LAND USE OPTIMIZATION FOR
IMPROVED TRANSPORTATION SYSTEM PERFORMANCE
CASE STUDY: ANKARA

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This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

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ABSTRACT

LAND USE OPTIMIZATION FOR
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CASE STUDY: ANKARA

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This thesis investigates the effects of urban land use on transportation system performance in terms of various land use factors such as density, mixed or single land use, jobs-housing balance, street patterns, transit accessibility. Reviewed studies show that urban land use has considerable effects on transportation system performance measures which are average travel distances per person, level of service, air quality, gasoline consumption etc. Based on the obtained results, it is concluded that one of the basic reasons behind increasing auto dependency and outcoming problems in recent years is lack of coordination between land use and transportation system.

The obtained results are used to analyze land use impacts on transportation system of Ankara. Urban transportation planning decisions, deficiencies in implementation and resulted problems are discussed in terms of land use and transportation interaction. Possible land use regulations which can contribute to relieve transportation problems of Ankara are proposed.

Keywords: Urban transportation, land use, automobile dependency, transit, Ankara.

ÖZ

İYİLEŞTİRİLMİŞ ULAŞTIRMA SİSTEMİ PERFORMANSI İÇİN
ARAZİ KULLANIMI OPTİMİZASYONU
ANKARA ÖRNEĞİ

ALAYLI, Berna
Yüksek Lisans, İnşaat Mühendisliği Bölümü
Tez Yöneticisi: Prof. Dr. Ayhan İNAL

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Bu tez kentsel arazi kullanımının, ulaştırma sistemi performansı üzerindeki etkilerini; nüfus yoğunluğu, heterojen yada tek yönlü arazi kullanımı, konut-iş dengesi, sokak desenleri, toplu taşıma uygunluk gibi çeşitli arazi kullanımı faktörleri açısından incelemektedir. İncelenen çalışmalar, kentsel arazi kullanımının; kişi başına ortalama yolculuk mesafeleri, servis seviyesi, hava kalitesi ve enerji tüketimi gibi ulaştırma sistemi performans faktörleri üzerine önemli etkileri olduğunu ortaya koymuştur. Bu sonuçlara dayanarak, son yıllarda artan özel otomobile bağımlı kentsel gelişmeler ve beraberinde getirdiği sorunların altında yatan temel nedenlerden birinin, arazi kullanımı ve ulaşım sistemi arasındaki koordinasyon eksikliği olduğu sonucuna varılmıştır.

Elde edilen çıkarımlar ışığında; Ankara kentinde arazi kullanımının ulaşım sistemi üzerine etkileri değerlendirilmiştir. Ulaşım planlama kararları, uygulamadaki aksaklıklar ve beraberinde getirdiği sorunlar, arazi kullanımı ve ulaşım etkileşmi açısından tartışılmıştır. Ankara'nın ulaşım sorunlarının aşılabilmesini sağlayabilecek olası arazi kullanım düzenlemeleri önerilmiştir.

Anahtar Kelimeler: Kentiçi ulaşım, arazi kullanımı, otomobil bağımlılığı, toplutaşım, Ankara.

To My Family

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LIST OF ABBREVIATIONS

ABB	Ankara Büyükşehir Belediyesi
AMANBP	Ankara Master Plan Bureau
AŞTİ	Intercity Bus Terminal of Ankara
BART	Bay Area Rapid Transit
CBD	Central Business District
CDOT	California Department of Transportation
CPOT	City of Portland Office of Transportation
CPW	Community Planning Workshop
CUTR	Center for Urban Transportation Research
FHWA	Federal Highway Administration
IDOT	Iowa Department of Transportation
LOS	Level of Service
LRT	Light Rail Transit
MDOT	Michigan Department of Transportation
METU	Middle East Technical University
SOV	Single Occupancy Vehicle
TCDD	Turkish State Railways
TCRP	Transit Cooperative Research Program
TDM	Transportation Demand Management
TND	Traditional Neighborhood Development
TOD	Transit Oriented Development
TRB	Transportation Research Board

TS-M	Transit Station-Mixed
UK	United Kingdom
US	United States of America
UCTC	University of California Transportation Center
UTP	Urban Transportation Planning
VTPI	Victoria Transport Policy Institute
VMT	Vehicle Miles of Travel

CHAPTER 1

INTRODUCTION

The idea that urban can be formed to effect travel behavior still remains valid. (Boarnet & Crane, 2001) The reason behind that is the strong link between land use and transportation in such a way that “a city can be considered as a locational arrangement of activities or a land use pattern.” This pattern affects human behavior which in turn shapes the land use pattern. Interaction between activities comes out as movement of people and goods which is the definition of transportation. (Khisty & Lall, 1990, p. 9)

Up to now, engineers and planners rarely try to change urban form to affect travel behavior. Instead they prefer studying on existing urban form and design transportation system to satisfy the current demand and the future demand. (Boarnet & Crane, 2001)

Increasing mobility with added capacity gives people more freedom to spread over a wide area, however sprawl development brings lots of problems. After it was understood that sprawl causes inevitable automobile dependency and consequently air pollution, excess energy usage, inequity between people etc. planners have started to share the goal of limiting automobile useage and also realized that the best way to achieve this goal is reshaping land use.

One of the most important planning strategies of the last decade is the idea of New Urbanism. In spite of different suggestion and projects, the planners share common ideas about importance of mixed use, grid like, more compact, clustered and pedestrian friendly land developments to save people from automobile dependency and to encourage people to walk more.

Jobs-housing balance is another subject of debate, according to the defender of jobs-housing balancing; locating people and work opportunities in separate areas makes automobile a requirement for commuters. However if designers plan cities in mixed use form and put jobs near where people live commonly, people can walk or use other facilities such as transit (Boarnet & Crane, 2001)

In this context the main goal for engineers and planners is to devise land use and transportation system that makes the maximum contribution to the welfare of community. So, aim for designer should be to minimize time spent, energy and cost by making transportation system more efficient or planning the land use so as to minimize the amount of travel which contributes to achieve an efficient transportation system. (Blunden, 1973)

In this thesis, particularly the best possible or optimal land use patterns are investigated to make transportation system more efficient. In the first chapter, objectives and scope of the study are explained. In the second chapter, studies about land use impact on transportation system are investigated considering various land use factors. In the third chapter, interaction between urban transportation system and land use of Ankara is evaluated based on inferences of literature survey. Finally, in chapter 4, literature survey is summarized briefly and proposals for Ankara are put forwarded.

1.1 Objectives of the Study

The aim of this thesis is five-fold. Firstly, it aims to determine the effects of land use patterns on transportation system performance, and to determine land use and transportation relationship. The second aim is to determine problems related with land use – transportation interaction and the best possible solutions or land use patterns for them. In short the thesis seeks to answer to the question of which land use pattern causes which result. Next two objectives of the study are to analyze land use and transportation interaction in Ankara and to propose solutions for problems considering the points realized in the literature review. As a final purpose, the study aims to become basis for future studies which are related to land use optimization for improved transportation system.

1.2 Scope of the Study

The scope of the thesis includes definitions of basic concepts included in the thesis, the review of literature about effect of urban form on transportation system in metropolitan area and emphasizing basic points observed from the literature review. Other important part of the thesis is the case study: Ankara. This part covers analysis of land use and transportation system of Ankara, problems of Ankara related with land use-transportation system and solutions to observed problems in the light of the literature review.

CHAPTER 2

LITERATURE REVIEW

2.1 What is Transportation?

Transportation is one of the basic requirements of people such as food, shelter, clothing, and security. So it has an important portion in human culture. Also transportation has various effects in the progress in the world. For instance, it provide link between where people live and where people work, manufacturers and consumers. Transportation facilities give opportunities for different activities such as work, shopping, recreation and allow people to reach hospitals, schools, etc. (Khisty & Lall, 1990)

Transportation can be defined as "the services provided for the movement of persons and goods (freights) between different locations." (Çetinel, n.d, p. 1) The reason for people and goods to move from an origin to a destination is explained by Khisty and Lall (1990) with three conditions:

> (1) complementarity, the relative attractiveness between two or more destinations; (2) the desire to overcome distance, referred to as transferability, measured in terms of time and money needed to overcome this distance and the best technology available to achieve this; (3) intervening opportunities to competition among several locations to satisfy demand and supply. (p. 9)

The decisions between alternative travel ways for movements of people and goods shape mode choices depending on some factors such as time, speed, efficiency, costs, safety and convenience.

2.2 The Link between Land Use and Transportation System Performance

The link between land use and transportation is one of the important subjects in transportation studies. (Meyer & Miller, 1984) This subject often becomes a matter of discussion between town planner, the sociologist and economist. They argue which comes first, transport or land use. This is a futile discussion like chicken and egg argument.

> The truth is that traffic is the joint consequence of land use potential and transport capability. It is intuitively obvious that neither land use nor transport on its own can cause or generate traffic and traffic is, in fact, the medium in which both find expression.(Blunden, 1973, p.1)

As activities spread according to land use pattern, people travel to access them. Considering this, how people decide where to live and how firms decide where to perform their economic activity are important questions. Households and firms are two main parts of the agents in the urban market. They select their location to reach maximum benefit. The consequent interaction between land use and transportation occurs in two ways via agents. First location pattern of activity cause a trip pattern and second location of each activity is affected by transportation system.

It can be said that the land use and transport interaction is the result of human behavior. Land use sets the location of opportunities and transport needs come to exist by the need to access these opportunities. (Martinez, 2000)

Land use and transportation interaction has a cyclic nature, as seen in Figure 2.1. In such a way that, land use is a basic determining factor for movement and activity, this activity is defined as trip generation which conducts infrastructure investment such as, streets, bus systems etc. After adding such facilities to system, accessibility of area increases, this change in accessibility influences land value and usage, then this charge affect trip generation and the process continues until it reaches steady state condition. (Khisty & Lall, 1990)

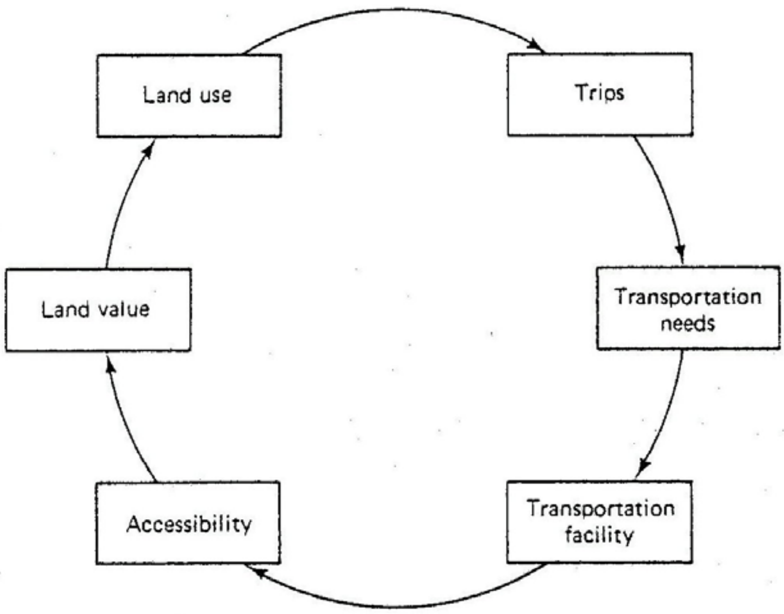

Figure 2.1: Land use and transportation cycle (Khisty & Lall, 1990)

2.3 Performance Measures

> A transportation system may be defined as consisting of the fixed facilities, the flow entities, and the control system that permits people and goods to overcome the friction of geographical space efficiently in order to participate in a timely manner in some desired activity.(Ce 451, nd, para. 3)

The performance measure is a specific activity or physical change that can measure transportation system performance. (City of Portland Office of Transportation, n.d). Different performance measures are needed to analyze and to improve transportation system. Measuring performance depends on the aim it serves. In this study, the performance measures which are affected mainly by land use changes are considered.

Performance measures can be listed as follows (Transportation Research Board, 2001);

- Accessibility**:**

"Accessibility is an ability to obtain desired goods, services and activities" (Victoria Transport Policy Institute(a), 2005).

- Mobility**:**

"The ability to move people and goods from place to place, or the potential for movement" (City of Portland Office of Transportation, n.d).

- Traffic level of service **:**

> Level of service (LOS) is a qualitative measure describing operational conditions within a traffic stream and their perception by motorists and or passengers. Factors such as speed and travel time, freedom to maneuver, traffic interruptions, comfort and convenience are generally included as conditions affecting LOS (Khisty & Lall, 1990, p. 221).

- Congestion**:**

> A condition characterized by unstable traffic flows that prohibits movement on a transportation facility at optimal legal speeds. Recurrent congestion is caused by constant excess volume compared with capacity. Nonrecurring congestion is caused by actions such as special events and/or traffic accidents (Puget Sound Regional Council, 2001).

- Delay**:**

"Difference between actual travel time and free-flow travel time" (California Department of Transportation, 2000, p. 140).

- Travel time**:**

The time it takes to travel from origin to destination.

- Mode split**:**

> The percentage of trips taken by each of the possible modes of travel (motor vehicle, transit, bicycle, walk). Mode split does not refer to the number of trips. For example, the number of trips by a particular mode may increase, but the percentage of trips by that mode may stay the same or be reduced if there is also growth in the overall number of trips for other modes (CPOT, n.d).

- Vehicle kilometers of travel:

"The number of kilometers traveled within a specific geographic location" (State of North Carolina Department of Transportation, n.d).

- Transit accessibility**:**

"Ability to do work trips by transit with walk access" (TRB, 2001).

- Environmental quality

"Helping to maintain and enhance the quality of the natural and human environment" (CDOT, 2000, p. 140).

- Air Quality**:**

"The levels of pollution and lengths of exposure" (State of North Carolina Department of Transportation, n.d).

- Safety**:**

"Minimizing the risk of death, injury, or property loss" (CDOT 2000, p. 141).

- Equity**:**

"Equity refers to the distribution of resources and opportunities" (VTPI(b), 2005).
"In transportation, a normative measure of fairness among transportation users" (Puget Sound Regional Council, 2001).

- Transportation Cost**:**

  Transportation cost is a cost which includes vehicle costs, travel time costs, road and parking facility cost, congestion costs, cost of traffic crashes, environmental costs, fuel externalities and etc (VTPI, 2005j).

- Reliability**:**

"Providing reasonable and dependable levels of service by mode" (CDOT, 2000, p. 141).

- Affordability**:**

> Transportation affordability means that user financial costs of transport are not excessive particularly for basic access (that is, travel with high social value, such as access to medical services, essential shopping, work, school) for lower-income people. This is a critical equity objective, since it affects the cost burdens and opportunities available to disadvantaged people (VTPI, 2005c).

2.4 Land Use Impacts on Transportation System Performance

Land use (also called Land Development or Spatial Development) means treatment of the landscape, including the location and design of buildings, transportation infrastructure, parks and farms, greenspaces, etc. Basic land use categories for built environment are given below.

• Residential (single- and multi-family housing)
• Commercial (stores and offices)
• Industrial
• Institutional (schools, public offices, etc.)
• Transportation facilities (roads, parking, etc.)
(Litman, 2005b)

In this part of the study, effect of different land use pattern (also called community design, urban form, the built environment, spatial planning, and urban geography (Litman, 2005a)) on transportation system performance is examined in terms of land use factors defined below. Performance measures which are defined in part "2.3 Performance Measures" are used as an indicator when investigating effects on performance of transportation system.

Land Use Factors:

- Accessibility
- Density and clustering
- Land use mix
- Connectivity
- Roadway design and management
- Parking supply and management
- Walking and cycling conditions
- Transit quality and transit accessibility

(Litman, 2005a, Litman, 2005b)

2.4.1 From Accessibility Point of View

Accessibility means the ability to reach opportunities such as desired goods, services and activities. Access is the ultimate goal of most transportation activity, with the exception of some cultural and sportive activities that aim the movement on its own (e.g., cruising, historic train rides, horseback riding, jogging, and tracking) (VTPI, 2005d).

Various factors affect accessibility. If accessibility is thought as an activity to reach something necessary, then a land use pattern followed, a transportation mode used and the speed reached become important factors.

VTPI (2005d) gives an example to explain the effects of spatial distributions of destinations to accessibility. According to the example, there are 12 destinations which serve different needs. These destinations are placed along a road and the home which is origin at the same time located at one end of the road as shown in Figure 2.2.

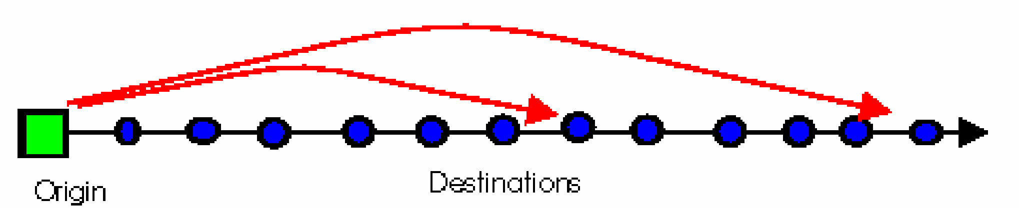

Figure 2.2: Accessibility from a location at one end of a roadway VTPI (2005d)

If destinations spread over wide area as in Figure 4, travel distances and consequent travel needs increase. Conversely, close destinations cause for walking, cycling, and transit to become convenient transportation options.

In the light of above findings it can be said that shorter travel distances allow using different transport choice and if other factors are fixed, then increased density causes increase in accessibility.

Another configuration is shown in Figure 2.3. In this figure the origin is located at center of the road, which is better than the previous one, because this reduces average travel distance to reach destinations.

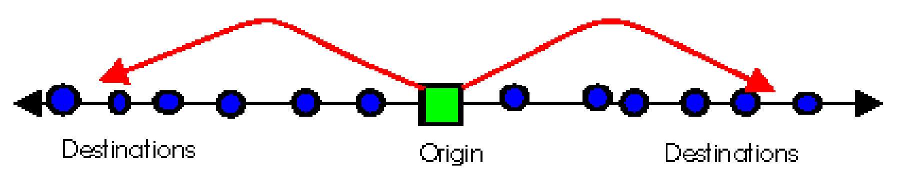

Figure 2.3: Accessibility from a location in the center of a roadway (VTPI, 2005d)

One another configuration is a loop road, as shown in Figure 2.4.

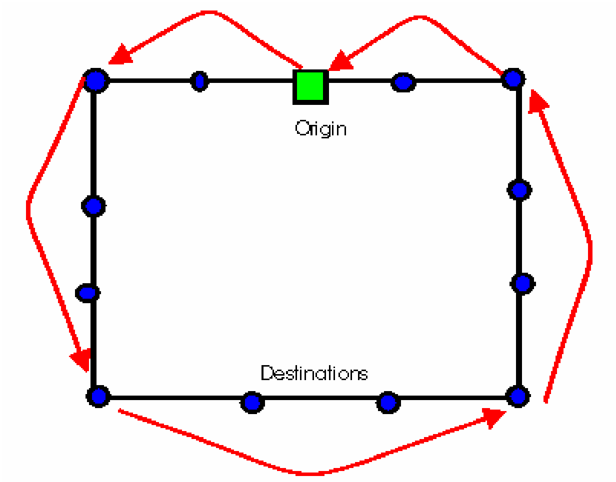

Figure 2.4: Accessibility from a location on a loop road (VTPI, 2005d)

Last two figures show effect of crossroad configuration to accessibility. In Figure 2.5 it is easily seen that arranging destinations along branch of crossroad increases access.

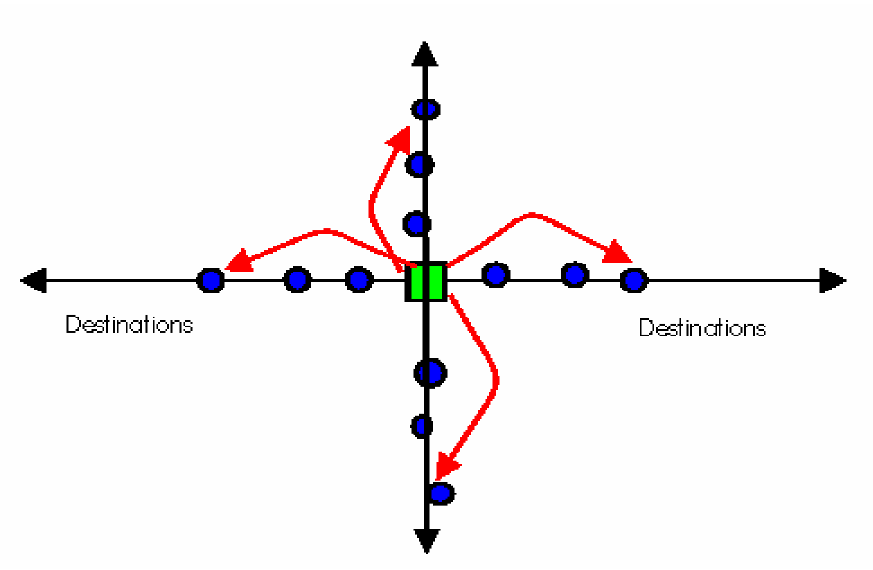

Figure 2.5: Accessibility from a crossroads (VTPI, 2005d)

If connections are constituted between destinations, route options and access increase as shown in Figure 2.6.

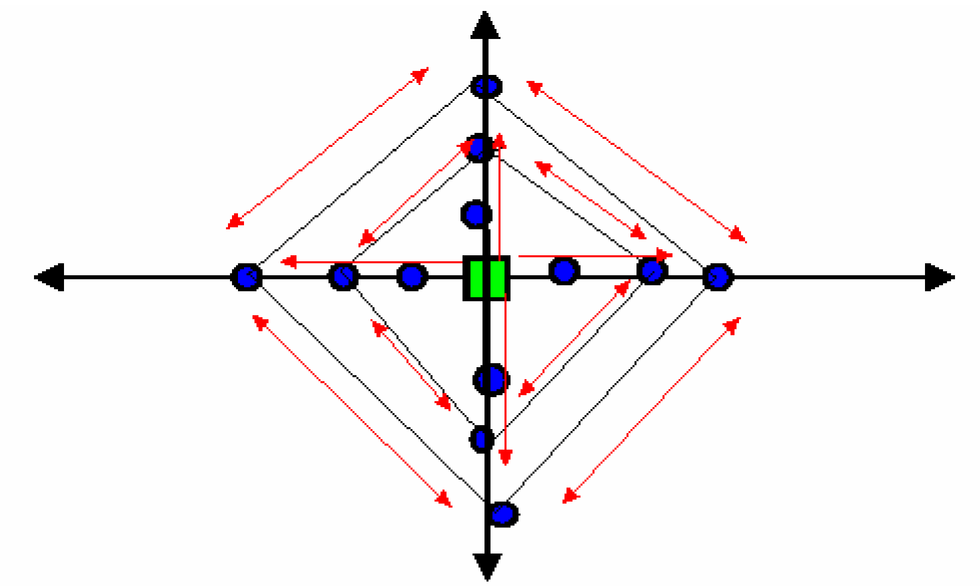

Figure 2.6: Accessibility from a crossroads with connections (VTPI, 2005d)

It can be concluded that central locations and connected road networks increase accessibility and route options also reduce average travel distance.

2.4.2 From Density and Clustering Points of View

Density

Density means the number of people or employment in an area. It can be measured by the number of residents, housing units or employees per acre[1] as in the Table 2.1 below (VTPI, 2005d).

According to a research performed by Newman, Kenworthy, Laube, Barter, Raad, Paboon, and Gulia (1999) covering 46 major cities around the world, it is conluded that "the more centralized is the city in terms of both population and jobs, the less auto dependent it will be and the less transportation energy it will use." (p. 580)

In this context Fouchier (1996b) carried out a research about auto ownership and mobility which confirm findings of Newman & Kenworthy et al. (1999). He reported that as density increases auto ownership decreases (as cited in Fouchier, 2000). Additionally, Fouchier (2000) determined that in low density outer region of Paris people prefer using automobile because of longer distance between residence and employment, lack of public transport and convenient parking place. In high density inner part the situation is totally inverted. Automobiles do not attract people because of cost and scarcity of parking place and congestion. Easiness of public transport is another factor for people not to choose private autos.

Transportation Research Board also investigates the relation between vehicle miles[2] of travel (VMT) and urban density by a graph using statistical data of 65 largest U.S. urbanized areas. According to Figure 2.7 which is obtained using these data, higher densities tend to have less reliance on auto travel. And also there is a general behavior that as density decreases vehicle miles of travel increases. (Kuzmyak, Pratt, Douglas, Spielberg, 2003)

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[1] 1acre = 4046.86 m^2
[2] 1mile= 1609.34 m

Table 2.1: Land Use Categories (VTPI, 2005d).

Category	Description	Density	Accessibility
Commercial Center	Cluster of commercial activity, including central business districts (CBDs), minor commercial districts, and malls.	30+ employees/acre.	Usually multimodal, with automobile, truck, transit and pedestrian access.
High Density Urban	Multi-story buildings with mixed land use (housing, shops and offices adjacent to each other).	30+ residents/acre 12+ units/acre	Pedestrian oriented, with transit for longer trips. Driving is difficult.
Medium Density Urban	2-3 story buildings. Shops within residential neighborhoods.	10-30 residents/acre 5-12 units/acre	Mixed: walking, cycling, transit and driving.
Town	Medium-size mixed-use urban center (generally less than 20,000 residents).	10-20 residents/acre 5-10 units/acre	Walking and cycling within the community. Driving and transit for longer trips.
Village	Medium-size mixed-use center (generally less than 2,000 residents).	10-20 residents/acre 5-10 units/acre	Walking and cycling within the community. Driving for longer trips.
Suburban	Dispersed, single-use development. 1-2 story buildings.	2-10 residents/acre 1-5 units/acre	Automobile dependent. Some transit, ridesharing and cycling.
Exurban	Mixed farms and residential located near an urban area where many residents commute and shop.	< 2 residents/acre < 1 unit/acre	Automobile dependent. Some ridesharing and cycling.
Rural	Mostly farms and undeveloped lands, with a relatively independent economy (i.e., few residents commute or shop in an urban area).	< 1 residents/acre < 0.5 unit/acre	Automobile dependent. Some ridesharing and cycling.

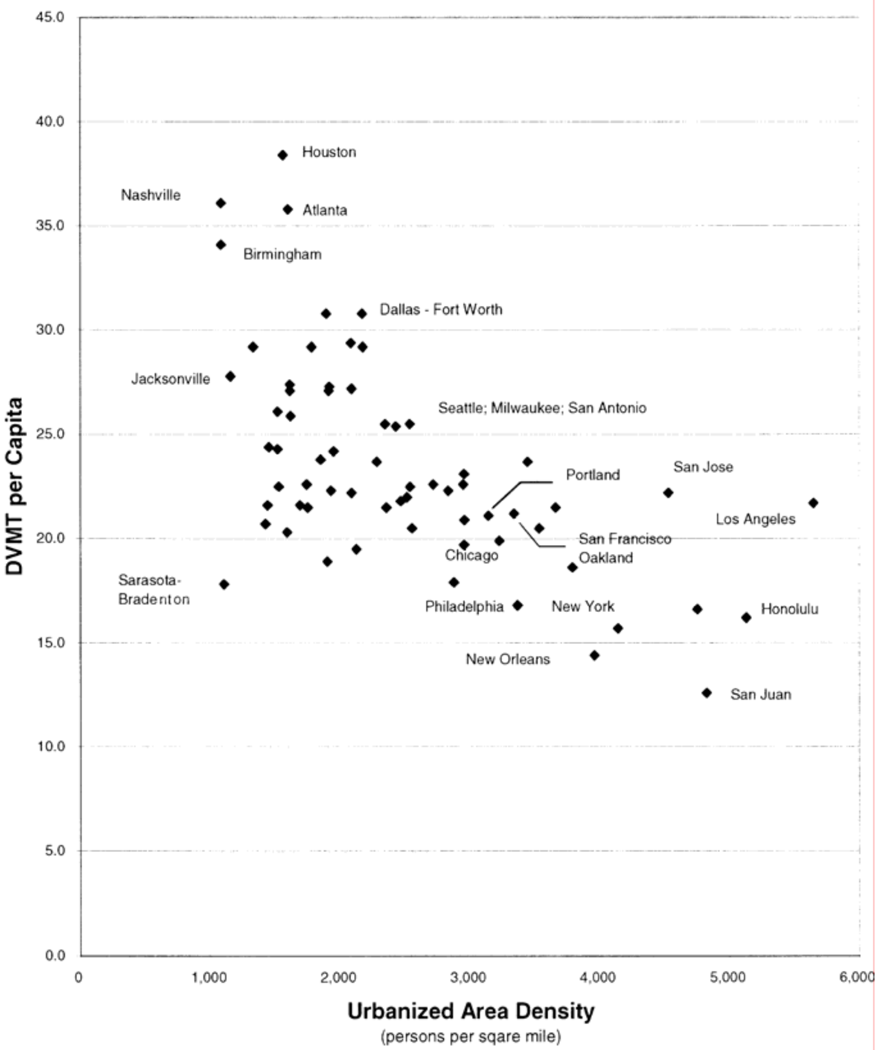


Figure 2.7: Daily vehicle miles of travel (DVMT) versus population density in the 65 largest U.S. urbanized areas – 1998 (Kuzmyak, et al., 2003).

In another study by Holtzclaw (1994), effects of household density, accessibility to public transport, accessibility to neighborhood shopping and pedestrian and bicycle accessibility on vehicle miles of travel using data of twenty-eight communities in California were investigated. The hypothesis that, residents drive less when they live in communities with higher densities, more transit service, nearby shopping (restaurants, markets, drugstores, etc.) and pedestrian friendly environment was tested.

As a result of the analysis, it was obtained that auto ownership decreases as density increases, vehicle miles traveled per household (VMT/HH) increases as household density, the transit accessibility, nearby shopping and pedestrian friendlessness decrease and the data are fairly well fit by decreases in VMT of 25 to 30 percent every time density doubles between densities of 1.8 and 101 households per residential acre (Holtzclaw, 1994).

Diepen, (2000) emphasize effect of urban density using British and Dutch National survey data. From these data Diepen suggests that higher density reduces travel activity.

- British survey shows that auto usage decreases with rising density whereas non-auto modes, bus or train or going walking, increases with a rising density. Total distance traveled also higher in lower density areas because of automobile travel (Diepen, 2000). (Figure 2.8-2.9)

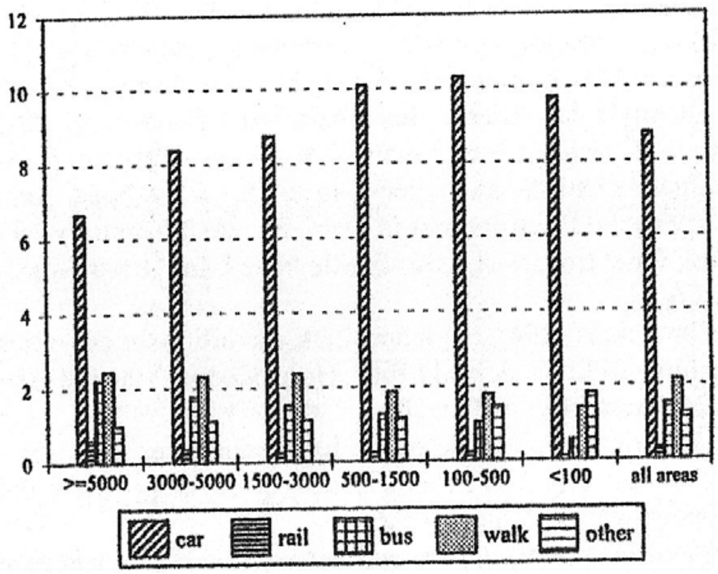


Figure 2.8: Distance traveled per person per week in the UK by mode and population density: 1985/86 (Diepen, 2000)

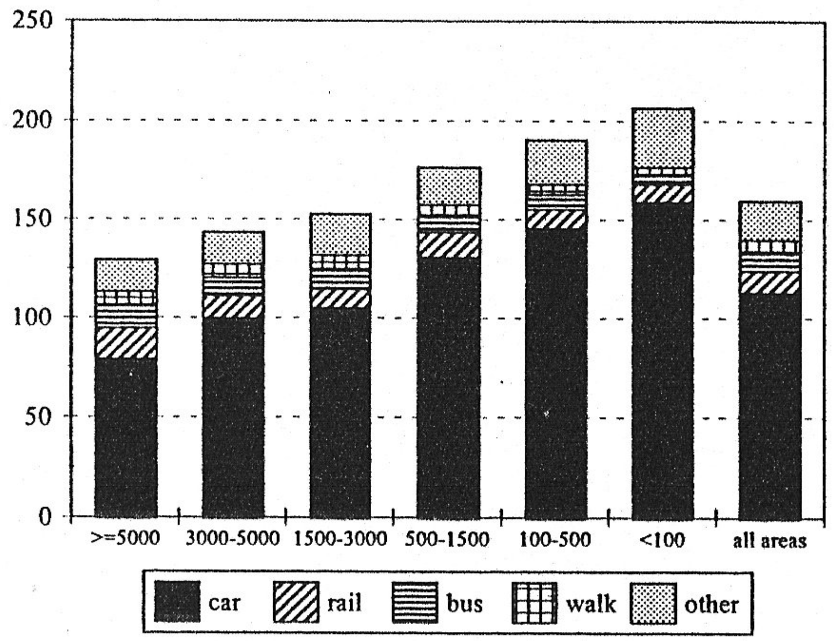


Figure 2.9: Number of journeys per person per week in the UK by mode and population density: 1985/86 (Diepen, 2000)

- Dutch survey shows that the travel frequency and auto usage is higher in lower density areas and non-auto modes, rail, bus and walking, decrease with declining density. Dependently, total distance traveled increases with declining density (Diepen, 2000).(Figure 2.10-2.11)

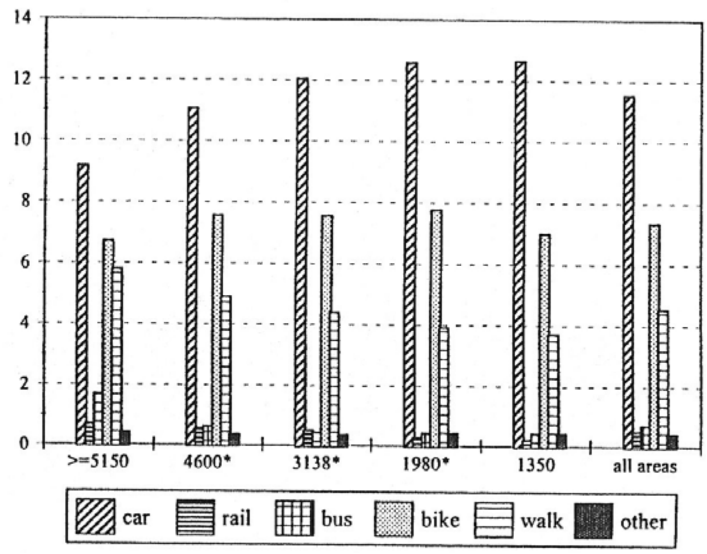


Figure 2.10: Distance traveled per person per week in The Netherlands by mode and population density: 1995 (Diepen, 2000)

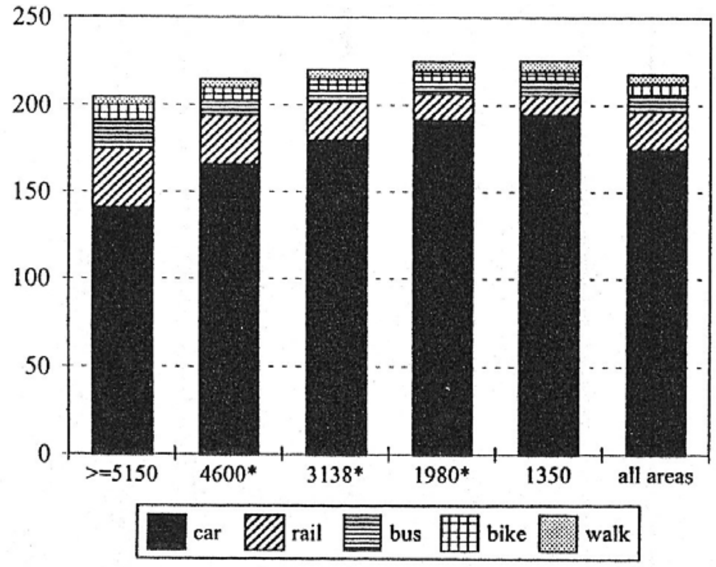


Figure 2.11: Number of journeys per person per week in The Netherlands by mode and population density: 1995 (Diepen, 2000)

Clustering

Clustering (also called compact development) means locating and organizing people or destinations together, usually within convenient walking distances. Clustering improves accessibility by shortening travel distances and improving transportation options. If clustering is implemented in a pedestrian area, it is possible to perform several daily activities with one vehicle trip, which is beneficial to trip makers. This is impossible in dispersed area in where destinations are located along commercial strip or spread throughout a suburban area. It is an important part of land use management strategies. Considerable travel reductions can be achieved, if clustering is implemented with other TDM (Transportation Demand Management) strategies, such as pedestrian improvements, parking management, ridesharing, transit improvements and traffic calming (VTPI, 2005f,2005d).

