain change in that part of the neighborhood. Around Dikimevi station, less regular patterns are observed.

In a study by Litman (2012), "**connectivity index**" was introduced which is used to evaluate the network connection of destinations. It is found by dividing the number of roadway links by the number of roadway nodes. This index can also be used for non-motorized transport modes. Street connectivity indicates how densely the streets are connected with each other. In this study this index has been calculated regarding each station (Table 34).

Table 34 Connectivity index of each station (500 m)

Name of station	Node	Link	Index
Tandoğan	35	50	1,428571
Bahçelievler	81	115	1,419753
Kurtuluş	67	94	1,402985
Emek	60	82	1,366667
Aşti	33	44	1,333333
Dikimevi	82	108	1,317073
Beşevler	48	63	1,3125

Litman (2012) argued that high index stands for increased choice of travel and more direct connections. Litman (2012) evaluated the connectivity index of a simple box, a four-squared grid and a nine-square grid. The results are 1.0, 1.33 and 1.5 respectively. Cul-de-sacs and dead ends reduce the index value. It is found that a minimum of 1.4 is needed for a walkable urban environment.

In Table 14, it is seen that Tandoğan, Bahçelievler and Kurtuluş station areas have the highest value for a walkable environment (1,4). Emek, Aşti, Beşevler and Dikimevi station areas also have high levels for this connectivity index (1,3). These values are the result of grid patterns in these neighborhoods.

In the following sections, measures of connectivity and accessibility which were revealed from literature will be analyzed regarding each station. This analysis will give more detailed information regarding the vicinity of each station from accessibility and connectivity point of view.

Aşti

- Integration to other modes

Bus stops and taxi ranks are located next to the station. Konya Road is the main road connecting the station to the other parts of the city. Dolmuş is a competing mode in the area. Ulus-Seyran, Gölbaşı, İskitler, Etlik, Tunalı, Hacettepe, Gar, Tandoğan dolmuş are available. Additionally, there are buses to Akköprü, Gölbaşı, Ulus, Kızılay, Aktepe and Uyanış. Employee services are also used by the ministries next to the station which has a negative effect on the use of transit system. There are also additional bus systems and dolmuş along the streets around the station (90th street, 8th street and so on) (Figure 68).

- Parking

There is a parking area next to the station with a capacity of 150 vehicles. There is also a bicycle park (capacity: 100 bicycles). However, there is no fare integration between the parking area and the transit system. It is also observed that streets are used for on-street parking. However, it is a tow away zone which prevents long term parking. There is also an area next to the station which used by trucks and caterpillars for parking purpose (Figure 68).

- Pedestrian activity

There are three entrances in the station. Two of them are located on the western part which is next to Gazi University faculties. The other one is at the Bus Terminal. Two parts are connected each other by an underpass along the Konya Road.

Observing the vicinity of the station it is found that lighting and landscaping is poor in the area. Main streets are mostly well-lit; however it is not the case in the side streets. All the streets have sidewalks. In some of the streets their quality is poor; while some streets have good conditioned sidewalks.

Towards 90th street, there is a steep ramp in the area which makes walking difficult and it might be harder in the winter time and with heavy carriage. The other parts of the neighborhood are mostly on flat terrain.

Integration with other modes **Parking**

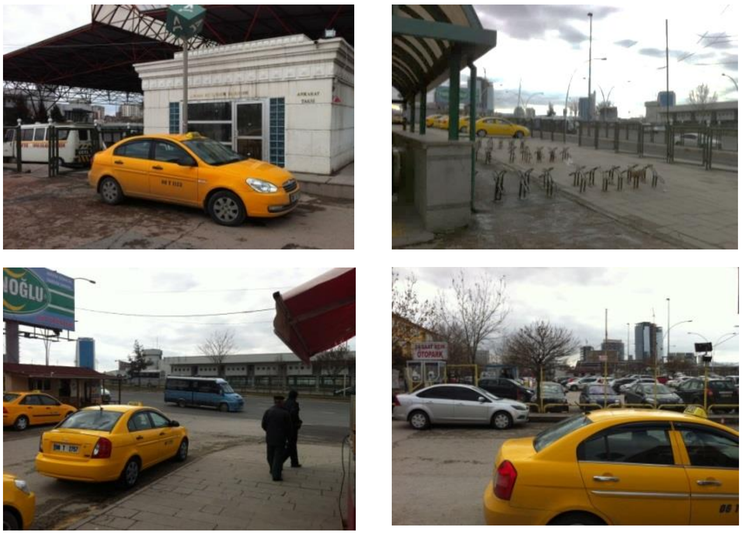


Figure 68 Aşti

➢ To sum up:

Hereby, regarding the walkability measures, a check-list is given below (Table 35). The (+) sign shows the presence of the measure in the area and (-) sign means that this measure is not present.

Table 35 Accessibility and connectivity measures in the vicinity of the station

Measures (Aşti)	Presence	Poor	Average	Good
Lighting	+	√		
Interface with parking (on street parking)	+		√	
Ease of pedestrian crossing	+	√		
Landscaping and tree-lined streets	+	√		
Flat terrain	+	N/A		
Availability of sidewalks	+	√		

In conclusion, the vicinity of the station do not perform well in terms of accessibility and connectivity measures.

Emek

- Integration to other modes

Dolmuş is a competing mode in the area. There are dolmuş to Sıhhiye, Cebeci, Keçiören and Kızılay. Parallel to Konya Road, on the 4th street Sıhhiye-Cebeci-Dikimevi dolmuş also operates.

- Parking

Along most streets, on-street parking on each side of the street is observed. However, it is observed that mostly these parking areas are used for other purposes than using Ankaray.

- Pedestrian activity

There are four entrances in the station. Two of them are located in the eastern side. There is no link to Konya Road after getting of the station from this side. There are two entrances in the other side of Konya Road which is accessible by an underpass.

Lighting and landscaping is on an average level in the area. Most of the streets are well-lit. There are small parks between the residential areas which provides playing environment for the children.

Underpasses **Parks** **Pedestrian movement** **Stairs**

Figure 69 Emek

All the streets have sidewalks. Most of the streets have good conditioned sidewalks. On the 4th street, there are also arrangements for disabled people. There are also pedestrian lights and pedestrian lanes easing the movement (Figure 69).

There are stairs, ramps and slope changes at western part of the station. It is observed that main streets directing pedestrians to the station are located on flat terrain in the eastern parts, which might ease walking. However in the eastern parts, it might also get hard to walk with heavy carriage along the streets.

- To sum up:

Hereby, regarding the walkability measures, a check-list is given below (Table 36). The (+) sign shows the presence of the measure in the area and (-) sign means that this measure is not present.

Table 36 Accessibility and connectivity measures in the vicinity of the station

Measures (Emek)	Presence	Poor	Average	Good
Lighting	+		√	
Interface with parking (on street parking)	+			√
Ease of pedestrian crossing	+		√	
Landscaping and tree-lined streets	+		√	
Flat terrain	+-	N/A		
Availability of sidewalks	+			√

In conclusion, the strength of the vicinity of the station are availability of sidewalk and interface with parking. On the other hand, in terms of lighting, landscaping and ease of pedestrian crossing, this area performs on an average level.

Bahçelievler

- Integration to other modes

Station has been strongly integrated to other transport modes such as dolmuş, public transport buses and taxi. Dolmuş and bus routes which are parallel to the rail transit route might have a negative effect on the ridership levels of the rail transit system attracting passengers from rail to others.

- Parking

Transit station is accessible by motorized vehicles, but there are no parking areas serving the station. Along most streets, on-street parking on each side of the street is observed. However, it is observed that mostly these parking areas are used for other purposes than using the Ankaray (Figure 70).

- Pedestrian activity

Station is located next to Konya Road. There are two entrances to the station which is on the same side of the street. There are traffic signals and pedestrian crossings on both Konya Road and Bahriye Üçok Street. Apart from the main road, there are mostly two-lane streets around the neighborhood. There are inadequate number of pedestrian crossings and traffic signals on these streets.

In designing streets, tree-lined streets and well-lit environment show high quality for walkability. Observing the vicinity of the station it is found that lighting is on an average level and landscaping is at a good level in the area. Additionally, all the streets have sidewalks. Most of the streets have good conditioned sidewalks.

Table 37 Accessibility and connectivity measures in the vicinity of the station

Measures (Bahçelievler)	Presence	Poor	Average	Good
Lighting	+		√	
Interface with parking (on street parking)	+			√
Ease of pedestrian crossing	+		√	
Landscaping and tree-lined streets	+			√
Flat terrain	+	N/A		
Availability of sidewalks	+			√

- To sum up:

It is observed that on-street parking, landscaping and availability of sidewalks that might affect the usage of the rail transit system are the strengths of the vicinity of the station. Weaknesses are the inadequate pedestrian crossings and lighting. Besides these measures, vicinity of Bahçelievler station provides a pedestrian-friendly environment

.

Location of the station | **Parking** | **Landscaping**

Figure 70 Bahçelievler

Beşevler

- Integration to other modes

Station has been strongly integrated to other transport modes such as dolmuş, public transport buses and taxi. There are bus stops both in front of the station and across the street. Along the street, dolmuş and taxis operate. Dolmuş and bus routes which are parallel to the rail transit route might have a negative effect on the ridership levels of the rail transit system attracting passengers from rail to dolmuş (Figure 71).

- Parking

Transit station is accessible by motorized vehicles, but there are no parking areas serving the station. Along most streets, on-street parking on each side of the street is observed. However, it is observed that mostly these parking areas are used for other purposes than using the Ankaray (Figure 71).

- Pedestrian activity

There are four entrances to the station on both sides of the street. There are mostly two-lane streets around the neighborhood. However, there are inadequate pedestrian crossing signals. Additionally, all the streets have sidewalks. Most of the streets have good conditioned sidewalks.

Observing the vicinity of the station it is found that lighting and landscaping are on an average level. Additionally, all the streets have sidewalks. Most of the streets have good conditioned sidewalks (Figure 71).

- To sum up:

It is found out that all the measures except from on-street parking opportunities are on the average level. Along most streets, on-street parking on each side of the street is observed.

Table 38 Accessibility and connectivity measures in the vicinity of the station

Measures (Beşevler)	Presence	Poor	Average	Good
Lighting	+		√	
Interface with parking (on street parking)	+			√
Ease of pedestrian crossing	+		√	
Landscaping and tree-lined streets	+		√	
Flat terrain	+	N/A		
Availability of sidewalks	+			√

Tandoğan

- Integration to other modes

Station has been strongly integrated to other transport modes such as dolmuş, public transport buses and taxi. Dolmuş and bus routes which are parallel to the rail transit route might have a negative effect on the ridership levels of the rail transit system attracting passengers from rail to others.

- Parking

Transit station is accessible by motorized vehicles, but there are no parking areas serving the station. Along most streets, on-street parking on each side of the street is observed. However, it is observed that mostly these parking areas are used for other purposes than using Ankaray (Figure 72).

Integration with other modes | **Parking** | **Pedestrian movement**

Figure 71 Beşevler

- Pedestrian activity

There are two entrances to the station. There are mostly two-lane streets around the neighborhood. However, there are inadequate pedestrian crossing signals on these streets. Traffic signals in front of the station are adjusted to ease the vehicle movement not the pedestrian movement. Waiting time is too long. The strength of the vicinity of the station is that, most of the streets have sidewalks.There are few parks and one pedestrian street within the area.

Parking | **Pedestrian movement**

Figure 72 Tandoğan

➢ To sum up:

In terms of all measures, this area performs on an average level.

Table 39 Accessibility and connectivity measures in the vicinity of the station

Measures (Tandoğan)	Presence	Poor	Average	Good
Lighting	+		√	
Interface with parking (on street parking)	+		√	
Ease of pedestrian crossing	-	N/A		
Landscaping and tree-lined streets	+		√	
Flat terrain	+	N/A		
Availability of sidewalks	+		√	

Kurtuluş

➢ Integration to other modes

Station has been strongly integrated to other transport modes such as dolmuş, public transport buses and taxi. There are bus stops across the street. Along the street dolmuş and taxis operate. However, dolmuş routes which are parallel to the rail transit route might have a negative effect on the ridership levels of the rail transit system attracting passengers from rail to dolmuş. Private cars are also used to access the station. There is also access to the commuter train (Figure 74).

➢ Parking

Along most streets on-street parking on each side of the street is observed. Most of the buildings also have their own parking lots. There is no parking area for the purpose of transit use (Figure 74).

There are 6 entrances to the station from both sides of the main street. All the streets have sidewalks which are mostly in a good condition. However, in the parts closer to the squatter areas there are streets with no sidewalks. Only along the main street there are arrangements for disabled people.

In designing streets, tree-lined streets and well-lit environment show high quality for walkability. Observing the vicinity of the station it is found that lighting and landscaping is on an average level in the area.

There is a big park located next to the station which has an area of approximately 10 ha (Figure 73). Registry Office, playgrounds, table tennis facilities, running track, traffic education center are located inside the park. There are picnic tables, tennis courts and a wedding salon within the park. The park is integrated to the pedestrian activity pattern. It serves a nice pattern while walking to Kızılay.