VTPI (2005d) explains how different clustering configuration effect accessibility. As seen in Figure 2.12, clustering destination gives opportunity to reach several destinations with one trip.

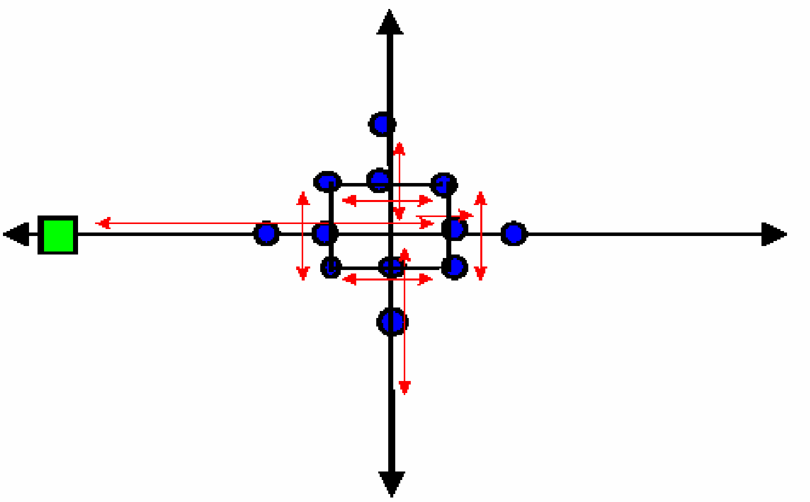


Figure 2.12: Accessibility with clustering of destinations (VTPI, 2005d)

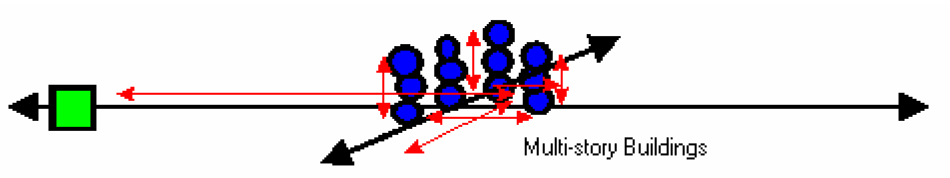


Figure 2.13: Accessibility with vertical clustering (VTPI, 2005d)

Figure 2.13 represents how multi-story buildings can accumulate destinations on top of each other to achieve greater density and accessibility. Accessibility increases as going down, because they are directly connected to sidewalks and parking facilities and VTPI (2005d) states that most new urbanist recommend medium-density development patterns with buildings limited to four to six stories to optimize accessibility.

There is also illustrative example about clustering of buildings in VTPI Transportation Demand Management Encyclopedia.

Office buildings, campuses, shopping malls, commercial districts and cities can be considered as examples of clustering. Density and clustering at a neighborhood scale (areas of less than a mile in diameter) supported with good pedestrian conditions creates multi-modal centers which are also called urban villages, transit villages or walkable centers (VTPI, 2005f).

Clustering is illustrated in Figure 2.14.

A. Part A represents a conventional suburban development with separated buildings and their parking. There are often no walking paths. Only automobile transportation can effectively serve such destinations.

B. Part B shows the same buildings. They are clustered together and directed toward the street, and their entranceways connected directly to sidewalks in contrast previous orientation which located behind parking. This increases pedestrian accessibility.

This type of land use also provides shared parking, particularly if the buildings have different peak demands. For example, office, restaurant and church can be good combination.

C. Part C shows eight buildings clustered around a park. As the size of cluster increases the efficiency of pedestrian improvements, rideshare and public transit service and other TDM strategies also increase.

D. Part D shows the eight-office building located into a park or campus, creating more convenient and attractive pedestrian connections between the buildings, improving access and supporting transportation options.

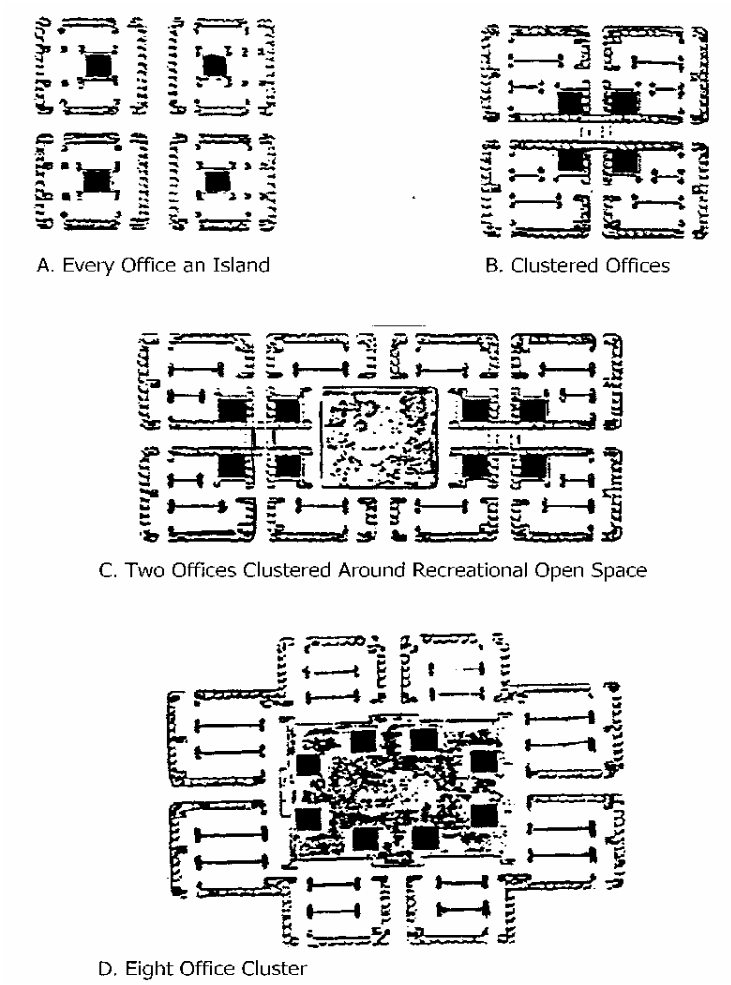


Figure 2.14: Clustering At the Building or Block Scale (VTPI, 2005f)

According to Figure 2.14; locating parking near destinations improves vehicle access, although it may reduce accessibility by other modes. Increased building height or reducing the amount of land around buildings devoted to parking can increase density and accessibility.

Land use density and clustering increase accessibility reducing distance between destinations and improving transportation options. So in higher density areas, people rely more on walking, cycling and transit, and less on driving. In these conditions, clustering and the quality of pedestrian conditions are important supportive factors. Land use density and clustering also reduce per capita impervious surface and the costs of providing public infrastructure and services (VTPI, 2005f, VTPI, 2005d).

2.4.3 From Land Use Mix Point of View

Land use mix can be defined as the relative proximity of different land uses within an area. A mixed-use neighborhood includes not just homes but also stores, offices, parks, and perhaps other land uses. (Handy, Boarnet, Ewing, Killingsworth, 2002)

Mixing residential, commercial, recreational, educational, and other land uses in districts and neighborhoods creates lively and diverse communities. Mixed land uses are critical to achieving places in which people can live, work, and play without being dependent on automobile travel (Vernez-Moudon et al., 2003).

In the past, many planners preferred single land uses to prevent location of improper land uses together such as residential units and factories. This segregation concept was incorporated into zoning codes and development practices. Such single land use patterns reduce accessibility, and cause people to travel more distance to reach desired activity and services, whereas mixed land use increase accessibility reducing travel distance. Increasingly, planners now recognize the value of land use mix. Although some types of land uses are unsuitable for clustering, such as residential and industrial, many common destinations can be clustered together, and can increase performance of transportation system (VTPI, 2005d).

Land use mix can occur at the different level such as neighborhood, or parcel level. Traditional urban neighborhoods mix commercial and residential uses at a smaller scale than modern suburban neighborhoods.

Typical examples are given in Figure 2.15 (Vernez-Moudon et al., 2003). In these figures land use patterns are investigated in circles within a one-half mile radius. Madison Beach and Wallingford are both Seattle neighborhoods developed in the early part of the 20th century, while Juanita and Kent's East Hill developed in the second part of the 20th century. Madison Beach and Wallingford have small commercial (red) and residential parcels, conversely Juanita and Kent East Hill have large parcels. (Brownson et al. as cited in Vernez-Moudon et al., 2003) The area used for commercial purposes in Kent East Hill is too large to create pedestrian friendly area (Vernez-Moudon et al., 2003).

Studies show that different land uses in a mixed-use community typically fall within the following ranges:

- Public uses (including park space and civic uses) – 5 to 15 percent of total land area
- Commercial retail space – 10 to 50 percent of total land area
- Residential development – 30 to 80 percent of total land area
- Employment – 20 to 60 percent of total land area

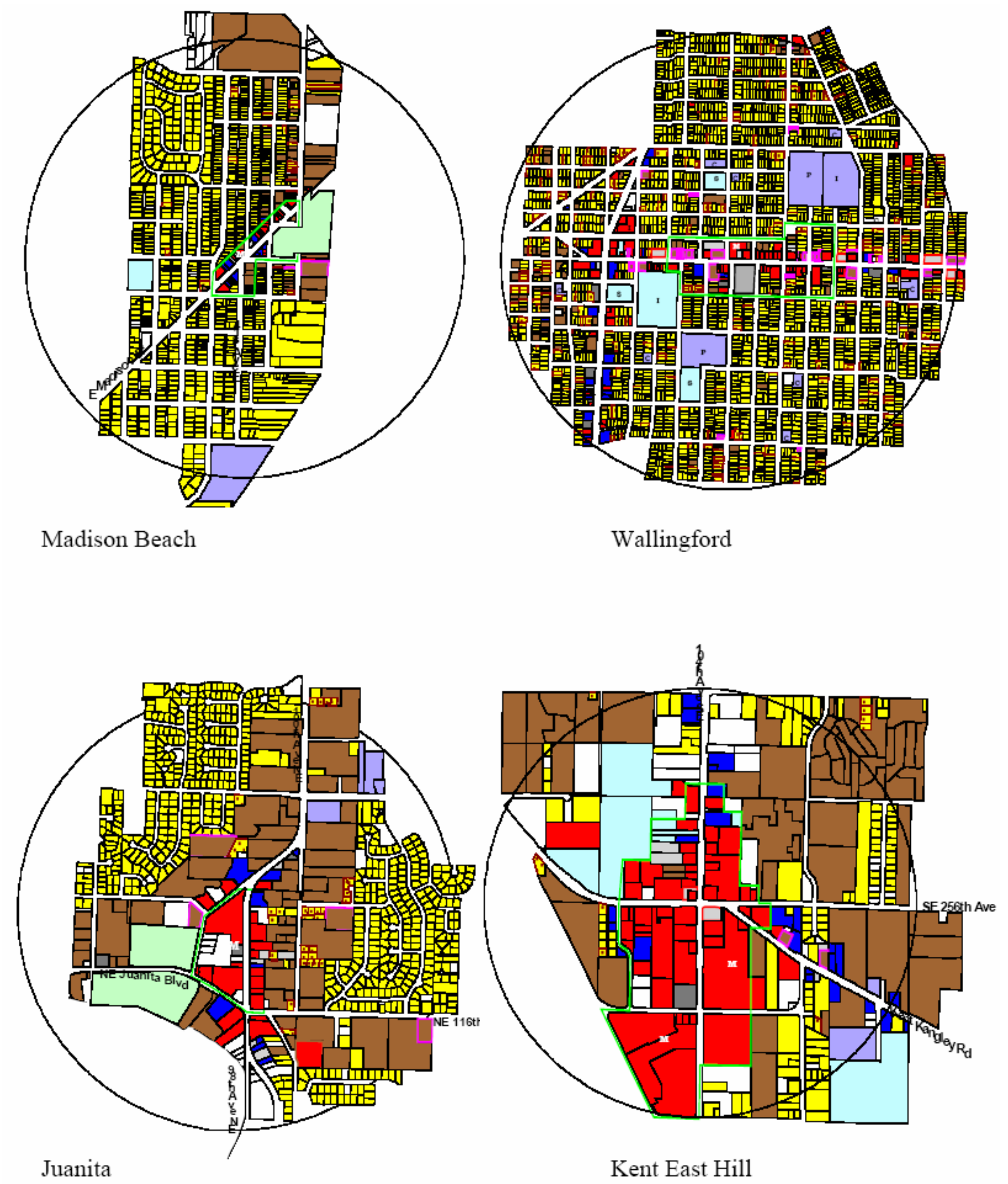


Figure 2.15: Typical mixing of uses in urban and suburban neighborhood (Vernez-Moudon et al., 2003)

Land use mix can occur vertically or horizontally at the parcel level. A vertical mix of use is possible when two or more land uses exist in a single building (Figure 2.16). It is convenient and successful in dense commercial areas with high pedestrian activity (Vernez-Moudon et al., 2003).

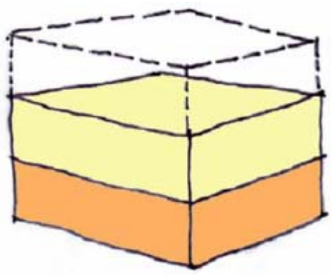


Figure 2.16: Vertical mix of use in a building or parcel (also called multiple-use building) (Vernez-Moudon et al., 2003)

These types of mixed use buildings typically have retail or services on the ground floor and residential or office above. Application of mixed-use buildings provides opportunity to substitute some motorized travel for nonmotorized travel. Also, adding residential development in mixed-use commercial and retail projects can add new housing types to an area, contributing to the diversity of a community. Residential units help to support local commercial establishments while the retail or services in a mixed-use developments increase economic activity (Figures 2.17 to 2.21).

Figure 2.17: Residential uses over retail (Vernez-Moudon et al., 2003)

Figure 2.18: Residential uses over retail (Vernez-Moudon et al., 2003)

Figure 2.19: Residential uses over retail and office (Vernez-Moudon et al.,2003)

Figure 2.20: Office over retail (Vernez-Moudon et al., 2003)

Figure 2.21: Ground floor retail in compact residential area (Vernez-Moudon et al., 2003)

A horizontal mix of use is applicable in areas where development density does not support vertical land use mix (Figure 2.22). It can be implemented also in suburban areas where multiple-use buildings generally do not exist (Vernez-Moudon et al., 2003).

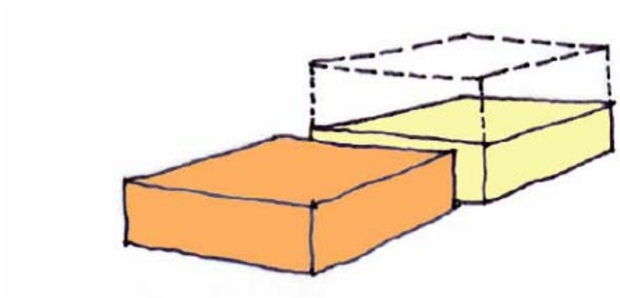
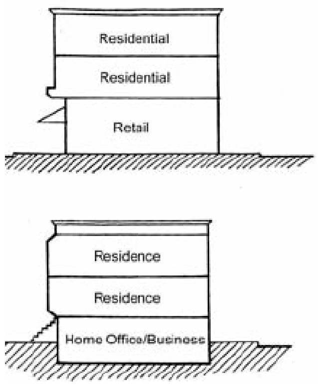


Figure 2.22: Horizontal mix of use in a parcel (Vernez-Moudon et al., 2003)

Both approaches are effective in reducing distances between activities and can help decrease the number of vehicular trips and support non-motorized travel (walking, bicycling, etc.). With mixed use, areas can function 24 hours, and seven days a week. Below some application are shown in Figure 2.23, Figure 2.24, Figure 2.25, Figure 2.26, about mixed use in Orenco Station, Hillsborough, west of Portland, Oregon (Vernez-Moudon et al., 2003).

Figure 2.23: Residential over ground floor retail (Vernez-Moudon et al., 2003)

Figure 2.24: Orenco Station live/work units (Vernez-Moudon et al., 200



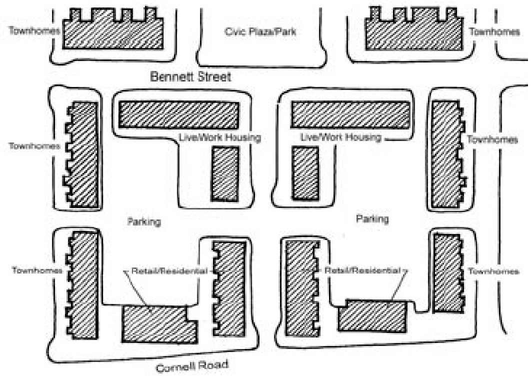


Figure 2.25: Vertical mixed use at Orenco Station (Vernez-Moudon et al., 2003)

Figure 2.26: Horizontal mixed use at Orenco Station (Vernez-Moudon et al.,2003)

Lots of studies were done to test relationships between mixed land use and travel behavior which give reliability to the claims of new urbanists who say compact, mixed-use, pedestrian-friendly designs can degenerate vehicle trips, reduce VMT per capita, and encourage non-motorized travel (Cervero, & Kockelman, 1997).

Cervero and Kockelman (1997) conducted a study incorporating 50 neighborhoods in the San Francisco Bay Area. As expected they found that people living in dense neighborhoods within building having vertical land use mix (e.g. offices and residences above ground-floor shops) and on street having four-way intersections travel significantly less personal VMT on average. Especially controlling factors like trip distance and transit service quality, pedestrian-friendly environments and the existence of convenience retail shop within a quarter mile of residences appears to induce commute trips via transit and non-motorized modes.

Findings from study of Frank and Pivo (1994) indicate that land use density and land use mix are both related to mode choice, even when non-urban form factors are controlled for both work trips and shopping trips.

> Relationships between employment density, population density, land use mix, and SOV usage were found to be consistently negative for both work and shopping trips. The relationships between employment density, population density, land use mix, and transit and walking were consistently positive for both work trips and shopping trips. (p. 51)

Holtzclaw (1994) states that vehicle miles traveled per household (VMT/HH) increases as nearby shopping decrease. Similar work is presented by Van and Senior (2000) in three neighborhoods of Cardiff in UK. The study suggests that mixed land uses encourage walking and cycling, and decrease auto use, for light food shopping trips and for trips to eat out.

2.4.3.1 Land Use Mix at Suburban Area

Cervero (1988) examined the benefits of developing mixed-use suburban workplaces in where offices, shops, banks, restaurants, and other activities are built closely. The effects of land use mix on the commuting choices of suburban workers were also studied with respect to an empirical analysis of some of the largest suburban employment centers in the United States.

Cervero (1988) says mixed-use developments can improve suburban mobility and reduce local traffic congestion;

- **By reducing motorized travel:**

Land use mix reduces motorized travel and congestion in two basic ways.

-First, as different land uses have different trip generation rates, so multiple use floorspace produce fewer trips than the same floorspace used for single purpose, such as office.

-Secondly, noon hour activities can be made by walking or cycling because of availability of needs at short distance. For example, office workers prefer to spend their lunch time at shops and restaurants which are located within the development rather than going an off-site shopping center using automobile when they work in a mixed-use setting. And also employments are able to dwell on-site or nearby, thus some motorized travel during morning and evening peak periods can also be replaced by walking and cycling.

- **By spreading trips out more evenly throughout the day:**

With a combination of office, retail, recreational, and other land uses on a site, distribution of trips becomes more equally during the day and week. In contrast, with a single land use, many trips intensify in the morning and evening peak hours. Mixed use development also enable efficient use of infrastructure thus reduces the need to expand roads serving suburban job centers.

- **By encouraging more workers to carpool and vanpool:**

> Mixed use development can also be a boon to ridesharing. Unless restaurants, shops, and banks are located nearby, most workers will find it necessary to drive their own cars in order to reach lunch-time destinations and run midday and after-work errands. From a mobility standpoint, the addition of noon-hour traffic usually poses few problems. Rather, problems are encountered during the peak hours because of the surfeit of automobiles with a single occupant who drives in order to have a car available during the day and after work (p. 432)

- **By allowing shared-use parking arrangements:**

Mixed land use can allow shared parking arrangements which can reduce the project size and help creation of pedestrian friendly environment. Different land uses need parking space at different time periods. For example the same parking facility used by office workers from 8-5 on weekdays can serve restaurant and cinema during the evening and on weekends provided that offices, stores, and cinema lie in reasonable proximity to one another. This shared use can reduce the space needed for parking 20 to 30 percent, so overall size of a project might be scaled down which helps to control sprawl and encourage more walk trips.

Cervero (1988) developed a series of stepwise regression models in order to find out how the degree of land use variation influences the modes that suburban workers choose. Percent of floorspace in land use categories for 57 large suburban employment centers which are examined in study is given in Figure 2.27 below.

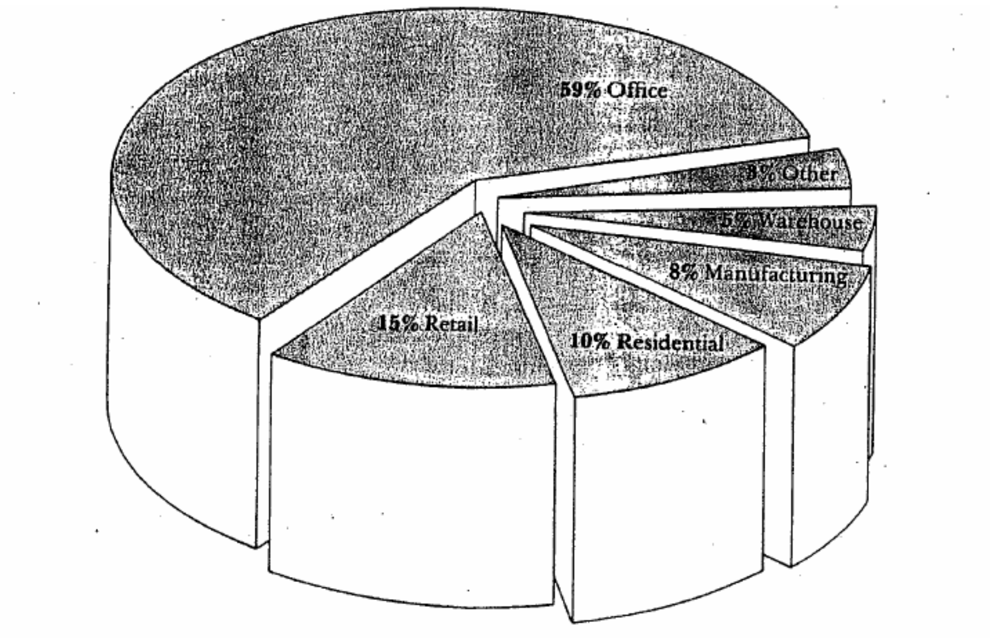


Figure 2.27: Percent of floorspace in land use categories for 57 large suburban employment centers in the United States (Cervero, 1988).

According to study below findings were obtained.

- **Effects on drive alone mode:** If all other factors are equal, increasing share of total floorspace for office by 20 percent in a suburban employment center, it leads to 2.4 percent higher share of work trips made by solo commuter when compared other center. This finding clearly confirms the proposition that single-use office environments encourage automobile travel. As a result mixed-use work environments should reduce auto dependency and cause workers to prefer other transportation options. It is also suggested that as the amount of retail space per employee in reasonable proximity to a suburban center increases, relative automobile dependency of suburban workers decreases. Thus, the share of office space and the relative availability of nearby retail activities are seen to have a considerable effect on the share of work trips made by automobile. (Cervero, 1988)

- **Effects on rideshare:** When jobs and housing units are imbalance that is to say that there is relative shortages of nearby housing, employees are more likely to live farther away, so vehicle-pool is needed. When housing is available nearby, relatively less commutes will be made in carpools or vanpools. So, jobs-housing balances can make converse effect on carpooling and vanpooling. For short distances, ridesharing is unattractive because picking up passengers is viewed as time consuming activity. Because of this, balancing jobs and housing growth may not necessarily reduce solo commuting. It might even induce some people to drive to work. In a balanced environment, even more commuters can prefer driving because of short distance, because of the fact that they use local streets it would not affect through traffic on freeways. Other primary benefit of jobs housing balances, of course, is that it encourages some employees to walk or cycle to work. (Cervero, 1988)

- **Effects on walking-cycling:** Walking and cycling trips are more likely to occur as floorspace used for retail activities increases in suburban employment center. The availability of retail activities, provide some workers to do personal business on foot, without being dependent on automobile. (Cervero, 1988)

Cervero (1991) conducted another study which investigates effects of single /mixed use buildings to travel behavior in suburban employment centers including six U.S. metropolitan areas. Required data was compiled for 83 randomly sampled individual buildings in the following suburban activity centers: Bellevue, Washington (near Seattle), 10 buildings; South Coast Metro (Orange County, California), buildings; Parkway Center (in northern Dallas), 12 buildings; Perimeter Center (north of Atlanta), 15 buildings; Tysons Corner (outside of Washington, D.C.), 16 buildings; and Southdale (near Minneapolis), 19 buildings. The 83 examined buildings were devoted only to office functions or to mixture of office, retail, and other functions. So, cases could be easily assigned as single-use office or mixed-office/retail sites. The study try to find the influence of project size, density, land use mix, and parking facilities on three measures of transportation demand: trip generation rates, work-trip mode splits, and automobile occupancy levels.

Findings from the study about land use mix can be summarized as follow:

- Mixed-use buildings are associated with low vehicle-trip generation rates since encourage employees to vanpool and carpool to work and reduce need of automobile providing on site retail shops etc.
- Existence of a retail component within a suburban office building can decrease vehicle-trip rates per employee by about 8 percent.
- Average vehicle occupancy is higher in mixed use buildings.
- Mixed-use activities have a relatively important positive influence on walking to work in suburbia.
- Transit share is greater in mixed-use and multi-story buildings. (Cervero, 1991)

2.4.3.2 Jobs-housing balance

Cervero (1989) says that it is easier to define what jobs-housing imbalance is than to define what jobs-housing balance is. If workers commute over an hour each day because of unaffordable or insufficient housing within reasonable proximity of their workplaces, this means jobs - housing balance could not be achieved. The jobs-housing balancing is breaking down the barriers that are forcing people to accommodate farther from their workplaces than they would choose. (Cervero, 1989).

Cervero (1989) expresses benefits of jobs-housing balance as follows:

- The existence of affordable housing closer to suburban job centers increases the residential opportunities. So commute distances can be shortened, consequently vehicle miles traveled decrease.
- The share of walking and cycling increase by means of shortened commute distance.
- Jobs-housing balance segregate neighborhood traffic from regional through traffic, in such a way that bringing people and jobs closer together reduces the number of autos entering regional traffic flows since motorists do not have to leave the local street network.

- Congestion, energy consumption and the emission of vehicle pollutants decrease because of reasons given in the above items.

Cervero (1989) explains reasons behind jobs-housing imbalance based on Suburban Chicago. He claims that region's imbalance can be attributed to the shortage of affordable housing suited to the income level of local employment, and restrictive zoning and the congestion problems comes out sharing the same limited freeways to commute long distances by thousands of workers.

He gives proposals to set jobs-housing balance as follows.

- To prevent segregation, zoning should be “turned on its head”, this means integration of different land uses.
- A new office project may be allowed provided that it is located within a specified radius of an existing high-density residential area.
- Multifamily and moderate-income housing can be encouraged by allowing developers to increase densities, giving tax credits to mixed-use projects etc (Cervero, 1989).

2.4.4 From Roadway Design Point of View

Streets are public areas for many activities and functions. They provide paths for walking, places for talking, rights of way for utilities, and facility for the movement, stopping and storage of motor vehicles (Deakin, Homburger, Bosselman, Smith and Beukers, 1989).

> Streets evolved over many centuries to perform two transportation functions: provision of access to individual parcels of land, and provision of an infrastructure for movement between various origins and destinations. However these functions make competing demands on the street; in most situations a trade of must be made as to the relative importance of access and movement.
>
> - Access can be interpreted to include the existence of driveways connecting the street with private property and the availability of part of the street for parking and loading.
> - Movement comprises both the capacity to move quantities of vehicles or people and the ability to do so at a reasonably high speed (Deakin et al., 1989, p. 21).

The relationship between access and movement function of streets is shown in Figure 2.28.

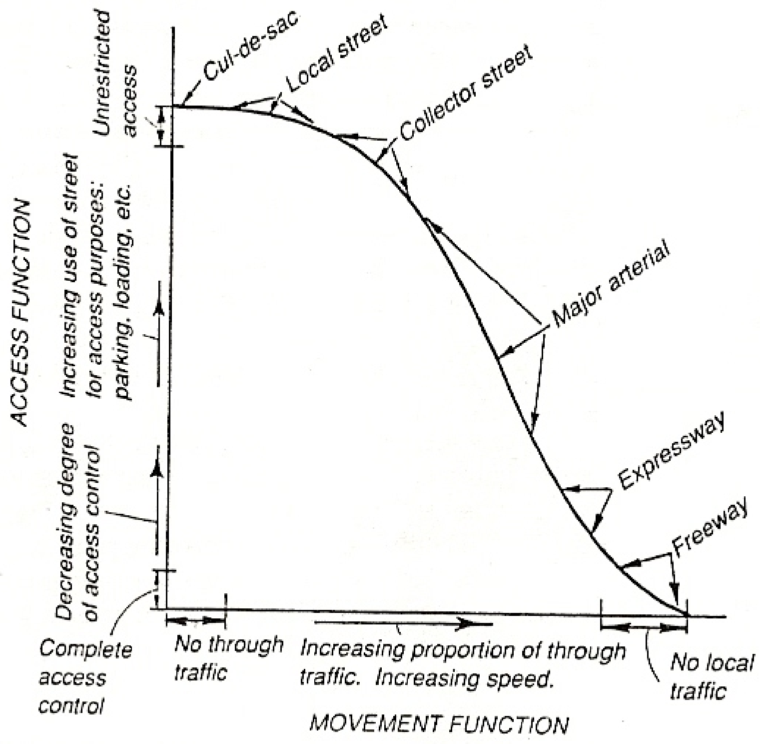
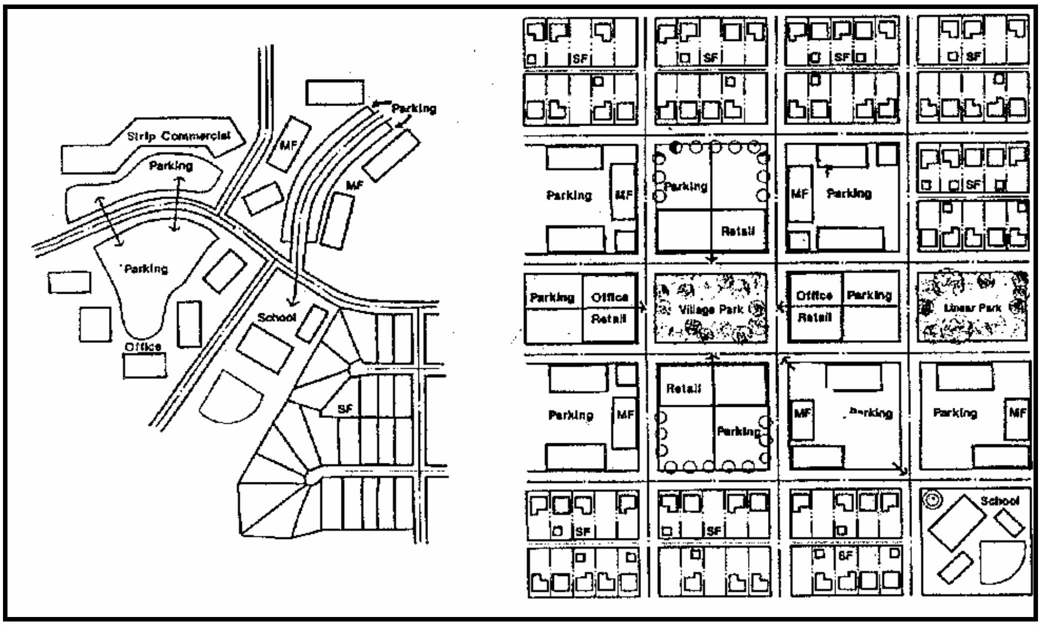


Figure 2.28: Schematic relationship between access and movement function of streets. (Deakin et al., 1989)

When the studies about street design are investigated, two basic development types stand out. They are traditional neighborhood development (TND) which is called neotraditional neighborhood development and conventional suburban development. (Figure 2.29)



Hierarchical Road System ***Connected Road System***

Figure 2.29: Hierarchical and Connected Road Systems (Kulash, Anglin and Marks, 1990 as cited in Crane, 1999)

The evolution of street design between interconnected grid and cul-de-sacs is represented in Southworth and Ben-Joseph (1997) as shown in Figure 2.30.

Interconnected Grid Fragmented Grid Cul-de-sacs

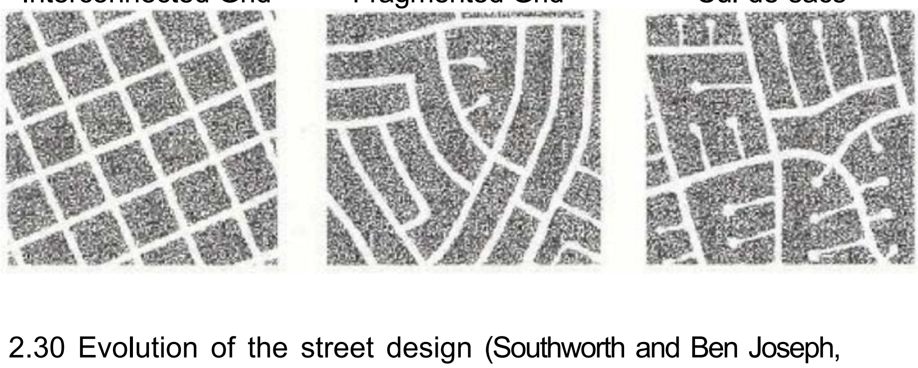


Figure 2.30 Evolution of the street design (Southworth and Ben Joseph, 1997)

Conventional suburban development, favored during the 1960s through the 1990s, has a roadway design which is composed of a poorly-connected, hierarchical network, with many cul-de-sacs. (Figure 2.29) This increases the amount of travel required to reach destinations, channels traffic onto arterials, and creates barriers to walking and cycling. A hierarchical road network emphasizes mobility by supporting higher traffic volumes and speeds on fewer roads (VTPI, 2005g). In such a way that, in the conventional system, the first level of the hierarchy is local streets, intended for direct property access. The second level is the collector, intended to gather traffic from local streets and transfer it to the final level. The final level is the arterial street which serves longer distance mobility and does not aim to serve as direct access to properties. As for left turn, the conventional suburban development design permits left-turn movements at a few major intersections which need multiphase signals. So long traffic signal delays at intersections are inseperable parts of this design (Kulash, 1990).

Traditional or neotraditional neighborhood development which has evolved since the 1970’s features many of the properties of urban designs of 50 to 100 years ago (Kulash, 1990). A small, connected, dense road network which is a part of neotraditional design emphasizes accessibility by providing more direct travel with traffic distributed over more roads, offering more routes and making nonmotorized modes more feasible. (VTPI, 2005g) In other words the TND trips, which use minor arterial, collector and local streets, are characterized by low maximum speed, more frequent short delays at intersections and a greater number of turning movements (Kulash, 1990) (Figure 2.29). So, having improved connectivity, neotraditional neighborhood is a part of new urbanism and smart growth land use policies (VTPI, 2005g).

Features of TND are denoted in Kulash (1990) as follows:

Network of streets: The TND has a highly connected dense street network which means many available routes for a certain trip. If the primary route for a trip is unavailable because of traffic conditions, alternates can be used. The dense network is in contrast with the hierarchical pattern of most suburban development.

Street cross-section: Street cross-sections in the TND that are not greater than two travel lanes plus on-street parking place, which means a maximum pavement width of 40 feet[1].

Reduced or non-existent hierarchy of streets: The TND either reduces or eliminates the hierarchy of conventional functional classifications related with streets.

Lateral clearance: TND allows and even encourages the reduction in lateral clearance between street and the fixed objects (trees, street furniture) on the side of the street.

On-street parking: On-street parallel parking is one of the main principles of TND. This parking is designed to provide buffer area to pedestrians on the sidewalk, to provide street activity and also for the supply of parking although this parking source can serve only a small part of the overall parking demand in a business district, and finally to enclose the sidewalk space.

Short traffic signal cycles: Traffic signal periods are less than 60 seconds in accordance with TND. Short traffic signals are convenient for pedestrian activity creating more frequent gaps in traffic for pedestrian crossings.

Two-phase signals: These signals simply turn green for the entire traffic, with no turn arrows. These are convenient for dense street network, because of availability of more locations for left-turn movements. Two-phase operation facilitates a reduced cycle time.

Curb radius: TND uses reduced curb radius, at intersections to decrease the speed of turning automobiles and to decrease the walking distance for pedestrians crossing the street. (Kulash, 1990)

2.4.4.1 Roadway Connectivity

Connectivity means the directness of links and the density of connections in path or

[1] 1 feet=0.3048 m

road network (VTPI, 2005g).

> Connectivity implies a system of streets with multiple routes and connections serving the same origins and destinations; it relates not only to the number of intersections along a segment of street, but also to how an entire area is connected by the street system (Community Planning Workshop, 2003, p.1).

In contrast to conventional design which uses hierarchic streets, connected areas have below characteristics:

Grid pattern

- Highly connected areas have dense, rectilinear, and grid-like pattern of arterial, collector, and local streets with many points of access. An example of grid pattern is shown in Figure 2.31.

Figure 2.31: Connected street pattern, in Eugene, Oregon (CPW, 2003)

- Grid pattern makes travel more direct with shorter travel distances, as a result travel time reduces, accessibility increases, and vehicle miles traveled reduce.
- Besides offering drivers, pedestrians, and bcyclists multiple direct routes for traveling short distances, grid pattern also releases them from being forced onto an arterial road. This facilitates walking and bicycling to local destinations such as shops, schools etc.
- Highly connected areas also have few closed-end streets which are roads with only one main entrance/exit to any street such as cul-de-sacs, dead-end and looped streets.
- Grid pattern uses narrow streets with sidewalks or off-street paths which support nonmotorized travel.

- One another feature of grid pattern is frequent intersections that create a pedestrian-scale block pattern.
- Lastly, grid pattern is convenient for transit use because transit stops are more accessible from neighborhoods. (CPW, 2003).

Small block size

Street patterns in most suburban developments consist of large blocks with dead end, internal cul-de-sac streets. Such auto dependent patterns cause problems for motorized and nonmotorized travel in such a way that all trips without regarding their purpose are forced to collectors or arterials. Because of this, travel distance increases and route options decrease.

Example of an area with large block and its contrast with small block are represented in Figure 2.32. Although they serve the same population, the small block area has greater total street and sidewalk length than the large block area (Vernez-Moudon et al., 2003).

Benefits of small block size can be summarized as follows.

- Connected street patterns (typically having 200 to 400 feet block length) better accommodate the development of town centers in contrast with typical strip developments located along arterial roads with large blocks. (CPW, 2003).
- Small blocks facilitate pedestrian travel because their frequent intersections create more direct routes, shorter travel distances between trip origin and destination. Starting from this point, cutting the size of large parcels (apartment complexes, retail centers, and their attendant parking lots) and street blocks into small block is essential for accommodating pedestrian travel (Figure 2.33) (Vernez-Moudon et al., 2003). It is recommended in Vernez-Moudon et al. (2003) that residential and commercial block perimeters should range from 300 feet to 800 feet to enable walking by providing direct routes between origins and destinations for pedestrians and to slow down vehicular traffic.

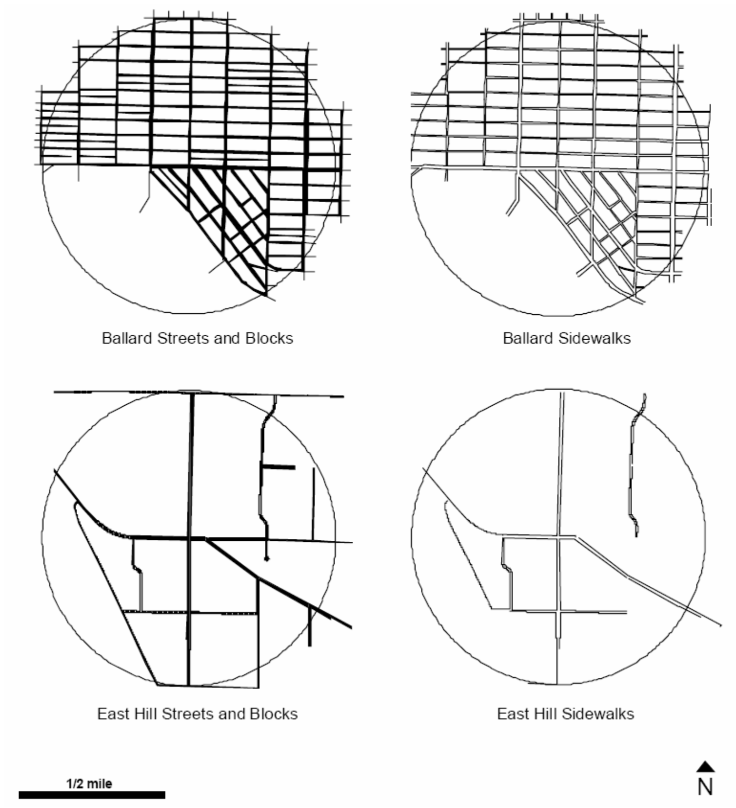


Figure 2.32: Networks of streets, blocks, and sidewalks (Hess 2001 as cited in Vernez-Moudon et al., 2003).

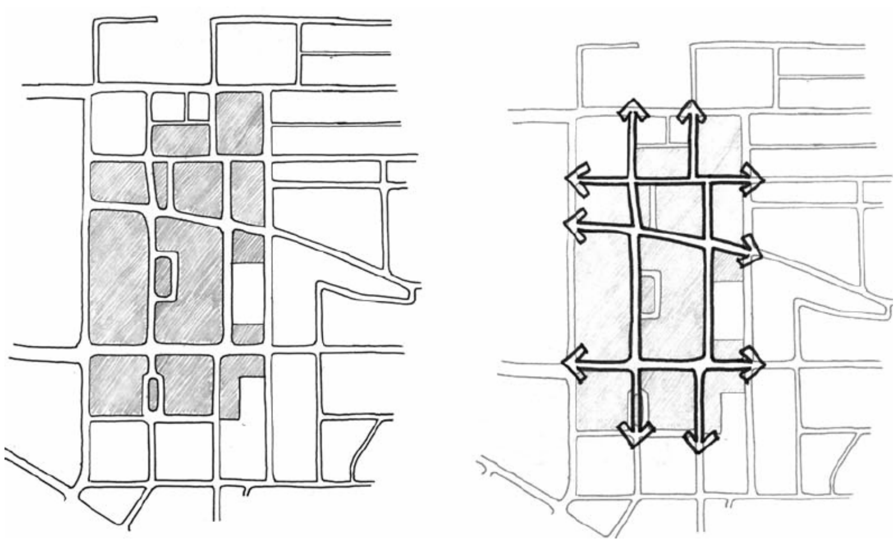


Figure 2.33: Development is broken into series of short blocks. (Vernez-Moudon et al., 2003)

- Finally, short blocks also slow down speeds of motor vehicles by offering an increased number of decision points for both motorized and nonmotorized travel (Vernez-Moudon et al., 2003).

The number of intersections and the number of blocks increases from grid street pattern to cul de sac street pattern as illustrated in Figure 2.34.

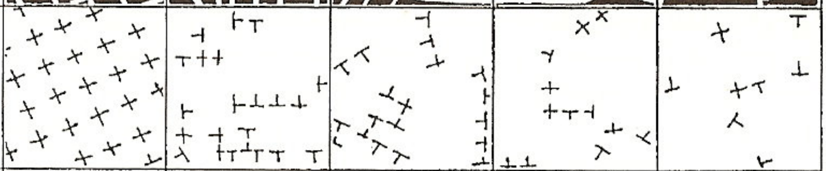
	Gridiron (c. 1900)	Fragmented Parallel (c. 1950)	Warped Parallel (c. 1960)	Loops and Lollipops (c. 1970)	Lollipops on a Stick (c. 1980)
Street Patterns					
Intersections					
Lineal Feet of Streets	20,800	19,000	16,500	15,300	15,600
# of Blocks	28	19	14	12	8
# of Intersections	26	22	14	12	8
# of Access Points	19	10	7	6	4
# of Loops & Cul-de- Sacs	0	1	2	8	24

Figure 2.34: Comparison of street patterns (Southworth and Owen, 1993 as cited in Southworth and Ben Joseph, 1997)

Capacity

Kulash (1990) asserted that a densely connected network has more traffic capacity than the same street area designed using large hierarchic streets independently from traffic demand and reduction of travel distance.

According to him the main reason behind efficiency of the dense network of small streets is that street efficiency reduces as their size increases. So, as streets get larger deficiency is obtained instead of efficiency.

Actually, the reason for capacity reduction is intersections which control the capacity of any street network. If there were not the intersections, streets would have ideal capacity, but unfortunately streets have to share the intersections with other streets. So their capacities reduce. (Kulash, 1990).

Kulash (1990) explain this with an example using two different street patterns. In the first example, a single large intersection is considered which is typical of the conventional suburban development.

Assumptions:

- The intersection has four-lane divided and six-lane divided arterial streets as shown in Figure 2.35, each having left-turn lanes and protected left-turn signals. (Appendix A)

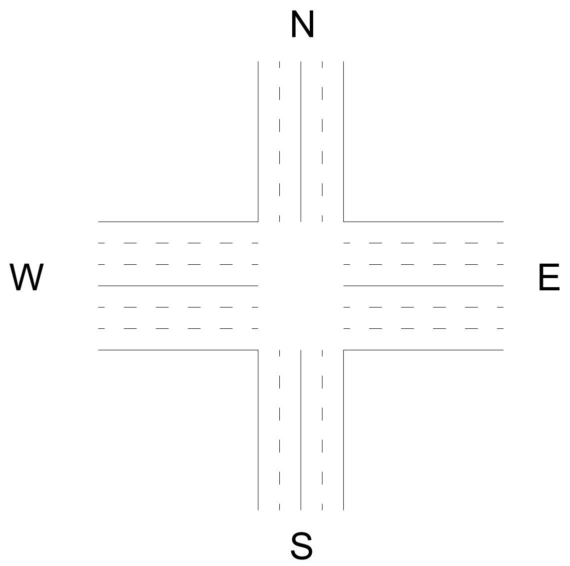


Figure 2.35: Intersections in a Conventional Street Design (Alba, 2003, as cited in Alba and Beimborn, 2004).

- The intersection is operating at close to peak-hour conditions, and the congestion affects the traffic service up to a level-of-service (LOS) 'D' at the intersection.

- Traffic volumes of the six-lane street and the four-lane street are assumed as 3,000 vph and 2,000 vph respectively, and turning movements of the six-lane street and the four-lane street are assumed 300 and 200 vph, respectively, for the major left turn movements.

In the second example the same amount of traffic is put on the same amount of pavement, but on a differently configured road system.
Assumptions:

- In this configuration a pair of two-lane streets intersecting three parallel two-lane streets (Figure 2.36).

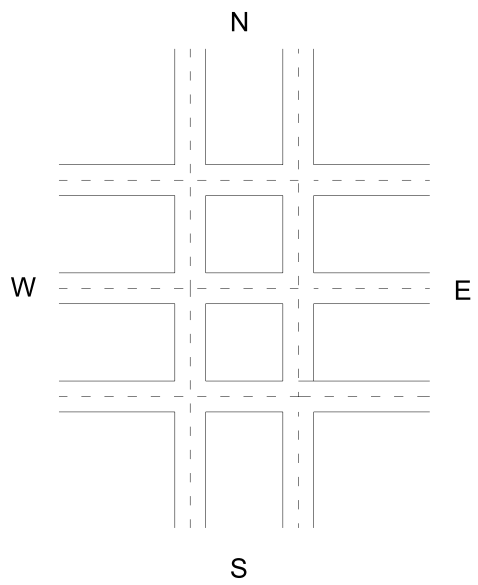


Figure 2.36: Intersections in a Neotraditional Street Design, (Alba, 2003, as cited in Alba & Beimborn, 2004)

- The total number of lanes and the total amount of pavement stays the same as in the Figure 2.35.
- The main difference between the two intersections is in the number of intersections in each system. The TND has six intersections while conventional suburban development has one.

So, TND reduces the turning movement load at any given intersection to a one-sixth. Consequently, the TND system can carry greater traffic volumes at the same level of traffic service.

Kulash (1990) says that he got the same result about TNDs performance through the standard transportation modeling process. He tested two examples in his model which involves generating the trips, distributing them to their probable destinations and then assigning them to the street network that is in place.

As a result Kulash (1990) found that;

> the TND was perfectly capable of carrying the traffic. The level of service on the arterial streets actually improved in our prototype, because of the diversion to local streets. Collector street traffic virtually disappeared. Local street service, despite the shift of traffic to them, was virtually unchanged. The explanation lies in the ability of the large mileage of connected local streets in TND to absorb large amounts of traffic.

Turning movement

The densely connected network that is built into the TND provides many opportunities for left turning. This is contrast with the conventional suburban development pattern, in which left turns are collected from multiple locations and focused at a single location.

TND not only provides more opportunity to make turns, but it also decreases the hardship of a given turning movement. Because, it is easier to make a left turn across a respectively narrow street, than a wide street as existing in conventional street systems (Kulash, 1990).

Safety

- Traffic calming devices such as curb extensions, crosswalks, landscaping, etc. are complementary part of TND to slow traffic speeds.
- By means of traffic calming devices, low speeds on local streets result in reduced accident severity.
- TND street design improves emergency vehicles accessibility and their ability to respond quickly (CPW, 2003).

Walking and cycling

Good pedestrian access necessitates continuity of pedestrian links. However, “sidewalks frequently terminate at the edge of the property, at the end of parking lots, or when a change in topography or other obstacles occurs” (Vernez-Moudon et al., 2003, p. 52).

Cities should be designed to prevent such occurrences, making walking, cycling and wheel chair use safe, convenient, and comfortable as seen from given example in Figure 2.37 and Figure 2.38. Especially, for transit stops and commercial areas, pedestrian paths should be provided along all streets. Bikeways should be part of a continuous network and link employment centers, schools, and other community facilities (Vernez-Moudon et al., 2003).

Figure 2.37: Pedestrian routes provide direct links to destinations (Vernez-Moudon et al., 2003).

Figure 2.38: Bicycle routes as a part of continuous network (Vernez-Moudon et al., 2003).

TND and Non-Motorized Travel

Kulash (1990) expresses that TND perform well as pedestrian environment. He explains actual mechanics of why TND works so well and produces friendliness to non-motorized travel as follows.

1-Direct Routing:

TND improves the routes of nonmotorized travel with more direct routing. Because dense street network of TND provides shorter distance bringing many more origin/destination pairs into walking and bicycle distance.

2-A Better Bicycle and Pedestrian Environment:

A series of small streets create better environment for bicycle and pedestrian than a hierarchy of a few larger streets. A two-lane street that is the main support of the TND network is more convenient for walking and cycling than multilane street. The enlarged intersection size on multilane street has a discouraging impact on pedestrian and cyclist. Competitive and aggressive driving which result driver to loose their attention on walk/bike traffic is also one another threat for nonmotorized travel.

3- Alternative Routes:

With the dense street network, TND concept offers many combinations of alternative routes available for a certain origin-destination pair. Availability of alternative route options for TND and conventional design can be compared using Figure 2.39. The walker or cyclist can choose their routes in response to real-time conditions. The alternative routes prevent large number of bicycle and walk trips to be done by the use of arterial streets (Kulash, 1990).

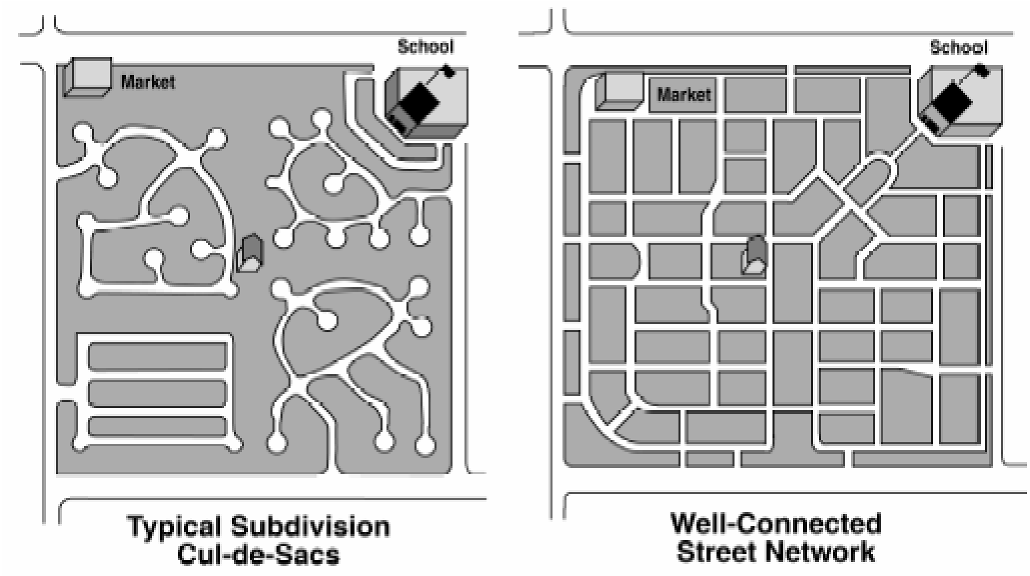


Figure 2.39: Typical patterns of TND and convensional design (Oregon Department of Transportation and Oregon Department of Land Conservation and Development, 2000)

2.4.4.2 Access Management

Access management is defined by FHWA as

> the process that provides access to land development while simultaneously preserving the flow of traffic on the surrounding road system in terms of safety, capacity, and speed. It is an effort to limit the number of conflict points, provide sufficient spacing between access points, and provide adequate on-site circulation and storage (Federal Highway Administration, 1999).

Engineers and planners are looking into access management because of increasing traffic congestion, traffic accidents, and the high costs of road improvements. Especially strip commercial areas where driveways exist frequently need access management tools. Too many driveways that are potential for turning in or out make drivers uncertain creating conflict point. Besides this, lack of turn lanes slow traffic and reduce the carrying capacity of the road (Michigan Department of Transportation, 1996).

Access management is a requirement to solve these problems and to increase performance of well connected street network. It aims “to achieve a safe and efficient flow of traffic along a roadway while preserving reasonable access to abutting properties” (MDOT, 1996, p. 4).

Benefits of Access Management

Access management program can play an important role in maintaining highway capacity, reducing crashes, and preventing costly roadway investments. It benefits the traveling public providing faster and safer travel. A well managed corridor increases business vitality (Iowa Department of Transportation, 2000).

Highway Capacity

Driveways have negative impact on the arterial’s traffic capacity. Each new driveway that is installed on an arterial reduces traffic speed. Effect of access management on highway service level is investigated performing before and after studies of access management projects which basically aims to limit or separate conflict points and to remove slower traffic from through traffic in Iowa. It was found that the level of service was raised one full level during the peak traffic hour at studied sites. The findings are shown in Table 2.2 (IDOT, 2000).

Table 2.2: Improvement in peak hour traffic service levels due to access management applications (IDOT, 2000).

Project Location	Before Project	After Project
Ames	C	B
Ankeny	C/D	B
Clive	D	B/C
Des Moines	D	B/C
Fairfield	B	B
Mason City	B	B
Spencer	B	B

Crash Rates

According to study done in Iowa, the most significant results related with the access management projects were obtained from traffic safety. Before and after studies of access management projects in Iowa determined that 40 percent reduction was achieved in average crashes per vehicle mile traveled Again almost 25 percent decrease was observed in personal injury crashes, and property-damage-only crashes were reduced by half (Figure 2.40),(Figure 2.41) (IDOT, 2000).

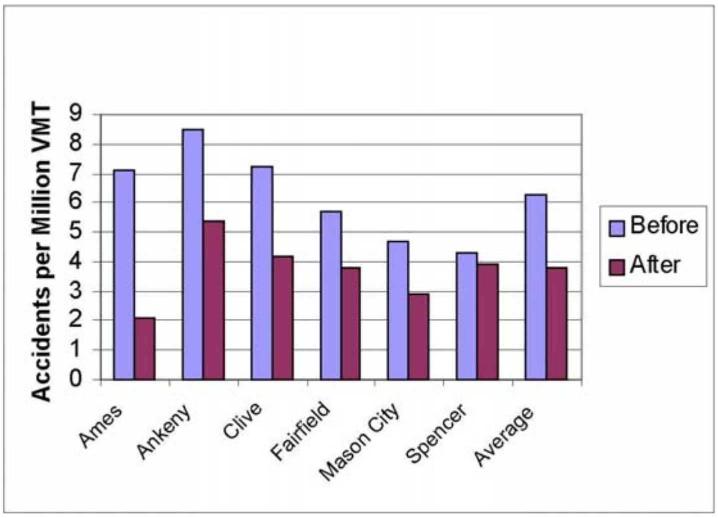


Figure 2.40: Crash reduction by city along access controlled corridors. (IDOT, 2000).

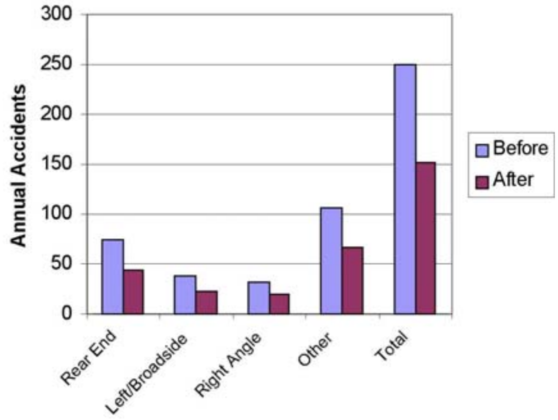


Figure 2.41: Crash reduction by crash type along access controlled corridors (IDOT, 2000).

The Community Environment and Economy

Results of analysis that is performed for five business case in Iowa show that performance of businesses located within access management corridors were generally better in terms of economic activities than in surrounding communities. The graph compares sales between access corridor and other communities (Figure 2.42). As seen from Figure 2.42 retail sales within the access corridors exceed other community sales activity between the years 1992 and 1995. At least, it can be said that access management did not negatively affect business activity (IDOT, 2000).

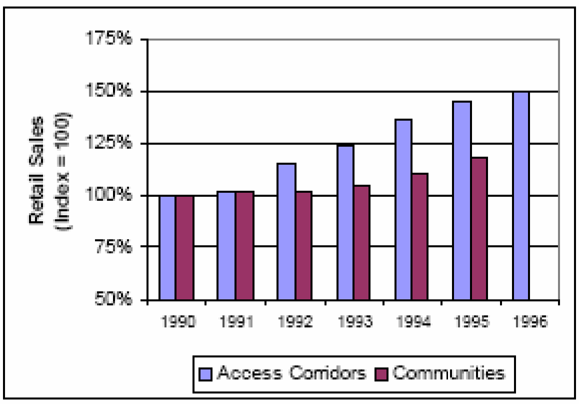


Figure 2.42: Retail sales activity along access controlled corridors (IDOT, 2000)

If access management is not applied then below problems can come out.

- The performance of transportation system will deteriorate, and conflicts will increase.
- Poorly planned strip commercial development will be induced.
- The number of private driveways will increase; this means more traffic conflicts, crashes and congestion.

- Roads widening will need to reduce capacity lost in transportation system.
- Neighborhood streets will be used as a bypass road to leave from congested intersections (MDOT, 1996).

Access Management Principles

Michigan Department of Transportation determines access management principles in six subtitles (MDOT, 1996).

1) Limit the number of conflict points.
2) Separate conflict points.
3) Separate turning volumes from through movements.
4) Locate traffic signals to facilitate traffic movement.
5) Maintain a hierarchy of roadways by function.
6) Limit direct access on higher speed roads.

1) Limit the number of conflict points

Several methods reducing conflict points are explained below.

a) Median

If number of conflict points increases then probability of crashes increases as well. Intersections typically have the greatest potential for conflict. For example, if a four-lane road intersects with a two-lane road, 36 conflict points come into existence (Figure 2.43). In the case of signalization the number of conflict points reduces to 22 (MDOT, 1996).

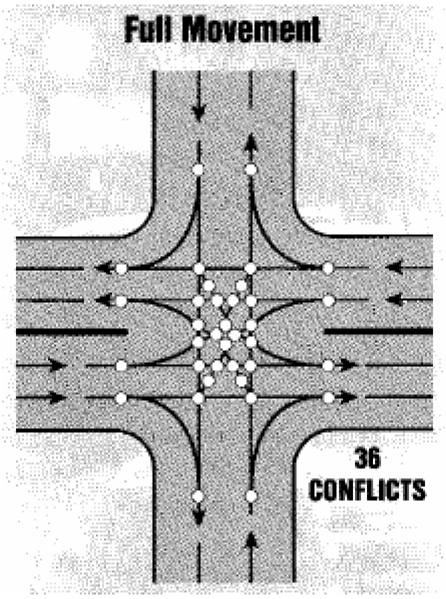


Figure 2.43: Conflict points of a intersection of four-lane road with a two-lane road. (MDOT, 1996).

Construction of median also reduces the number of conflict. For example, if a four-lane undivided roadway intersects with driveway, 11 conflict points come into existence as shown in Figure 2.44. In the case of construction of raised median with opening, conflict points reduce to 6. If the median opening does not provide (restrictive raised median) then only two conflict points exist. (Figure 2.45) (MDOT, 1996).

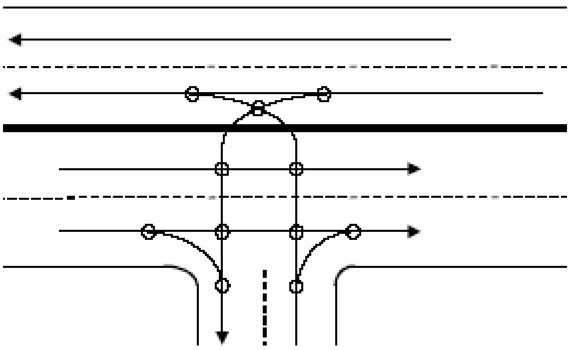


Figure 2.44: A four-lane undivided roadway intersects with driveway (IDOT, 2000

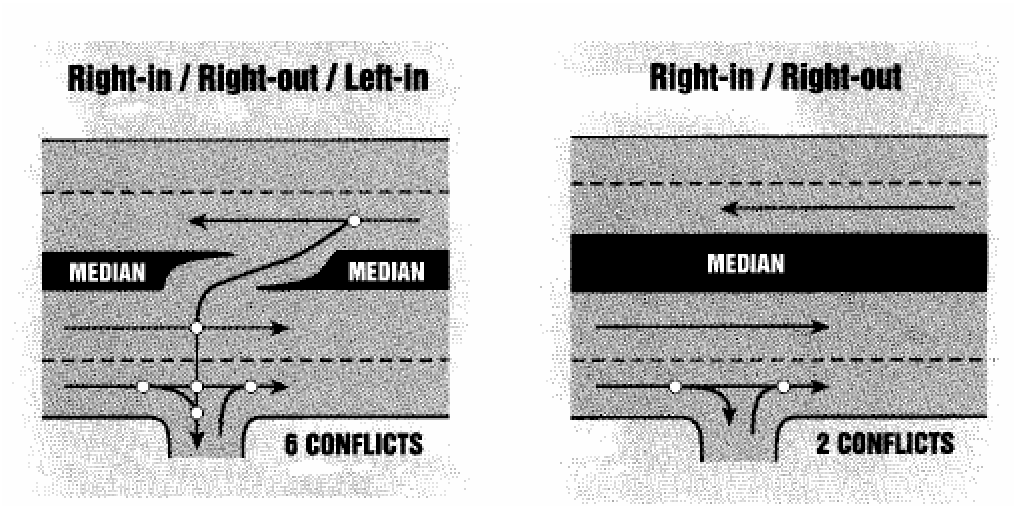


Figure 45: Constraction of median with or without opening (MDOT, 1996).

In addition, too closely spaced driways can be combined to one, this reduce conflict points from 24 to 11 as seen in Figure 2.46.

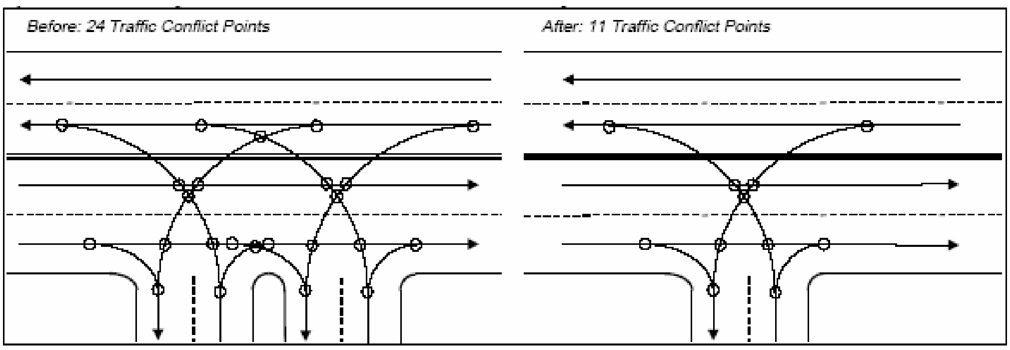


Figure 2.46: Reduction of conflict points from driveway consolidation of two closely spaced driveways on a four-lane undivided highway. (IDOT, 2000)

b) Restrict the number of driveways per lot

Restricting the number of driveways per lot is basic requirement to limit the number of driveway. It is recommended in CUTR (1998) that one driveway per parcel is acceptable.

c) Increase minimum lot frontage on major roads

Minimum lot frontage should be larger for lots placed on major roadways. Narrow lots creates problem on major roads because they cause frequent driveways. Also lots need to be in larger size on major roads to provide adequate flexibility in site design and to increase separation of access points. Figure 2.47 shows the lot frontage requirements (CUTR, 1998).