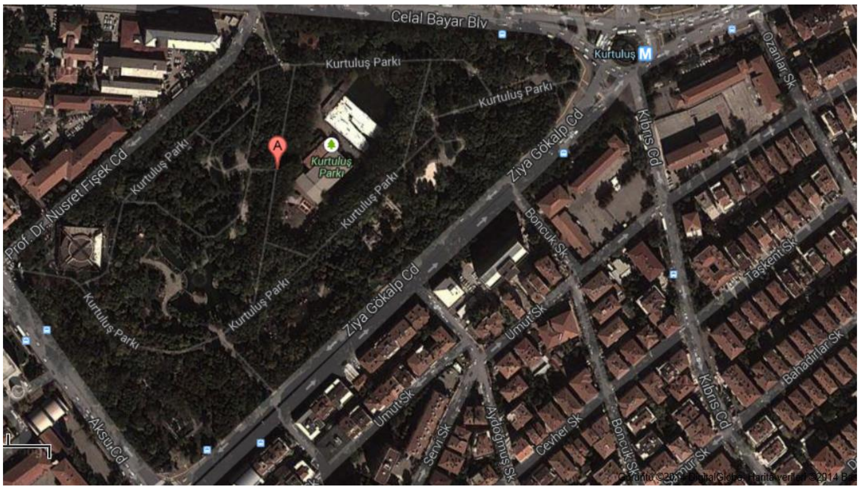


Figure 73 Kurtuluş Park

Integration with other modes	Parking	Pedestrian movement	Landscaping	Slope changes and stairs

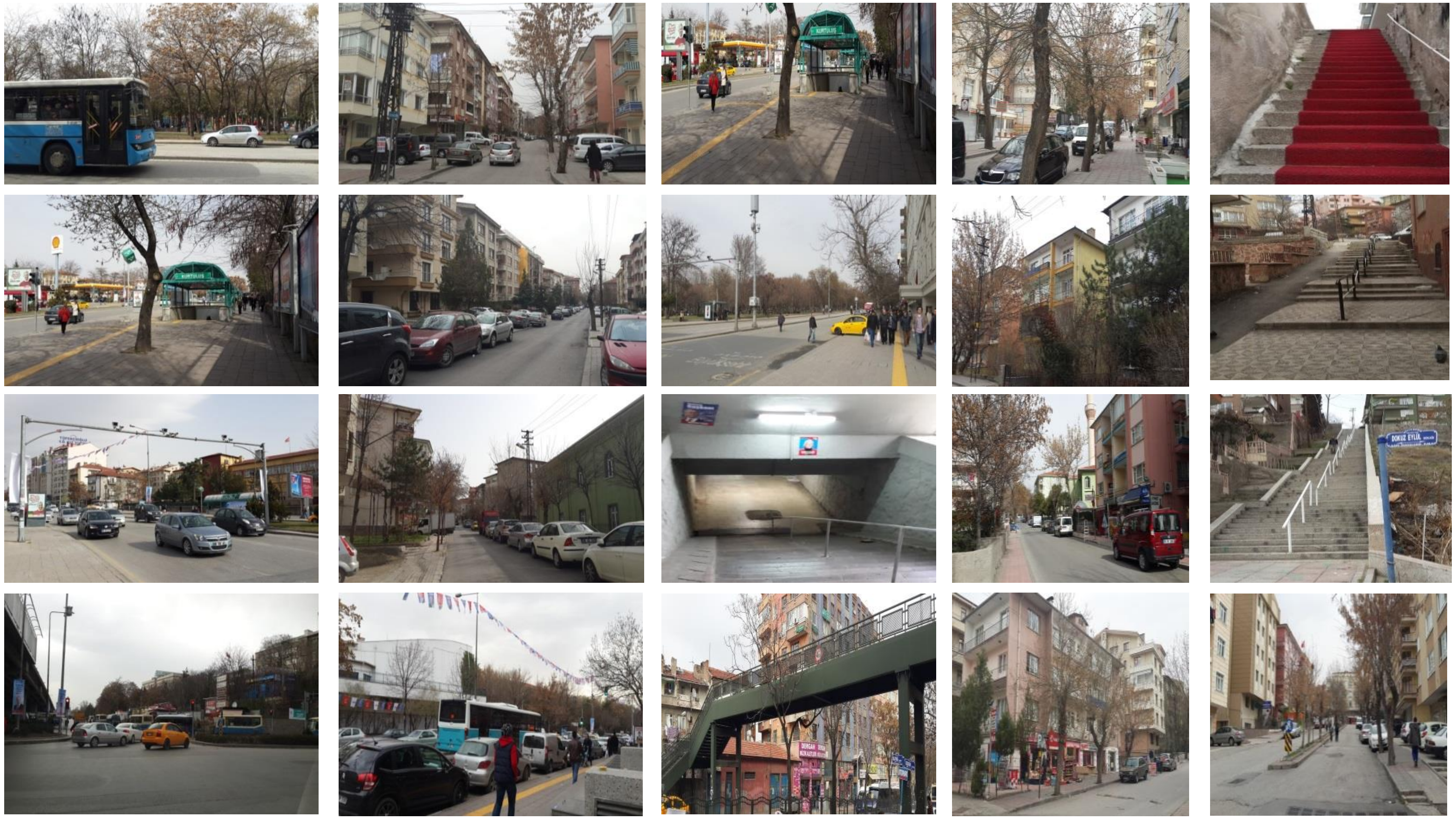


Figure 74 Kurtuluş

205

Hamamönü also offers different activities both to the residents of the neighborhood and others. There are squares, parks and cafes in the area (Figure 75)

Figure 75 Hamamönü

There are also ramps and slope changes around the station. Below is the map of these changes. Blue arrows show the direction of the slope changes (Figure 76).

In most parts of the neighborhood, stairs are used which make walking difficult and it might be harder in the winter time and with heavy carriage.

Figure 76 Slope change

There are mostly one-way streets around the neighborhood. There are two main streets which are highly congested and have a negative effect on the pedestrian movement (Figure 77). Only, along Cemal Gürsel Street there are traffic signs.

Figure 77 Main streets

Along Tepebaşı Street pedestrian activity is interrupted with fences and with an overpass pedestrians are allowed to cross the street.

Commuter rail divides the area into two parts. There is one underground pass and one above ground pass which connects both sides. Otherwise, pedestrian activity is interrupted by big fences.

- To sum up:

Strengths and weaknesses of Kurtuluş station area are revealed. It is observed that integration with other modes, landscaping and availability of on-street parking which might affect the usage of the rail transit system are the strengths of the vicinity of the station.

Table 40 Accessibility and connectivity measures in the vicinity of the station

Measures (Kurtuluş)	Presence	Poor	Average	Good
Lighting	+		√	
Interface with parking (on street parking)	+			√
Ease of pedestrian crossing	-		N/A	
Landscaping and tree-lined streets	+			√
Flat terrain	+-		N/A	
Availability of sidewalks	+		√	

Dikimevi

- Integration to other modes

Station has been strongly integrated to other transport modes such as dolmuş, public transport buses and taxi. There are bus stops across the street. Along the street dolmuş and taxis operate. However, dolmuş routes which are parallel to the rail transit route might have a negative effect on the ridership levels of the rail transit system attracting passengers from rail to dolmuş. Private cars are also used to access the station. There is also access to the commuter train (Figure 79).

- Parking

Transit station is accessible by motorized vehicles, but there are no parking areas serving the station. Along most streets, on-street parking on each side of the street is observed. However, it is observed that mostly these parking areas are used for other purposes than using the Ankaray (Figure 79).

- Pedestrian activity

There are small parks between the residential areas which provides playing environment for the children.

Figure 78 Main streets

Lighting and landscaping is on an average level in the area. Most of the streets have sidewalks. In some of the streets their quality is poor; while some streets have good conditioned sidewalks. Along the main streets there are arrangements for disabled people (Figure 78). Pedestrian activity is interrupted by trees, waste containers or rough pavement on the streets (Figure 79).

Main streets have 2 or 3 lanes in each direction. There are few pedestrian crossings. On the other hand, in the side streets, there are difficulties crossing the street due to lack of pedestrian crossings.

There are also ramps and slope changes around the station. In most parts of the neighborhood, stairs are used which make walking difficult and it might be harder in the winter time and with heavy carriage.

The underpass is not well-lit and there is no sign indicating that the underpass leads to the other parts of the neighborhood. Transit passengers who do not know the neighborhood might easily get lost in the area. Overpasses are also provided in the area in order to maintain pedestrian crossing and access to the commuter rail.

Integration with other modes	Parking	Parks	Different type of sidewalks	Stairs and slope changes	Overpass and underpass

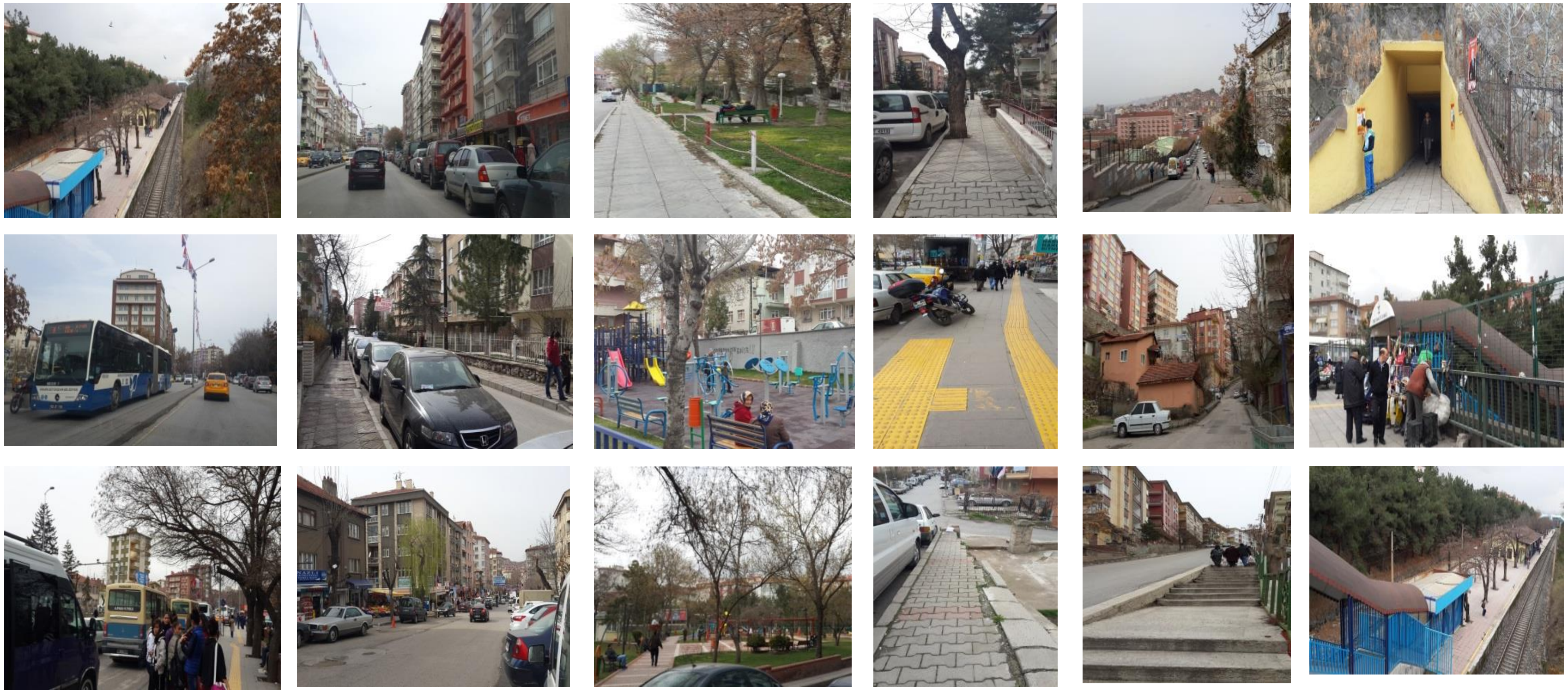


Figure 79 Dikimevi

- To sum up:

The strength of the area is the opportunity of on-street parking. On the other hand, it is found that lighting and landscaping are on an average level and there are poor quality sidewalks. Additionally, it is observed that main streets directing pedestrians to the station are located on inclined land which might cause problems in the winter time.

Table 41 Accessibility and connectivity measures in the vicinity of the station

Measures (Dikimevi)	Presence	Poor	Average	Good
Lighting	+		√	
Interface with parking (on street parking)	+			√
Ease of pedestrian crossing	-	N/A		
Landscaping and tree-lined streets	+		√	
Flat terrain	+-	N/A		
Availability of sidewalks	+	√		

7.2.4. Summary

It should be kept in mind that this study aims at understanding the link between station area design and transit usage. Analysis focuses on whether the surroundings of selected Ankara Metro and Ankaray transit stations are “transit encouraging” neighborhoods (from the point of view of increased transit usage).In the previous sections these parameters are revealed and each station has been analyzed accordingly. Findings will be given according to each parameter below:

Density

- It is found that densities around all the stations analyzed are higher than the densities that are defined as the level that would reduce automobile dependence and encourage public transit in the literature.
- Considering the built-up area and residential density, **Emek** station area with a density of 544 p/ha is the densest area among the stations analyzed in the study.
- It is followed by **Dikimevi** (453 p/ha), **Bahçelievler** (446 p/ha) and **Kurtuluş** (395 p/ha) station areas.
- **Beşevler** station area has the lowest residential density as it comprises big university campuses.

Diversity

- When the built up environment is taken into consideration, residential uses are the main uses around the transit stations.
- Vicinity of Emek (86,35%) and Dikimevi (81,12%) stations are mostly composed of residential areas.
- Beşevler staton is located in a neighborhood in which the buildings are mostly vertically mixed use (ground floor for commercial purposes, upper floors residential).
- Bahçelievler, Tandoğan and Aşti station areas have the highest mixed use characteristics, whereas Emek and Dikimevi stations have the lowest.

Accessibility and connectivity

In the previous section, a wide range of measures have been analyzed for each station. Regarding the connectivity/beta index, it was found that Tandoğan, Bahçelievler and Kurtuluş station areas have the highest value for a walkable environment (1,4). Emek, Aşti, Beşevler and Dikimevi station areas also have high levels for this connectivity index (1,3). These values are the result of grid patterns in these neighborhoods.

Analysis of each station was followed by a table that incorporated all the measures together in order to reveal the better performing transit stations. It should be noted that every measure may not have the same effect on transit usage; in other words each measure may have a different weight; for instance presence of the sidewalk might affect walking to the station more strongly than the landscape and tree-lined streets. However, it is not a straightforward task to assign weight to each measure. Understanding the relative values of each measure require an analysis that focuses on user's preferences and perceptions; and therefore cannot be made solely by the researcher. Proposing such a value system within this study would be subjective and arbitrary. In other words, to assign relative values to the measures requires a major research and cannot be carried out within the scope of this study. As a result, in order to keep the analysis simple, it was decided that presence of each measure has a score of 2, where lack of the measure gets 0. If one part of the neighborhood has the measure but the other part is lacking of it, then a score of 1 is given. Quality of each measure has also been graded (Good: 1, Average: 0, Poor:-1). At the end, all the grades are added up. Below, a table (Table 42) which shows the ranking of the stations according to accessibility and connectivity attributes is given.