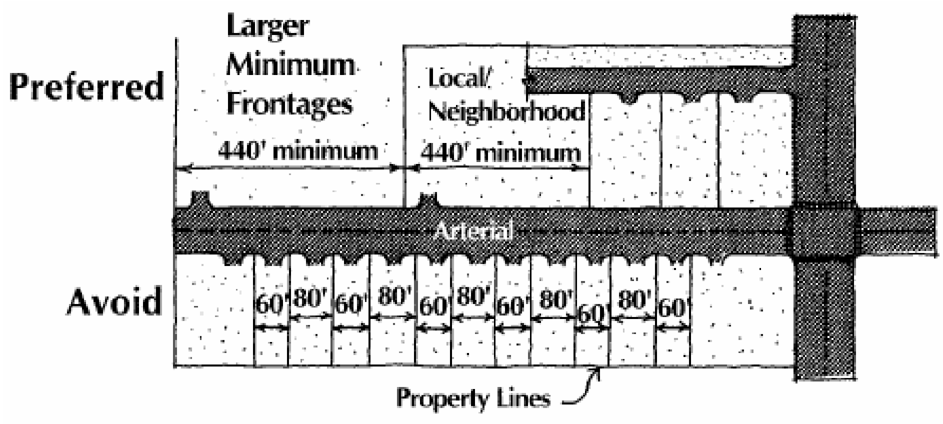


Figure 2.47: Lot frontage requirements. (CUTR, 1998)

d) Regulate the location, spacing, and design of driveways

Driveway spacing standards arrange the minimum distance between driveways throughout the major roads (CUTR, 1998). Driveway spacing is shown in Figure 2.48.

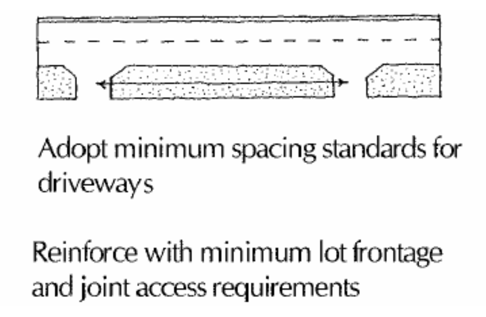


Figure 2.48: Driveway spacing standards (CUTR, 1998)

Driveway spacing standards should be based on speed limits, the classification of the roadway, or the volume of traffic generated by a development (IDOT, 2000). Improvement provided by these standards can be listed as follows.

- Providing a minimum distance between driveways along an arterial reduces the number of access points that a driver must take attention. This makes easier the driving task and reduces the possibility for conflicts and crashes. (IDOT, 2000)
- Driveway spacing standards also encourage the sharing of driveways for smaller parcels which provide opportunity to devote more area for pedestrians and landscaping (CUTR, 1998).
- Driveway standards ensure adequate sight distance for exiting vehicles to turn easily, and for motorists on the roadway to have adequate time to avoid a collision (Figure 2.49) (CUTR, 1998).

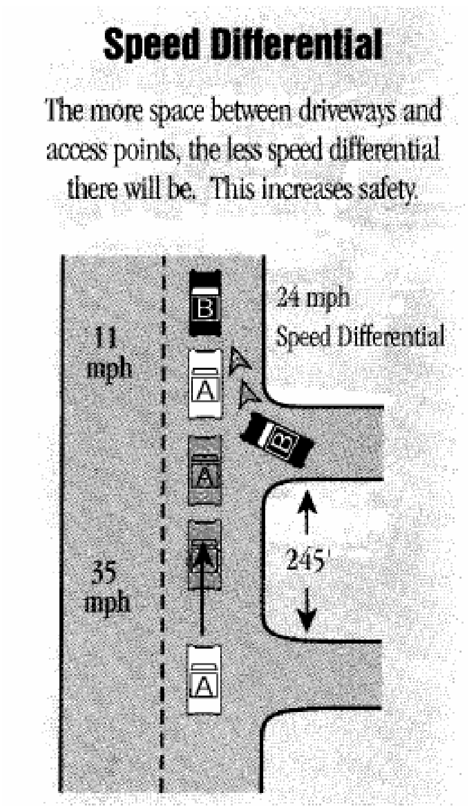


Figure 2.49: Driveway distance (MDOT, 1996).

- Standards also arrange the depth of the driveway area which is called driveway throat length.

> Where driveways are too shallow, vehicles are sometimes obstructed from entering the site causing others behind them to wait in through lanes. This blocks traffic and increases the potential for rear-end collisions (CUTR, 1998).

Commercial driveway entrances should be designed to prevent waiting vehicles on the arterial as shown in Figure 2.50 (IDOT, 2000). Insufficient throat length and poor site planning is also shown in Figure 2.51.

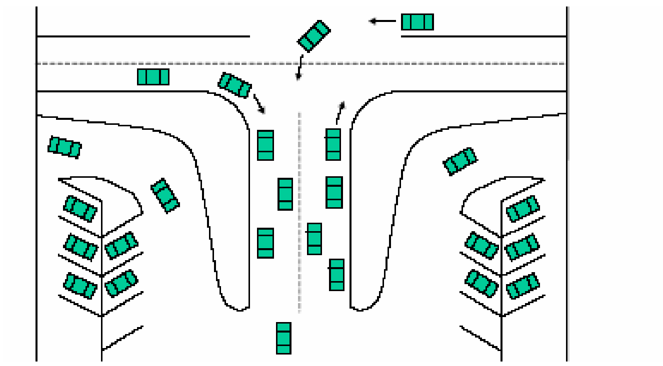


Figure 2.50: Adequate throat length (IDOT, 2000).

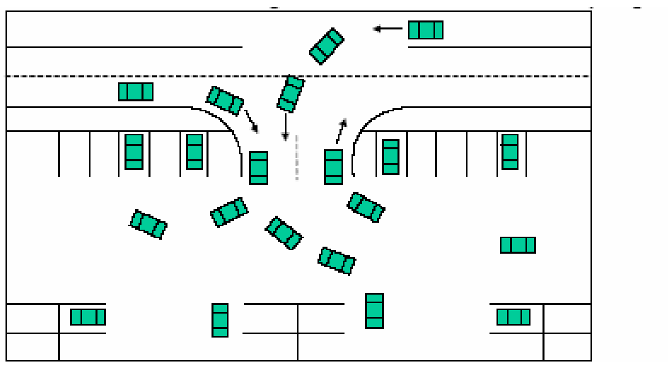


Figure 2.51: Inadequate throat length (IDOT, 2000).

Finally, as mentioned above these minimum driveway standards are acceptable for major roads, so shorter access spacings can be allowed on lower classification roadways and roadways which is divided by raised center median (IDOT, 2000).

e) Connect parking lots and consolidate driveways

Shared driveways are another way for limiting the number of conflict points along an arterial. Joint access which is "driveway serving multiple sites" and cross access which is "internal connections between adjacent sites" serve this aim (IDOT, 2000, p. 50). Internal connections between properties provide vehicles to travel between businesses without re-entering the major roadway. Joint and cross access strategies help to use roadway capacity efficiently increasing accessibility for customers, emergency vehicles and delivery vehicles (Figure 2.52-2.53-2.54) (CUTR, 1998).

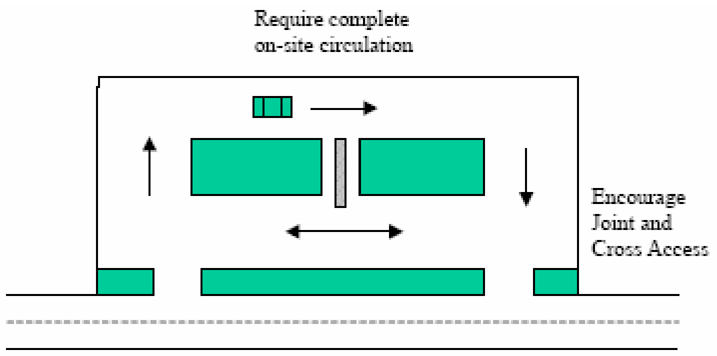


Figure 2.52: Shared commercial driveways (IDOT, 2000).

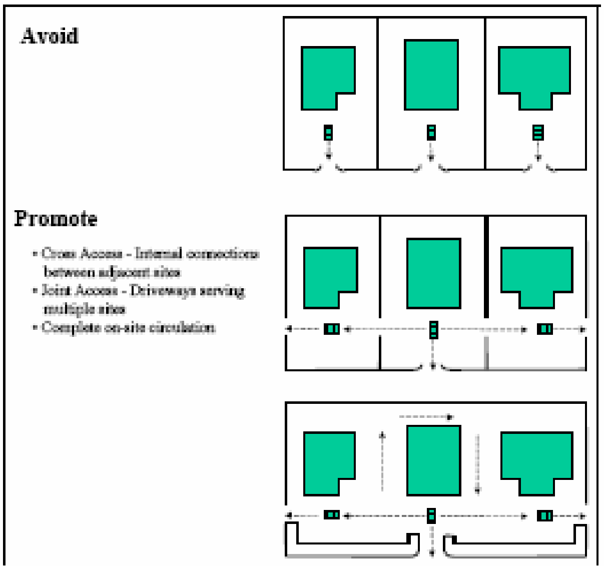


Figure 2.53: Shared commercial driveway recommendations (IDOT, 2000).

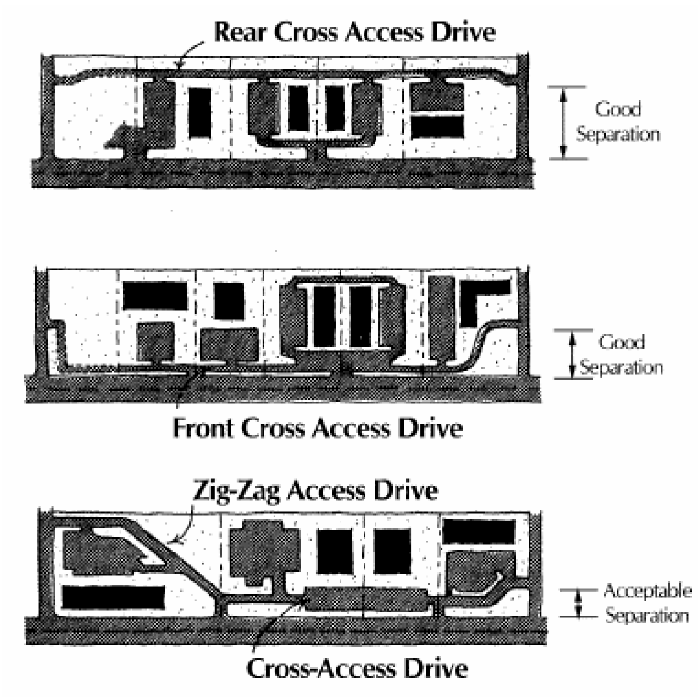


Figure 2.54: Cross access (CUTR, 1998).

f) Provide residential access through neighborhood streets

Residential access points on major roadways cause in dangerous conflicts between high-speed traffic and residents using this access points. Subdivisions should always be arranged providing residential access to lots fronting on major roadways (also defined as "reverse frontage") (Figure 2.55). A variation of this approach permits lot splits on arterials provided that shared driveway is used (CUTR, 1998) (Figure 2.56).

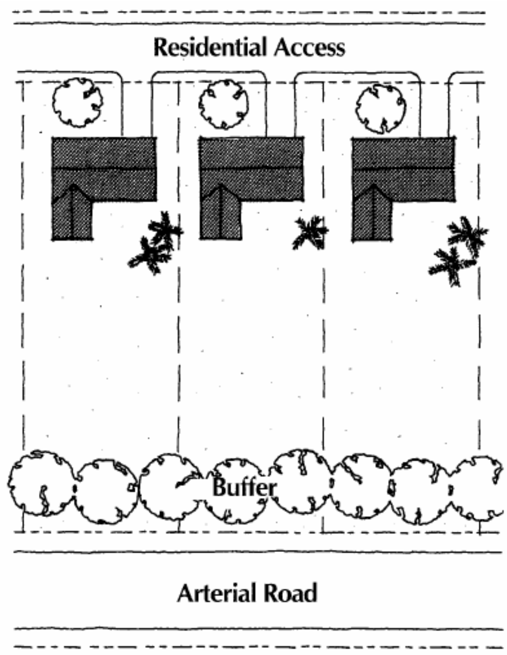


Figure 2.55: Reverse frontage (CUTR, 1998).

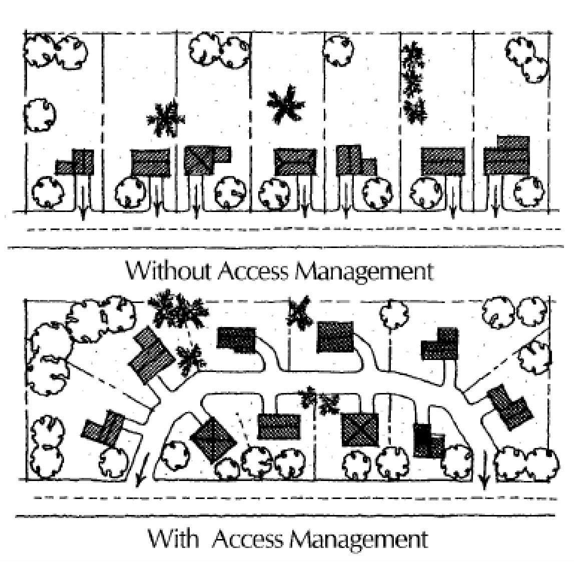


Figure 2.56: Shared access (CUTR, 1998).

Other potential for conflicts is flag lot.

> Some property owners subdivide their land into lots shaped like flags to avoid the cost of platting and providing a road. Instead, the flag lots are stacked on top of each other, with the "flag poles" serving as driveways to major roads (Figure 2.57). This results in closely spaced driveways that undermine the safety and efficiency of the highway (CUTR, 1998, p. 4-5)

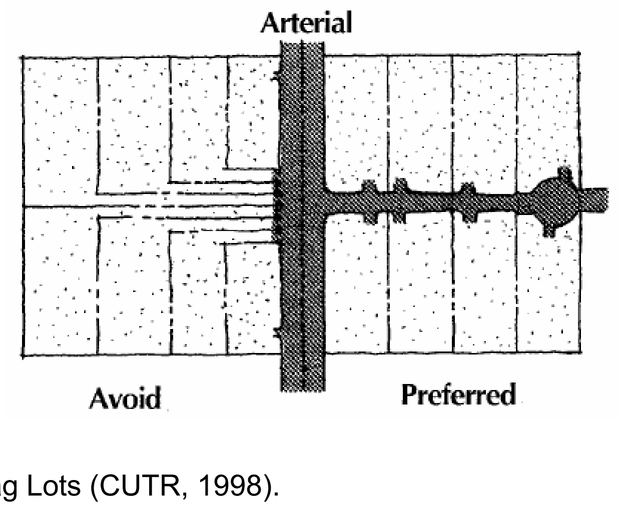


Figure 2.57: Flag Lots (CUTR, 1998).

2) Separate Conflict

Separating conflict points reduces traffic conflict. Effective ways include;

- providing minimum distances between intersections and driveways
- applying corner clearance standards that locate driveways away from the critical approach areas of intersections (MDOT, 1996).
- constructing a frontage road which provide multiple businesses to use one driveway (CUTR, 1998).

Locating driveways and connections relatively far from intersections reduces the number of conflict points and provides more time and space for vehicles to turn or to be added safely moving traffic. This distance between intersections and driveways is defined as corner clearance. Adequate corner clearance can also be provided by using a larger minimum lot size standarts for corner lots (CUTR, 1998) (Figure 2.58).

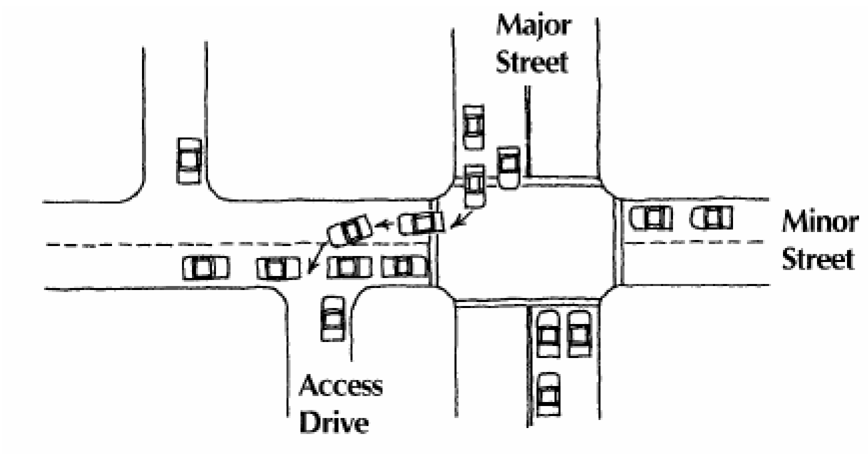


Figure 2.58: Inadequate corner clearance (CUTR, 1998).

3) Separate turning volumes from through movements

Vehicles typically slow before turning. When turning vehicles are removed from the main flow of traffic, traffic speed is better maintained. In addition to maintaining speed, roadway capacity is preserved and accident potential is reduced. The difference in speed between through vehicles and turning vehicles is also reduced, which also creates safer driving conditions (MDOT, 1996, p. 21).

Separating right and left turn lanes, median openings, and providing some conditions for driveways are tools for separating turning volume efficiently.

a) Right Turn Deceleration Lanes

Right turn lanes and tapers separate turning vehicles from through traffic. And they also reduce time which pass during through traffic allows turning vehicle to exit the arterial (Figures 2.59-2.60). Right turn lanes can be cost effective driveways which serve large developments, such as a medium-sized or larger shopping center. For lower-volume driveways, tapers may be used to separate turning vehicles from the roadway more quickly (IDOT, 2000).

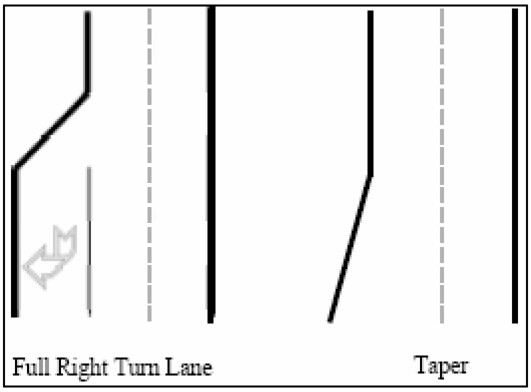


Figure 2.59: Right turn lanes (IDOT, 2000).

Figure 2.60: Right turn lane and taper (IDOT, 2000).

b) Left Turn Lanes

The left turn lane isolates the turning vehicle from through traffic and provides a safe area where the left turning vehicles can locate while waiting to make a turn. A left turn lane is required when arterial traffic reaches a specified volume. It reduces delay and conflict when left turning process being achieved and when autos behind the turning vehicle slowing down, stopping, or passing on the right of the turning vehicle. Median strip can also be used to control left turns (Figures 2.61-2.63) (IDOT, 2000).

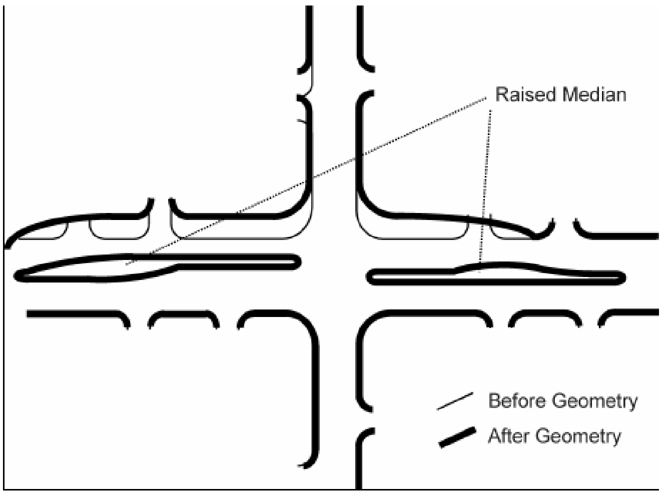


Figure 2.61: Left turn lane with raised median at intersection (IDOT, 2000)

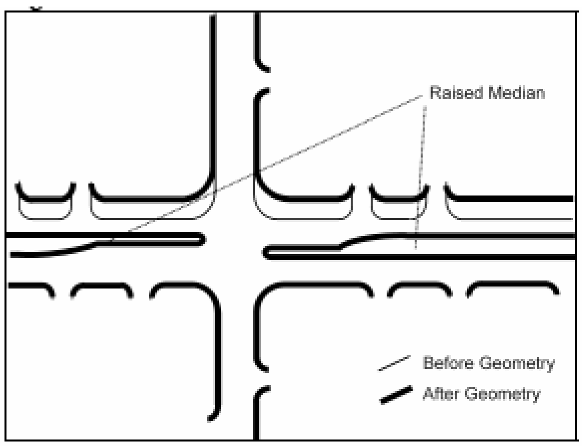


Figure 2.62: Left turn lanes with continuous raised median at intersection (IDOT, 2000).

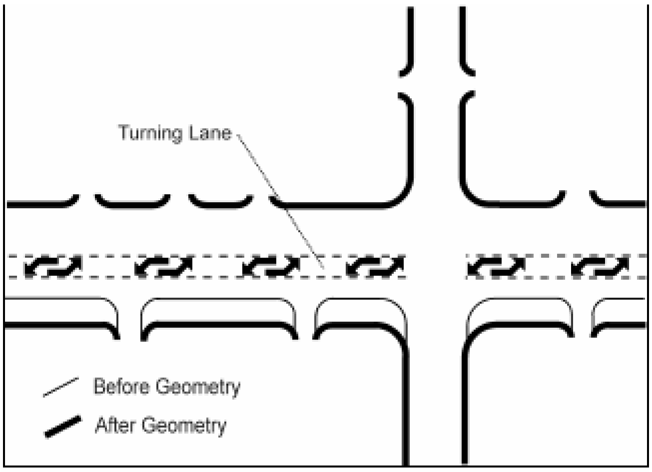


Figure 2.63: Continuous two-way left turn lane (IDOT, 2000).

4) Locate traffic signals to facilitate traffic movement

Poorly spaced and uncoordinated signals deteriorate the performance of arterial reducing traffic safety, road capacity and traffic speed. Providing an efficient signalization system is a part of access management (MDOT, 1996). MDOT (1996) proposes that distances of one-half mile or more distance is between signals are convenient.

5) Establish a hierarchy of roadways

Although few communities recognize the importance of a particular roadway function, it is a requirement to achieve goals of the access management. If basic function of the road is high speed, high volume or long distance travel, access function of the road is limited. On the contrary, the main function of local roads is to provide accessibility. Arterial and collector roads can be classified between these two. A typical road hierarchy is illustrated in Figure 2.64 (MDOT, 1996).

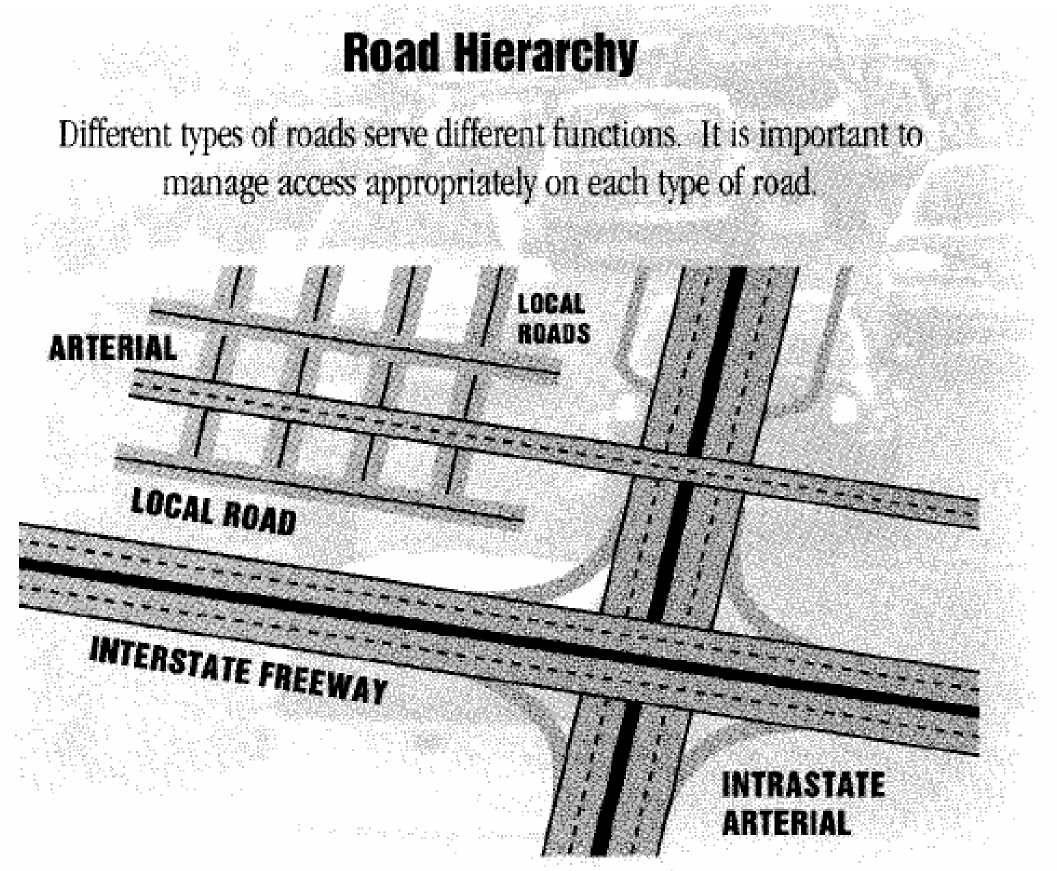


Figure 2.64: Road Hierarchy (MDOT, 1996)

6) Limit direct access on higher speed roads

The main achievement of access management is keeping the functional integrity of high speed, high capacity roads by limiting direct access to these roads. Limiting direct access also reduces crash risk and need for highway widening. “Providing direct access to these roads essentially confers a private benefit at great public cost. Only where no other alternative exists, should such a benefit be conferred”(MDOT, 1996, p. 24).

2.4.5 From Transit Accessibility Point of View: Transit Oriented Development (Transit villages)

2.4.5.1 Description

Transit oriented development (TOD) or transit village concept is a combination of ideas from the disciplines of urban design, transportation, and market economics (Cervero & Bernick, 1996).

It is an urban form which designed to maximize access by transit and nonmotorized transportation (VTPI, 2005h). Basically the transit village is a compact, mixed-use development, centered around the transit station. By design, TOD encourages residents, workers, and shoppers to drive auto less and ride mass transit more. The transit village spread roughly a quarter mile from a transit station which is a distance that can be travelled in about 5 minute by foot (Cervero & Bernick, 1996).

Density of TOD decreases gradually from its core to outwards. For example, TOD consists of a center which is a rail or bus station and surrounding relatively high-density development, with gradually lower-density going outwards. For example, TOD center or transit station can be surrounded firstly by a few multi-story commercial and residential buildings then several blocks of townhouses and small-lot single-family residential, finally larger-lot single-family housing can be located farther away (VTPI, 2005h)

TOD neighborhoods typically have a diameter of one-quarter to one-half mile (stations spaced half to 1 mile apart), which represents pedestrian scale distances (VTPI, 2005h; Cervero & Bernick, 1996).

Transit villages share many of the principles of traditional communities given below.

- a commercial center within walking distance of a majority of residential units,
- a well-connected gridiron street network,
- narrow roads with curb-side parking (to buffer pedestrians),
- back-lot alleys,

- mixed land uses, and
- varying styles and densities of housing.

Their distinguishing feature is that the train station and its close surroundings work as the focal point of community (Cervero & Bernick, 1996).

Additionally, it must emphasized that transit oriented development does not have only physical effect. It has social and economic dimensions. TOD provides people to make face to face contact. Today's auto-oriented communities isolate people by age and income and by confining them to their autos and security-controlled subdivisions. People feel themselves as a part of the community in TOD developments by means of attractive features (Cervero & Bernick, 1996).

2.4.5.2 Reasons behind supporting public transportation

Outcoming problems of increasing automobile dependence are basic reasons for supporting public transportation (also called as transit or mass transit). Because of auto travel, traffic congestion, air pollution, energy consumption, social inequity etc. increase. Details of these items are given below.

Traffic congestion

Public transportation is one of the possible alternatives to road expansion for reducing traffic congestion. Highway departments have realized that building highway out of congestion is not possible. New roads or expanded roads only provide temporary relaxation. New capacity attracts new demand, which is called by planners induced demand. Because, after opening new road people changes their routes to benefit advantages of new road. So, the road reaches it capacity again in a short time. As for transit, it can induce modal shifts with concentrated development around transit nodes. Replacing auto trips with transit trips can help reducing traffic congestion along corridors served by rail. In this perspective, it can be accepted that transit village development is a type of transportation demand management (Cervero & Bernick, 1996).

Air quality

Air pollution is very important effect of auto dependence issue. It causes to think about alternative solutions to auto travel. Cervero and Bernick (1996) state that air pollution is largely result of auto-dependent developments; they also express that more than 100 U.S. cities have serious air pollution problems (Cervero & Bernick, 1996).

Energy Conservation

In spite of existing of far more fuel efficient vehicles today than before, decrease in energy consumption cannot be achieved because these gains have been offset by increasing traffic volumes and lengthening trip distances (Cervero & Bernick, 1996). Transit villages could save energy in two ways. First one, more compact development, in theory, should shorten distance between origin and destination. And second one, exchange of some auto trips to mass transit should lower per capita energy consumption. Furthermore, using nonpetroleum energy sources for electrical power need of rail transit is another advantage of mass transit. Because, it relieves nation's dependence on foreign countries (Cervero & Bernick, 1996).

Neighborhood revitalization

Transit villages provide opportunity to revitalize undeveloped neighborhoods served by rail. It invites private investments with its capability of attracting people regularly to transit nodes. So transit oriented development offers a new approach to induce economic growth (Cervero & Bernick, 1996).

Public safety

One another positive side of mass transit is public safety. Residents think that the transit village is a secure and safe place to live.

> Because, residents themselves are the most valuable asset in this regard. They become the eyes of the community 24 hour a day. Many districts surrounding transit stations are perceived as unsafe places in part because they are often vacated after 6 p.m. and on weekends.(Cervero & Bernick, 1996, p.10-11).

Alternative suburban living and working environments

Transit villages give chance to live in suburban area without being dependent on automobile and with availability of services and activities which belong to city life. Besides that, transit villages offer different housing choices which serve different income group and different life style."The diversity of housing in transit villages can mean a much needed increase in the stock of affordable housing" (Cervero & Bernick, 1996, p. 9).

Pedestrian friendliness

Transit villages are pedestrian friendly areas with

- mixed land uses,
- vertical mixed use buildings,
- narrow tree-lined streets,
- wide sidewalks, (Cervero & Bernick, 1996).

Social Equity

Auto oriented developments create social inequity by separating significant segment of society isolating physically and socially. Those who are too poor, disabled, young, or old to own or drive an automobile are devoid of many activities which require auto travel (Cervero & Bernick, 1996).

Quality of life

Cervero and Bernick (1996) claim that the least articulated but most deeply felt reason for many Americans to support mass transit is feeling that something is seriously absent in suburbia. They also states that many people now feel that the city's problems have also migrated to the suburbs and consequently, quality of life in suburban is rapidly deteriorating.

2.4.5.3 The built environment and the demand for transit

Density and compactness

As origins and destinations spread over a region, people more likely access to an automobile than take a transit. So, low density developments are not proper for transit (Cervero & Bernick, 1996).

From their study of 46 major cities around the world, Newman & Kenworthy et al., (1999) reach a conclusion that

> the more centralized is the city in terms of both population and jobs, the less auto dependent it will be and the less transportation energy it will use...... As cities become denser and more centralized, the efficiency with which transportation energy is burned increases markedly. Likewise, the energy consumed per passenger kilometer within the public transportation system diminishes systematically as cities become denser and more centralized. There are two main reasons for this. First, the cities tend to become more rail oriented, which is the most efficient mode of public transportation and the loadings on all transit modes tend to increase with increasing density and centralization (p. 580).

It is possible to see these results from below graphs. When the graps about urban density, private passenger transportation energy use, vehicle kms per person, modal split, transit service and use according to city groupings are investigated, it is seen that as density increases, per capita energy use and per capita automobile use decrease, while the per capita transit service and use increase (Figure 2.65-2.66-2.67-2.68-2.69)

Metropolitan density

As shown in the Figure 61, the US and Australian cities which are the most auto oriented cities in the investigated cities also have the lowest densities.