Table 42 Summary of accessibility and connectivity measures of selected Ankaray stations

Measures (Aşti)	Presence	Poor	Average	Good	Score
Lighting	2	-1			8
Interface with parking (on street parking)	2		0		
Ease of pedestrian crossing	2	-1			
Landscaping and tree-lined streets	2	-1			
Flat terrain	2		N/A		
Availability of sidewalks	2	-1			
Measures (Emek)	**Presence**	**Poor**	**Average**	**Good**	**Score**
Lighting	2		0		13
Interface with parking (on street parking)	2			1	
Ease of pedestrian crossing	2		0		
Landscaping and tree-lined streets	2		0		
Flat terrain	1		N/A		
Availability of sidewalks	2			1	
Measures (Bahçelievler)	**Presence**	**Poor**	**Average**	**Good**	**Score**
Lighting	2		0		14
Interface with parking (on street parking)	2			1	
Ease of pedestrian crossing	2		0		
Landscaping and tree-lined streets	2				
Flat terrain	2		N/A		
Availability of sidewalks	2			1	
Measures (Beşevler)	**Presence**	**Poor**	**Average**	**Good**	**Score**
Lighting	2		0		14
Interface with parking (on street parking)	2			1	
Ease of pedestrian crossing	2		0		
Landscaping and tree-lined streets	2		0		
Flat terrain	2		N/A		
Availability of sidewalks	2			1	

Table 42 (Continued)

Measures (Tandoğan)	Presence	Poor	Average	Good	Score
Lighting	2		0		10
Interface with parking (on street parking)	2		0		
Ease of pedestrian crossing	0	N/A			
Landscaping and tree-lined streets	2		0		
Flat terrain	2	N/A			
Availability of sidewalks	2		0		
Measures (Kurtuluş)	**Presence**	**Poor**	**Average**	**Good**	**Score**
Lighting	2		0		11
Interface with parking (on street parking)	2			1	
Ease of pedestrian crossing	0	N/A			
Landscaping and tree-lined streets	2			1	
Flat terrain	1	N/A			
Availability of sidewalks	2		0		
Measures (Dikimevi)	**Presence**	**Poor**	**Average**	**Good**	**Score**
Lighting	2		0		9
Interface with parking (on street parking)	2			1	
Ease of pedestrian crossing	0	N/A			
Landscaping and tree-lined streets	2		0		
Flat terrain	1	N/A			
Availability of sidewalks	2	-1			

It is found that amongst the stations along Ankaray analyzed in the study:

- The vicinity of **Bahçelievler** (15) and **Beşevler** (14) stations have the highest scores. On the other hand, the vicinity of **Aşti** (8) station is the lowest ranking station when analyzing the presence of accessibility and connectivity parameters followed by **Dikimevi** (9) station.
- Additionally, when the conditions of each measure are compared, it is also observed that **Bahçelievler** and **Beşevler** station areas are found to be the most walkable environments amongst the stations analyzed in the study.
- In **Aşti** station ares, almost half of the parameters indicate poor conditions.

CHAPTER 8

ASSESSING THE LINK BETWEEN BUILT ENVIRONMENT CHARACTERISTICS AND RAIL TRANSIT USAGE

8. Introduction

The literature review revealed the significance of land use patterns and built environment characteristics in travel behavior. It has been discussed in earlier chapters of this study that investing in public transit infrastructure is not sufficient to change the travel behavior into a sustainable manner; such travel behavior change also requires 'macro' land use and 'micro' neighborhood design principles. These principles are to complement and support the public transport network. Compactness, density, mixed-land use, diversity, settlement size, walkability and connectivity have been analyzed as land use and built environment characteristics that play a crucial role in promoting more sustainable travel patterns in the urban environment.

From this point of view, as it was mentioned before, in this study the following questions are asked:

- Is there a link between the built-environment attributes around transit stations and the usage of that particular transit station?
- Is a frequently used transit station also a station with a "transit encouraging built-environment"?

8.1. Approach of analysis

At this stage of the study, an attempt was made to identify the measures or indices that seem to explain the ridership levels of the stations in the most effective way. In other words, each measure (density, diversity, accessibility, connectivity and integration with public transport) analysed here are separately compared with the ridership figures to see whether those stations that perform the best in terms of that measure are also the stations that have a higher ridership. For instance, from the point of view of the density measure, stations with the highest population density in their vicinity would be expected to be those that have the highest ridership. It is intended to find out relations between the indicators analysed and the ridership. For this reason two different approach of analysis is used: Qualitative (Ranking Analysis) and Quantitative.

8.1.1. Qualitative Analysis: Ranking analysis

In the ranking analysis, as shown in the tables, all the values are listed for each station (Table 43). Accordingly, the stations are given a rank from 1 to 14 (1 being the first, 14 being the last) (Table 44). This ranking is also applied to each system separately (Table 45-46).

These ranks are added up to find the total score of each station. Lower score means a better performing transit station area in terms of transit-encouraging parameters. As it is seen from the tables, each station is ranked differently according to each measure.

Table 43 Values

Name of station	Ridership (pass./month)	Density (p/ha)	Diversity	Conn. Score	Conn. Index (link/node)	D.freq. bus systems	D.Freq. dolmuş	Integration (d.fr.bus+ dolmuş+ commuter rail)
Batıkent	700.119	193	0,91	11	1,228571429	970	426	1396
Ostim	270.404	81	1,16	7	1,360655738	450	670	1120
Macunköy	119.780	53	0,81	4	0,857142857	144	0	144
Hastane	388.783	1.086	1,20	8	1,363636364	290	510	800
Demetevler	296.115	1.868	1,21	10	1,328767123	84	570	654
Yenimahalle	152.436	709	0,96	12	1,34375	52	510	562
İvedik	222.922	277	0,89	6	1,222222222	483	640	1123
Aşti	480.883	313	0,63	8	1,333333333	414	502	916
Emek	110.160	544	1,06	13	1,366666667	335	310	645
Bahçelievler	220.089	446	0,67	15	1,419753086	55	262	317
Beşevler	428.915	250	0,71	14	1,3125	529	482	1011
Tandoğan	167.747	338	0,60	10	1,428571429	1600	522	2122
Kurtuluş**	277.015	395	0,73	11	1,402985075	1107	770	2053
Dikimevi**	675.915	453	0,96	9	1,317073171	1335	2334	3845

*For the diversity parameter: Low value=High rank

** Only these stations have access to the commuter rail with a daily frequency of 176.

Pale Blue: Minimum value, Dark Blue: Maximum value

Table 44 Ranking (Coloured)

Dependent Variable	Name of station	Independent Variables							Total
Ridership		Density	Diversity	Conn.Score	D.freq.bus systems	D. Freq.dolmuş	Conn. Index	Integ.with all modes	
1	Batıkent	12	8	6	4	11	12	4	57
8	Ostim	13	12	12	7	3	6	6	59
13	Macunköy	14	6	14	14	14	14	14	90
5	Hastane	2	13	10	10	7	5	9	56
6	Demetevler	1	14	8	12	5	9	10	59
12	Yenimahalle	3	9	4	14	8	7	12	57
9	İvedik	10	7	13	6	4	13	5	58
3	Aşti	9	2	11	8	9	8	8	55
14	Emek	4	11	3	9	12	4	11	54
10	Bahçelievler	6	3	1	13	13	2	13	51
4	Beşevler	11	4	2	5	10	11	7	50
11	Tandoğan	8	1	7	1	6	1	2	26
7	Kurtuluş	7	5	5	3	2	3	3	28
2	Dikimevi	5	10	9	2	1	10	1	38

1	2	3	4	5	6	7	8	9	10	11	12	13	14

High rank — Low rank

Highest score	Lowest score

Table 45 Ranking for Ankara Metro

Dependent Variable	Name of station	Independent Variables							Total
Ridership		Density	Diversity	Conn.Score	D.freq.bus systems	D. Freq.dolmuş	Conn. Index	Integ.with all modes	
1	**Batıkent**	5	3	2	1	6	5	1	**23**
4	**Ostim**	6	5	5	3	1	2	3	**25**
7	**Macunköy**	7	1	7	5	7	7	7	**41**
2	**Hastane**	2	6	4	4	4	1	4	**25**
3	**Demetevler**	1	7	3	6	3	4	5	**29**
6	**Yenimahalle**	3	4	1	7	4	3	6	**28**
5	**İvedik**	4	2	6	2	2	6	2	**24**

1	2	3	4	5	6	7

High rank — Low rank

Highest score | Lowest score

Table 46 Ranking for Ankaray

Dependent Variable	Name of station	Independent Variables							Total
Ridership		Density	Diversity	Conn.Score	D.freq.bus systems	D. Freq.dolmuş	Conn. Index	Integ.with all modes	
2	**Aşti**	6	2	7	5	4	5	5	**34**
7	**Emek**	1	7	3	6	6	4	6	**33**
5	**Bahçelievler**	3	3	1	7	7	2	7	**30**
3	**Beşevler**	7	4	2	4	5	7	4	**33**
6	**Tandoğan**	5	1	5	1	3	1	2	**18**
4	**Kurtuluş**	4	5	4	3	2	3	3	**24**
1	**Dikimevi**	2	6	6	2	1	6	1	**24**

1	2	3	4	5	6	7

High rank — Low rank

Highest score | Lowest score

Regarding Ankara Metro stations:

- **Batıkent** station has the highest level of ridership. As it is seen from the table, daily frequency of all modes passing along the station is the highest amongst the stations analyzed in the study. However, regarding vertical mix use and density levels, the station area has the lowest levels.
- In the Ostim station area**, employment density** levels are the highest. Ridership level of this station might be the result of this parameter.
- **Hastane** station has the second highest level of ridership. It is also the second ranking station regarding **density** levels**.** The neighborhood is **vertically mixed use**. Additionally, connectivity index that has a positive effect on the walkability is also high. These parameters explain the high ridership levels.
- **Demetevler** station area has the **highest density levels** amongst the station areas. Regarding **connectivity and accessibility parameters**, it has also high levels. On the other hand, it is the lowest diverse nighborhoods analyzed in the study. There are mostly residential uses within the area. Additionally, integration with the other modes is relatively low.
- **Yenimahalle** station's ridership level is one of the lowest levels in the study. On the other hand, regarding **density** and **connectivity**, this station area holds one of the highest positions. Moreover, low level of ridership of Yenimahalle station might be explained by the dolmuş and services providing different transport opportunities to the passengers and low diversity
- Ridership level of **İvedik** station can be explained by looking at the integration with other modes. On the other hand, the station area is in the last ranks regarding connectivity and density.

Regarding Ankaray stations:

- **Aşti** station has the second highest level of ridership. However, this station is one of the lowest ranking station when all the parameters besides diversity are taken into account. High ridership level might be the result of its location. The station is located next to the Inter Bus Terminal, which attracts passengers all over the city.

- Although **Emek** station area has the highest level of density, it has the lowest level of ridership. There are a limited number of trips made by bus systems and dolmuş and diversity is low, which might have a negative effect on the use of the station. Additionally, regarding connectivity and connectivity index, this station area has an average level.
- **Bahçelievler** station's ridership level is one of the lowest levels in the study. However, regarding connectivity and accessibility, connectivity index, diversity and density parameters, this station area holds one of the highest positions. Especially, regarding **connectivity score** it holds the highest position. On the other hand, number of trips made by bus and dolmuş are the lowest, which might negatively effect the use of the station.
- **Beşevler** station has the lowest levels regarding **density** and **connectivity index**. However, it is the second highest ranking station when connectivity/accessibility is analyzed. So, the ridership level of this station might be explained by these parameters.
- Regarding **daily frequency of all modes**, **Tandoğan** station has one of the highest stations. In the area, **connectivity index** and **diversity** are also high. Ridership level of this station might be the result of these parameters.
- Ridership level of **Kurtuluş** station can be explained by looking at the connectivity index and daily frequency of buses, dolmuş and commuter rail systems. On the other hand, the station area is in one of the lowest ranking stations regarding diversity.
- **Dikimevi** station is the first ranking station regarding ridership. As it is seen from the table, daily frequency of bus lines and dolmuş along the station is the highest amongst the stations analyzed in the study. On the other hand, it is also one of the lowest ranking stations regarding **connectivity and accessibility, connectivity index and diversity** parameters.

8.1.2. Quantitative analysis

Considering the fact that ranking analysis would not be significant by itself, quantitative analysis is made using IBM SPSS 22 Windows between the independent variables and ridership levels in order to support the findings of the previous section at this stage of the study. Hence, there might be big differences amongst each ranking station e.g. this difference might be 1% or 50%. By applying ranking analysis we might ignore this fact.

In the analyses, firstly a collinearity analysis is carried out to understand the relationship between ridership and other variables such as density, diversity, connectivity score, connectivity index, daily frequency of dolmuş, bus and all systems. It would be helpful to understand whether two variables are related to each other. A positive covariance indicates that as one variable deviates from the mean, the other variable also deviates in the same direction. Secondly, Principal Component Analysis (PCA) is made in order to simplify the variables. It aims to group possibly correlated variables. Thirdly, single factor regression has been carried out to predict one variable from another. In the study, dependent variable is the ridership level. Independent variables are density, diversity, connectivity index, connectivity score, daily frequency of bus systems, daily frequency of dolmuş, daily frequency of commuter rail and integration. Additionally, best fit analysis is carried out by using Microsoft Excel to observe the relationships. Finally, in order to reveal the different aspects and magnitude of each element, multivariate regression analysis is carried out to understand the planning and design parameters influencing the use of the transit systems.

Since transfer stations have extremely higher ridership values, quantitative analyses were performed with and without the extreme values. The analysis was made both for all the stations and for Ankara Metro and Ankaray separately. “Market segmentation principle”, which is used to subdivide the sample into groups that have similar characteristics, was used for the division of the sample.

Additionally, in order to find out the extreme values, “3 sigma limits” calculation, which is used to assess the data within three standard deviations from the mean, was found. However, regarding the limited data “2 sigma limits” calculation was more accurate and used accordingly. Consequently, Batıkent and Dikimevi stations were found as the extreme values and they were excluded from the analysis. Accordingly, data comprising all the stations is called “all data” and data in which the outliers are excluded is called “trimmed data”.

Furthermore, LnRidership values were also used to overcome potential scale problems, because sometimes there is no direct relation and it may give more meaningful results when natural log of variables are used.

Detailed quantitative analysis framework is given in Figure 80. Definition of the independent and dependent variables used in the quantitative analysis are also shown in Table 47. Ridership values and all the related spatial parameters and integration values are presented in Table 48. The descriptive statistics of these variables show that;

- Considering all data, the average ridership value is 322.235 with a standard deviation of 183.855. Looking at these average values, ridership values of Batıkent (700.119) and Dikimevi (675.915) stations stand out as extreme values, as they are twice as bigger than the average ridership value. The average decreases when the extreme values are taken out from the analysis. Average ridership value is 261.271 with a standard deviation of 120.887.

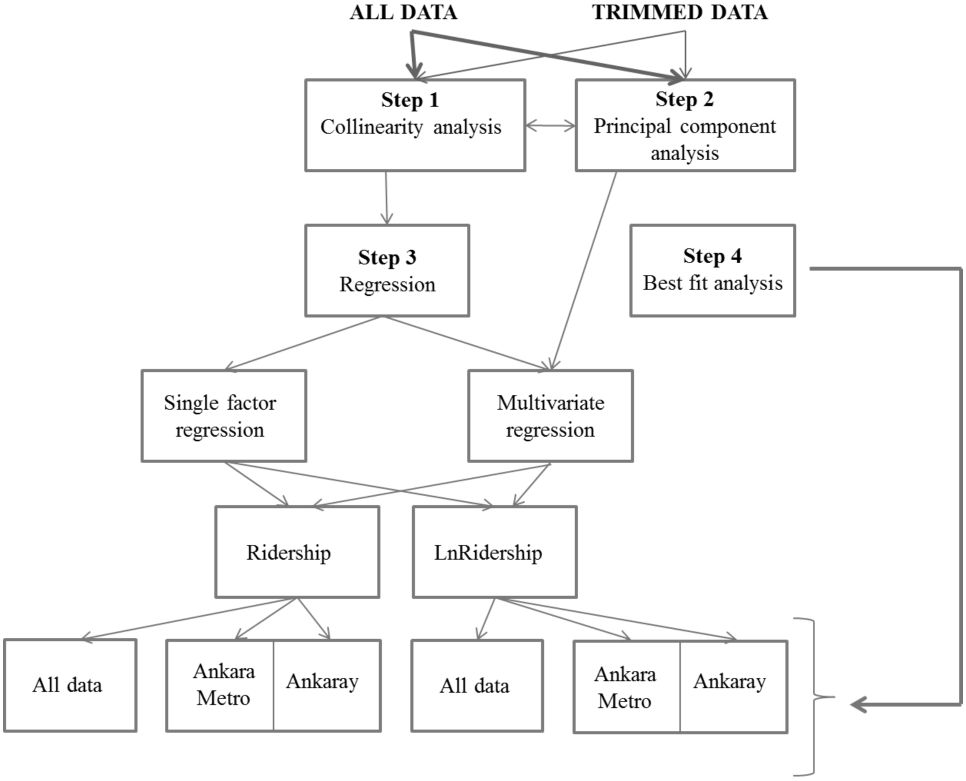


Figure 80 Quantitative analysis framework

Table 47 Definitions

Variables	**Abbreviation**	**Definition**
Ridership	-	Passengers/month
Ln Ridership	LnRide	(Ln) Passengers/month
Density		Number of residents and workers per hectare
Diversity	-	A calculation is made assuming that an ideal transit station would have 33,33% residential, 33,33% commercial and 33,33% other uses.From this point of view, proximity to this ideal is assessed.
Connectivity score	C_score	Total score of connectivity measures
Connectivity index	C_index	Link/node
Daily frequency of bus systems	Daily_f_bus	Transfers included.
Daily frequency of dolmuş	Daily_f_dolmuş	Transfers included.
Daily frequency of commuter rail	Daily_f_com_rail	Transfers included.
System	Dummy_Metro	-

Table 48 Ridership and related spatial parameters

Name of station	Ridership	Density	Diversity	C_score	C_index	Daily_f_ bus	Daily_f_ dolmuş	Daily_f_ _com_rail	Integration
Batıkent*	700.119	193	0,91	11	1,2286	970	426	0	1396
Ostim	270.404	81	1,16	7	1,3607	450	670	0	1120
Macunköy	119.780	53	0,81	4	0,8571	144	0	0	144
Hastane	388.783	1.086	1,20	8	1,3636	290	510	0	800
Demetevler	296.115	1.868	1,21	10	1,3288	84	570	0	654
Yenimahalle	152.436	709	0,96	12	1,3438	52	510	0	562
İvedik	222.922	277	0,89	6	1,2222	483	640	0	1123
Aşti	480.883	313	0,63	8	1,3333	414	502	0	916
Emek	110.160	544	1,06	13	1,3667	335	310	0	645
Bahçelievler	220.089	446	0,67	15	1,4198	55	262	0	317
Beşevler	428.915	250	0,71	14	1,3125	529	482	0	1011
Tandoğan	167.747	338	0,60	10	1,4286	1600	522	0	2122
Kurtuluş	277.015	395	0,73	11	1,4030	1107	770	176	2053
Dikimevi*	675.915	453	0,96	9	1,3171	1335	2334	176	3845
Average	322.235	500	0,89	10	1,3061	561	608	25	1193
Std. Dev.	183.855	457	0,20	3	0,1375	480	512	62	918
Trimmed data									
Average	261.271	530	0,89	10	1,3117	462	479	15	956
Std. Dev.	120.887	506	0,23	3	0,1532	461	206	51	607

*Outliers

a. Collinearity analysis

SPSS is used to analyze the correlations between variables. Pearson Correlation analysis is summarized in Table 49 below. When all the stations are included in the analysis, following significant correlation are found between the studied variables.

- Ridership is found to be correlated with daily frequency of dolmuş and integration at the 0,05 level where the correlation value is 0,564 and 0,547 respectively. The variables have a moderate positive correlation.
- There is a significant relationship between density and diversity at the 0,05 level where the correlation value is 0,559. The variables have a moderate positive correlation.
- Diversity is correlated with Ankara Metro at the 0,05 level where the correlation value is 0,627.
- Connectivity score is is siginificantly correlated with connectivity index at where the correlation value the correlation value is 0,616.
- Daily frequency of bus systems is found to be correlated with daily frequency of dolmuş and commuter rail at the 0,05 level (2-tailed); with integration at the 0,01 where the correlation value is 0,540, 0,562 and 0,862 respectively.
- Daily frequency of dolmuş is correlated with daily frequency of commuter rail and integration at the 0,01 where the correlation value is 0,752 and 0,891 respectively.
- Daily frequency of commuter rail is correlated with integration at the 0,01 level where the correlation value is 0,780.

Regarding LnRidership, only correlation between LnRidership and integration decreases (Pearson Correlation value: 0,501), the other correlations are found the same as the correlations performed with ridership values.

Table 49 Correlation analyses (ridership)

Correlations

		Ridership	Density	Diversity	C_score	C_index	Daily_f_bus	Daily_f_dolmuş	Daily_f_com_rail	Integration	Dummy_Metro
Ridership	Pearson Correlation	1	-,052	,025	,031	,071	,400	**,564***	,342	**,547***	-,082
	Sig. (2-tailed)		,860	,933	,917	,810	,156	,036	,231	,043	,781
	N	14	14	14	14	14	14	14	14	14	14
Density	Pearson Correlation		1	**,559***	,154	,287	-,327	,042	-,068	-,152	,239
	Sig. (2-tailed)			,038	,599	,320	,255	,887	,816	,604	,411
	N			14	14	14	14	14	14	14	14
Diversity	Pearson Correlation			1	-,212	,009	-,351	,143	-,096	-,110	**,627***
	Sig. (2-tailed)				,466	,975	,218	,626	,743	,708	,016
	N				14	14	14	14	14	14	14
C_score	Pearson Correlation				1	**,616***	-,009	-,062	,019	-,038	-,524
	Sig. (2-tailed)					,019	,974	,834	,947	,897	,054
	N					14	14	14	14	14	14
C_index	Pearson Correlation					1	,242	,244	,160	,273	-,455
	Sig. (2-tailed)						,404	,401	,585	,344	,102
	N						14	14	14	14	14
Daily_f_bus	Pearson Correlation						1	**,540***	**,562***	**,862****	-,432
	Sig. (2-tailed)							,046	,037	,000	,123
	N							14	14	14	14
Daily_f_dolmuş	Pearson Correlation							1	**,752****	**,891****	-,259
	Sig. (2-tailed)								,002	,000	,372
	N								14	14	14
Daily_f_com_rail	Pearson Correlation								1	**,780****	-,408
	Sig. (2-tailed)									,001	,147
	N									14	14
Integration	Pearson Correlation									1	-,397
	Sig. (2-tailed)										,159
	N										14
Dummy_Metro	Pearson Correlation										1
	Sig. (2-tailed)										
	N										14

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Table 49 (Continued-LnRide)

Correlations

		LnRide	Density	Diversity	C_score	C_index	Daily_f_bus	Daily_f_dolmuş	Daily_f_com_rail	Integration	Dummy_Metro
LnRide	Pearson Correlation	1	,031	,027	,035	,186	,347	**,534***	,326	**,501**	-,072
	Sig. (2-tailed)		,916	,927	,904	,523	,224	,049	,255	,068	,807
	N	14	14	14	14	14	14	14	14	14	14
Density	Pearson Correlation		1	**,559***	,154	,287	-,327	,042	-,068	-,152	,239
	Sig. (2-tailed)			,038	,599	,320	,255	,887	,816	,604	,411
	N			14	14	14	14	14	14	14	14
Diversity	Pearson Correlation			1	-,212	,009	-,351	,143	-,096	-,110	,627*
	Sig. (2-tailed)				,466	,975	,218	,626	,743	,708	,016
	N				14	14	14	14	14	14	14
C_score	Pearson Correlation				1	**,616***	-,009	-,062	,019	-,038	-,524
	Sig. (2-tailed)					,019	,974	,834	,947	,897	,054
	N					14	14	14	14	14	14
C_index	Pearson Correlation					1	,242	,244	,160	,273	-,455
	Sig. (2-tailed)						,404	,401	,585	,344	,102
	N						14	14	14	14	14
Daily_f_bus	Pearson Correlation						1	**,540***	**,562***	**,862****	-,432
	Sig. (2-tailed)							,046	,037	,000	,123
	N							14	14	14	14
Daily_f_dolmuş	Pearson Correlation							1	**,752****	**,891****	-,259
	Sig. (2-tailed)								,002	,000	,372
	N								14	14	14
Daily_f_com_rail	Pearson Correlation								1	**,780****	-,408
	Sig. (2-tailed)									,001	,147
	N									14	14
Integration	Pearson Correlation									1	-,397
	Sig. (2-tailed)										,159
	N										14
Dummy_Metro	Pearson Correlation										1
	Sig. (2-tailed)										
	N										14

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

This analysis is also carried out by using the trimmed data (See Appendix). When Dikimevi and Batıkent stations are excluded as the outlier values, the correlations increase in the following cases compared to the analysis performed with all data:

- density and diversity where the correlation value is 0,581.
- diversity and Ankara Metro where the correlation value is 0,700.
- connectivity score and Ankara Metro where the correlation value is 0,623.
- connectivity score and connectivity index where the correlation value is 0,647.
- daily frequency of bus and integration where the correlation value is 0,941.

When LnRidership values are used in the analysis, there are significant increases in the correlations between followings cases compared to the analysis performed with all data:

- connectivity score and Ankara metro where the correlation value is 0,623.
- connectivity index and daily frequency of dolmuş where the correlation value is 0,624.

b. Principal component analysis (PCA)

In this section, principle component analysis is carried out using SPSS 22 Windows. The analysis is performed by both using the all data and trimmed data:

i) PCA was conducted regarding 8 measures. An initial analysis was run to obtain eigenvalues for each component in the data (Table 50). Three components have eigenvalues over 1. Considering the all data, PCA suggests that there are variables that act together in mainly 3 groups:

Table 50 Principle component analysis (all data)

Communalities

	Initial	Extraction
Density	1,000	,795
Diversity	1,000	,842
ConnectivityScore	1,000	,851
ConnectivityIndex	1,000	,829
D.freq.bussystems	1,000	,798
D.Freq.dolmuş	1,000	,886
D.Freq.comm.rail	1,000	,738
Integration	1,000	,980

Extraction Method: Principal Component Analysis.

Total Variance Explained

	Initial Eigenvalues			Extraction Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3,345	41,818	41,818	3,345	41,818	41,818
2	1,814	22,677	64,495	1,814	22,677	64,495
3	1,559	19,491	83,986	1,559	19,491	83,986
4	,482	6,027	90,013			
5	,368	4,600	94,613			
6	,233	2,909	97,522			
7	,198	2,478	100,000			
8	-1,643E-16	-2,053E-15	100,000			

Extraction Method: Principal Component Analysis.

Component Matrix[a]

	Component		
	1	2	3
Density	-,195	,820	,292
Diversity	-,207	,559	,697
C_Score	,060	,519	-,761
C_Index	,341	,688	-,489
Daily_f_bus	,854	-,219	-,143
Daily_f_dolmuş	,859	,195	,334
Daily_f_comm_rail	,845	,039	,153
Integration	,982	-,003	,122

Extraction Method: Principal Component Analysis.

a. 3 components extracted.

1. Public transport measures (daily_f_bus, daily_f_dolmuş, daily_f_comm_rail, integration)
2. Land use measures (density, c_index)
3. Walkability measures (diversity, c_score)

In each group, measures that are higher than 0,500 is taken in the group. However, some variables might be included in more than one group by considering this threshold. In these circumstances, highest relations are considered and a mutually exclusive approach is adopted.

It is seen that connectivity index is in the land use group. However, it was included in the walkability parameters throughout the study. For the land use efficiency in the neighborhoods, grid pattern (c_index high) might be used to bring more population resulting in more density. It is seen that connectivity index has a indirect contribution to land use. It is also observed in the third group, where diversity, which is a land use parameter, is parallel with connectivity score (walkability parameter).

ii) Considering the trimmed data, PCA also suggests 3 main groups (Table 51):

1. Public transport measures (daily_f_bus, daily_f_dolmuş, daily_f_comm_rail, integration)
2. Land use measures (density, diversity, c_index)
3. Walkability measures (c_score)

For the land use measures group, it is found that diversity also acts parallel to density and connectivity index when the extreme values are excluded. Additionally, for the walkability group, only connectivity score is included unlike the raw data results.

Table 51 Principle component analysis (trimmed data)

Communalities

	Initial	Extraction
Density	1,000	,741
Diversity	1,000	,868
ConnectivityScore	1,000	,944
ConnectivityIndex	1,000	,890
D.freq.bussystems	1,000	,849
D.Freq.dolmuş	1,000	,852
D.Freq.comm.rail	1,000	,463
Integration	1,000	,965

Extraction Method: Principal Component Analysis.

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3,259	40,743	40,743	3,259	40,743	40,743
2	1,993	24,914	65,657	1,993	24,914	65,657
3	1,320	16,500	82,157	1,320	16,500	82,157
4	,678	8,471	90,628			
5	,427	5,342	95,970			
6	,234	2,926	98,895			
7	,088	1,105	100,000			
8	-7,974E-17	-9,967E-16	100,000			

Extraction Method: Principal Component Analysis.

Component Matrix[a]

	Component		
	1	2	3
Density	-,168	,834	,135
Diversity	-,390	,674	,512
C_Score	,259	,412	-,841
C_Index	,632	,610	-,344
Daily_f_bus	,860	-,317	,098
Daily_f_dolmuş	,727	,434	,369
Daily_f_comm_rail	,660	-,058	,156
Integration	,954	-,099	,212

Extraction Method: Principal Component Analysis.

a. 3 components extracted.

c. Single factor regression analysis

In order to understand the relationship between the independent variables and ridership levels R^2 values are calculated. As R^2 value reaches close to 1, the relationship gets stronger. On the other hand, as this value gets closer to 0, it means that there is not much of a linear relationship between the dependent variable and independent variables. In the meantime, it is important to check the significance of the estimated coefficients (β's) by monitoring the t-statistics (t>1,65 suggests that the coefficient is statistically significant at a level of less than 0,05). So, when $R^2 \geq 0,500$ and t>1,65, this indicates a promising relationship with significant estimated values. When R^2 increases then the relationship gets stronger.