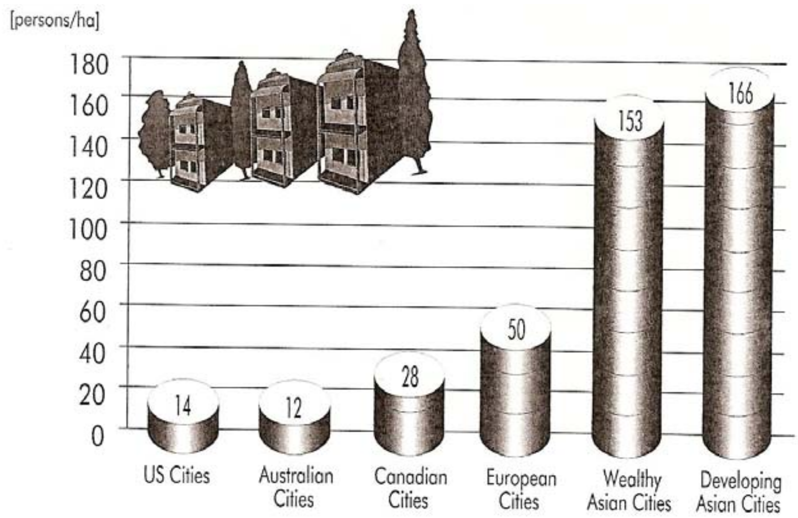


Figure 2.65: Urban density by city groupings, 1990 (Newman & Kenworthy et al., 1999)

Private passenger transportation energy use

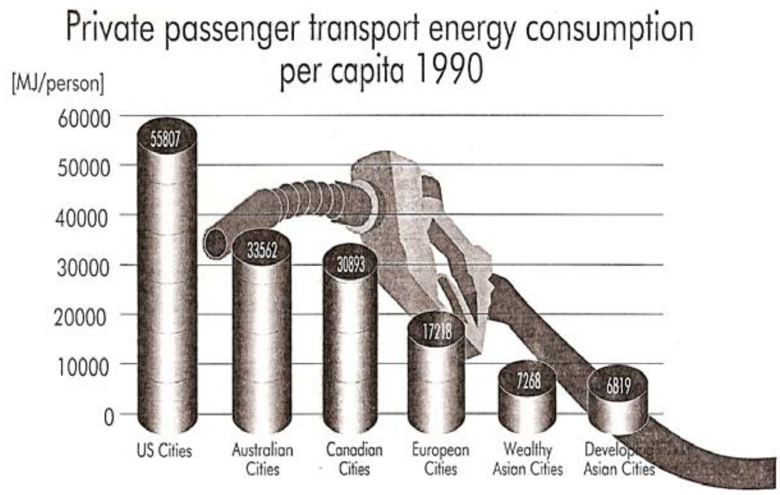


Figure 2.66: Private transportation energy consumption per capita by city groupings, 1990 (Newman & Kenworthy et al., 1999)

Vehicle ownership and use

The most basic indicator of automobile dependence in cities is vehicle ownership and use.

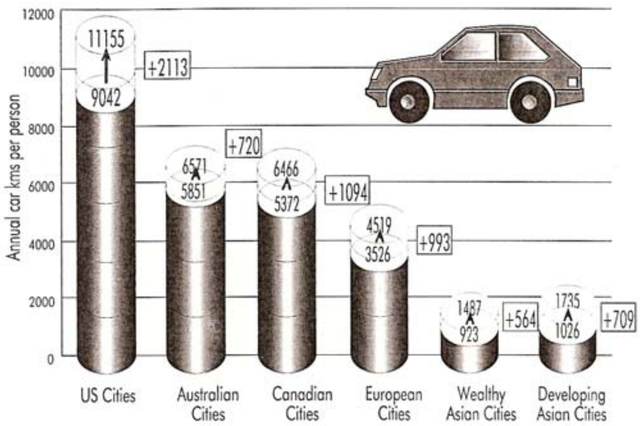


Figure 2.67: Trends in auto use per capita by city groupings, 1980-1990 (Newman & Kenworthy et al., 1999)

Modal split for to journey to work

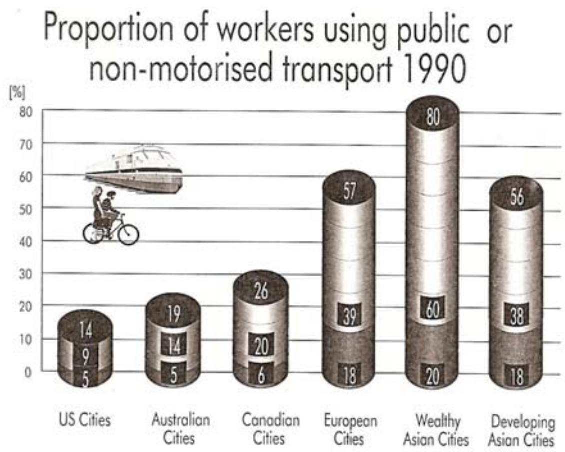


Figure 2.68: Proportion of work trips undertaken by transit and non-motorised modes by city groupings (transit top part of columns, walking and cycling lower part) (Newman & Kenworthy et al., 1999)

Public transportation service and use

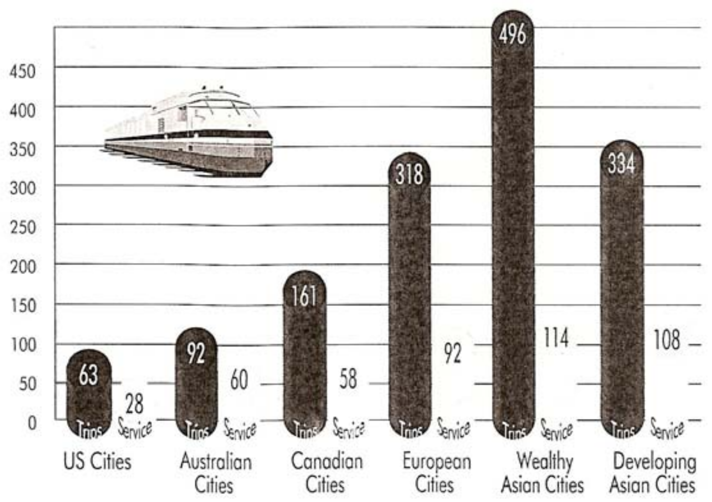


Figure 2.69: Transit trips per capita and vehicle kilometers of service per capita by city groupings (Newman & Kenworthy et al., 1999)

The significance of the density factor can be seen also in the below graphs which show automobile kms per capita versus urban density (Figure 2.70) and public transportation modal split versus urban density (Figure 2.71).

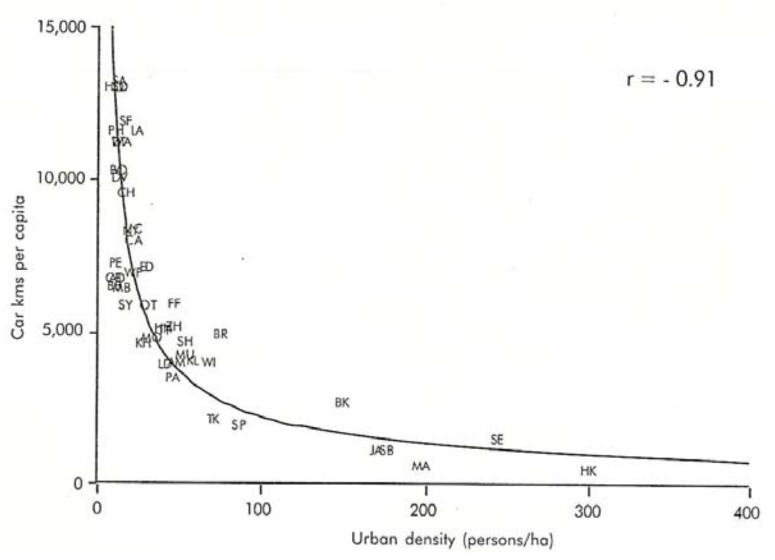


Figure 2.70: Auto use per capita and urban density in global cities (Newman & Kenworthy et al., 1999)

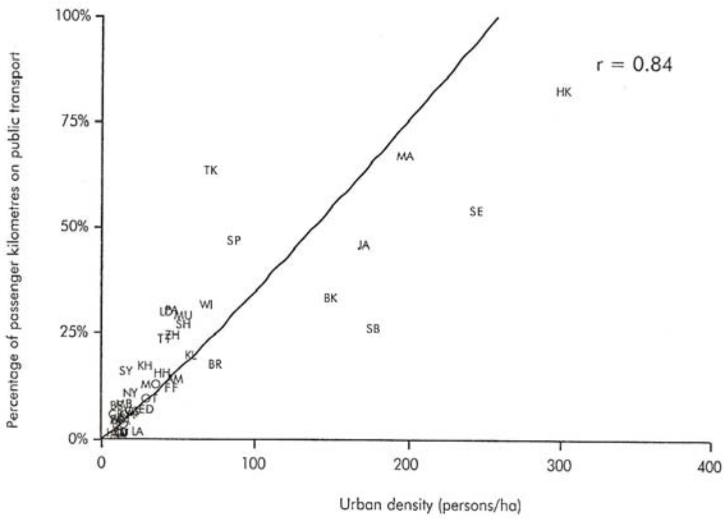


Figure 2.71: Public transportation modal split and urban density in global cities, (Newman & Kenworthy et al., 1999)

Reasons why transit use increases with rising density

Pushkarev and Zupan (1977) explain the transit use depending on auto ownership, residential density, nonresidential density, and distance from downtown.

Auto ownership

They asserted that the vehicle ownership could make greatest difference in transit use. However, the number of autos owned by households depends on development density and transit service besides family income and the number of persons of driving age:

- Higher residential density tends to lower auto ownership: When households of the same income and size are compared, ten times increase in residential density results a decrease in auto ownership about 0.4 autos per household. Because in dense areas, auto parking and use are less convenient and costly and also there are alternative ways of travel including walking.

- The presence of rail transit further decreases auto ownership: Effect of a nearly located rapid transit station is equal to a tenfold increase in residential density.
- Auto ownership is also affected by destination of the trips in such a way that, two households who live in the same density might own different number of autos depending on density of workplace they work.

In addition to auto ownership, two further factors influence transit use:

- the density of the nonresidential destination: as nonresidential density increases, auto owners more likely to use transit and
- the quality of transit service: availability of commuter rail, proximity to a rapid transit station, and the frequency of bus service encourage auto owners to public transport.

Nonresidential density

According to Pushkarev and Zupan (1977), the density of nonresidential area or downtown is most important for transit use, because of its multiple effects of reducing auto ownership of commuters, restricting auto use, and providing convenient transit service in two ways:

- by high frequency of transit service which is necessary to serve large numbers of riders
- by short access walks by means of compact land use arrangement.

As a summary, they emphasize that "high residential density by itself does little for transit if there is no dominant place to go". (p. 174)

Findings of Newman & Kenworthy et al. (1999) confirm the study of Pushkarev and Zupan (1977) through below graphs. In Figure 2.72, proportion of jobs in the central business district and the inner area is shown by city groupings. If this figure is compared with Figure 2.68 and Figure 2.69, it is seen that US, Australian, and Canadian cities which have relatively low proportion of jobs in CBD and inner area have less transit usage than European, Wealthy Asian, and Developing Asian Cities which have relatively high proportion of jobs in CBD and inner area.

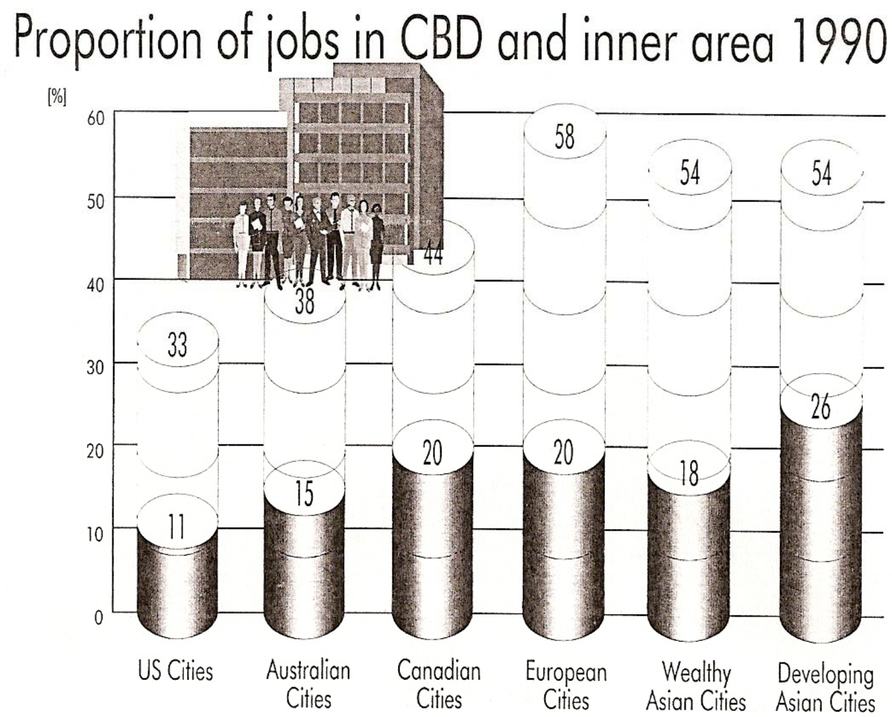


Figure 2.72: Proportion of jobs in the central business district and the inner area by city groupings, 1990. (Note: the lower figure refers to the proportion of jobs in the central business district, whereas the higher figure refers to the proportion of jobs in the inner area (including the central business district)) (Newman & Kenworthy et al., 1999).

Additionally, Figure 2.73 shows the relationship between the centralization of jobs in the inner area and the proportion of the city's workforce who take transit to work. From Figure 2.73, it is apparent that the centralization of jobs causes higher transit use to work for the entire metropolitan workforce.

Distance effect

Pushkarev and Zupan (1977) state that the distance between a particular residential area and a nonresidential destination is a very important factor for transit usage. They also claim that "the willingness to make trips falls off very sharply with distance. As a result, trips to a downtown will be found in large numbers only from fairly close proximity to that downtown" (p. 173).

As a result, the density (which usually depends on size) of non-residential concentration is most important factor for public transportatipon, then distance from it, then residential density.

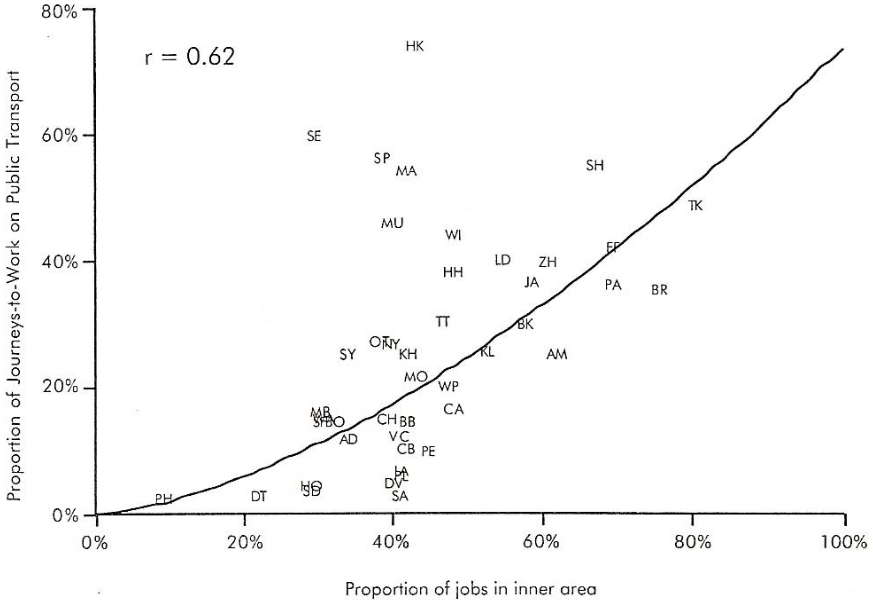


Figure 2.73: Job centralization in the inner city and mode split to transit for the journey to work, 1990 (Newman & Kenworthy et al., 1999).

Density effects on Light Rail Transit (LRT) Commuter Rail and Heavy Rail (Metro) Demand

Density effects on Light Rail Transit

Cervero and Zupan (1996a) performed an analysis which includes the data of 19 light rail lines having a total of 261 non-CBD stations across 11 U.S. cities which are Baltimore, Boston, Buffalo, Cleveland, Los Angeles, Philadelphia, Pittsburgh, Portland, Sacramento, San Diego, St. Louis.

Figures from 2.74 to 2.76 show the predicted boardings at stations for different values of the variables. In each graph distance to the CBD is shown on the x-axis and predicted boardings are shown on the y-axis for a family of lines. For each graph all variables held constant except one to determine how much change is produced by the variations.

Figure 2.74 compares ridership for different CBD employment densities. As seen from graph higher density result a large increase in ridership. The influence is more exaggerated near the core.

In Figure 2.75 independent variable is residential density. Here the residential density has a notable effect. It can be seen from graph that as density increase, the number of daily boarding increase dependently. For example densities of 20 people per acre generate about two times the number of riders generated by densities of 10 people per acre at 10 miles distance to CBD.

The impact of access modes which are used to reach station is shown in Figure 2.76. For light rail stations the greater effect belongs to feeder buses on ridership level than the availability of parking and naturally, providing both feeder buses and parking has the greatest effect.

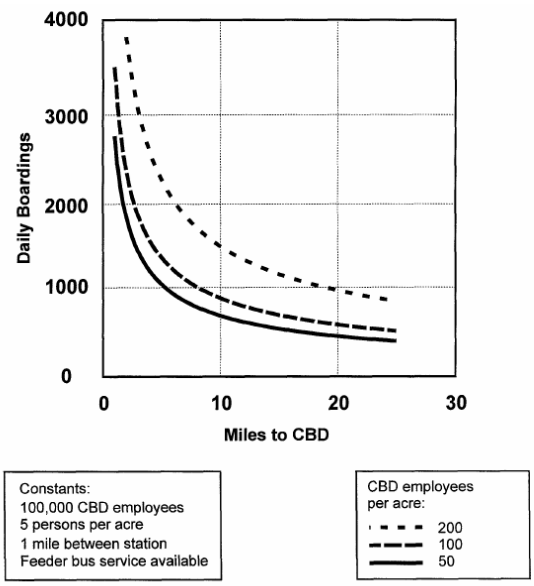


Figure 2.74: Light Rail Station Boardings by Distance to the CBD and CBD Employment Density (Cervero and Zupan, 1996a).

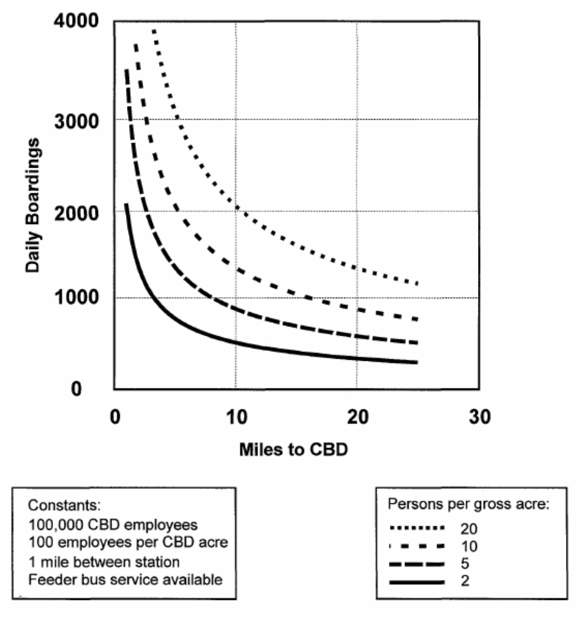


Figure 2.75: Light Rail Station Boardings by Distance to the CBD and Residential Density (Cervero and Zupan, 1996a).

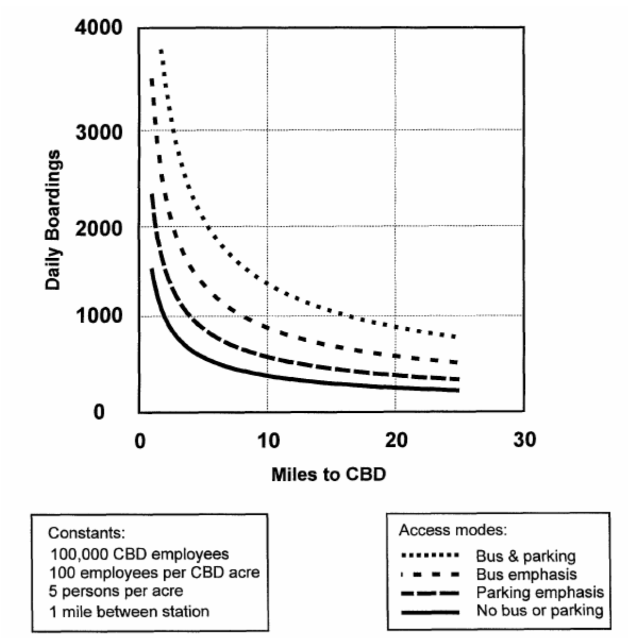


Figure 2.76: Light Rail Station Boardings by Distance to the CBD and Access modes (Cervero and Zupan, 1996a).

Density effects on Commuter Rail

Cervero and Zupan (1996a) performed also an analysis which includes the data of 47 commute rail lines and 550 stations across 6 U.S. cities which are Boston, Chicago, Los Angeles, Philadelphia, San Francisco, Washington.

Figures from 2.77 to 2.79 show the commuter rail station ridership for different values of the variables. In each graph distance to the CBD is shown on the x-axis and predicted boardings are shown on the y-axis for a family of lines. For each graph all variables hold constant except one to determine how much change is produced by the variations. In all cases the concave shape of the curves represents the rising ridership with distance until about 35 miles, after 35 miles it begins to fall.

Figure 2.77 shows that as CBD employment density increases daily boardings for commuter rail increase largely. The effect for commuter rail is greater than the effect for light rail.

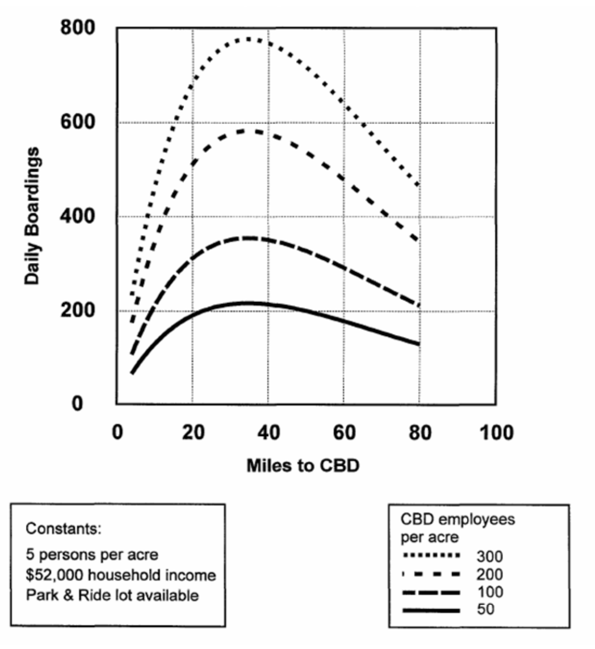


Figure 2.77: Commuter Rail Station Boardings by Distance to the CBD and CBD Employment density (Cervero and Zupan, 1996a).

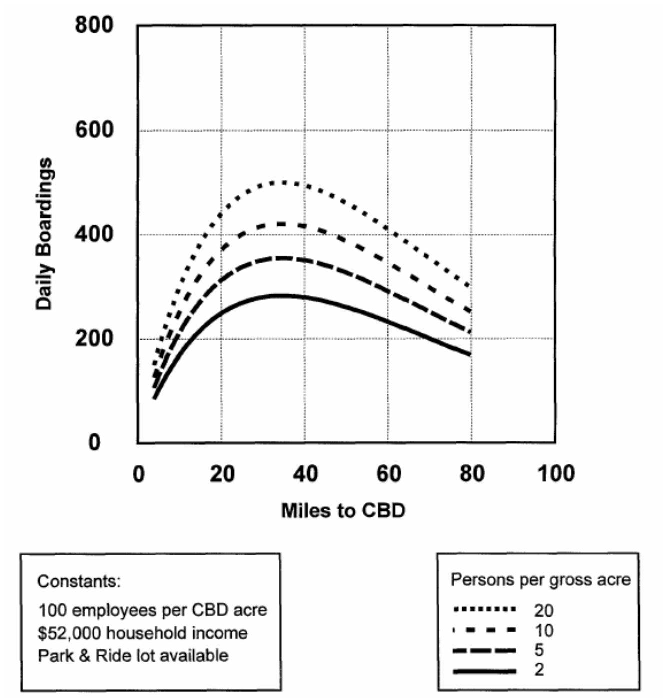


Figure 2.78: Commuter Rail Station Boardings by Distance to the CBD and Residential density (Cervero and Zupan, 1996a).

Lastly, Figure 2.79 indicates the impact of access modes available at commuter rail stations on ridership. Access modes are much more effective for commuter rail than it was for the light rail and parking availability effect ridership more than feeder buses for commuter rail different from light rail (Cervero and Zupan, 1996a).

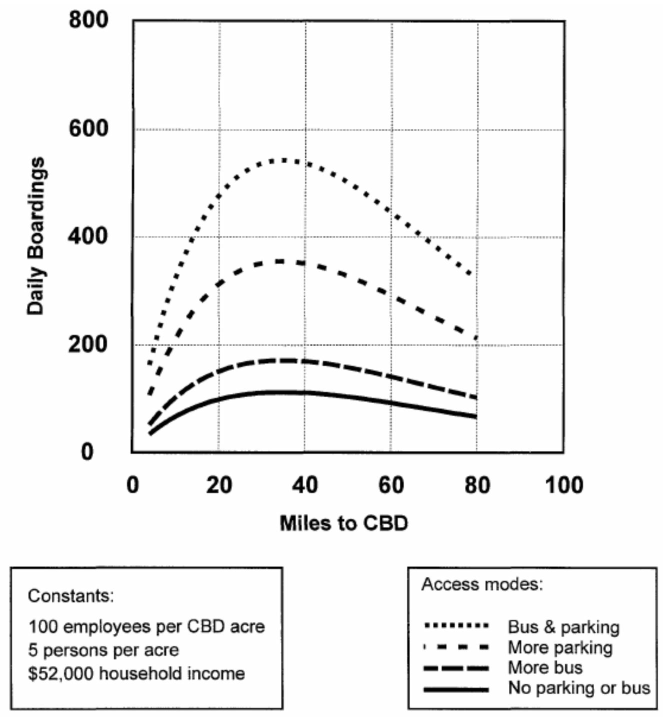


Figure 2.79: Commuter Rail Station Boardings by Distance to the CBD and access modes (Cervero and Zupan, 1996a).

Density effects on heavy rail: The case of Bay Area Rapid Transit (BART)

Another demand model analysis study was developed by Robert Cervero using 1990 ridership and land use data for the 34 BART stations (shown in Figure 2.80) in Cervero and Bernick (1996). BART's average catchment area (from where primary transit ridership is captured) is denoted as 90 mi^2 with radius of about 7 mi.

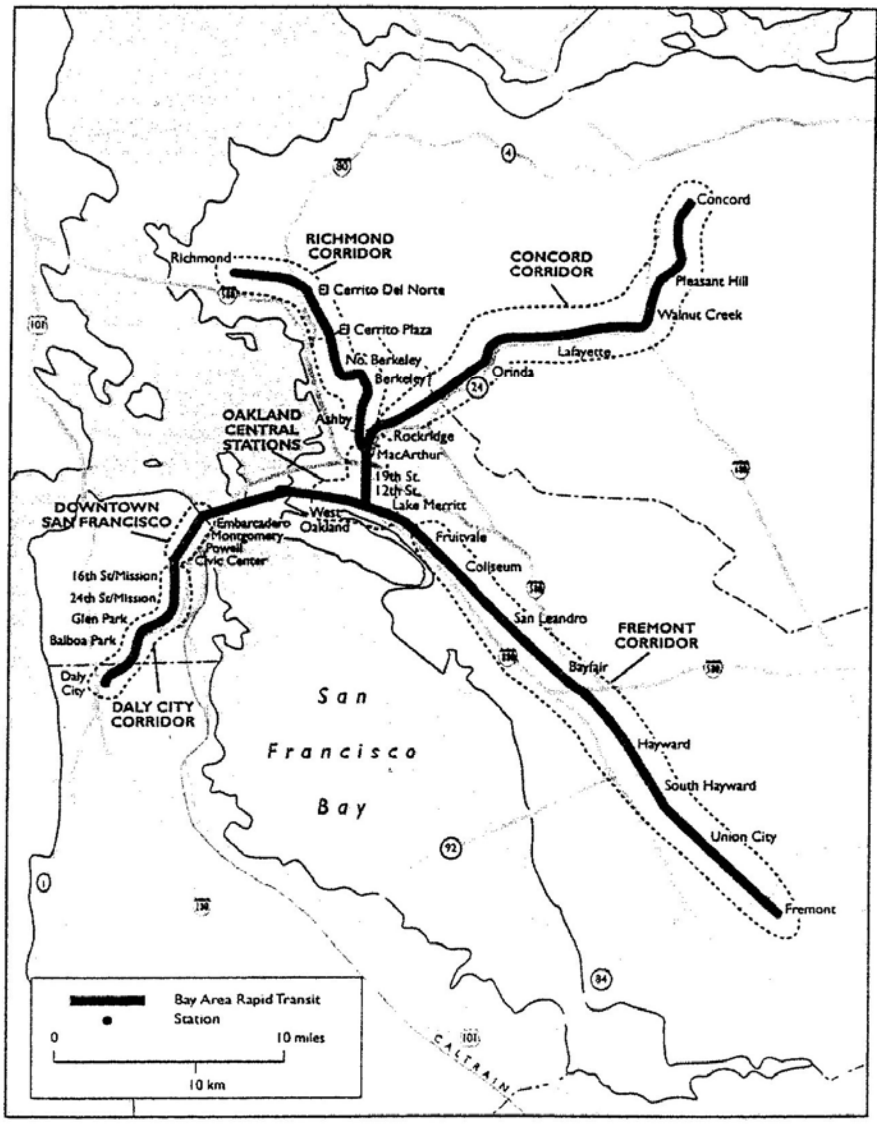


Figure 2.80: Bay Area Rapid Transit System (BART), 1995, (Cervero & Bernick, 1996)

According to study, BART ridership rise with population and employment densities (within 2 mi of stations). On average, an increase of 10 workers per acre for a radius of 1 to 2 mi of a BART station results an increase in the weekday turnstile counts entering and leaving the station by 6.5 per 1000 catchment population. Additionally an increase of 1000 inhabitants per square mile results an increase of 8 more rail trips per 1000 residents on average (Cervero & Bernick ,1996).

In the Figure 2.81, the impacts of employment densities on ridership are plotted for three different fare scenarios-$1, $2, and $3 fares to downtown San Francisco. The Figure 2.81 shows that ridership rates rise with employment densities and fall with price. (Cervero & Bernick ,1996).

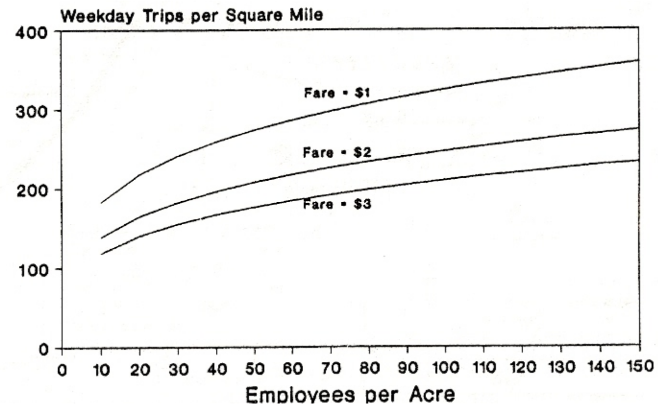


Figure 2.81: BART Weekday Rail Trips Per Square Mile of Catchment Zone by Employment Density and Fare to San Francisco's CBD, (Cervero & Bernick, 1996).

Relationship is stronger as a function of population densities, as seen in Figure 2.82.

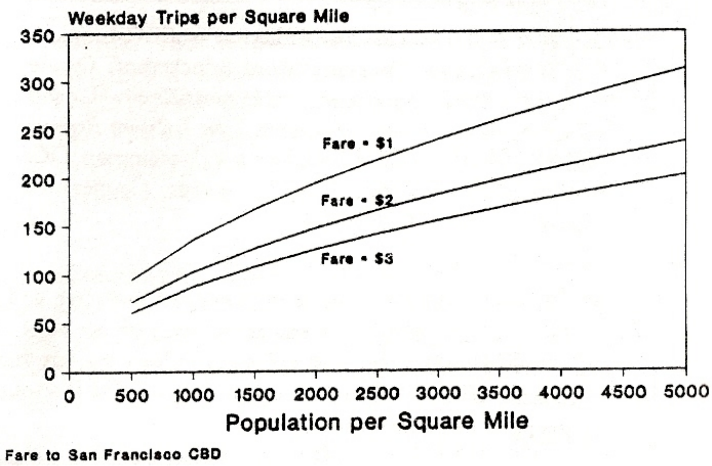


Figure 2.82: BART Weekday Rail Trips Per Square Mile of Catchment Zone by Population Density and Fare to San Francisco's CBD, (Cervero & Bernick, 1996).

Land use diversity

Land use mix or land use diversity is a part of TOD. Cervero and Bernick (1996) explain the effect of land use mix on public transportation as below:

- Mixed land uses can encourage people to walk or ride to various destinations instead of making auto travel.

- Mixed land uses also enable to use resource efficiently. For example; shared parking provides using less area for parking purpose.

- Locating retail shops, restaurants etc. near suburban employment center allow people to walk or cycle to these destinations during lunch time. Eliminating necessity of auto usage in the midday might also cause people to choose public transportation instead of driving to work. Because they do not need automobile to perform midday activities.
- If the same amount of floorspace is used for multiple purposes such as offices, shops, and residences, trips would be spread uniformly throughout the day and week. This reduces the amount of peak road capacity required. Furthermore the savings from this policy can be benefited by transit operators. Balanced land use causes balanced, bidirectional traffic flows. So, buses and trains will serve more fully and efficiently instead of being near empty as in the case of residences and workplaces located in the two poles of a particular region (Cervero and Bernick, 1996).

- Another form of mixed land uses that is a part of the transit village concept is a balance of jobs and housing. Jobs-housing balance reduces vehicle miles of travel (VMT), freeway traffic and tailpipe emissions by means of shortening commute trips. (Cervero, 1989)

Application of mixed use near rail station is called TS-M (transit station-mixed).TS-M includes a wide range of commercial, service, and residential uses which serve transit users and residents in the area.

The purpose of the TS-M zone is to:

a) Promote the optimum use of transit facilities by providing the orderly development near transit station and improving both vehicular and pedestrian access;
b) Provide for the basic requirements of the workers and residents of transit station areas;
c) Provide for the minor shopping needs of travelers at stations.
d) Minimize the dependence on automobile transportation by providing, residential areas, the retail commercial uses and professional services at station area to contribute to the self-sufficiency of the community. (Cervero and Bernick, 1996).