In order to show and explain the analysis, single regression analysis for all data will be given as an example. Please see Appendix for all the results. When the stations of both lines (Ankara Metro and Ankaray) are analyzed regarding all the measures, it is seen that for Model 6 and Model 8, R^2 values have reached to approximately 0,300 level, however these do not show a significant relationship (Table 52). When the analysis is made separately for each system, for the Ankara Metro the relation between ridership and daily frequency of bus systems (R^2=0,687; t=3,31) and integration (R^2=0,522, t=2,34) are found to be significant (Table 53). Regarding Ankaray only, the relation between ridership and connectivity index (R^2=0,592, t=-2,70) and daily frequency of dolmuş (R^2=0,596, t=2,72) are significant. Regarding connectivity index, there is a reverse relation (Table 54).

Table 52 Single regression analysis for all data

Model	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6		Model 7		Model 8		Model 9	
Dependent Variable	Ridership		Ridership		Ridership		Ridership		Ridership		Ridership		Ridership		Ridership		Ridership	
R square	0,003		0,001		0,001		0,005		0,160		0,318		0,117		0,299		0,007	
Data Size	14		14		14		14		14		14		14		14		14	
Variables	β	t	β	t	β	t	β	t	β	t	β	t	β	t	β	t	β	t
Constant	332668,06	4,23	302186,90	1,26	303711,69	1,67	198521,16	0,39	236264,66	3,16	199303,06	2,93	296529,42	5,51	191576,97	2,63	337246,29	4,51
Density	-20,85	-0,18																
Diversity			22453,31	0,09														
C_Score					1879,13	,11												
C_Index							94718,47	0,25										
Daily_f_bus									153,36	1,51								
Daily_f_dolmuş											202,28	2,36						
Daily_f_comm_rail													1022,36	1,26				
Integration															109,48	2,26		
Dummy_Metro																	-30023,57	-0,28

Table 53 Single regression analysis for Ankara Metro

Model	Metro_Model 1		Metro_Model 2		Metro_Model 3		Metro_Model 4		Metro_Model 5		Metro_Model 6		Metro_Model 7	
Dependent Variable	Ridership		Ridership		Ridership		Ridership		Ridership		Ridership		Ridership	
R square	0,000		0,015		0,197		0,074		0,687		0,029		0,522	
Data Size	7		7		7		7		7		7		7	
Variables	β	t	β	t	β	t	β	t	β	t	β	t	β	t
Constant	307756,21	2,72	159877,03	0,30	57031,91	0,24	-57824,43	-0,10	129036,66	1,84	236943,95	1,20	29743,57	0,23
Density	-0,88	-0,01												
Diversity			144456,55	0,28										
C_Score					30195,44	1,11								
C_Index							293555,96	0,63						
Daily_f_bus									504,37	3,31				
Daily_f_dolmuş											147,91	0,39		
Daily_f_comm_rail														
Integration													334,95	2,34

Table 54 Single regression analysis for Ankaray

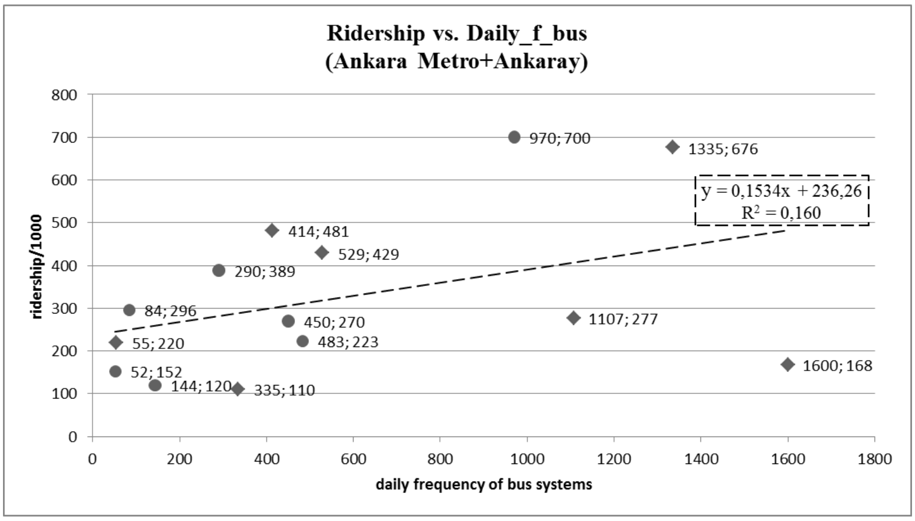
Model	Ank_Model 1		Ank_Model 2		Ank_Model 3		Ank_Model 4		Ank_Model 5		Ank_Model 6		Ank_Model 7		Ank_Model 8	
Dependent Variable	Ridership		Ridership		Ridership		Ridership		Ridership		Ridership		Ridership		Ridership	
R square	0,089		0,006		0,250		0,592		0,040		0,596		0,225		0,345	
Data Size	7		7		7		7		7		7		7		7	
Variables	β	t	β	t	β	t	β	t	β	t	β	t	β	t	β	t
Constant	572920,95	1,65	271318,67	0,68	771915,84	2,24	4643575,80	2,91	283800,98	2,00	178384,21	2,27	281558,80	3,25	186382,02	1,62
Density	-602,31	-0,70														
Diversity			86099,50	0,17												
C_Score					-38033,59	-1,29										
C_Index							-3146297,41	-2,70								
Daily_f_bus									69,60	0,46						
Daily_f_dolmuş											214,60	2,72				
Daily_f_comm_rail													1107,42	1,20		
Integration															96,81	1,62

As seen from the analysis, when the analysis is made separately for each system, more significant results are achieved.

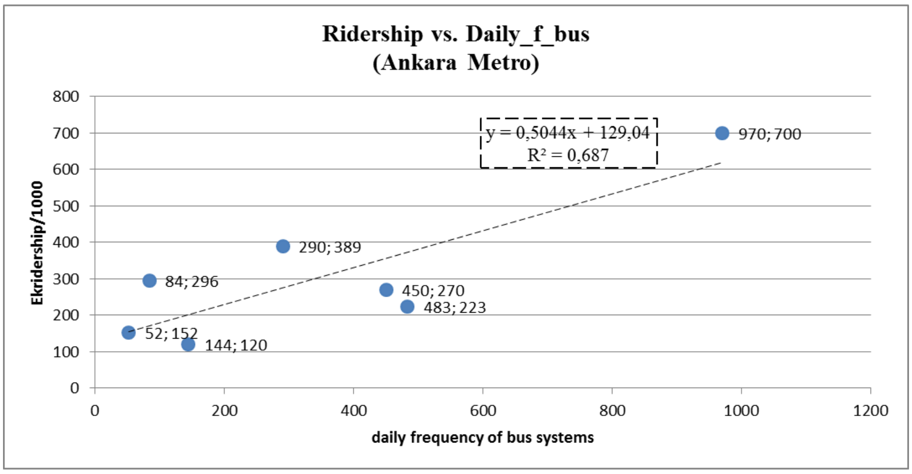
To see the impact of analyzing two systems separately, best fit analysis approach is used. Model 5 is given as an example in Figure 81. It is seen that when the two systems are analyzed together there is a low relation (R^2=0,160). When only Ankara Metro system is analyzed, it is found that there is a significant linear relation with ridership (R^2= 0,687). Regarding Ankaray, there is still low relation between ridership levels and daily frequency of bus systems (R^2=0,040).

Single regression analysis is also carried out with ridership values with trimmed data, LnRide values both with all data and trimmed data (See Appendix). In Table 55 and Table 56, summary of the analysis showing the significant results are given. Infilled boxes indicate that there is a reverse relation between independent and dependent variables.

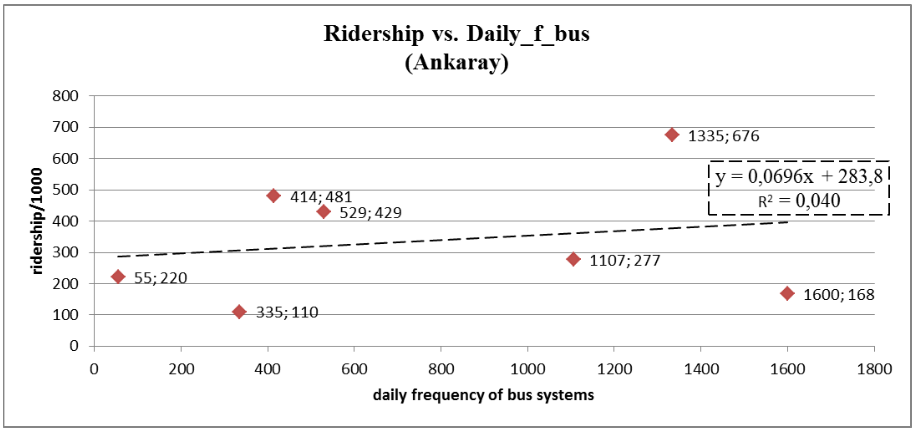
It is found that although there are significant results, for specific cases these are also reverse relations. For instance, when the analysis is applied separately for each corridor, it is found that for each corridor there is a promising relation between ridership and connectivity index. However, for Ankaray, regarding connectivity index there is reverse relation. This might be because high index might result in more walkable environments encouraging people to walk rather than using the systems. A reverse relation is also observed regarding diversity for Ankara Metro. In the literature, it is found that a transit station area with a mixed use characteristic would be positively affected in terms of riderhip levels. Furthermore, non-linearity in the data was also studied by fitting the variables in Microsoft Excel (Figure 81). It is observed that R^2 values are increased when analyzing the non-linear relationships. It is seen when analyzing all data for C_index Ankaray (Ridership) and Daily_f_dolmuş Ankaray (Ridership); trimmed data for Density Ankaray (LnRide) and C_index Metro (LnRide). Only for C_index Metro (LnRide), there is an exponential relationship, the others mentioned above have polynomial relationships..



(a)



(b)



(c)

Figure 81 Trendline analysis between ridership and daily_f_bus for a) all data (Ankaray +Metro), b)Ankara Metro only, and c) Ankaray only

Table 55 Best linear regression models

Dependent variable	**Data**	**Data size**	**R^2**
Ridership	C_index $_{Ankaray}$	All	R^2=0,592
Ridership	Daily_f_dolmuş $_{Ankaray}$	All	R^2=0,596
Ridership	Daily_f_bus $_{Metro}$	All	R^2=0,575
Ridership	Integration $_{Metro}$	All	R^2=0,618
LnRide	Density $_{Ankaray}$	Trimmed	R^2=0,660
LnRide	Diversity $_{Metro}$	Trimmed	R^2=0,772
LnRide	C_index $_{Metro}$	Trimmed	R^2=0,533

*Infilled: Reverse relation.

Table 56 Best non-linear regression models

Dependent variable	**Data**	**Data size**	**R^2**
Ridership	C_index $_{Ankaray}$	All	R^2=0,689
Ridership	Daily_f_dolmuş $_{Ankaray}$	All	R^2=0,600
Ridership	Daily_f_bus $_{Metro}$	All	R^2=0,780
Ridership	C_score $_{Metro}$	Trimmed	R^2=0,852
LnRide	Density $_{Ankaray}$	Trimmed	R^2=0,664
LnRide	Diversity $_{Metro}$	Trimmed	R^2=0,780
LnRide	Diversity $_{Ankaray}$	Trimmed	R^2=0,558
LnRide	C_index $_{Metro}$	Trimmed	R^2=0,540
LnRide	Integration $_{Metro}$	Trimmed	R^2=0,634

*Infilled: Reverse relation.

d. Multivaritate regression analysis

In the following, multivarite analysis results are given (Please see Appendix for detailed analysis).

When the analysis is performed for all the systems, no significant results are achieved (Figure 82).

However, when the analysis is carried out regarding each system:

- For Ankara Metro, there is a significant relation between ridership and bus systems and density (R^2=0,902). Furthermore, the analysis is repeated with

LnRide values and it is found that there is significant relation between LnRide and integration (See Appendix).

- For Ankaray, highest relation is found between ridership and daily frequency of dolmuş (R^2=0,596, t=2,718) (See Appendix).

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	D.Freq.dolmuş		Stepwise (Criteria: Probability-of-F-to-enter <= ,050, Probability-of-F-to-remove >= ,100).

a. Dependent Variable: Ridership

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,564[a]	,318	,261	164009,924

a. Predictors: (Constant), D.Freq.dolmuş

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	150445751605,938	1	150445751605,938	5,593	,036[b]
	Residual	322791062695,562	12	26899255224,630		
	Total	473236814301,500	13			

a. Dependent Variable: Ridership

b. Predictors: (Constant), D.Freq.dolmuş

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	199303,057	67995,450		2,931	,013
	D.Freq.dolmuş	202,285	85,535	,564	2,365	,036

a. Dependent Variable: Ridership

Excluded Variables[a]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics Tolerance
1	Density	-,076[b]	-,304	,766	-,091	,998
	Diversity	-,057[b]	-,227	,824	-,068	,980
	ConnectivityScore	,066[b]	,264	,796	,079	,996
	ConnectivityIndex	-,071[b]	-,277	,787	-,083	,941
	D.freq.bussystems	,135[b]	,461	,654	,138	,708
	D.Freq.comm.rail	-,188[b]	-,504	,625	-,150	,434
	Integration	,216[b]	,397	,699	,119	,206

a. Dependent Variable: Ridership

b. Predictors in the Model: (Constant), D.Freq.dolmuş

Figure 82 Multivariate analysis (all data)

8.2. Station area design and transit usage link

The analysis was carried out using three different approaches. Firstly, a land use analysis was made revealing the characteristics of each station area. Different uses and building types around the transit stations were shown producing land use maps and a number of measures that help define the characteristics of the built environment around stations.

Secondly, for each measure (density, diversity and connectivity/accessibility) calculations were made according to the data collection in the field analysis.

For *density*, both residential and employment density calculations were made. It is found that Demetevler station area has the highest total density (1868 p/ha) and Macunköy station area has the lowest total density (53 p/ha) amongst the stations. It should be kept in mind that these values are higher than the densities that are defined as the threshold below which automobile dependency would become inevitable (35-40 p/ha (residential and employment), Newman and Kenworhty, 2006.

Regarding *diversity*, total usage area of each use (commercial, residential, other) were calculated and a percentage has been found showing the variety of uses within the area by the author. It is seen that Tandoğan station area has the highest mixed use characteristic whereas Demetevler station has the lowest.

For the analysis of *connectivity/accessibility*, firstly connectivity index for each station has been calculated. Connectivity index is found by dividing the number of links by the number of nodes. It is analyzed that Tandoğan has the highest connectivity index. On the other hand Macunköy station has the lowest index. In the vicinity of Macunköy station, working places and empty lots cover most of the area. This low index is the outcome of this pattern.

Thereafter, in order to keep the analysis simple, check lists that were prepared during the field analysis and afterwards were transformed into score tables. As a result, each station has been given a total score showing their connectivity/accessibility characteristic (lighting, interface with parking, ease of pedestrian crossing, landscaping, flat terrain, availability of sidewalks). Bahçelievler station area holds the highest position regarding this parameter whereas Macunköy station area has the lowest score.

Finally, qualitative (ranking) and quantitative (single-factor and multivariate regression) analyses were made using the data produced in the former stages of the study. This has been done in order to assess the link between transit station area design and transit usage.

In the qualitative analysis, stations were ranked with respect to the scores they achieved in the station area analysis. For each measure and for the sum of all measures, stations were ranked from highest scoring to lowest scoring, and then it was assessed whether this ranking is compatible with the ranking of the stations from the highest ridership station to the lowest.

For Ankara Metro; Batıkent, Ostim, Hastane and İvedik station areas have the highest scores. High ridership level of Batıkent and Hastane stations are compatible with the station area scores whereas in the case of Ostim and İvedik there is no significant link between station area design and ridership.

For Ankaray; Tandoğan, Kurtuluş and Dikimevi station areas have the highest scores. Tandoğan is expected to carry more passengers since it is the first ranking station regarding the total score, however it is one of the least ranking stations regarding ridership values. The link is not well explained by the qualitative analysis. On the other hand, this link is observed by looking at the ridership of Dikimevi station (which is the first ranking station).

It is found that Ankaray station areas are the top seven ranking station areas regarding ranking analysis. It is also expected to have the same pattern when looking to the ridership levels:

- Only Dikimevi (rank 3) and Beşevler (rank 5) stations are explained well by analyzing this relationship. They are ranked 2 and 4 respectively when looking at the ridership levels.
- Tandoğan (rank 1) is expected to carry more passengers since it is the first ranking station regarding the total score, however it is one of the least ranking stations regarding ridership values (rank 11).
- Kurtuluş station would be expected to carry more passengers since it is the second ranking station (rank 7 in ridership).
- Aşti station has one of the highest ridership levels (rank 3), whereas it is the seventh ranking station when looking to the parameters. High ridership level might be the result of its location. The station is located next to the Intercity Bus Terminal, which attracts passengers all over the city.

While this ranking analysis was the first step of assessment, it was acknowledged that a simple ranking from highest scores to lowest would be misleading since the differences between scores are not addressed. In other words, the difference of score between two consecutive stations may be that the second station scores 90% below the first station or 10% below. Just ranking without addressing the magnitude of differences would not be sufficient; and therefore, a quantitative approach has also been applied.

Regarding the regression analysis, it is analyzed that *density* does not appear to be an indicator that can explain the variations between different ridership levels of different stations. Although R^2 value for Ankaray is significantthere is a reverse relationship.

There seems to be a strong relation when analyzing the *diversity* parameter regarding Ankara Metro, however it shows a reverse relation (R^2=0,772).

Regarding *connectivity/accessibility*, it is found that there is low relation. In the case of *connectivity index* for both systems there is a promising relation. However, in the case of Ankaray as the index increases ridership level decreases.

The link between *integration with all systems* regarding Ankara Metro is higher than R values for merely dolmuş and bus systems.

It was also found that **context specific results** have been different than the overall results and would give more insights about the selected stations. In addition to the overall analysis, two separate analyses were made regarding the corridors.

Finally, it is seen that when combining different planning and design parameters by applying a multivariate analysis, no statistically significant results have been found when the two systems are analyzed together. These measures explain variations in stations' ridership better when each corridor is analysed separately.

CHAPTER 9

DISCUSSIONS AND CONCLUSION

Main findings and discussions

This study focused mainly on the argument that land-use planning and urban design policies are required to make the vicinity of transit stations less car-dependent, more walkable and more transit-friendly. From this point of view, a literature review has been made in order to analyze the vicinity of rail transit stations and to reveal the parameters that would foster the use of these modes in the case study. Recent movements in planning and urban design that emphasise public transport such as New Urbanism, urban villages, transit oriented development (TOD), pedestrian friendly design and New Pedestrianism were examined and parameters that would promote more sustainable mobility patterns in the urban environment were revealed:

- In the studies of Black (1996) and Jabareen (2006) **compactness** is highlighted as an essential element of the built environment if sustainable patterns of urban development and mobility are to be attained.
- According to Stead and Banister (2001), Jabareen (2006) and Litman (2014), **density** is a strong component of the urban character that determines whether a built environment becomes car-dependent or not.

- Stead and Banister (2001), Jabareen (2006), Newman and Kenworthy (1996), Jacobs (1961; cited from Jabareen, 2006) and Cervero (2002) stress on the **mixed land use** characteristic of the urban areas, as yet another factor that can foster mode usage of public transport and walking.
- **Diversity** (Jacobs, 1961; cited from Jabareen, 2006) **settlement size** (Stead and Banister, 2001) and **walkability** (Eva Lesliea et.al. 2005; Reid Ewing, et al., 2006; Jabareen, 2006) characteristics were also revealed as effective in citizen's travel behavior and usage of sustainable modes of transport, i.e. public transport, walking and cycling.

Density is found to be an essential factor in the decision making process of transit users. It is argued that in high-density areas the transit usage also increases. In a research by Transportation Research Board of the National Academy (1996), it is analyzed that the density strongly influences the mode choice. In a low-density area, high-capacity transit systems became unattractive and therefore huge investments are wasted (Gordon, Richardson, 1997).

Regarding *diversity,* it is found that a greater mix use would increase the percentage of walking trips. A mixed use environment provides different types of opportunities such as residential, retail or office use in proximity, which affect walkability (Chow, 2014).

Every trip starts and ends with walking. Therefore, creation of pedestrian-friendly environments is also important in the success of transit modes. Pedestrian routes should be short, continuous, direct and convenient. Street network and connectivity which is determined by the presence of sidewalks, pedestrian paths and their continuity, placing and shaping of blocks, have critical effects on the length of trips from all points in the system to all others. It becomes important to avoid barriers in the pedestrian movement (Southworth, 2005). A grid network provides the simplest street pattern and is often emphasized as the preferred model in neo-traditional neighborhood design. It increases walkability by providing a better sense of direction. On the other hand, circuitous routes, cul-de-sacs and dead ends decrease walkability, resulting in a decreased ridership for transit modes. These characteristics are gathered together under *connectivity/accessibility* parameter in the study.

While there are many studies in the world that aim at studying the link between transit station area design and transit usage, such a study is limited in Turkey and in fact such studies are limited in developing country context with the exception of some studies made in Chinese cities. This may be due to the fact that transit usage is still relatively high in most developing country cities and the strategies of such transit-friendly design may have not yet become crucial planning policies. However, the case of Turkey and Ankara is different in that transit usage is decreasing in the face of rapidly increasing automobile usage. As a result, Ankara case was selected as the case study.

While the main focus of the study is to assess the link between transit station area design and transit usage, it was crucial to provide a comprehensive picture of transport and land use in Ankara and therefore the analysis was not carried out only on station area design, but included larger scales of analysis as well. The city has been divided into three scales as macro, meso and micro:

- Macro scale: Whole city→Ankara
- Meso scale: Existing rail transit systems (before the extension of the systems)→Ankara Metro (Corridor I) and Ankaray (Corridor II)
- Micro scale: Vicinity of transit station→defined by the walking distance (min.500 m, max. 800 m)

For each scale, different methodologies revealed from the literature have been used regarding the parameters found to have an influence on the transit ridership (density, diversity and accessibility and connectivity).

Descriptive analysis was used regarding macro and meso scales. In the macro scale, it is found that although there are advantages due to compactness, Ankara has faced a rapid sprawl which changed the form of the city. Urban form of Ankara has gone through a process of controlled decentralization through two proposed corridors to southwest and west. Along the western corridor, Ankara Metro has been constructed.

On the other hand the planned rail transit system on the south-western corridor could be finished merely on March 2014 (planned opening year: 2000) and could not be incorporated to the study due to its recent opening. Ankaray, which is the second rail transit system analyzed in the study has been located in the inner city operating between Dikimevi and AŞTİ. In this corridor, formerly there was a busway operating between Dikimevi-Beşevler.

Unlike the TOD or New Urbanism approaches in the literature, there is a lack of integration between urban development and transport policies regarding Ankara. There has been transportation master plans and studies, however they are not fully implemented.

Additionally, considering public transport modes in Ankara, it is found that rubber-wheeled vehicles are used more than rail transport systems. Rail transport only correspond to 5,4% (Ankara Metro 3,3% and Ankaray 2,1%) of total travels. The metro does not play a significant role in transport terms, it only covers 3,3% of all motorized trips in 2012. Actual metro ridership level in the western corridor has achieved only 27% of the forecasted value (Özgür, 2011). Moreover, there is no fare integration system and parking policy in the city. Existing fare system in Ankara is not transit-encouraging. There are no regulations on the integration of parking areas and transit system. The city is a car-oriented city.

In the meso scale analysis, it is found that most of the neighborhoods around the corridors have higher densities than the densities that are defined as the level that would reduce automobile dependence and encourage public transit in the literature (35-40 p/ha, Newman and Kenworhty, 2006) Besides, two corridors have different uses located along the lines. Along Corridor I (Ankara Metro), there are mostly mass housing and industrial areas whereas, along Corridor II (Ankaray) there are socio-cultural activities with financial services, production services and residential areas, government offices. This corridor holds mostly residential and commercial areas. Also, both corridors are integrated to other transport modes such as bus, commuter rail or cable car systems.

It is also observed that Ankara is lacking integrated transport policies. It is seen that apart from the parameters revealed from the literature (density, diversity, connectivity/accessibility), for the Ankara case **integration** to other modes become significant. For this reason, in the micro scale analysis this has been corporated as an additional parameter. As it was mentioned by Dalkmann and Brannigan (2007), a shift strategy is an effective tool to reduce private car usage and change travel behavior. Urban form should be supported by non-motorized and public transport modes. In this respect, integration between different modes becomes significant in increasing the use of the systems.

Since the study aims at understanding the link between station area design and transit usage, a significant part of the analysis focuses on whether the surroundings of selected Ankara Metro and Ankaray transit stations are “transit encouraging” neighborhoods (from the point of view of increased transit usage).

Therefore, in the micro scale, firstly the link between the neighborhood design around transit stations and the usage of that particular transit station has been analyzed. Both Ankara Metro and Ankaray stations were analysed. As discussed throughout the analysis and shown in the macro and meso scale analysis, the characteristics of the two lines are quite different however: the metro line represents a major development corridor in the city with both suburban development and decentralised industry and other working areas. Ankaray is an inner city line that serves well-established relatively old urban fabric of the city that feature both residential and (predominantly) work/office areas due to the proximity to the CBD.

Throughout the analysis, it has been kept in mind that designing neighborhoods is not a straightforward process. The design parameters might change from one location to the other. From this perspective, using these parameters in a context dependent way would give more significant results. Therefore, in the study, an overall analysis and a separate analysis for each corridor have been made. For all the parameters used in the study the overall relations are too low. It is found that significant results are achieved *when the analysis is made separately* for each transit line:

- ✓ For Ankara Metro, **connectivity index, daily frequency of bus systems** and **daily frequency of all systems** are significant in explaining the ridership levels of the stations. Only **diversity** is reversely related.
- ✓ For Ankaray, relations between ridership and **daily frequency of dolmuş** is high for this corridor. For **connectivity index** and **density,** there are also high relations whereas, it is a reverse relation.

Secondly, an attempt was made to combine different parameters together applying multivariate analysis with a view to analyze whether the surroundings of any given transit station is a "transit encouraging" neighborhood. It is seen that when combining different planning and design parameters, no statistically significant result have been found when the two systems are analyzed together. There might be different aspects affecting this reality such as there being limited number of data and similar stations in this case study area. In addition, these measures explain variations in stations' ridership better when each corridor is analysed separately. Hence, two corridors have different characteristics. Additionally, it is found in the PCA that some measures are interrelated or synchronous. When analyzing two or more of them together, it might negatively affect each other. Moreover, this analysis might provide more significant results if higher number of stations are included.This can only be done after the opening of other rail lines in Ankara or by including other rail transit systems and their stations in different cities.

Finally, it is aimed to find the clear link between the spatial parameters and the use of particular transit stations. It is analyzed that as Batıkent and Dikimevi are the top ranking stations regarding ridership levels, and only **integration with bus systems, dolmuş and commuter rail** is found to be influencing this high rate. Moreover, the fact that these are end-stations might have a positive effect on the ridership values. On the other hand, Tandoğan station should have been carrying more passengers regarding all the parameters. But, it is one of the least ranking stations regarding ridership levels. Additionally, Tandoğan and Kurtuluş station areas are found to be the transit-friendly station areas amongst the others selected in the study whereas the link between ridership and all the parameters is well explained in the cases of Dikimevi and Beşevler station areas.

In the study, link with density and ridership has been found insignificant for the two selected systems. It does not imply that when planning to build a rail transit system, density parameter is unimportant. On the contrary, density specifically is one of the main essential factors in the decision making process of these systems. In the literature, it is found that density strongly influences the mode choice. In a low-density area, high-capacity transit systems become unattractive and therefore huge investments are wasted. Especially for the transit-oriented development projects, 35-40 p/ha is found to help to increase transit usage. However, as it was mentioned before, for Ankara, selected transit systems have not been built with a purpose to offer transit oriented developments. All the developments around transit station in the study have quite high density levels. Ankara Metro has been located on the western corridor which is planned to be one of the two main corridors as a result of controlled decentralization. On the other hand, Ankaray was located on the former corridor of busway operating between Dikimevi-Beşevler. Having a variety of uses around the stations and located next to CBD, which has a positive influence on the ridership levels regarding this system. It was shown in the meso-scale analysis too that the corridors studies were already relatively high-density corridors. Perhaps as a result of this too, the variations of density between stations did not appear to be signidicant in explaining the variations of ridership levels across stations.

When the connectivity/accessibility measure is considered, it is found out that in the Ankara Metro corridor, which serves suburban development areas, connectivity index becomes more critical. This relation is also argued in the literature for New Urbanism and Transit-Oriented Development movements. It is observed for the Ankaray Corridor that this measure has a low influence on the ridership levels. This might be due to the different characteristics of the two corridors: in suburban areas that still experience development, these measures appear to be significant whereas in inner city corridors (like in Ankaray) the built environment is already well-established and transit usage patterns are formed over longer periods of time and hence the issue of pedestrian network may not be as crucial in such long-established older inner-city areas. Different parameters such as integration with dolmuş become crucial for the stations located in inner city.

Another significant finding of the study was that in the context of Ankara, public transport integration and infrastructure are still critically important in the usage of rail transit systems. Having feeder systems, frequent bus public transport services as well as dolmuş systems that support the urban rail stations are extremely important measures that increase urban rail ridership levels.