Related studies about land use mix

From their study of 50 neighborhoods in the San Francisco Bay Area, Cervero and Kockelman (1997) concluded that pedestrian-friendly environments and the existence of convenience retail shop within a quarter mile of residences induce commute trips via transit and non-motorized modes, especially controlling factors like trip distance and transit service quality.

Cervero (1988) performed a study which investigates the effects of developing mixed use suburban workplaces on commuting choices of suburban workers.

He found that if all other factors are equal, increasing share of total floorspace for office by 20 percent in a suburban employment center, leads to 2.4 percent higher share of work trips made by solo commuter. So, it is stated in his study that single-use office environments encourage automobile travel and it is also suggested that as the amount of retail space per employee in reasonable proximity to a suburban center increases, automobile dependency of suburban workers decreases (Cervero, 1988).

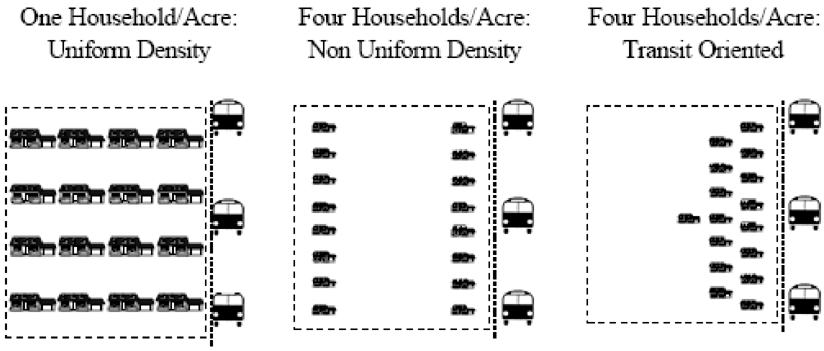
Similarly, Cervero (1991) conducted another study which investigates effects of single/mixed use buildings to travel behavior in suburban employment centers including six U.S. metropolitan areas.

As a result he concluded that:

- Mixed-use buildings encourage ridesharing reducing auto need owing to availability of on site retail.
- Existence of a retail component within a suburban office building can decrease vehicle-trip rates per employee by about 8 percent
- Transit share is greater in mixed-use and multi-story buildings. (Cervero, 1991)

2.4.5.4 Transit supportive design

One of the basic principles of TOD is focusing residential and commercial developments around existing stations (or bus stops) as a result of which transit rideship level increases. Figure 2.83 explain this idea with three different configurations of development patterns with varying levels of transit access. The area of every development pattern is 1 square mile with 640 households. Although overall density of the three development patterns is equal, they have very different levels of transit accessibility. The difference between average transit access distances amount to nearly eight minutes of extra walking time (Eash, nd).



Households	640	640	640
Area/Household	One Acre	Quarter-Acre	Quarter-Acre
Average Transit Access Distance	0.63 miles	0.63 miles	0.24 miles
Households < 0.5 Miles From Transit	220	320	640

Figure 2.83: Changing transit accessibility with varying development patterns (Eash, nd)

Pushkarev and Zupan (1977) explain transit supportive land uses through comparative examples.

- *Clustering or dispersing nonresidential space*:

If it is assumed that 10 million square feet nonresidential space is added to a growing urban area.

- One option is to create two different highway oriented nonresidential clusters, each 5 million square feet in size.
- Another is to create a unique new downtown of 10 million square feet.

In the second case, per capita transit trips within a 3 to 5 mile radius will be 50 to 70 percent higher than the trips generated from first option, in the case of same residential density.

- *Enlarging downtown size or raising nearly residential density*:

Assume;

- first option is increasing the size of a downtown from 10 to 20 million square feet,
- second option is increasing the residential density from 15 to 30 dwellings per acre within a few miles distance.

The first option generates per capita transit trips by three to four times higher than second option.

- *Increasing residential density near downtown or farther away*:

Assume there is a downtown of 10 million square feet; if the residential density is increased from 5 to 10 dwellings per acre within one mile of downtown, this will generate seventeen times higher trips than in the case of increasing residential density at a distance of 10 miles from downtown.

- *Scattering apartments or concentrating them near transit*:

Assume a rapid transit station is located 5 miles from a downtown of 50 million square feet of nonresidential floorspace. At a density of 15 dwellings per acre, the square mile surrounding the station will generate about 620 transit trips a day to the downtown.

- If the density of development is increased adding new apartments by 20 percent throughout the square mile, this will increase amount of transit trips by about 24 percent.
- If the apartments are clustered within 2000 feet of the station, keeping the rest of the neighborhood constant, transit trips will increase by 34 percent or more (Pushkarev and Zupan, 1977).

- *Downtown size and residential density related to public transportation*

Clustered nonresidential floorspace in downtowns and other compact development patterns are most effective land use policies for public transportation. For example, downtowns of 10 million square feet of gross nonresidential floorspace which is confined within less than 1 square mile begin to make moderately frequent bus service feasible and to attract sufficient proportion of trips by transit. However, downtowns which have 5 millions square feet of nonresidential floorspace can support only inadequate bus service. Clusters of nonresidential floorspace which are spread in suburban can only occasionally support inadequate bus service, i.e., provided that they contain shopping centers and residential area having density of about 7 dwellings per acre (Pushkarev and Zupan, 1977).

Newman, Kenworthy et. al. (1999) confirm findings of Pushkarev and Zupan (1977). Newman, Kenworthy et. al. (1999) express that very high job density in the CBD as in Toronto, New York, Tokyo etc., is strongly related to the presence of a high capacity rail network and similarly in the developing Asian cities, weak rail systems and dependence on low capacity and slow buses, cause to expand the CBD so as to maintain adequate accessibility.

As a result, according to Pushkarev and Zupan, (1977) residential density is less important for transit use than residential location, i.e., proximity to a downtown of substantial size or proximity to a rail transit line. If greater transit use is the goal, it is more important to put housing close to a downtown than to make it high density (p. 177)

The residential densities or downtown size required for associated transit service are given in the Table 2.3 and Table 2.4.

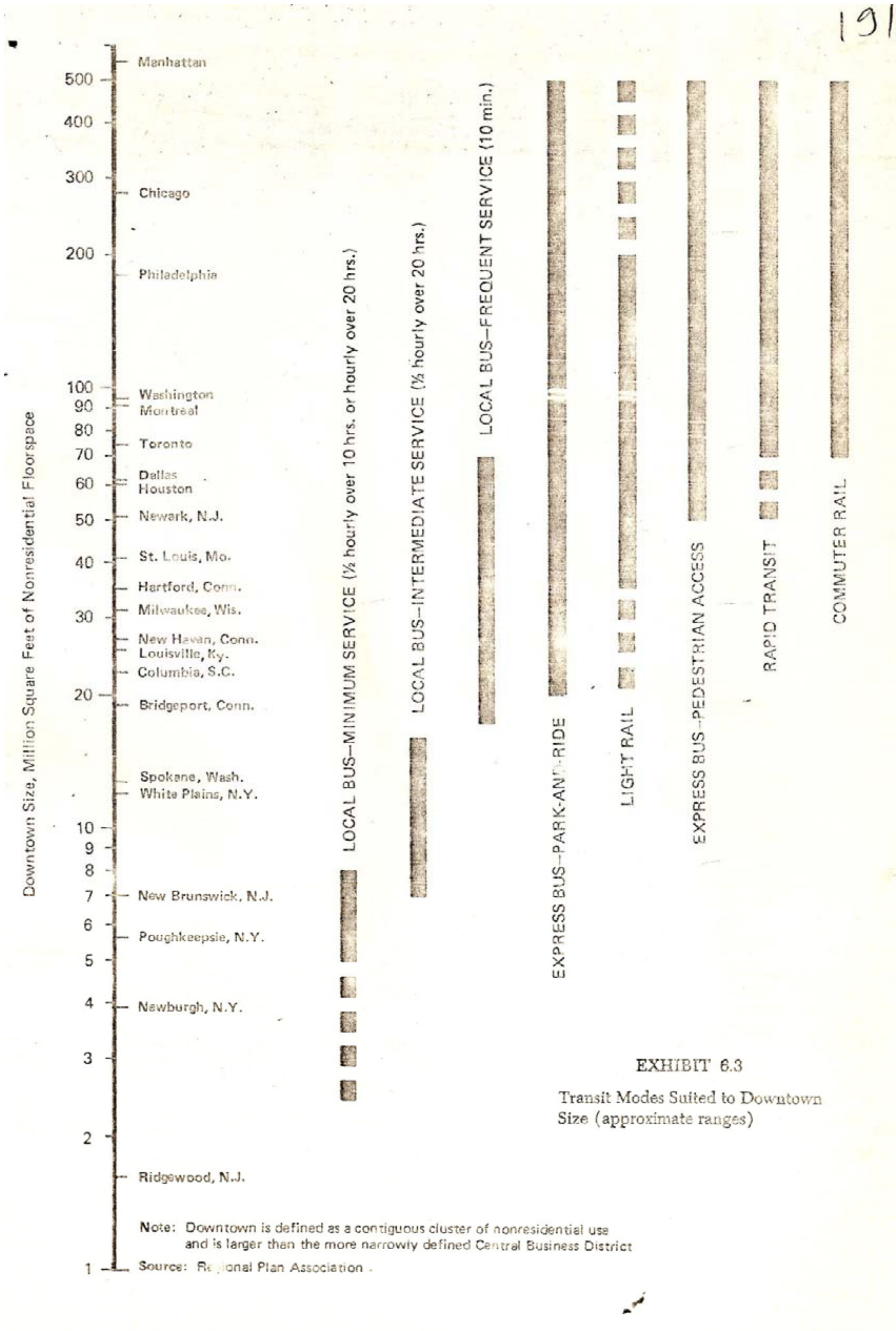
Table 2.3: Transit modes related to residential density (Pushkarev and Zupan, 1977).

Transit Modes Related to Residential Density

Mode	Service	Minimum Necessary Residential Density (dwelling units per acre)	Remarks
Dial-a-bus	Many origins to many destinations	6	Only if labor costs are not more than twice those of taxis
Dial-a-bus	Fixed destination or subscription service	3.5 to 5	Lower figure if labor costs twice those of taxis; higher if thrice those of taxis
Local bus	"Minimum," ½ mile route spacing, 20 buses per day	4	
Local bus	"Intermediate," ½ mile route spacing, 40 buses per day	7	Average, varies as a function of downtown size and distance from residential area to downtown
Local bus	"Frequent," ½ mile route spacing, 120 buses per day	15	
Express bus —reached on foot	Five buses during two hour peak period	15 Average density over two square mile tributary area	From 10 to 15 miles away to largest downtowns only
Express bus —reached by auto	Five to ten buses during two hour peak period	3 Average density over 20 square mile tributary area	From 10 to 20 miles away to downtowns larger than 20 million square feet of non-residential floorspace
Light rail	Five minute headways or better during peak hour.	9 Average density for a corridor of 25 to 100 square miles	To downtowns of 20 to 50 million square feet of nonresidential floorspace
Rapid transit	Five minute headways or better during peak hour.	12 Average density for a corridor of 100 to 150 square miles	To downtowns larger than 50 million square feet of nonresidential floorspace
Commuter rail	Twenty trains a day	1 to 2	Only to largest downtowns, if rail line exists

Source: Regional Plan Association

Table 2.4: Transit modes suited to downtown size (Pushkarev and Zupan, 1977).



Cervero and Zupan (1996b) explain effects of urban form through below items;

- "Compact regions with a limited number of subregional centers linked by transit can also support high transit ridership" (p. 5).

- "Subregional employment centers in rail transit corridors also have high levels of transit use. They provide bidirectional flows on the transit system" (p. 6)

- "Concentrating both origins and destinations in rail transit corridors dramatically increases transit use." (p. 8)

Cervero and Bernick (1996), determine the basic design principles of transit oriented development based on 1993 survey across the United States and Canada containing 26 examples of completed design guidelines.

Besides having compact and diverse land use, transit-supportive designs contain the following types of treatments:

- Continious and direct physical connections between major activity centers to minimize distances to transit stops (Figure 2.84).
- A gridlike street pattern that is supportive for direct bus routing and accessibility of transit rider; avoiding cul-de-sacs, and other curvilinear alignments that create long walking paths and force buses to extend their routes.
- Minimizing off-street parking supplies; where land costs are high, creating alternatives such as parking under buildings or at the back of buildings instead of in front.
- Providing pedestrian facility with attractive landscaping, varying building height, texture continuous and paved sidewalks, street furniture, and safe pedestrian crossing, etc.
- Proper arrangement of transit shelters, benches, and route information.
- Creating public open spaces (Cervero & Bernick, 1996).

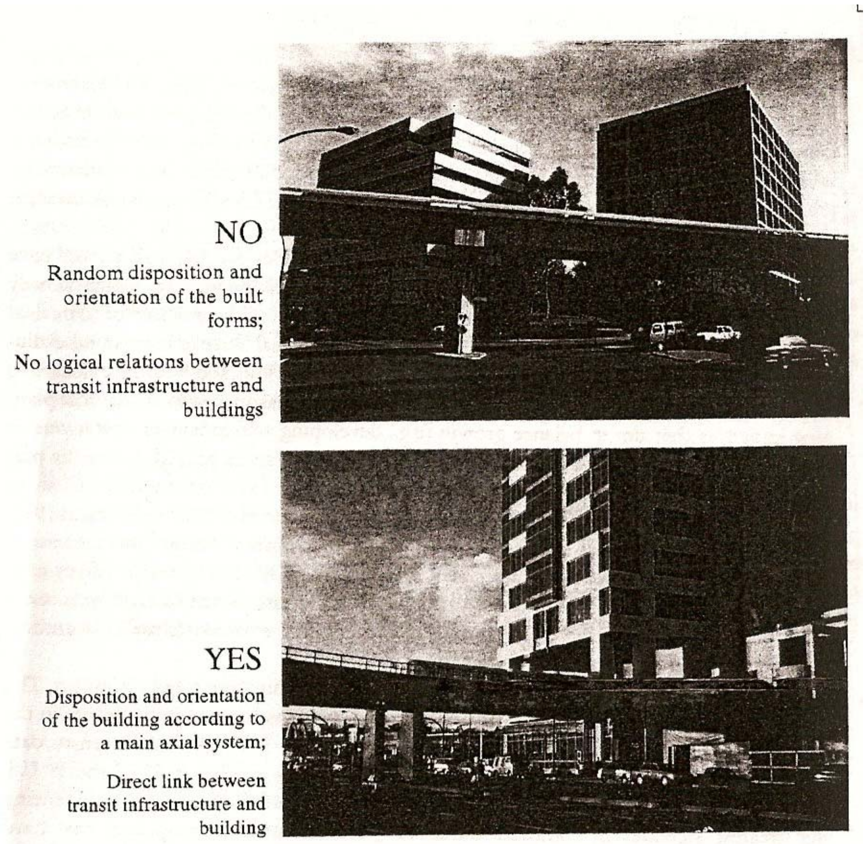


Figure 2.84: Building detachment versus building integration (Cervero & Bernick, 1996).

Some other items can be added to summary of Cervero and Bernick (1996). VTPI (2005h) determines basic design principles of TOD based on best practices investigated. Complementary principles are;

- Integration of transit and land use planning
- Management of parking to minimize the amount of land devoted to parking near transit (VTPI, 2005h).

As mentioned above parking provision is important factor for modal split. According to findings of Newman and Kenworthy (1999), more automobile dependent cities, US, Australian and Canadian Cities, have relatively more parking space than European, Wealthy Asian, and Developing Asian Cities which use transit relatively more. Figure 2.85 shows CBD parking spaces per 1000 jobs.

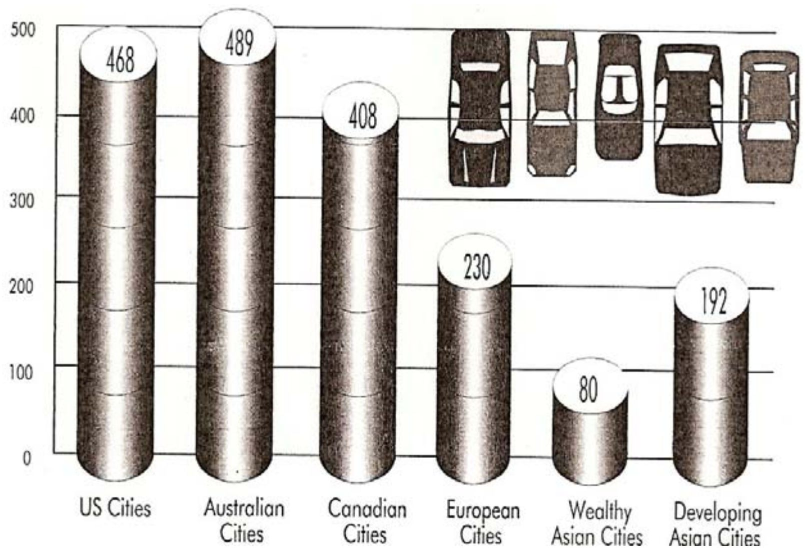


Figure 2.85: CBD parking spaces per 1000 jobs by city grouping, 1990 (Newman and Kenworthy et. al., 1999).

Additionally, Babalık (2002) determined the factors behind success and failure of urban rail systems according to eight new urban rail systems. Four of them are in USA (Miami, St. Louis, San Diego, Sacramento), three of them are in UK (Newcastle upon Tyne, Manchester, Sheffield), and one of them is in Canada (Vancouver). The determinations of study are given below in two headlines.

Factors that enhanced success

- Applying joint development project
- Increasing density through radial corridor
- Choosing proper location for station
- Integration of buses with transport system
- Locating car parks at station sites
- Redevelopment of city center
- City centre pedestrianization
- Integration of regional plan and system planning
- Modifying the local plan according to the rail system
- Redevelopment of old industrial areas
- Locating govermental buildings at stations.
- Strong CBD

Factors that hindered success

- Inproper urban form and low density
- Small and weak CBD
- Lack of extensive redevelopment project for the CBD
- Using surface car parks at station site
- Inproper route location
- Lack of bus integration with system
- Lack of coordination between rail system and local plan and recent urban projects
- Deterioration of high density residential areas

Transforming suburban neighborhoods into transit supportive environments

Figure 2.86 represents a typical auto-oriented commercial district with a large parking area, buildings without convenient pedestrian connections to main street, excessive driveways, no sidewalks, and poor landscaping.

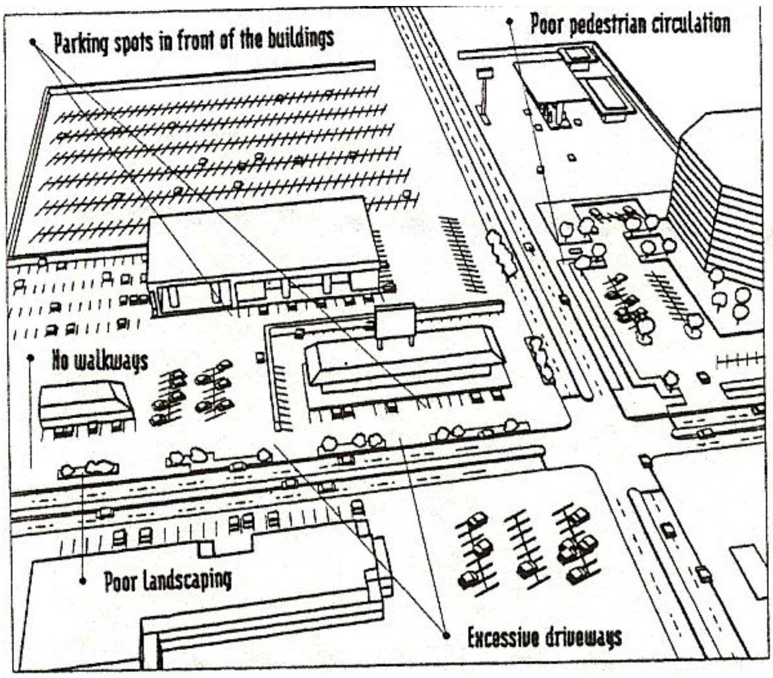


Figure 2.86: Auto-oriented commercial district unfriendly to pedestrians and transit users (Cervero & Bernick, 1996).

This inconvenient environment for walking and transit riding could be modified to make compact and pedestrian friendly. Firstly, less expensive arrangement could be done, for example; consolidating driveways, relocating parking, installing sidewalks, improving street crossings, improving the landscape and establishing new restaurants and retail shops. This might induce the intensification of uses, including the addition of residential units. Figure 2.87 shows the environment after these modification accomplished.

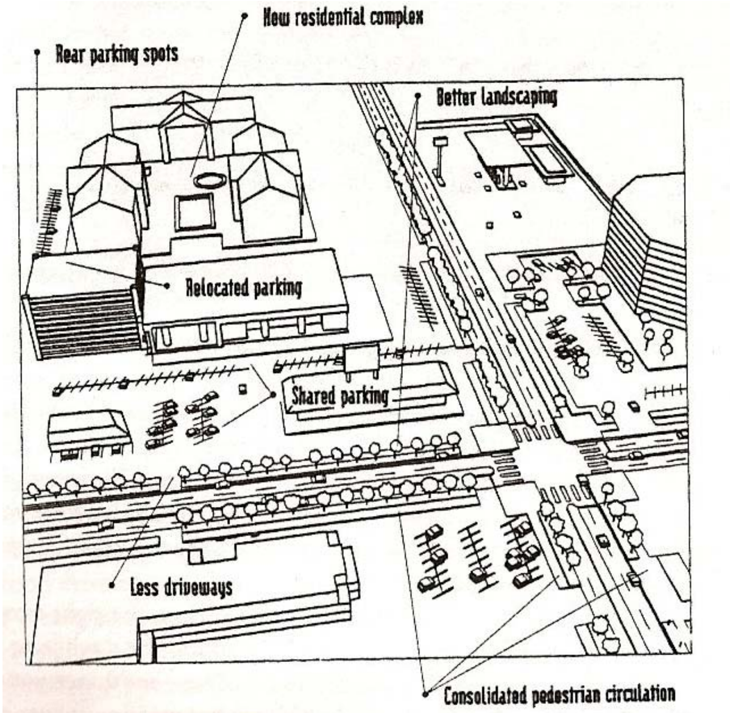


Figure 2.87: Initial improvements friendly to pedestrians and transit users (Cervero & Bernick, 1996).

The final stage of transformation is described by Figure 2.88. A light rail line penetrates the environment. The transformation of an auto-oriented commercial strip into a mixed-use, pedestrian friendly and transit suppotive neighborhood is accomplished with public plaza, additional landscaping improvements and additional housing.

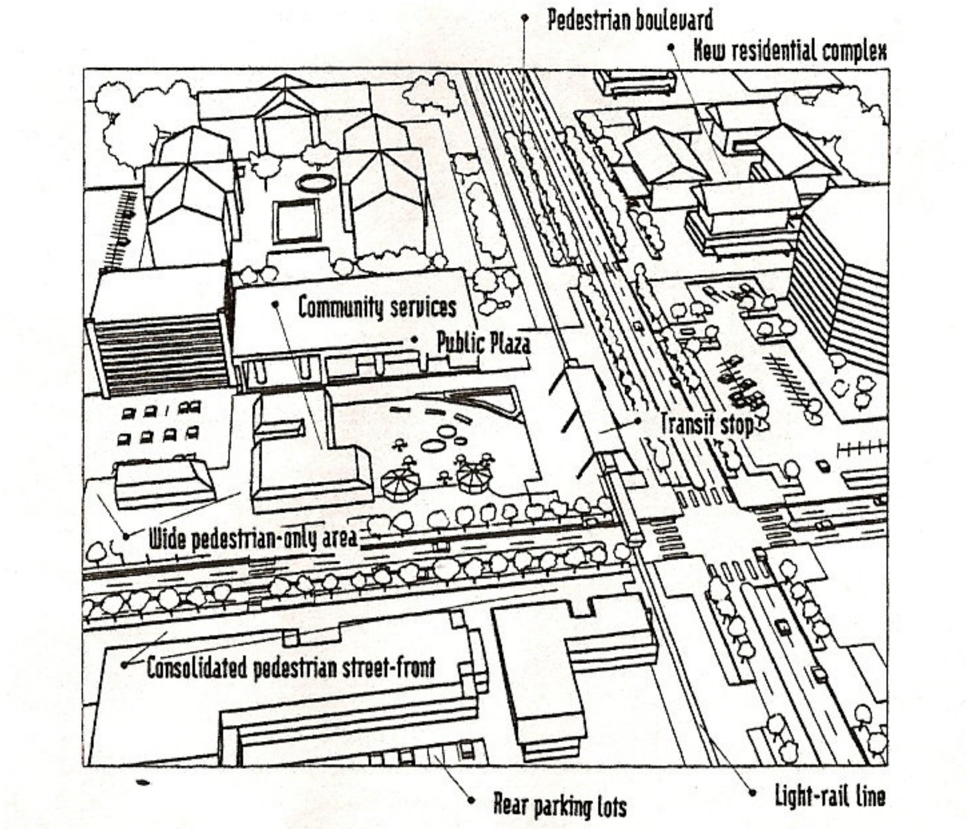


Figure 2.88: Transformation into a transit oriented neighborhood (Cervero & Bernick, 1996).

2.4.5.5 Comparison of auto oriented and transit oriented communities in terms of transit accessibility

Commuting in transit- versus auto-oriented communities

Bay Area's neighborhoods which were set up before World War II are relatively compact, many of them have finely grained grid streets, retail shops, a continious sidewalk system, and limited off-street parking. In contrast, postwar neighborhoods have auto-oriented characteristics with wider and more curvilinear streets, few sidewalks, and a separation of land uses (Cervero & Bernick, 1996).

Cervero and Bernick, (1996) conducted a matched-pair analysis of seven sets of Bay Area neighborhoods shown in Figure 2.89. The matched-pair neighborhoods have similar characteristics regarding incomes, levels of transit services, topography, and geographic locations. However, they have different characteristics in terms of population densities, street systems, and historical patterns of development.

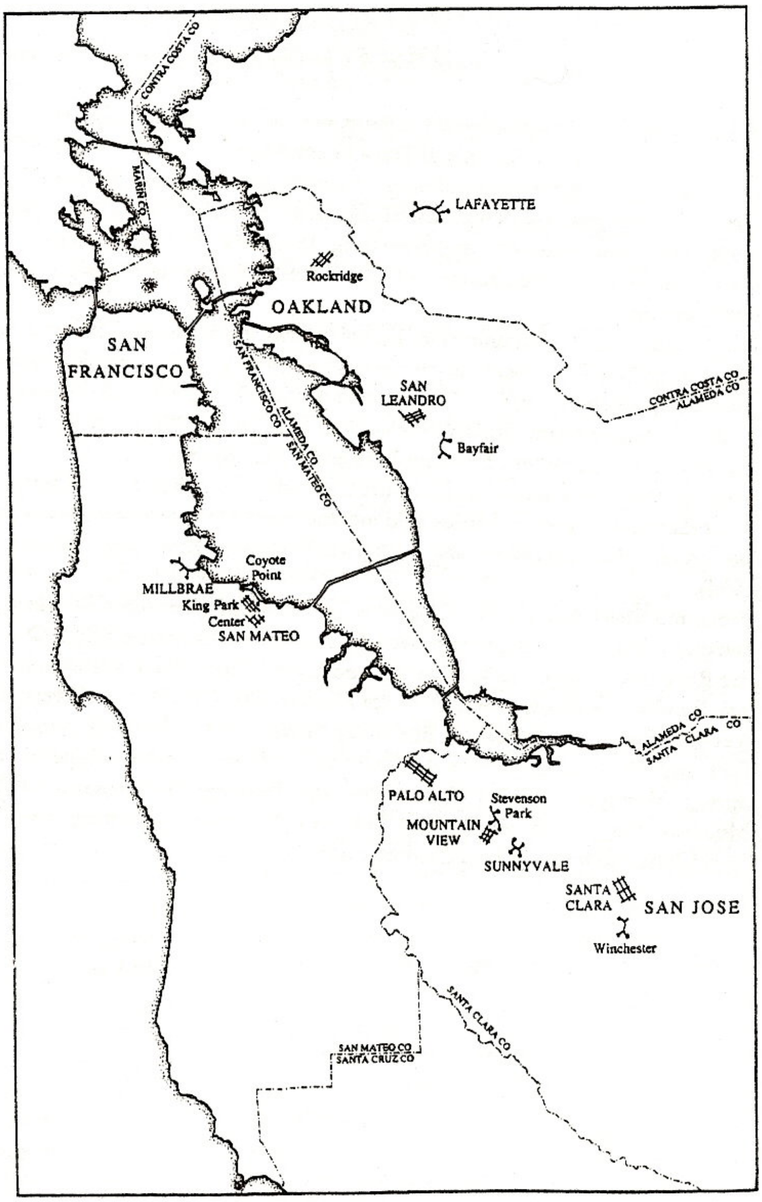


Figure 2.89: Location of Paired Neighborhoods in the San Francisco Bay Area (Cervero & Bernick, 1996).

Properties of the transit neighborhood of each pair:

- Initially located along a streetcar line;
- Primarily gridded street pattern (so more pedestrian oriented, with over 50 percent of its intersections four-way) and
- Laid out and built up before 1945.

Properties of the auto neighborhood of each pair:

- Laid out without considering public transportation, generally in areas without rail lines, either present or past;
- Curvilinear street pattern (so less pedestrian friendly, with over 50 percent of its intersections either three-way T- intersections or cul-de-sacs);
- Laid out and built up after 1945 (Cervero & Bernick, 1996).

Applying these criterias, the number of candidate neighborhood pairs in the Bay Area was reduced from 400 to 7. Neighborhoods have sizes from 0.25 to 2.25 mi^2. Overall neighborhoods have similar values in terms of median incomes and transit service types and transit neighborhoods have 35 to 50 percent more four-way intersections and higher residential densities. Table 2.5 and Table 2.6 show properties of neighborhoods comparatively (Cervero & Bernick, 1996).

Table 2.5: Comparison of Bay Area Neighborhoods: Control Factors, 1990-1992 (Cervero & Bernick, 1996).

Comparison of Bay Area Neighborhoods: Control Factors, 1990–1992

Transit Neighborhood	Auto Neighborhood	Median Household Income			Bus Service in Daily VMT per Acre			Type of Transit Service		Distance Between Centroids (in Miles)
		TN	AN	% Difference	TN	AN	% Difference	TN	AN	
Palo Alto	Mountain View-Stevenson Park	47,500	45,486	4.2	0.27	0.23	11.8	Bus, CR	Bus, CR	3.50
Santa Clara	San Jose-Winchester	32,400	34,826	7.5	0.66	0.58	11.4	Bus, CR	Bus	2.00
San Mateo-Center	San Mateo-Coyote/Point	37,159	38,873	4.6	0.47	0.22	53.3	Bus, CR	Bus	1.00
Oakland-Rockridge	Lafayette	46,512	43,108	7.3	1.43	0.12	91.5	Bus, HR	Bus, HR	6.00
Downtown Mountain View	Sunnyvale-Mary Ave	40,379	40,398	0.1	0.71	0.51	29.3	Bus, CR	Bus	1.75
San Mateo-King Park	Millbrae	32,080	31,829	0.8	0.53	0.65	23.2	Bus, CR	Bus, CR	3.50
San Leandro	Bayfair	30,115	31,282	3.9	0.87	1.00	14.3	Bus, HR	Bus, HR	2.00

Note: TN = Transit Neighborhood; AN = Auto Neighborhood; CR = Commuter Rail; HR = Heavy Rail

Data Source: 1990 United States Census, STF-3A, and data from local transit agencies.

Table 2.6: Characteristics of Bay Area Neighborhoods: Differentiation Criteria, 1990-1992 (Cervero & Bernick, 1996).

Characteristics of Bay Area Neighborhoods: Differentiation Criteria, 1990–1992

		% X Intersections			% Cul-de-Sacs			Net Residential Density (Dwelling Units per Acre)		
Transit Neighborhood	Auto Neighborhood	TN	AN	% Difference[1]	TN	AN	% Difference[1]	TN	AN	% Difference
Palo Alto	Mountain View-Stevenson Park	62.4	15.5	46.9	2.4	24.2	21.9	6.27	6.25	0.3
Santa Clara	San Jose-Winchester	63.6	28.3	35.3	3.5	18.9	15.4	6.18	4.03	53.3
San Mateo-Center	San Mateo-Coyote/Point	67.0	19.2	47.8	3.2	20.5	17.3	6.91	5.00	38.2
Oakland-Rockridge	Lafayette	44.7	9.6	35.1	10.5	4.0	6.5	5.32	2.12	150.9
Downtown Mountain View	Sunnyvale-Mary Ave	69.8	32.1	37.7	3.2	19.6	16.4	7.08	8.31	17.4
San Mateo-King Park	Millbrae	65.9	29.0	36.9	5.5	19.6	14.1	6.89	5.09	35.4
San Leandro	Bayfair	64.5	26.1	38.4	5.4	10.2	4.8	7.34	5.94	23.6

Note: TN = Transit Neighborhood; AN = Auto Neighborhood

[1]Percentage point difference.

Data Source: 1990 United States Census, STF-3A, and field surveys.

The values of modal splits and trip generation rates for work trips made by transit are shown in Figure 2.90 and Figure 2.92, and made by walk-bicycle are shown in Figure 2.91 and Figure 2.93 for paired communities.

In all communities, pedestrian-bicycle modal splits are higher in transit neighborhoods than in auto neighborhoods and trip generation rates are also higher in transit neighborhoods than in auto neighborhoods except Downtown Mountain View and San Mateo King Park (Figure 2.91, Figure 2.93). Moreover, all transit neighborhoods except Central Palo Alto and San Leandro generate more transit trips and have higher shares of transit trip than their auto-oriented matches (Figure 2.90, Figure 2.92) (Cervero & Bernick, 1996).

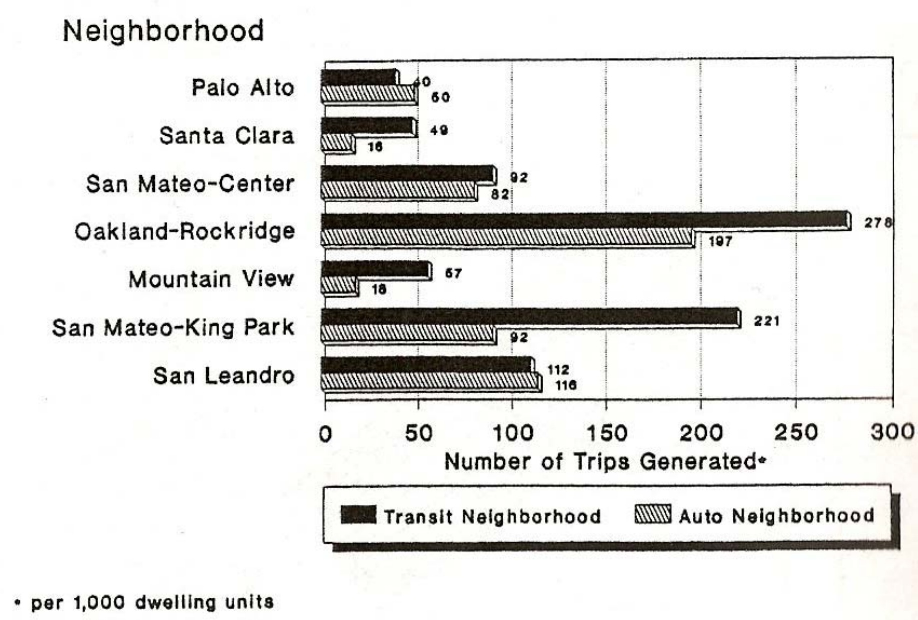


Figure 2.90: Neighborhood comparison of transit work trip generation rates, 1990 (Cervero & Bernick, 1996).

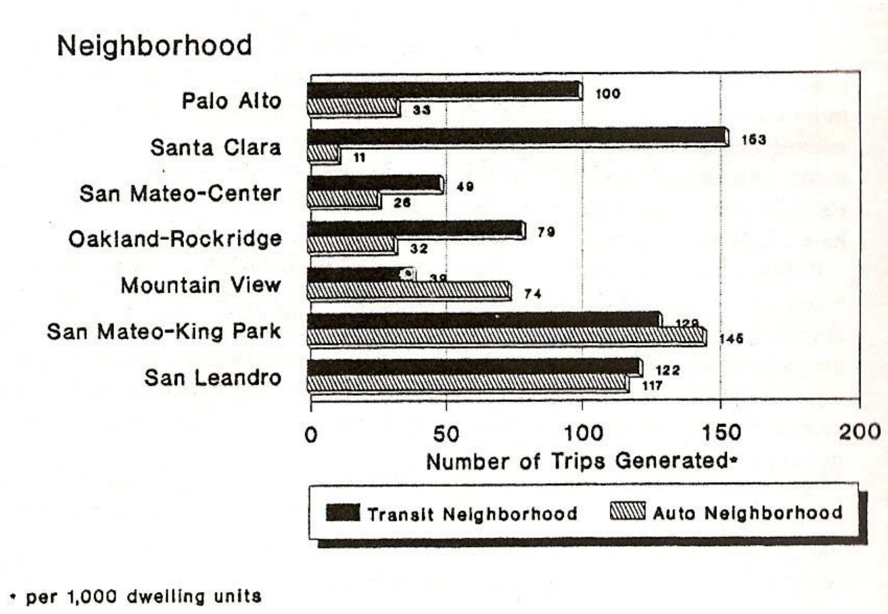


Figure 2.91: Neighborhood comparison of walk-bicycle work trip generation rates, 1990 (Cervero & Bernick, 1996).

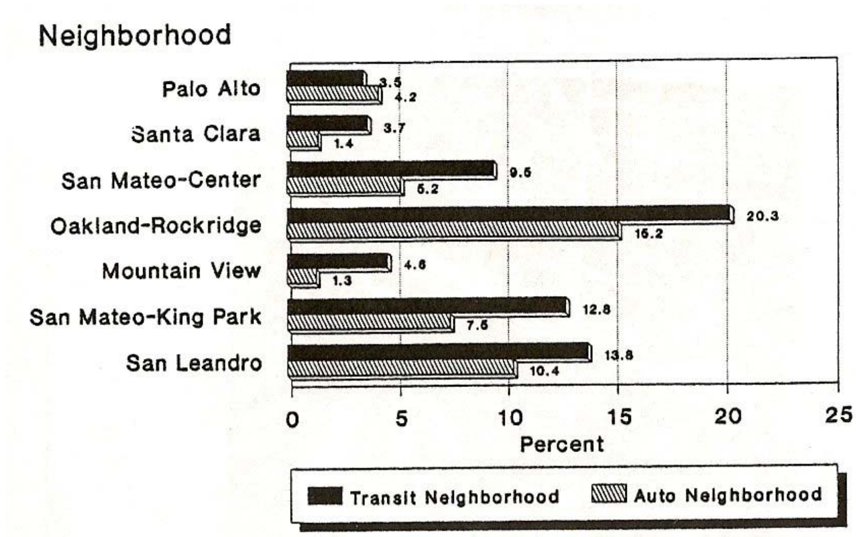


Figure 2.92: Neighborhood comparison of transit modal splits, 1990 work trips (Cervero & Bernick, 1996).

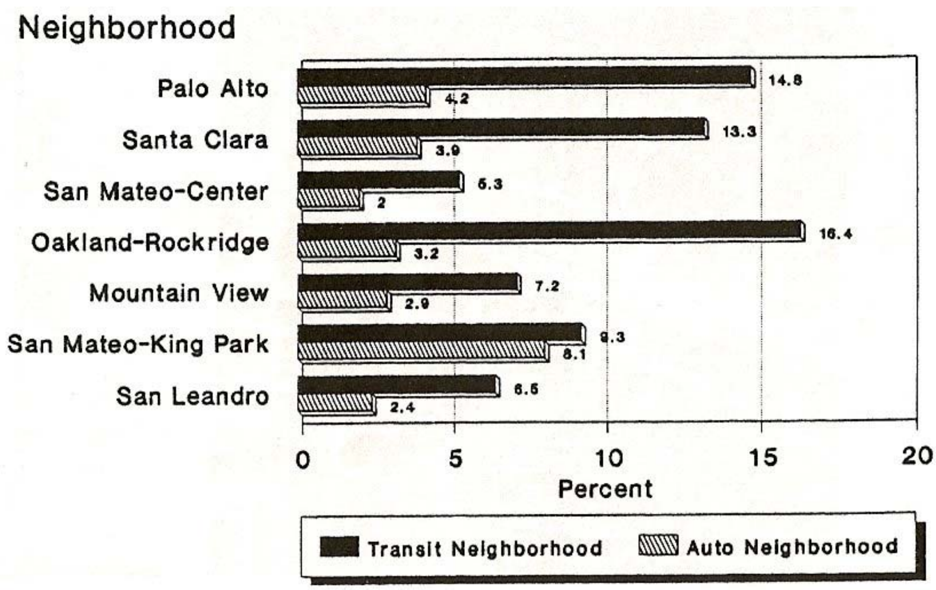


Figure 2.93: Neighborhood comparison of walk-bicycle modal splits, 1990 work trips (Cervero & Bernick, 1996).

Cervero and Bernick (1996) concluded that the evidences which show transit-oriented neighborhoods are less auto-dependent is fairly persuasive in the Bay Area. They also claim that although findings are persuasive, it does not mean that commuting behavior is totally different in transit-oriented and auto-oriented neighborhoods in the Bay Area. Because, commute trips made by auto travel is double of trips made by transit or walking-bicycling in the case of all transit neighborhoods (Cervero & Bernick, 1996).

Outcomes of study

The region's overall form has an important effect on modal choice. "Island of transit oriented development in a sea of freeway-oriented suburbs will do little to change fundamental commuting habits". So transit oriented neighborhood cannot be isolated. It must be part of a transit metropol (Cervero & Bernick, 1996, p. 111).

> Another conclusion is that the evaluations of how built environments, including transit-oriented development, impact travel demand are taking place in a distorted marketplace of cheap automobile travel and a failure of price externalities. It is no surprise that the effects of built environments on travel have been suboptimal in a world of suboptimal pricing. This, we argue, is not so much an indictment of transit villages or any other physical planning initiative as it is an indictment of how we currently price and manage our transportation and land resources. Surely if fuel costs $4 per gal, as in most of Europe, and all workers have to pay at least $5 per day for parking to cover true costs, then the commuting impacts of transit oriented development in the Bay Area or elsewhere would no doubt be far greater (Cervero & Bernick, 1996, p. 111).

Nonwork Travel in Transit- versus Auto-oriented Neighborhoods

Similar analysis is carried out by Cervero and Radisch (1995) with neighborhood pair of Rockridge and Lafayette to investigate effects of transit oriented development on nonwork trips. For this study, survey data were gathered from 620 randomly sampled households in the two neighborhoods. Basic properties of communities are given below.

Rockridge neighborhood

The Rockridge neighborhood of Oakland features the properties of the transit oriented design having (Figure 2.94);

- Very compact pattern with mix of housing containing mostly apartments and detached units in small lots.
- Grid street pattern and mixed land uses.
- Pedestrian friendly storefront design with shops typically 40 ft or less in width which allow to locate four or more shops on a typical block.
- Pedestrian friendly building orientation with direct opening to sidewalk.
- Vertical mix of buildings with stores having office or residential units above.
- On the street or behind building parkings.
- Continious sidewalks and pedestrian paths (Cervero & Radisch, 1995).

Lafayette Neighborhood

The Lafayette, lies west of the East Bay hills, is in contrast with Rockridge having (Figure 2.94);

- Large-lot housing
- Strong automobile orientation.
- Less regular and more curvilinear street network.
- Wider streets.
- More coarsely grainded land use mix and no mixing vertically within structures.
- Poor pedestrian connections due to the elongated block faces and circuitous pathways (Cervero & Radisch, 1995).

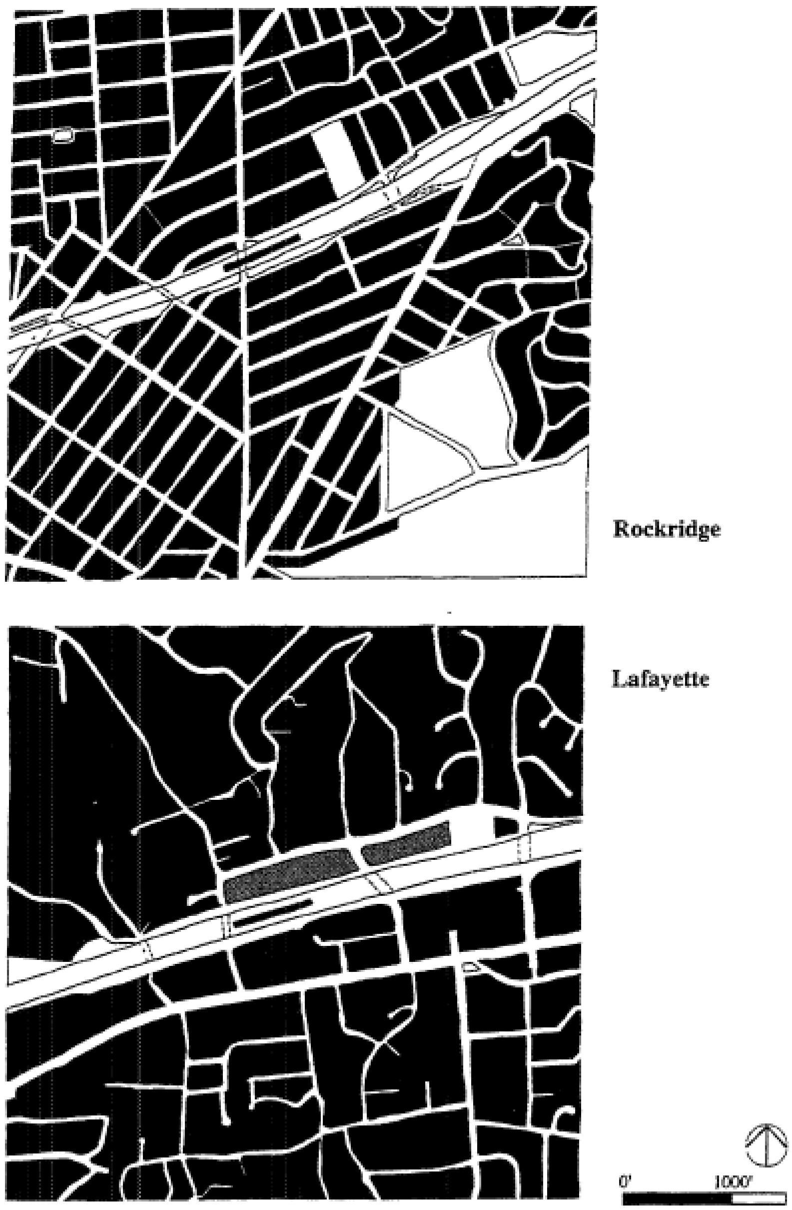


Figure 2.94: Comparison of Street and block patterns, Rockridge and Lafayette (Cervero & Radisch, 1995).

Similarities and differences

Table 2.7 summarizes the similarities and differences of the two case study neighborhoods. Both neighborhoods are on the Concord BART line and they have a rail station near their commercial districts (Cervero & Radisch, 1995).

Table 2.7: Comparison of Rockridge and Lafayette communities, 1990, (Cervero & Radisch, 1995).

Comparison of Rockridge and Lafayette Communities, 1990			
	Rockridge	**Lafayette**	**% Difference**
Common Characteristic			
Household and Housing Attributes			
Median household income	$58770	$61071	3.92
Person per household	2.2	2.5	13.64
Median housing value	$322595	$392853	21.78
Median Monthly rent	$682	$843	23.61
Resident Attributes			
Median age	37.3	39.8	6.70
Percent persons who are white	73.8	88.2	14.40
Percent adults college educated	44.5	40.7	-3.80
Transportation attributes			
BART headways(min,A.M. Peak)	3	3	0.00
No. Of bus lines serving area	3	3	0.00
Differing Characteristics			
Residential Attributes			
Housing density (units per square mile)	2194	655	-234.96
Percent housing that is single-family detached	63.6	78.4	14.80
BART Station Vicinity			
Blocks per square mile	103	47	-119.15
Intersections per square mile	127	64	-98.44
T-intersections	37	85	129.73
Four-way intersections	29	8	-262.50
Cul-de-sacs	5	31	520.00
Retail District Attributes			
Average block length(ft, major roads)	80	380	375.00
Percent of blocks with curbcuts	100	10	-90.00

Comparison of nonwork trips

Cervero and Radisch (1995) express that for all nonwork trips, such as travel for shopping, personal business, recreation, and medical appointments, Rockridge residents made less auto trip as a result of Rockridge's more compact structure. However, even for equal trip length, Rockridge have greater nonauto shares than Lafayette. (Figure 2.95).

For example, for nonwork trip distance of 1 mi or less, Rockridge have 15 percent less auto trip share and 22 percent more walking trip share than Lafayette (Cervero & Radisch, 1995).

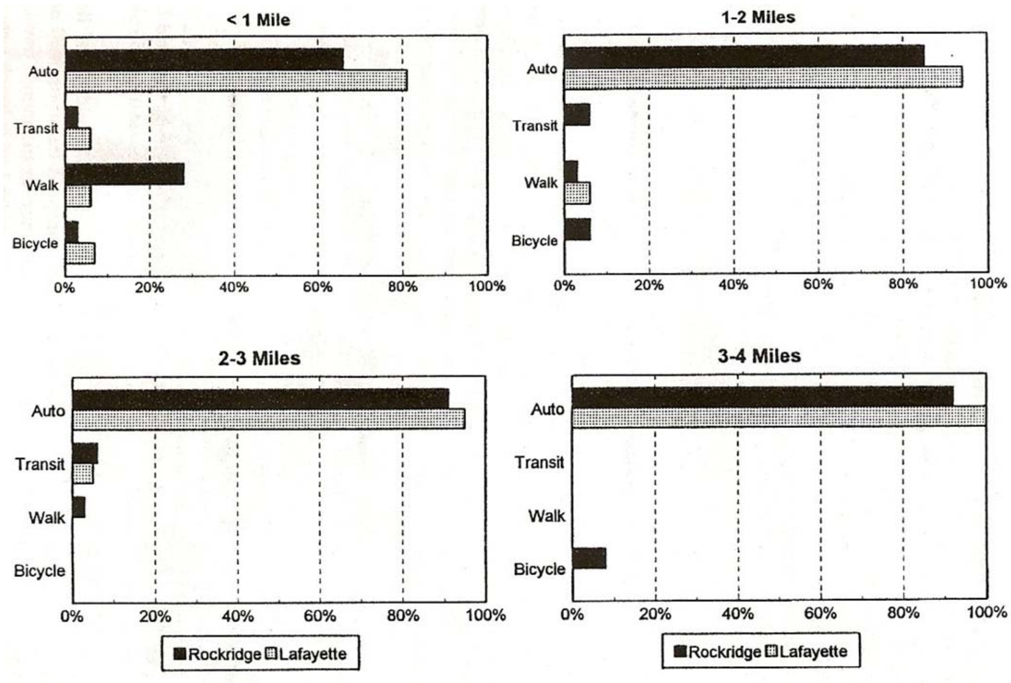


Figure 2.95: Nonwork trip modal split percentages, four distance categories (Cervero & Radisch, 1995).

A statistical model which predict the probability of nonauto travel was also developed by Cervero and Radisch (1995). They claim according to Figure 2.96 that the probability of making nonwork trip by by foot or some other nondriving mode for a Rockridge resident with one automobile available is 0.35 and for Lafayette resident with one automobile available is 0.17. From these plots, Cervero and Radisch (1995) infer that relatively compact, mixed-use, transit-oriented neighborhoods have nearly a 10 percent higher share of nonwork trips by nonauto modes such as foot, bicycle, or transit, when factors like vehicle availability and income are controlled.

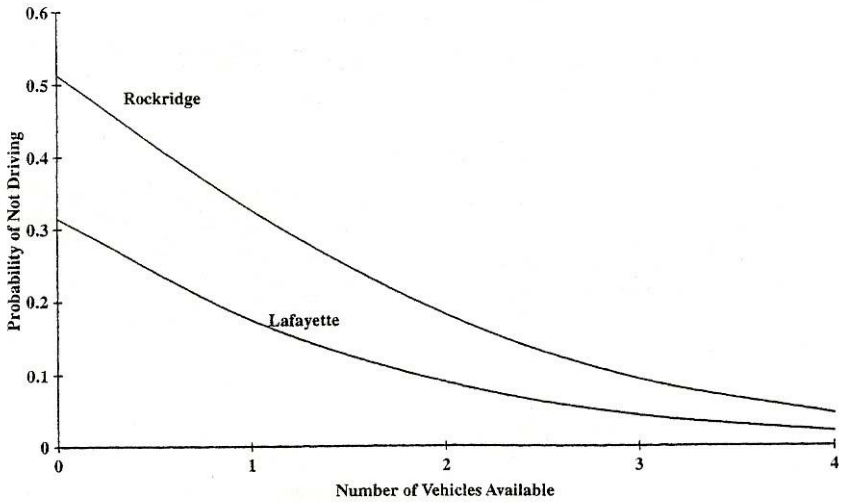


Figure 2.96: Nonwork trips by nondriving modes as a function of neighborhood origin and vehicle availability (Cervero & Radisch, 1995).

Finally in their survey of the two neighborhoods, Cervero and Radisch (1995) compiled data about the mode by which residents reached their respective BART stations. They found that share of walking trips to the Rockridge BART station and Lafayette station by foot is 31 percent and 13 percent respectively. For both neighborhoods, 94 percent of the walk trips to BART stations were made within 1 mi in length. Rockridge also have a 7 percent higher share of bus access trips to BART. In contrast, 81 percent of surveyed Lafayette residents chose park-and-rode or kiss-and-rode, while just 56 percent of Rockridge residents chose park-and-rode or kiss-and-rode (Cervero & Radisch, 1995).

As a result the higher percentage of walking and transit riding by residents of Rockridge lends notable credibility to the transit oriented design. A transit oriented neighborhood creates walk trips as a substitute for automobile trips (Cervero & Radisch, 1995).

CHAPTER 3

CASE STUDY ANKARA

3.1 History of Urban Planning in Ankara

The urban planning process is summarized in seven periods given below in Transportation Master Plan Report prepared by EGO, Department of Planning and Rail Systems (EGO, 1995a).

1. Period before Jansen Plan (1923-1932)
2. Period of Jansen Plan (1932-1957)
3. Period of Uybadın-Yücel Plan (1957-1969)
4. Period of Ankara Master Plan Bureau (AMAMBP) (1969-1984)
5. 2015 Structure Plan
6. Period of 1984-1993
7. 2025 Master Plan

Summary of these planning periods is given in the following sections.

3.1.1 Period before Jansen Plan (1923-1932)

At the beginning of 1920's, Ankara had population about 20 000 - 25 000 with a quite poor economy. After the law issued on October 13, 1923, Ankara became the capital city of the new Republic, which made the greatest impact to the development of the city.

Being new capital of Türkiye, redevelopment of Ankara became inevitable. In the concept of redevelopment period, city management was one of the problems to be solved at the first step. Due to insufficiencies in existing law dated 1882, a new law named "planlama mevzuatı" was issued on planning legislation on March 24, of 1925.

By means of this new “planlama mevzuatı” law, political arguments on *expropriation* and *speculation*[1] problems were tried to be solved. Based on this law dated 1925, 400 hectare[2] of land at Sıhhiye was expropriated, which caused “the old and new Ankara debate”. In this expropriated area a plan prepared by Lörcher was implemented.

Before Jansen Plan, the problems related with the development of the city were tried to be solved with partial approaches. In other words, all the implementations for development of the city were realized without a city master plan.

A development plan competititon was arranged between Jausseley, Brix and Jansen after understanding inadequacy of this approach. The winner of the competition was Jansen’s Plan, which is shown in Map 3.1 (EGO, 1995a).

3.1.2 Period of Jansen Plan (1932-1957)

Between 1932 and 1950, many structures such as residential, public buildings; health, educational and recreational facilities were erected in the new capital according to Jansen Plan (EGO and METU City and Regional Planning Department Study Group, 1987).

In this period “speculations” were the major problem in the urban development for Ankara. Due to problems like unexpected increase in Ankara’s population (It is predicted that the population of Ankara would be 300 000 in 1978, but Ankara reached this population at the beginning of 1950), Jansen’s Plan became invalid and did not meet the requirements. (EGO, 1995a).

In the late 1940’s, unauthorized houses started to release in the city. Because of unplanned development resulted by unauthorized housing and speculative tendencies, a new development plan was required at the beginning of 1950’s and an international competition was arranged for new development plan by Directorate of Ankara Urban Planning in 1954. (EGO, 1995a)

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[1] Land Speculation: Land speculation means owning land with the expectation of selling it to earn profits from the increase in land values.

[2] 1Hectare=10000 m^2

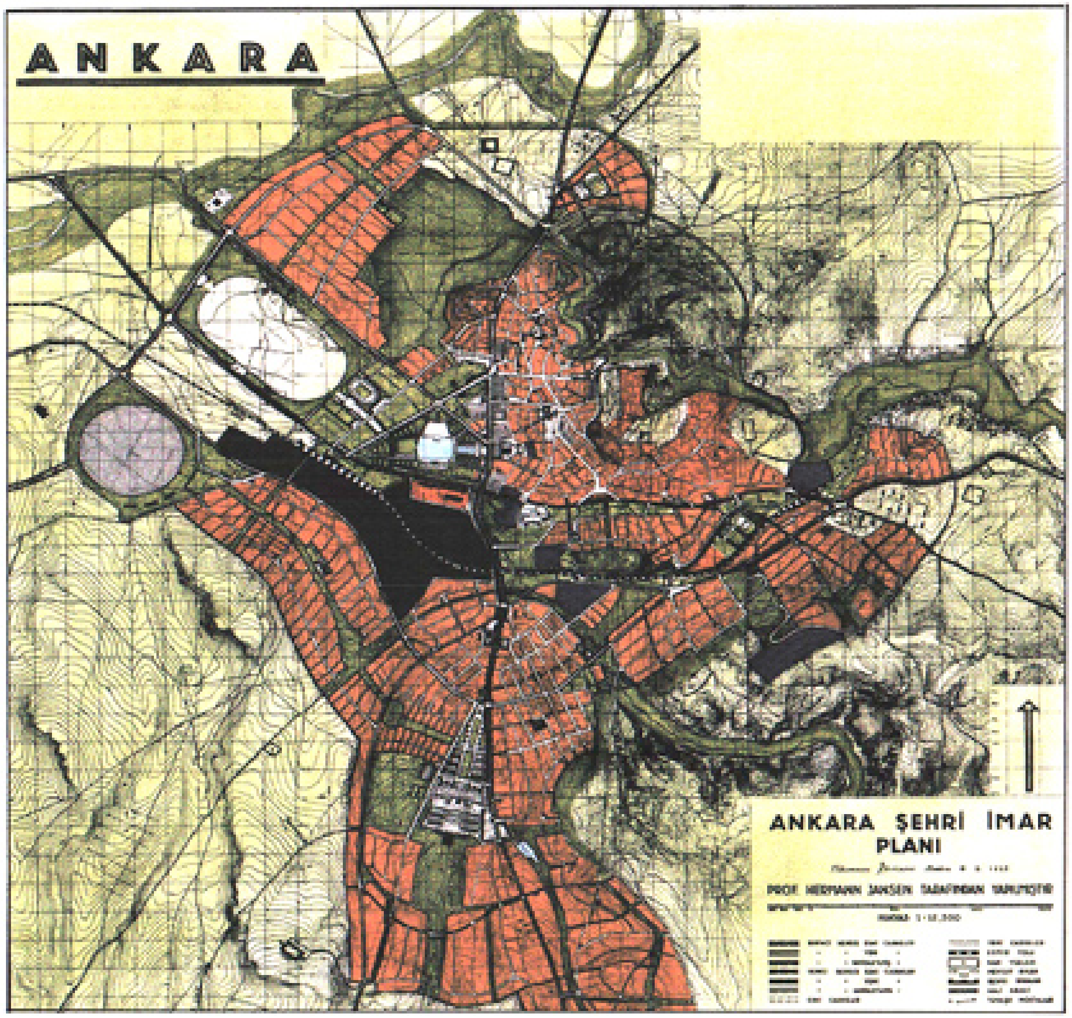
3.1.3 Period of Uybadın-Yücel Plan (1957-1969)

The project which was prepared by the Raşit Uybadın and Nihat Yücel won the competition organized by Directorate of Ankara Urban Planning in 1954 (Map 3.2). The plan was developed assuming that the population of Ankara would reach 750 000 in 2000. However, Ankara reached this population in 1965 (EGO, 1995a).

Uybadin Yücel Plan was a plan that had a limited perspective in such a way that it was directed by current growth instead of directing future urban development. Additionally phenomenons of squatting and CBD development were not considered adequately (EGO, 1995a).

Ankara was designed as a compact and a single-centered city with population of 750 000 in Uybadın-Yücel Plan (EGO, 1995a). However, Uybadın-Yücel Plan was overloaded by the law titled “Sectoral Building Height Regulations” which made the building density to increase two or three times (EGO and METU CRP Study Group, 1987).

Another factor which affects development of Ankara negatively was disharmony between Directorate of Ankara Urban Planning and Ankara Municipality. In 1969, Ankara Master Plan Bureau (AMANPB) was founded in the body of Ministry of Development and Housing to direct the development which extended over the plan scope and to provide coordination between Ankara Municipality and Directorate of Ankara Urban Planning (EGO, 1995a).



Map 3.1: Jansen Plan (1932)

Map 3.2: Uybadın-Yücel Plan (1957)

3.1.4 Period of Ankara Master Plan Bureau (AMANPB) (1969-1984)

Ankara Master Plan Scheme was prepared by AMANPB based on the studies done in the 1970-1975 period (Map 3.3). This plan offered a general perspective for urban development implementations and it was not effective for local applications. So, Uybadin-Yücel and some other local plans were in use.

Apart from the Jansen Plan and Uybadin-Yücel Plan, the Master Plan prepared by AMANPB directed the urban development. Consistency of population forecast and determining problems of Ankara truly were basic reasons behind this. The study of Plan Bureu focused on the areas which were not planned by Uybadın – Yücel Plan. Directing the development on west corridor of city was aimed besides determining basic macroform of city by AMANPB.

Although, AMANPB made contribution to realization of Sincan Squatter Prevention Districts, New Settlements, The Batıkent Housing Project, Ankara Organized Industry Area, Kızılay Pedestrian District, protection of Old Ankara Project, Atatürk Cultur Site, Altın Park and some unplanned developments arised in the city. Speculations became major factor for the unplanned development (EGO, 1995a; EGO and METU CRP Study Group, 1987).

Map 3.3: Ankara Master Plan (1990)

3.1.5 2015 Structure Plan

2015 Structural Plan was prepared by METU City and Regional Planning Department with contribution of The Municipality of Greater Ankara Bureu of City Plan in 1986. The aim of the study was to develop the proposals of future urban form so as to provide required data for Ankara Urban Transportation Plan prepared by General Directorate of EGO.

At first, factors that affect urban form were analyzed in 2015 Structural Plan. These factors are grouped in four basic subtitles as below.

1. Topography of the city
2. Development of population, work force and employment and change in economic basis in Ankara
3. Progress of location choice for state buildings, industrial buildings, development of urban transportation services, supply of infrastructure, distribution of land ownership and transfer of land in urban area.
4. The process of urban planning

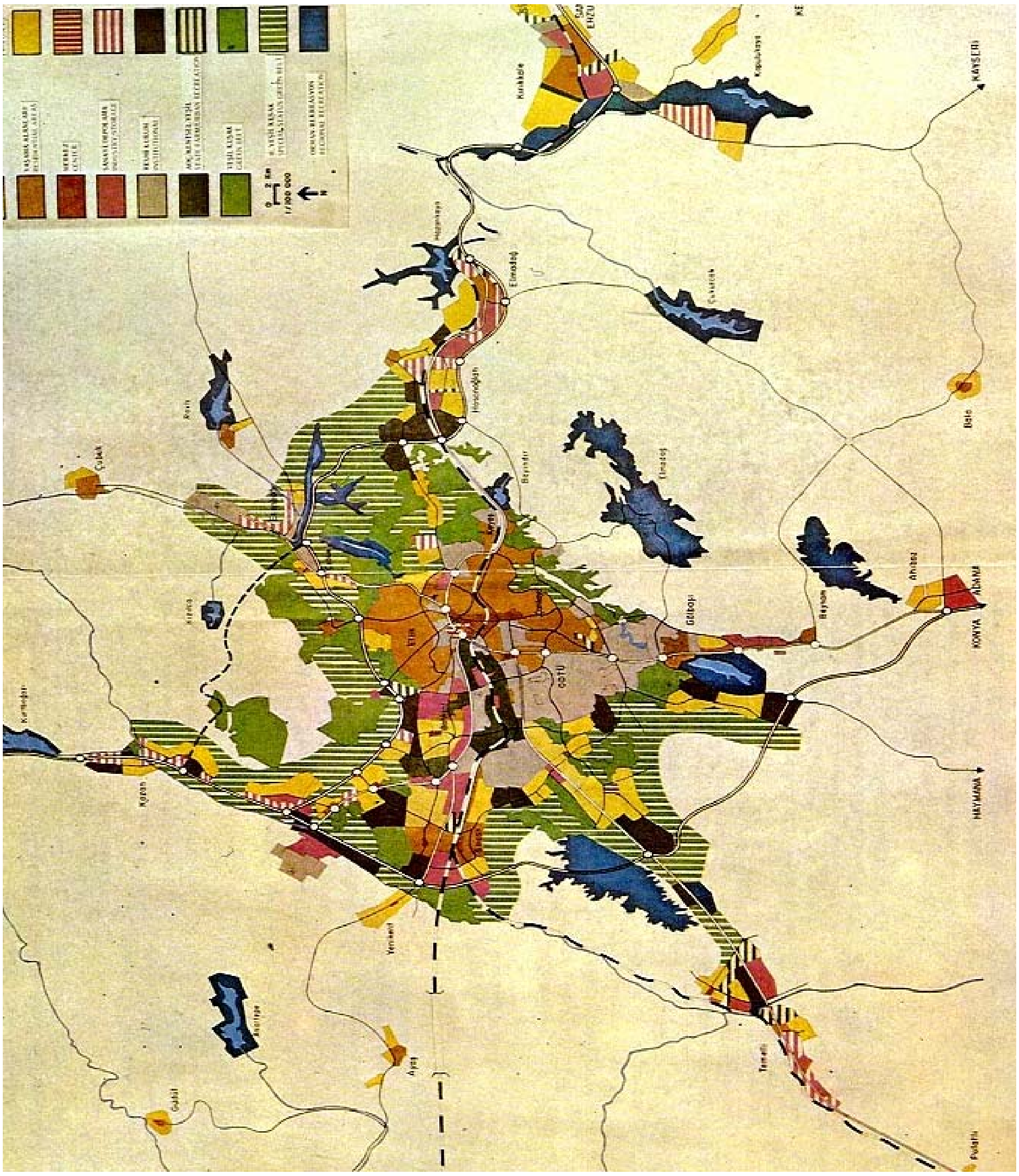
The study analyses determining factors of urban form and explains the determination process of urban form. Urban form was examined under six subtitles.

1. Settling pattern in Ankara metropolitan impact area.
2. How the Ankara metropolitan area spreads throughout the natural environment and development of differentiation of land use in time.
3. Change in urban density in time
4. Change of CBD of Ankara in time
5. Differentiatian of residential areas in terms of income level
6. Evaluation of urban form including planning decision.

After these studies, a macroform proposal scale of which is 1/100 000 is developed for year of 2015 (Map 3.4). While this proposal was being developed, macropolitics related with location of metropolitan area were defined as follows.

1. New developments must be spread out of the existing bowl in where current development exists.
2. The population of newly developing areas should not exceed 300 000
3. Decentralization should be performed by strengthening developments within a circle having radius of 35-40 km surrounding the city or providing new settlements around locations in where new projects are expected to be realized.
4. Different job opportunities and residential units should accommodate in areas developed as a result of decentralization.
5. Employment distribution should be used as a tool for realizing decentralization objectives.
6. Decentralization should be performed on a star shape metropolitan form so as to provide transit supportive development.
7. Proposed form should give opportunity to produce better alternative for future.
8. The greenbelt which is being formed around the city should be widened to length of 8-10 kms to create microclimatic effect.

Besides these macropolitics, population and employment projections were made. According to projection it is predicted that the population of Ankara will be 5 000 000 and the work force will be 1 504 000 by the year of 2015. After that service employment and population distributions are calculated using Lowry-Garin model.