Contribution to the literature

In the light of these findings, following recommendations can be made for the planning and design of urban rail transit station areas. The following points also address the different findings that the Ankara case, i.e. the Turkish context provided, when compared to the findings of the literature:

1) Firstly, it is found that context specific results have been different than the overall results and would give more insights about the systems and their relation with the urban environment. A system which is located inner city or in the suburban development area might have different results while analyzing the link. This should be kept in mind while doing analysis on different systems or on systems with stations having different characteristics. “Market segmentation principle”, which is used to subdivide the sample into similar groups, result in more significant outcomes.
2) In the meso scale analysis it is found that along the two rail transit corridors, there are dense urban areas holding different land use characteristics. These densities are found to be much higher than the densities that would promote transit usage as argued in the literature. In addition to the diversity analysis which provided different results for each transit station area, high density

characteristics is also observed in the micro scale analysis. However, it is seen that density and diversity does not appear to explain the differences in ridership levels of different stations. In cities such as Ankara, similar to most developing country cities of South America and Asia, there is an ongoing intensive, i.e. high density, urban development process. It is possible that due to this already high development density and diversity, the influence of spatial parameters such as density and diversity on transit usage is relatively low in such cities. Their influence is lower than expected when considering the Western literature on the relation between urban density, diversity and transit usage.

It might be useful to include diversity in terms of socio-economic attributes and also travel activity patterns while analyzing these parameters. t The need for motorised trips, and hence transit trips, might be lower in more dense and diverse areas because people might tend to walk for meeting their local needs (shopping, going to school, going to work and so on). Further research might be required to see whether these parameters just explain the micro travel patterns in favour of walking. On the contrary, when the density and diversity is low, people may tend to use more motorised journeys, and hence rail transit systems too. In order to reveal these relations, detailed survey studies would be helpful. Moreover, as it was mentioned in the previous sections, dolmuş is a competing mode along the systems which might have a negative effect on the use of these systems. Therefore, density and diversity alone might not explain the relations with the transit usage.

3) For the dense inner city transit station areas, the literature does not provide insights explaining the factors which would increase the transit usage. On the other hand, it is found that spatial parameters would be significant in the suburban development corridors than inner city areas. For instance, connectivity index has been found as a significant parameter influencing the usage of transit stations in suburban areas. Connectivity index increases walking to the stations which has a positive effect in the use of the rail transit system. Additionally, this pedestrian network should also be supported by

high quality of accessibility measures such as lighting, parking, pedestrian crossing, landscaping, flat terrain and sidewalks in order to create walkable and transit-friendly environments which increases walkability to the stations. These should be kept in mind while designing transit-encouraging neighborhoods.

4) Another main finding of the study is that in developing cities such as Ankara, where there is high public transport usage (more than 50%) transit integration becomes substantial. It is possible that in developing countries with high public transport usage, transit integration is as infleuncial as the spatial parameters. The significance of integration might also be an outcome of road oriented macro scale transport policies in Ankara. As described before, in Ankara, rubber-wheeled public transport systems (bus or dolmuş) are the main transport modes whereas rail transit systems only constitute approximately 6% of daily travel. Furthermore, regarding the link between frequencies of different modes, integration and ridership, in cities like Ankara where there are few lines of rail transit systems, not only the walkable radius but a wider catchment area should be incorportaed in the researches.

From this point of view, the impact of transit integration should not be ignored in Ankara as well as in the other cities while planning rail transit systems. It is seen that on the one hand increasing the frequency of bus systems, dolmuş or commuter rail have a direct infleunce on the ridership levels of rail transit system, on the other hand from a certain point onwards it may start to compete with the rail system that has a negative effect on the ridership values. It should also be kept in mind that integrated fare systems are a part of integrated transit and they are needed to create a better performing transport system. Dolmuş or private bus systems might not create additional passengers for the rail transit systems since they are not included in the integrated fare system and transfer fares in the Ankara case. They require passengers to pay full fares in transfers. The municipal buses offer a reduced fare when there is a transfer from/to rail transit systems.

Limitations and Further Research

This research focused on the link between transit station area design and transit usage. However there have been some limitations. Lack of data in all scales (macro, meso, micro) was the main constraint of the study. There were no travel surveys or geographic database for transit station site. The study made by the Ankara Greater Municipality in 2007 was used as the basis, however detailed land use field survey was needed and the data was created by the author. This field survey took approximately 10 months. If the data was available at the time of the study, there might have been further analyses and outcomes. A study that assesses the relation between staion area design and transit usage would require more stations in order to produce more reliable outcomes. Due to data limitations this was not possible.

However, this constraint resulted in a positive way that one of the contributions of the study has become the data that it collected and presented. There was no study that has gathered these data together for the Ankara rail transit systems. With the completion of this study, there is a now a rather detailed data regarding the built environment around Ankara urban rail stations. Further studies can build on this data, as well as use the findings of this research and further develop the argument.

For future research, it is possible to widen the scope of this study by adding new lines and stations in Ankara. It might also be possible to have a study focusing on the comparison of other rail systems in Turkey, such as İstanbul, İzmir, Bursa, Antalya, Eskişehir, Kayseri, etc. It might also be a fruitful study to have a comparison of metro-tram station area design and transit usage link since these two technologies have different interfaces with the built environment.

It would also be valuable to further elaborate the findings of this study with regards to the differences between rail lines with more suburban development characteristics (such as the Ankara Metro) and inner city systems (such as Ankaray). Such comparisons may help build stronger discussions and theories as to the link between station area characteristics and transit usage.

Another significant point is that in the study, the decision making process regarding the site selection of each station has not been analyzed. It might also be useful to incorporate this issue and provide suggestions regarding site selection criteria of rail transit stations.

User surveys and questionnaires were also considered in this study at earlier stages to see whether station area design affects users' perceptions and decisions on using the urban rail systems. However, due to the need to create its own data with regards to density, diversity and connectivity/accessibility, such a user survey could not be included in the study as that would also require a different analysis framework with additional research questions, which was beyond the scope of this study. However, further studies may incorporate a user perspective onto the findings of this study. It might be possible to analyze the influence of density, diversity and connectivity on the choice of the users.

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APPENDIX A

BUILT-UP DENSITIES IN CORRIDOR I

Table 57 Built up densities along Corridor I

Sub-District	Neighborhood	Built-Up Density (P/Ha)
Yenimahalle	Anadolu	332
	Barış	326
	Çarşı	303
	Ergenekon	299
	Esentepe	259
	Gayret	118
	Işınlar	218
	Ragıp Tüzün	244
	Tepealtı	286
	Yeni Çağ	188
	Yunus Emre	218
	TOTAL	253
Karşıyaka	Karşıyaka	447
	Yeşilevler	105
	Barıştepe	0
	TOTAL	331
Ostim	İvedik	103
	Macun	0
	TOTAL	153
Demet	Aşağı Yahyalar	0
	Demet	448
	Demetgül	201
	Demetlale	770
	Mehmet Akif Ersoy	222
	Özevler	423
	Yirmibeş Mart	320
	TOTAL	399

Table 57 (Continued)

Batıkent	Batı Sitesi	230
	Ergazi	232
	İlk Yerleşim	102
	İnönü	178
	Kardelen	64
	Kent Koop	208
	Uğur Mumcu	173
	Yeni Batı	80
	TOTAL	158
Gazi	Emniyet	288
	Gazi	171
	TOTAL	230
İskitler	Zübeyde Hanım	519
	TOTAL	462
Varlık	Varlık	104
	TOTAL	104
Ulus	Doğanbey	433
	TOTAL	216
Kızılay	Cumhuriyet	17
	Kızılay	95
	Kocatepe	117
	Korkutreis	62
	Meşrutiyet	64
	Sağlık	32
	TOTAL	65

Source: EGO, 2007

APPENDIX B

BUILT-UP DENSITIES IN CORRIDOR II

Table 58 Built up densities along Corridor II

Devlet	Devlet	31
	Namık Kemal	105
	TOTAL	68
Kocatepe	Fidanlık	121
	Kültür	157
	Tınaztepe	361
	TOTAL	213
Maltepe	Anıttepe	255
	Eti	28
	Maltepe	242
	Mebusevleri	332
	Yücetepe	635
	TOTAL	298
Bahçelievler	Bahçelievler	272
	Emek	175
	Yukarı Bahçelievler	185
	TOTAL	211
Söğütözü	Beştepeler	175
İncesu	Arkatopraklık	303
	İleri	429
	İncesu	387
	Öb Cebeci	300
	TOTAL	355

Table 58 (Continued)

Cebeci	Cebeci	403
	Çamlıtepe	277
	Dilekler	318
	Ellinciyıl	207
	Ertuğrul Gazi	350
	Fakülteler	371
	Topraklık	295
	TOTAL	318
Hamamönü	Gündoğdu	414
	Erzurum	185
	TOTAL	451

Source: EGO, 2007

APPENDIX C

CORRELATION TABLES TRIMMED DATA

Table 59 Correlation table (ridership-trimmed data)

Correlations

		Ridership	Density	Diversity	C_score	C_index	Daily_f_bus	Daily_f_dolmuş	Daily_f_com_rail	Integration	Dummy_Metro
Ridership	Pearson Correlation	1	,139	-,074	,020	,268	-,010	,394	,041	,129	-,169
	Sig. (2-tailed)		,666	,819	,950	,400	,976	,205	,899	,689	,600
	N	12	12	12	12	12	12	12	12	12	12
Density	Pearson Correlation		1	**,581***	,175	,266	-,313	,183	-,084	-,183	,308
	Sig. (2-tailed)			,048	,586	,403	,321	,570	,795	,568	,330
	N			12	12	12	12	12	12	12	12
Diversity	Pearson Correlation			1	-,211	,012	-,472	,164	-,216	-,322	**,700***
	Sig. (2-tailed)				,511	,970	,121	,611	,501	,308	,011
	N				12	12	12	12	12	12	12
C_score	Pearson Correlation				1	**,647***	-,001	,042	,110	,023	**-,623***
	Sig. (2-tailed)					,023	,997	,896	,735	,945	,030
	N					12	12	12	12	12	12
C_index	Pearson Correlation					1	,326	**,624***	,188	,475	-,447
	Sig. (2-tailed)						,301	,030	,559	,119	,145
	N						12	12	12	12	12
Daily_f_bus	Pearson Correlation						1	,428	,440	**,941****	-,479
	Sig. (2-tailed)							,165	,152	,000	,116
	N							12	12	12	12
Daily_f_dolmuş	Pearson Correlation							1	,446	**,701***	,022
	Sig. (2-tailed)								,146	,011	,946
	N								12	12	12
Daily_f_com_rail	Pearson Correlation								1	,569	-,302
	Sig. (2-tailed)									,053	,341
	N									12	12
Integration	Pearson Correlation									1	-,381
	Sig. (2-tailed)										,221
	N										12
Dummy_Metro	Pearson Correlation										1
	Sig. (2-tailed)										
	N										12

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Table 60 Correlation table (LnRide trimmed data)

Correlations

		LnRide	Density	Diversity	C_score	C_index	Daily_f_bus	Daily_f_dolmuş	Daily_f_com_rail	Integration	Dummy_Metro
LnRide	Pearson Correlation	1	,185	-,038	,028	,340	,027	,511	,105	,202	-,109
	Sig. (2-tailed)		,565	,907	,930	,279	,933	,089	,745	,528	,735
	N	12	12	12	12	12	12	12	12	12	12
Density	Pearson Correlation		1	**,581***	,175	,266	-,313	,183	-,084	-,183	,308
	Sig. (2-tailed)			,048	,586	,403	,321	,570	,795	,568	,330
	N			12	12	12	12	12	12	12	12
Diversity	Pearson Correlation			1	-,211	,012	-,472	,164	-,216	-,322	**,700***
	Sig. (2-tailed)				,511	,970	,121	,611	,501	,308	,011
	N				12	12	12	12	12	12	12
C_score	Pearson Correlation				1	**,647***	-,001	,042	,110	,023	**-,623***
	Sig. (2-tailed)					,023	,997	,896	,735	,945	,030
	N					12	12	12	12	12	12
C_index	Pearson Correlation					1	,326	**,624***	,188	,475	-,447
	Sig. (2-tailed)						,301	,030	,559	,119	,145
	N						12	12	12	12	12
Daily_f_bus	Pearson Correlation						1	,428	,440	**,941****	-,479
	Sig. (2-tailed)							,165	,152	,000	,116
	N							12	12	12	12
Daily_f_dolmuş	Pearson Correlation							1	,446	**,701***	,022
	Sig. (2-tailed)								,146	,011	,946
	N								12	12	12
Daily_f_com_rail	Pearson Correlation								1	,569	-,302
	Sig. (2-tailed)									,053	,341
	N									12	12
Integration	Pearson Correlation									1	-,381
	Sig. (2-tailed)										,221
	N										12
Dummy_Metro	Pearson Correlation										1
	Sig. (2-tailed)										
	N										12

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

APPENDIX D

SINGLE REGRESSION

ANKARA METRO+ANKARAY

Table 61 Single regression models using LnRide (all data)

Model	Model 1_ln		Model 2_ln		Model 3_ln		Model 4_ln		Model 5_ln		Model 6_ln		Model 7_ln		Model 8_ln		Model 9_ln	
Dependent Variable	LnRide		LnRide		LnRide		LnRide		LnRide		LnRide		LnRide		LnRide		LnRide	
R square	0,001		0,001		0,001		0,035		0,121		0,285		0,106		0,251		0,005	
Data Size	14		14		14		14		14		14		14		14		14	
Variables	β	t	β	t	β	t	β	t	β	t	β	t	β	t	β	t	β	t
Constant	12,50	51,35	12,46	16,79	12,46	22,08	11,52	7,47	12,29	51,92	12,16	56,46	12,45	74,23	12,15	52,15	12,56	54,24
Density	3,853E-05	,11																
Diversity			0,08	0,09														
C_Score					0,01	0,12												
C_Index							0,77	0,66										
Daily_f_bus									0,00	1,28								
Daily_f_dolmuş											0,00	2,19						
Daily_f_comm_rail													0,00	1,19				
Integration															0,00	2,01		
Dummy_Metro																	-0,08	-0,25

Table 62 Single regression models using ridership (trimmed data)

Model	Model 1_trim		Model 2_trim		Model 3_trim		Model 4_trim		Model 5_trim		Model 6_trim		Model 7_trim		Model 8_trim		Model 9_trim	
Dependent Variable	Ridership		Ridership		Ridership		Ridership		Ridership		Ridership		Ridership		Ridership		Ridership	
R square	0,019		0,006		0,000		0,072		0,000		0,155		0,002		0,017		0,028	
Data Size	12		12		12		12		12		12		12		12		12	
Variables	β	t	β	t	β	t	β	t	β	t	β	t	β	t	β	t	β	t
Constant	243611,30	4,53	296199,73	1,94	254106,35	2,16	-15894,40	-,05	262460,89	4,96	150289,95	1,70	259839,45	6,80	236679,11	3,39	280801,50	5,50
Density	33,32	,45																
Diversity			-39430,64	-,24														
C_Score					728,58	,06												
C_Index							211307,83	,88										
Daily_f_bus									-2,58	-,03								
Daily_f_dolmuş											231,69	1,36						
Daily_f_comm_rail													97,59	,13				
Integration															25,73	,41		
Dummy_Metro																	-39061,50	-,54

Table 63 Single regression models using LnRide (trimmed data)

Model	Model 1_ln_trim		Model 2_ln_trim		Model 3_ln_trim		Model 4_ln_trim		Model 5_ln_trim		Model 6_ln_trim		Model 7_ln_trim		Model 8_ln_trim		Model 9_ln_trim	
Dependent Variable	LnRide		LnRide		LnRide		LnRide		LnRide		LnRide		LnRide		LnRide		LnRide	
R square	0,034		0,001		0,001		0,116		0,001		0,261		0,011		0,041		0,012	
Data Size	12		12		12		12		12		12		12		12		12	
Variables	β	t	β	t	β	t	β	t	β	t	β	t	β	t	β	t	β	t
Constant	12,28	57,63	12,44	20,34	12,33	26,19	10,96	8,86	12,36	58,45	11,80	35,68	12,36	81,37	12,22	44,36	12,42	60,44
Density	0,00	0,60																
Diversity			-0,08	-0,12														
C_Score					0,00	0,09												
C_Index							1,07	1,14										
Daily_f_bus									2,831E-05	,09								
Daily_f_dolmuş											0,00	1,88						
Daily_f_comm_rail													0,00	0,33				
Integration															0,00	0,65		
Dummy_Metro																	-0,10	-0,35

APPENDIX E

SINGLE REGRESSION

ANKARA METRO

Table 64 Single regression models for Ankara Metro using LnRide (all data)

Model	Metro_Model 1_ln		Metro_Model 2_ln		Metro_Model 3_ln		Metro_Model 4_ln		Metro_Model 5_ln		Metro_Model 6_ln		Metro_Model 7_ln	
Dependent Variable	LnRide		LnRide		LnRide		LnRide		LnRide		LnRide		LnRide	
R square	0,022		0,127		0,192		0,220		0,575		0,152		0,618	
Data Size	7		7		7		7		7		7		7	
Variables	β	t	β	t	β	t	β	t	β	t	β	t	β	t
Constant	12,403	36,791	11,192	7,330	11,739	16,405	10,584	6,563	11,992	48,684	12,000	21,546	11,575	32,803
Density	0,00	0,34												
Diversity			1,26	0,85										
C_Score					0,09	1,09								
C_Index							1,53	1,19						
Daily_f_bus									0,00	2,60				
Daily_f_dolmuş											0,00	0,95		
Integration													0,00	2,84

Table 65 Single regression models for Ankara Metro using ridership (trimmed data)

Model	Metro_Model 1_trim		Metro_Model 2_trim		Metro_Model 3_trim		Metro_Model 4_trim		Metro_Model 5_trim		Metro_Model 6_trim		Metro_Model 7_trim	
Dependent Variable	Ridership		Ridership		Ridership		Ridership		Ridership		Ridership		Ridership	
R square	0,294		0,752		0,031		0,435		0,098		0,311		0,278	
Data Size	6		6		6		6		6		6		6	
Variables	b	t	b	t	b	t	b	t	b	t	b	t	b	t
Constant	190341,20	3,46	-269753,47	-1,82	194098,11	1,38	-168320,30	-0,71	200230,52	2,63	133523,06	1,51	139014,34	1,52
Density	75,70	1,29												
Diversity			492610,09	3,49										
C_Score					6081,94	0,36								
C_Index							329093,69	1,75						
Daily_f_bus									165,71	0,66				
Daily_f_dolmuş											223,90	1,34		
Integration													139,99	1,24

Table 66 Single regression models for Ankara Metro using LnRide (trimmed data)

Model	Metro_Model 1_ln_trim		Metro_Model 2_ln_trim		Metro_Model 3_ln_trim		Metro_Model 4_ln_trim		Metro_Model 5_ln_trim		Metro_Model 6_ln_trim		Metro_Model 7_ln_trim	
Dependent Variable	LnRide		LnRide		LnRide		LnRide		LnRide		LnRide		LnRide	
R square	0,286		0,772		0,046		0,533		0,144		0,462		0,411	
Data Size	6		6		6		6		6		6		6	
Variables	β	t	β	t	β	t	β	t	β	t	β	t	β	t
Constant	12,09	49,33	10,02	15,86	12,06	19,54	10,31	10,81	12,10	36,79	11,73	33,73	11,77	32,17
Density	0,00	1,27												
Diversity			2,21	3,68										
C_Score					0,03	0,44								
C_Index							1,62	2,13						
Daily_f_bus									0,00	0,82				
Daily_f_dolmuş											0,00	1,85		
Integration													0,00	1,67

APPENDIX F

SINGLE REGRESSION

ANKARAY

Table 67 Single regression models for Ankaray using lnRide (all data)

Model	Ank_Model 1_ln		Ank_Model 2_ln		Ank_Model 3_ln		Ank_Model 4_ln		Ank_Model 5_ln		Ank_Model 6_ln		Ank_Model 7_ln		Ank_Model 8_ln	
Dependent Variable	LnRide		LnRide		LnRide		LnRide		LnRide		LnRide		LnRide		LnRide	
R square	0,216		0,019		0,198		0,480		0,025		0,422		0,196		0,242	
Data Size	7		7		7		7		7		7		7		7	
Variables	b	t	b	t	b	t	b	t	b	t	b	t	b	t	b	t
Constant	13,73	13,43	12,95	10,25	13,79	12,19	24,88	4,34	12,43	27,28	12,14	40,54	12,40	44,29	12,16	31,01
Density	0,00	-1,18														
Diversity			-0,50	-0,31												
C_Score					-0,11	-1,11										
C_Index							-9,00	-2,15								
Daily_f_bus									0,00	0,36						
Daily_f_dolmuş											0,00	1,91				
Daily_f_comm_rail													0,00	1,11		
Integration															0,00	1,27

Table 68 Single regression models for Ankaray using ridership (trimmed data)

Model	Ank_Model 1_trim		Ank_Model 2_trim		Ank_Model 3_trim		Ank_Model 4_trim		Ank_Model 5_trim		Ank_Model 6_trim		Ank_Model 7_trim		Ank_Model 8_trim	
Dependent Variable	Ridership		Ridership		Ridership		Ridership		Ridership		Ridership		Ridership		Ridership	
R square	0,612		0,247		0,105		0,515		0,041		0,097		0,000		0,006	
Data Size	6		6		6		6		6		6		6		6	
Variables	b	t	b	t	b	t	b	t	b	t	b	t	b	t	b	t
Constant	699026,527	4,071	600632,168	2,107	493795,555	1,555	3324510,455	2,248	315629,282	2,947	160836,716	,828	281558,800	3,839	299430,517	2,246
Density	-1097,703	-2,511														
Diversity			-436132,729	-1,146												
C_Score					-17999,498	-,685										
C_Index							-2209907,372	-2,059								
Daily_f_bus									-51,724	-,411						
Daily_f_dolmuş											252,735	,654				
Daily_f_comm_rail													-25,817	-,025		
Integration															-15,823	-,161

Table 69 Single regression models for Ankaray using LnRide (trimmed data)

Model	Ank_Model 1_ln_trim		Ank_Model 2_ln_trim		Ank_Model 3_ln_trim		Ank_Model 4_ln_trim		Ank_Model 5_ln_trim		Ank_Model 6_ln_trim		Ank_Model 7_ln_trim		Ank_Model 8_ln_trim	
Dependent Variable	LnRide		LnRide		LnRide		LnRide		LnRide		LnRide		LnRide		LnRide	
R square	0,660		0,374		0,077		0,343		0,018		0,149		0,009		0,000	
Data Size	6		6		6		6		6		6		6		6	
Variables	b	t	b	t	b	t	b	t	b	t	b	t	b	t	b	t
Constant	14,08	22,91	13,93	13,99	13,12	10,63	21,93	3,33	12,51	30,17	11,85	16,42	12,40	44,37	12,42	24,25
Density	0,00	-2,79														
Diversity			-2,05	-1,55												
C_Score					-0,06	-0,58										
C_Index							-6,90	-1,44								
Daily_f_bus									0,00	-0,27						
Daily_f_dolmuş											0,00	0,84				
Daily_f_comm_rail													0,00	0,19		
Integration															-6,914E-07	,00

APPENDIX G

MULTIVARIATE REGRESSION

ANKARA METRO

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	D.freq.bussystems		Stepwise (Criteria: Probability-of-F-to-enter <= ,050, Probability-of-F-to-remove >= ,100).
2	Density		Stepwise (Criteria: Probability-of-F-to-enter <= ,050, Probability-of-F-to-remove >= ,100).

a. Dependent Variable: Ridership

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,829[a]	,687	,624	119655,294
2	,950[b]	,902	,853	74733,343

a. Predictors: (Constant), D.freq.bussystems

b. Predictors: (Constant), D.freq.bussystems, Density

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	157111932701,098	1	157111932701,098	10,974	,021[b]
	Residual	71586946358,331	5	14317389271,666		
	Total	228698879059,429	6			
2	Regression	206358589039,270	2	103179294519,635	18,474	,010[c]
	Residual	22340290020,158	4	5585072505,040		
	Total	228698879059,429	6			

a. Dependent Variable: Ridership

b. Predictors: (Constant), D.freq.bussystems

c. Predictors: (Constant), D.freq.bussystems, Density

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	129036,663	70275,875		1,836	,126
	D.freq.bussystems	504,368	152,256	,829	3,313	,021
2	(Constant)	-21856,212	67147,119		-,325	,761
	D.freq.bussystems	663,637	109,178	1,091	6,078	,004
	Density	155,233	52,277	,533	2,969	,041

a. Dependent Variable: Ridership

Excluded Variables[a]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	Density	,533[b]	2,969	,041	,829	,759
	Diversity	,325[b]	1,375	,241	,567	,950
	ConnectivityScore	,360[b]	1,664	,171	,640	,989
	ConnectivityIndex	,226[b]	,880	,429	,403	,997
	D.Freq.dolmuş	,036[b]	,127	,905	,063	,973
	Integration	,067[b]	,127	,905	,063	,279
2	Diversity	,014[c]	,055	,960	,032	,527
	ConnectivityScore	,139[c]	,678	,546	,365	,668
	ConnectivityIndex	-,060[c]	-,274	,802	-,156	,671
	D.Freq.dolmuş	-,209[c]	-1,278	,291	-,594	,788
	Integration	-,391[c]	-1,278	,291	-,594	,226

a. Dependent Variable: Ridership

b. Predictors in the Model: (Constant), D.freq.bussystems

c. Predictors in the Model: (Constant), D.freq.bussystems, Density

Figure 83 Multivariate analysis for Ankara Metro (ridership)

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	Integration		Stepwise (Criteria: Probability-of-F-to-enter <= ,050, Probability-of-F-to-remove >= ,100).

a. Dependent Variable: lnride

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,786[a]	,618	,542	,39762

a. Predictors: (Constant), Integration

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1,279	1	1,279	8,090	,036[b]
	Residual	,790	5	,158		
	Total	2,070	6			

a. Dependent Variable: lnride

b. Predictors: (Constant), Integration

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	11,575	,353		32,803	,000
	Integration	,001	,000	,786	2,844	,036

a. Dependent Variable: lnride

Excluded Variables[a]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	Density	,335[b]	1,247	,280	,529	,953
	Diversity	,247[b]	,860	,438	,395	,978
	ConnectivityScore	,226[b]	,745	,498	,349	,913
	ConnectivityIndex	,079[b]	,220	,837	,109	,726
	D.freq.bussystems	,325[b]	,578	,594	,278	,279
	D.Freq.dolmuş	-,228[b]	-,578	,594	-,278	,565

a. Dependent Variable: lnride

b. Predictors in the Model: (Constant), Integration

Figure 84 Multivariate analysis for Ankara Metro (LnRide)

APPENDIX H

MULTIVARIATE REGRESSION

ANKARAY

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	D.Freq.dolmuş		Stepwise (Criteria: Probability-of-F-to-enter <= ,050, Probability-of-F-to-remove >= ,100).

a. Dependent Variable: Ridership

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,772[a]	,596	,516	139594,778

a. Predictors: (Constant), D.Freq.dolmuş

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	143949472673,419	1	143949472673,419	7,387	,042[b]
	Residual	97433510624,010	5	19486702124,802		
	Total	241382983297,429	6			

a. Dependent Variable: Ridership

b. Predictors: (Constant), D.Freq.dolmuş

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	178384,207	78741,443		2,265	,073
	D.Freq.dolmuş	214,596	78,956	,772	2,718	,042

a. Dependent Variable: Ridership

Excluded Variables[a]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	Density	-,443[b]	-1,889	,132	-,687	,971
	Diversity	-,290[b]	-,916	,411	-,417	,832
	ConnectivityScore	-,145[b]	-,401	,709	-,197	,742
	ConnectivityIndex	-,531[b]	-2,248	,088	-,747	,800
	D.freq.bussystems	-,340[b]	-,987	,380	-,442	,685
	D.Freq.comm.rail	-,291[b]	-,613	,573	-,293	,410
	Integration	-,726[b]	-1,044	,355	-,463	,164

a. Dependent Variable: Ridership

b. Predictors in the Model: (Constant), D.Freq.dolmuş

Figure 85 Multivariate analysis for Ankaray (ridership)

VITA

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2007-2009	METU Urban Design	MS
2002-2006	METU Department of City and Regional Planning	BS
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WORK EXPERIENCE

Year	**Place**	**Enrollment**
2011-Present	T.C. Ministry for EU Affairs	EU Affairs Expert
2008-2011	Gazi University Institute of Science and Technology Department of Traffic Planning And Implementation	Research Assist.
2007	Ankara Digital Animation	Designer

FOREIGN LANGUAGES

Advanced English

PUBLICATIONS

Özgür, Ö., 2011, Performance analysis of rail transit investments in Turkey: İstanbul, Ankara, İzmir and Bursa, Transport Policy, Volume 18, Issue 1, January 2011, Pages 147-155.

Özgür, Ö. 2010, Bir Kentsel Tasarım Sorunsalı:"Sağlıklaştırma", 8 Kasım Şehircilik Günü 34. Kolokyumu, 8-9-10 Kasım 2010 Kayseri, sf. 517-529.

HOBBIES

Ballet, Dancing, Music, Sports