Map 3.4: 2015 Structural Plan

2015 Plan is a structure plan which does not solve problems in detail but puts some general principles for urban development. Therefore, 2015 Structure Plan does not only supply required data for Ankara Transportation Plan but also directs the metropolitan development and give opportunity to define new application projects. With this plan, developments and transformation of unauthorized housing could not be realized. At the same time, residential areas constituted in Çayyolu, Beytepe and Gölbaşı with partial planning and employment center, Organized Small Industry Area located in Macunköy / İvedik are disrupted the jobs-housing balance emphasized in 2015 Structural Plan with their single use structure (EGO, 1995a).

3.1.6 Period of 1984-1993

After 1984, Greater Municipality was established and the power of Greater Municipality was extended. In this period AMANPB and Directorate of Ankara Urban Planning became a unit of Metropolitan Planning Bureu.

Because of partial planning and applications, done by Greater Municipality in urban peripherial area and by Governership of Ankara out of urban peripherial area, the planning objectives of 1990 Master Plan and 2015 Structural Plan could not be implemented. As a result, below problems have come out in the development of city macroform.

1. Disruption of jobs-housing balance
2. Disruption of balance of macroform sprawl and city center
3. Occurrence of instability in development direction of macroform
4. Occurrence of insufficiencies in transportation network
5. Increase in density of existing development via improvement policies
6. Excessive structuring in the valleys
7. Infrastructural insufficiencies due to high density.

Municipality of Greater Ankara Department of Urban Planning started to study on new Ankara Master Plan for 2025 due to these problems (EGO, 1995a).

3.1.7 2025 Master Plan

In 2025 Master Plan, it is accepted that urbanization problems of Ankara driving from high density and unplanned development can be solved keeping existing pattern as it is and spreading jobs and housing in accordance with the planning decision (Map 3.5).

It is estimated that the population of Ankara would be at least 5.5 million and at most 6.5 million in 2025. But, 2025 Master Plan aims to meet the demand of 8 million population. Macropolitics to be followed about spatial distribution of population are given below (EGO, 1995a);

1. New developments should be located out of main bowl to solve air pollution and other problems due to excessive density and to increase urban living standarts and new developments should have population less than 150 000 not to cause similar problems.
2. Borders of metropolitan development should be in the area, the radius of which is about 35-40 km, and new developments should be located around existing ones or planned projects.
3. It is seen that decentralization tendency of residential, industrial and public structures has been increasing. Using these tendencies jobs-housing ratios should be balanced in new developments and disrupted areas.
4. Metropolitan area should be developed on main corridors which connect city to outer parts and public transportation should be provided through these development corridors. Thus, flexible urban form is able to be formed without creating break down-build process and insufficiency of infrastructure.
5. City center should be redeveloped and balance of metropolitan area – center should be provided.
6. Greenbelt being constracted around city center should be evaluated as a whole project; it should be improved and extended towards to the city center through strips following valleys. Unused areas belonging to public and area stocks should be utilized for this aim without destroying its nature.
7. As much urban area as possible should be provisioned to land market and expropriated areas should be opened for use so as to support decentralization.

In accordance with these principles, 8 urban development corridors are defined. Institutional lands which use huge land has been tried to shift these corridors so as to provide mixed land use. (EGO, 1995a) (Map 3.6).

These corridors are;

1. North Ankara Development Corridor (KAGK): Urban services

Population: 100 000

Employment: 20 000

2. North-East Ankara Development Corridor (KDAGK): Out of border of Greater Ankara Municipality

Population: 25 000

3. East Ankara Development Corridor (DAGK): Urban services, public organizations, institutional service areas

Population: 30 000

Employment: 6 000

4. South Ankara Development Corridor (SAGK): Urban services, public organizations, high technology centers

Population: 75 000

Employment: 26 000

5. Haymana Road Development Corridor (HYGK): Urban services

Population: 50 000

Employment: 10 000

6. Tulumtaş-İncek Development Corridor (TİGK): Urban services

Population: 50 000

Employment: 10 000

7. South-West Ankara Development Corridor (GBAGK): Urban services, public organizations, institutional service areas

Population: 20 000

Employment: 50 000

8. West Ankara Development Corridor (BAGK): Urban services
Population: 75 000
Employment: 15 000

New development nodes are tried to be formed also in accordance with strategy of spreading outwards. For this aim, below developments and main economic activities are defined:

Kazan: Storage, public organizations, institutional service areas
Population: 150 000
Employment: 50 000

Temelli: Industry, storage
Population: 250 000
Employment: 85 000

Ahiboz: Industry, storage
Population: 150 000
Employment: 45 000

Elmadağ: Public organizations, institutional service areas
Population: 150 000
Employment: 45 000

Hasanoğlan: Urban services, public organizations, institutional service areas
Population: 50 000
Employment: 16 000

Important Projects Affecting Urban Development

Projects affecting urban development are grouped under five subtitles (EGO, 1995a).

1. Transportation projects

- Ankara by-pass road

  The by-pass road having a length of 108 km designed by General Directorate of Highway (Map 3.7)

- Intercity bus terminal

  Construction of new additional intercity bus terminals are proposed at main entrances of city to relieve the traffic load, assuming that Intercity Bus Terminal of Ankara (AŞTİ) will become inadequate to meet future travel demand and it will stay in urban settlement area.

- Rail system studies

  In 2025 Master Plan, heavy rail system, which has length of 14.6 km, 12 stations and capacity of 58 000 passenger per hour in one direction, between Kızılay-Batıkent (Ankara Metro) and light rail system, which has a length of 8.5 km, 8 stations and capacity of 25 000 passenger per hour in one direction, between Dikimevi-AŞTİ (ANKARAY) are aimed to be completed up to 1995.

- Urban distributer road system

  Transportation of Ankara is based on radial roads originated from center to the outer parts of the city. For supplying future demand, alternative road connection should be designed so as to connect neighbourhoods without passing through CBD.

- Connection between railroad and commuter rail

  It is predicted that Ankara Rail Road Station and West Station will become fundamental provided that TCDD Rapid Rail Project between Ankara – İstanbul is completed.

  A new rail road which starts from existing commuter rail station at Sincan and passes from settlements at north, after that joins to existing commuter rail station again passing from center of Batikent is proposed.

One another new rail project which connects Polatlı-Temelli corridor to Hasanoğlan is proposed parallel to urban development.

- Airports

  As, The Esenboğa Airport will be insufficient to meet the future demand, a new international airport at south around Kepezovası is proposed. After constructing new one, Esenboğa Airport will be used as a national airport.

  Military airports at Etimesgut and Güvercinlik will be moved to out of the city and Mürted Airport will be improved.

2. *Development of CBD*

   Arranging Kazıkiçibostanları as CBD to make CBD development consistent with urban form and to constitute central balance is one of the proposals of The 2025 Master Plan. Thus, 2025 Master Plan gives consideration on integration of old intercity bus terminal, Fen İşleri and Atatürk Cultural Center and establishing a new international trade center for CBD.

   North-West corridor which consists of small and middle scale industrial firms and residential developments relevant for low and middle income groups should redeveloped with high quality housing, public services, organizational building and other urban services so as to attract high income group to this area.

   It is predicted that north-west corridor will be the strongest and very attractive corridor of the city. But, location choice of high income groups is shifted central development to south and south-west, because of topographic conditions and lack of land, maintaining central development in this direction seems impossible.

3. *Industrial development*

   Important industrial projects are İvedik Small Industrial Area (480 ha), Section of İstanbul Road, TUSAŞ (1010 ha), BOTAŞ (200 ha), Integrated Facility for Meat (215 ha), Güvercinlik Storage Area and TIR parking area (160 ha). Except these, Temelli and Elmadağ-Hasanoğlan corridors are defined as main industrial corridors.

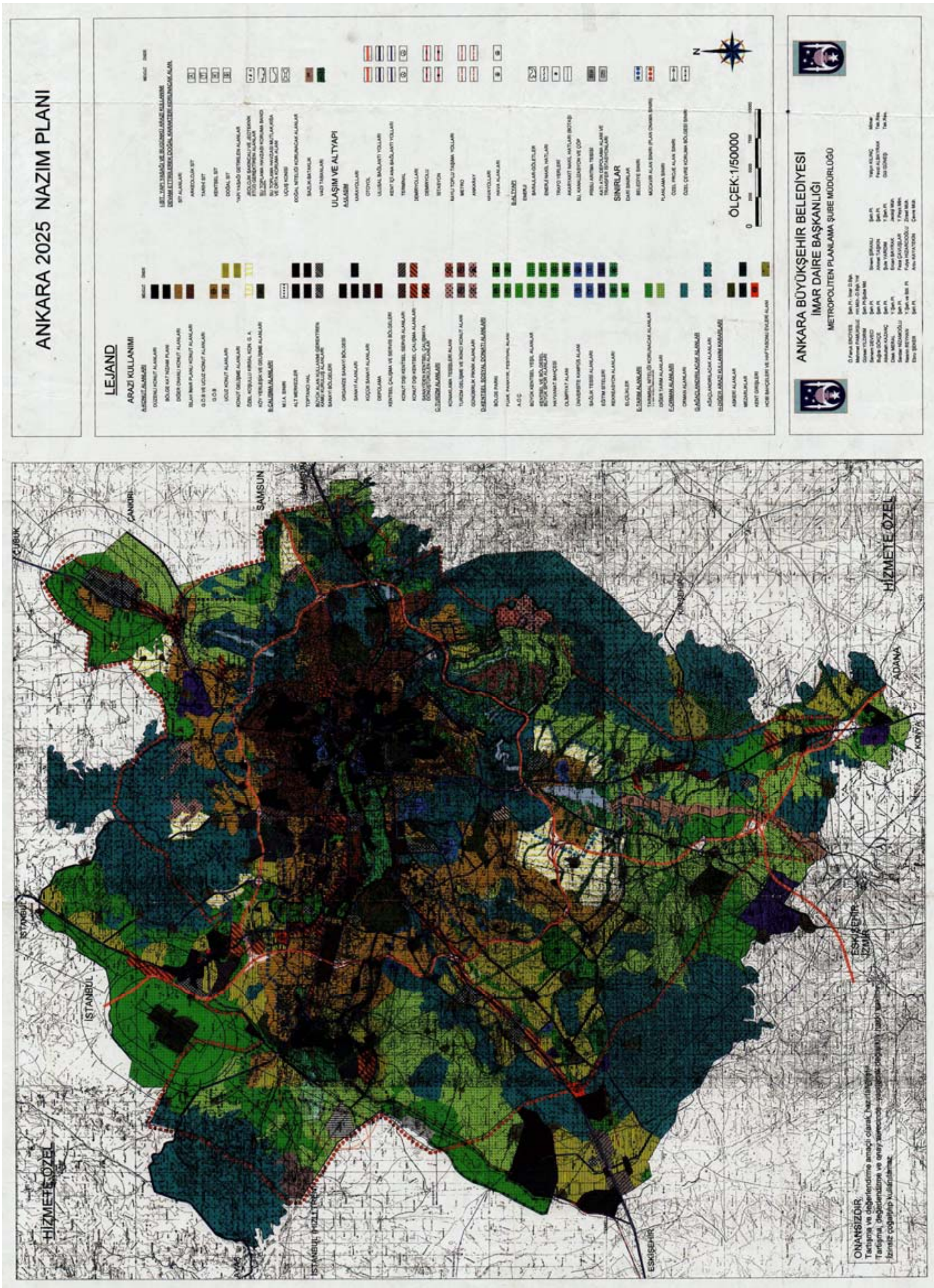
4. *Projects of new settlements*

   First residential area project developed is Doğukent Mass Housing Project which is projected for 20 000 residences and population of 100 000 between Samsun by-pass road and Bayındır Dam in area of 2 300 hectares. At west, planning studies are done for Alacaatlı (2500 ha) and Ballıkuyumcu-Peçenek settlement areas. At north, Projects for Yuva residential area (780 ha) which is projected for 17 000 residences and population of 76 000 and Ovacık Village and its surrounding (700 ha) which is projected for 12 000 residences and population of 50 000 are completed. At south, a new residential area is designed along Haymana road (3500 ha).

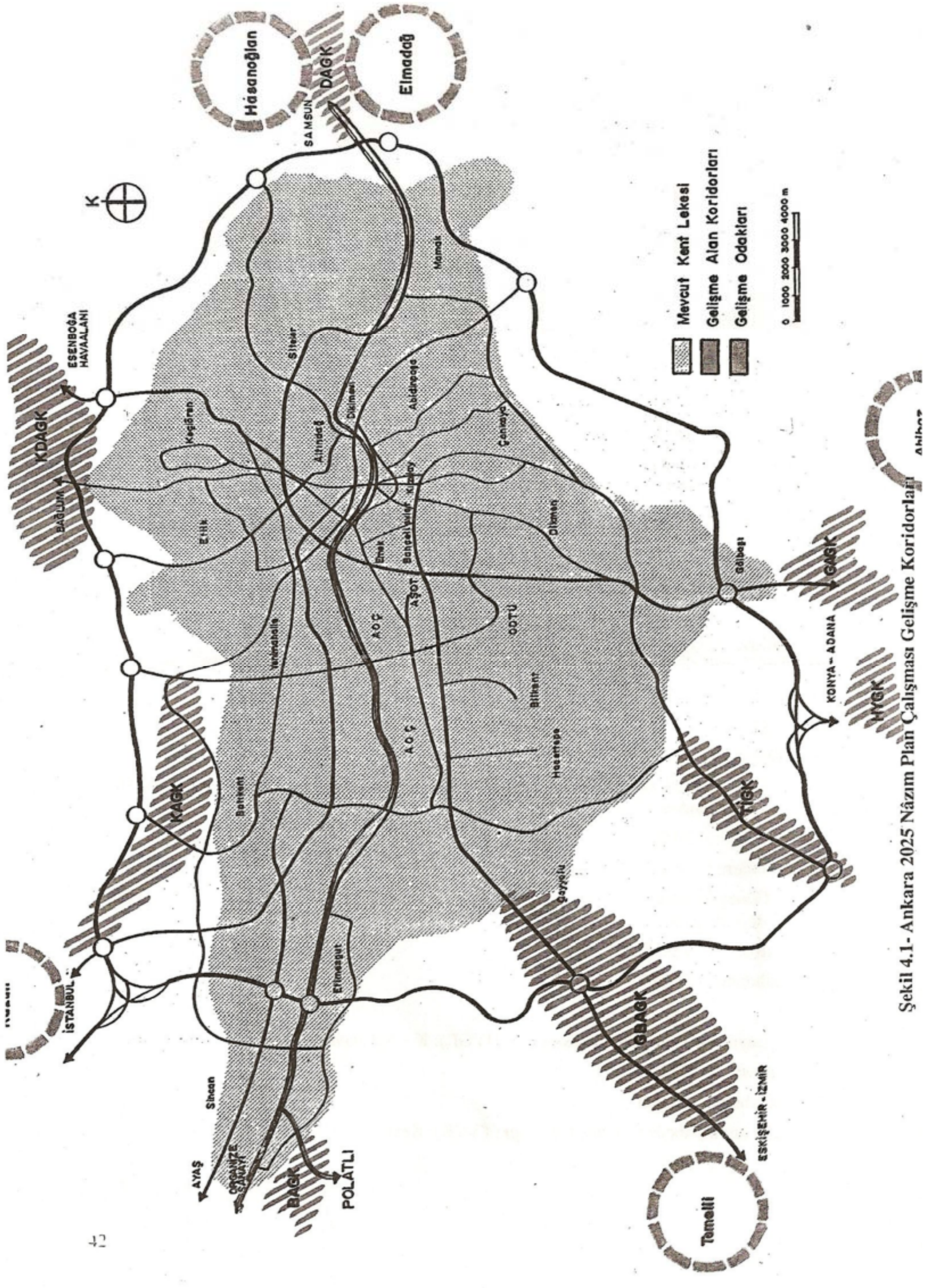
5. *Greenbelts*

   While the recreationing activities continue around city, the Dikmen and Portakal Çiçeği valley projects are developed to arrange those valleys of the city as greenbelts.

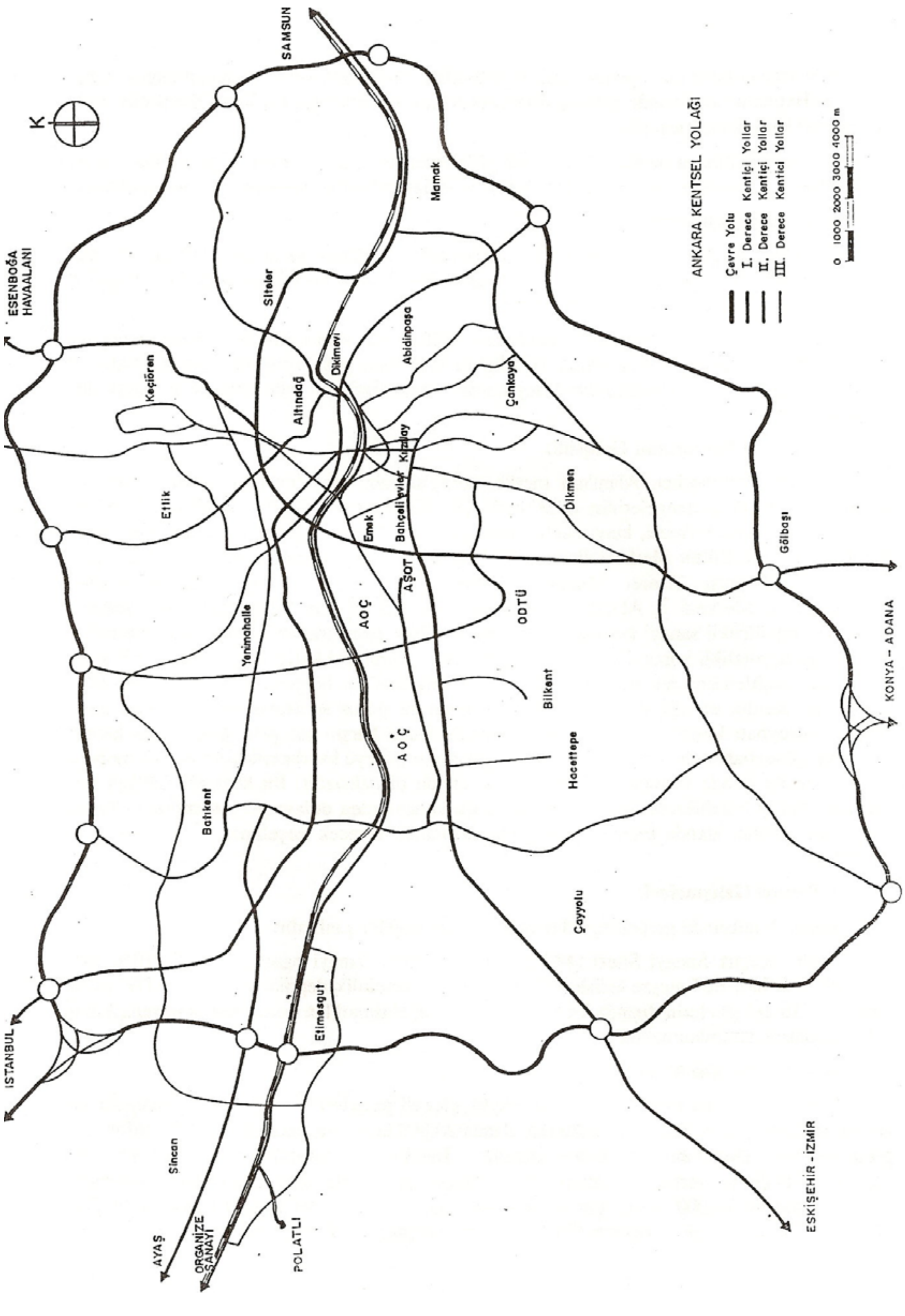
   İmrahor Valley Recreation Area Project required area of 3526 ha. Additionally, among the most significant water system of Ankara, Mogan, Eymir Lakes and İmrahor Basin are arranged as greenbelt.



Map 3.5: Ankara Master Plan (2025)



Map 3.6: Development Corridors (2025 Master Plan)



Map 3.7: Ankara Urban Road Network

3.2 History of Urban Transportation Planning

There are four studies carried out about Ankara Rail Transit System and Urban Transportation Planning (EGO, 1995a).

1. The Ankara Urban Transportation Survey is carried out by SOFRETU (France) and Ankara Municipality in 1972
2. Rail Transit System Study is carried out by EGO and Yapı Merkezi, during 1978-1984
3. Light Rail Transit System Study is carried out by Ankara Municipality and Transurb Consult (Belgium), during 1980-1984
4. Ankara Urban Transportation Study is carried out by EGO-Kanada Consortium and Kutlutaş, during 1985-1987

3.2.1 Ankara Urban Transportation Survey (Municipality of Ankara-SOFRETU: 1972)

A study which examines modernization of buses, reorganization of existing transportation system and constructing metro to solve the transportation problems of city was carried out by General Directorate of EGO and SOFRETU in October, 7, 1969 (EGO, 1995a).

The study included (EGO, 1995a);

a) Organization of administrative structure
b) Organization of operation routes and material maintanence
c) Fare collecting system
d) Transportation survey of bus routes and trolleybus
e) Determining demographic structure and intermediate term population forecast
f) Proposal of high capacity transportation system which would meet the future demand.

As a result, two staged, 14 km long, wholly underground heavy rail system (metro) was proposed. First stage of metro, which is 7 km long, was between Beşevler-Dikimevi and second stage of metro, which is also 7 km long, was between Dışkapı-Kavaklıdere. The project was rejected because (EGO, 1995a);

a) The proposed technology is completely dependent on French technology instead of using local technology.
b) Financing of project is not clear.

3.2.2 Studies done between 1978 and 1980

This study was carried out by specialist group in the body of General Directorate of EGO. Consultancy service was provided by Yapı Merkezi.

Study proposed a rail transit system at three stages. Proposed system is 25 kms long and 90% of which is at grade. In the first stage, a line, 3.5 km long, was proposed between Stad Hotel (Ulus) and Inonu Square (EGO, 1995a).

The project was rejected due to the following reasons (EGO, 1995a);

a) Proposed system was not based on comprehensive transportation survey and transportation master plan. In contrast, it was based on analysis of one corridor and did not take integration of system with bus and commuter rail into consideration.
b) Proposed line is not consistent with strategies of the Ankara Master Plan.
c) Forecasts about cost, revenue and predicted traffic were not realistic.

3.2.3 Project and Feasibility Studies done between 1980 and 1984

This study was carried out to evaluate the opinion of government about previous studies related with rail systems. The study was used home surveys of EGO-Yapı Merkezi but used the lower level of traffic projection. So that, the study concluded that light rail was applicable. Technical support was provided for the study from Transurb Consult, Belgian firm within the context of United Nations Technical Aid Program (EGO, 1995a).

The project was rejected by Ministry of Development and Housing because of below reason (EGO, 1995a);

a) Results of 1979 survey were used without updating

b) The study was not based on extensive land use plan and transportation master plan
c) The proposed capacity is not sufficient because of the fact that the project was done based on projection of year of 1990.

3.2.4 Ankara Urban Transportation Study, 1985-1987 (EGO-Canada Consortium-Kutlutaş)

Ankara Urban Transportation Study was started in 1985 with aggrement between General Directorate of EGO, Reid Crowther International Limited Company and Kutlutaş Engineering and Counseling Incorporated Company (EGO, 1995a).

Scope of Ankara Urban Transportation Study is (EGO, 1995a);

1. Transportation Survey
2. Transportation Master Plan
3. Conceptual Design and Feasibility
4. System Specialties and Draft Project

Aim of the Transportation Survey is twofold. First one is anayzing the existing transportation system of Ankara.Second aim is preparing general evaluation of element of transportation system. To achieve first aim, three different data were used (EGO, 1995a).

1. Land use data
2. Transportation survey data
3. Transportation system data

Aim of Transportation Master Plan was to develop a complete plan which intends evaluating and directing future tendencies. Studies serving these purposes can be grouped into two parts. First one is about land use. Population forecasts, work force predictions and updating Ankara Master Plan are in the scope of this study. Second one included activities related with Urban Transportation Master Plan such as prediction of the future transportation qualities, improving of urban transportation alternatives.

Purpose of third stage which is Conceptual Design and Feasibility was completing conceptual design and first economic and financial analysis so as to provide basis of next step. In this stage, besides determining routes, location of station and storage, environmental survey and financial anaysis were done and economic evaluation was made predicting cost and revenue for first priority line.

System Specialties and Draft Project formed fourth stage of the study. Aim of the study is determining service characteristics of rail transit system and preparing draft projects required for construction process.

Long-term 54.4 km rail system network of Ankara Light Rail Transit System (54.4 km) and 15 km long first stage (Batıkent-Kızılay) were approved in 1986 (EGO, 1995a).

3.3 Urban Transportation Plan of Ankara

3.3.1 Basic Principles of Urban Transportation

Main purposes of the Transportation Master Plan are to define urban transportation principles, strategies and major polices which direct proposed project and precaution and to set integrated transportation system.

Basic principles of urban transportation are defined to solve urban transportation problems and to obtain comprehensive perspective about urban transportation (EGO, 1995a). These are explained in eleven subtitles below.

1. *Integration of Land Use and Transportation*

   Improper land use cause high transportation demand. In this situation, evaluating land use decision instead of renewing transportation infrastructure in terms of high cost investment would be reasonable. Because of this reason, integration of land use and transportation is adopted as a basic policy for urban transportation planning.

Transportation Master Plan is based on a land use plan which intends to spread the city outside of dense and polluted bowl having problems of air pollution, traffic congestion etc. And public transportation is specified as main principle to achieve desired urban form through land use-transportation interaction.

2. Priority to People not Vehicles

The intraurban transportation investments which facilitate auto travel are not successful solving the transportation related problems and they are also high cost solutions. Bridges, grade separated intersections, car parks, by-pass roads relieve traffic temporarily, consequently, they stimulate more transportation demand resulting more traffic problems.

Considering relatively high share of public transportation in model split of Ankara, decision makers should give priority to public transportation for new investment, and existing infrastures should be utilized so as to benefit public transportation and pedestrians.

3. Increasing Level of Service for Users

Performance measures for transportation system are made up of following items;

- Speed/travel time: to reduce travel time increasing average speed by means of transit priority and traffic regulations and
- Reliability: to provide reliable transportation system and to inform public about service
- Cost: to minimize transportation cost
- Comfort: to reduce fullness of transit vehicles, to increase quality of vehicles and infrastructure etc.
- Safety:to take precautions for all modes of transportation
- Availability: to serve extensive transportation facility

Transportation projects should aim to optimize transportation system by maximizing public utility, minimizing negative effects and meeting requirements of the operating agencies.

4. Social Equity

Transit operations should be adopted as public service and transportation service should be provided for all social groups equally. Furthermore, transportation projects should tend to increase service quality served to the low income groups.

5. Economic Efficiency

Transportation services should be provided in an economic way. As a general strategy, transportation project intending to use existing infrastructure should be considered without disregarding long term projects.

6. Financial Efficiency

Transit agencies should aim to be self-sufficient provided that they do not load extra burden on low income groups and do not cause other loss. Necessity of subsidies is granted all over the world but this does not mean that subsidies are acceptable in all conditions. So, subsidy reqirements should be based on calculations which show expected benefits. Also cost minimization should be tried to maintain.

7. Energy Savings and Decreasing External Dependency

It is necessary to take precaution to reduce consumption of petroleum product and dependence on foreign technology considering Türkiye’s economic difficulties. A substantial amount of energy savings can be achieved in the field of transportation. When selecting transportation modes, environment friendliness and convenience to native sources should be taken into consideration.

8. Environmental Impacts

Impacts on natural and historical environment and the population should be evaluated before applying project. Negative impacts should be minimized as much as possible.

Probable impacts which can be considered in evaluation stage of project are given below,

- Passive effects (earthquake, flood, etc.)
- Accidents
- Health (air pollution, reducing sunlight etc.)
- Breaking down building, facility etc
- Noise
- Micro climate effects (shadowing, wind etc.)
- Transition losses
- Direction losses
- Natural and historical area destructions
- Esthetic changes

9. Integration of Short Term and Long Term Needs

Besides long term and extensive projects which serve multidimensional and comprehensive aims, long terms projects should be taken into consideration consistent with general planning objectives within the strategic planning concept.

10. Public Participation and Communication with Decision Makers

Appropriate measures should be developed to sustain communication between planners and groups affected from decisions in project evaluation process, therefore public participation would be increased.

11. Togetherness of Objectives and Multidimensional Evaluation of Projects

The principles mentioned above should be considered both in balance and multidimensionally, so that non monetary terms could be taken into consideration.

3.3.2 Objectives

General objectives of Transportation Master Plan are given below (EGO, 1995b);

- To achieve a transportation system which asists development of urban form and density.
- To direct transportation systems which facilitate development of transit oriented form.

- To increase living standarts relieving traffic congestion.
- To increase share of public transportation in modal split increasing accessibility and level of service.
- To adopt transit as a public service and to enhance equity.
- To ensure distributing resources efficiently.
- To perform required organization for metropolitan scale in the plan period.

Objectives of Transportation Master Plan for various transportation systems are given below (EGO, 1995a);

Rail Transit System

- Settlements which block the development of rail sytem in the area devoted to intracity stations and storage will not be allowed.
- Rail system lines will be considered at the design stage of building, substructure, road and intersection project and the coordination will be ensured with Greater Municipality of Ankara.
- Integration between land use and rail transit system will be achieved.
- Required transfer points will be constituted in applicable routes (Map 3.8).
- Auto travel will be restricted in city center providing efficient and comfortable transit system and integrating rail system with bus system and pedestrianized areas.
- Public transportation to CBD will be promoted in residential areas through parking facilities around rail stations, integration of systems and pedestrian connections. Required areas will be provided for parking, transfer and other services.

Commuter rail

- 37 km long Commuter Rail line between Sincan and Kayaş is operated by TCDD. Capacity of Commuter Rail system is 5400 passenger/hour/direction. System should be extended and improved to meet future transportation demand.

Map 3.8: Integration between Rail system line and transfer points

- The new Fatih-Eryaman-Batıkent Commuter rail project is conducted by Ministry of Transportation and General Directorate of State Airports Authority. Demand for 2015 is predicted as 12 000-18 000 passenger/hour/direction. But for remote future it is predicted that demand will necessitate heavy rail system.
- Commuter rails are proposed to Elmadağ, Polatlı and Temelli for the long term.
- There are 4 intersection points between proposed rail systems and commuter rail. Integration between commuter rail lines and other transportation systems should be ensured making required arrangements both operational and spatial so as to increase share of commuter rail in modal split.

Bus system

It is predicted that there will be 1 055 950 trips in 2015 and 48% of these trips will be met by rail transit and remaning part will be met by other public transportation modes.

- Bus system will be feeder system of rail system, and it will be major mode in areas having no railway facility.
- Effectiveness of minibus, private bus system and services(vanpool) which result from lack of public transit service will be diminished.

The main goal of Transportation Master Plan is giving priority to people not to vehicles, dependently, giving priority to transit vehicles.

- CBD will be divided into subareas and pedestrian traffic will be major mode in subareas and transit will be major mode between subareas to solve traffic congestion of CBD.
- Bus priority arrangements are needed in North corridors (Fatih Street, Etlik Street, İrfan Baştuğ Street), Kazım Karabekir Street, Çankırı Street). Necessary surveys should be done for arrangements such as;
  - Bus lane in the direction of traffic
  - Bus lane in the opposite direction of traffic
  - Public transportation in pedestrian region
  - Bus roads
  - Signalling priority at intersections

- The distance between bus routes should not exceed 800m.
- Bus routes should be as direct as possible and the distance between origin and destination by bus should not exceed 120% of the distance by automobile.
- Average distance between bus stops should be between 250m and 600m.
- Bus stop location and design guide should be prepared.

In the CBD, particularly through Atatürk Boulevard, the bus stops which spread linearly cause accumulation of vehicles and make difficult to transfer between modes.

- This problem will be solved by rail systems.
- Also, transfer between modes will be facilitated openning some streets to use of public transport and with arrangement of rail stations and bus stops so as to integrate with pedestrian regions.

Taxies

In Transportation Master Plan, contemporary taxi transportation is proposed as a system substitute for autos. Because, taxies can transport more passenger in a day than autos and also taxies are effective in reducing required parking area. But taxi prices are not as low as to discourage auto travel. Hence;

- Taxi prices and parking prices should be arranged so as to encourage taxi transportation.
- In CBD, taxi terminals should be located in entry of pedestrian district, near bus stops and rail stations. Additionally, taxi terminals should be taken into consideration in multistorey car parks - shopping centers near city center.

Pedestrians and pedestrian regions

Because of increasing trend of motorized vehicles after 1970, urban transportation plans have mainly dealed with infrastructures such as roads, intersections, bridges and consequently, pedestrian travel has ignored.

Some sidewalks are converted to road and car park and pedestrians have to share infrastructure with vehicles unfairly. Therefore, pedestrians are threatened by risk of injury and dead, air pollution and noise.

To improve condition of pedestrians series of precaution should be put into force;

- Signaling priority
- Application of infrastructure standards
- Saving sidewalks from vehicle occupation
- Grade separated pedestrian crossings
- Pedestrian district isolated from autos and integrated with public transportation facilities.

Pedestrian districts are created in CBD, residential areas and areas having historical places.

- For pedestrian areas in CBD, it is desired that to be remote from traffic chaos, air pollution vehicle occupancy and to increase activity diversity.
- For residential areas, it is desired that to be activity center for people.
- For historical places, it is desired that to save historical artifact.

Criteria for selecting pedestrian districts

- Areas which create pedestrian travel such as recreational areas, cultural centers, retail shops etc.
- Areas which are used as a car park or storage area
- Areas in where motorized travel is only seen in particular period.

Area between Dışkapı and Kavaklıdere is defined specially. In this area, auto travel will be restricted providing comfortable transit service, improved taxi transportation and applying parking policies. Pedestrian district integrated with rail stations and bus stops are proposed in the core and shopping centers and car parks are proposed around the core.

Pedestrianization should not be applied by closing a road to traffic; solutions should have aesthetic concern as well. Also pedestrianized streets should be connected each other more frequently. Especially in residential areas, traffic and pedestrian integration should be ensured with traffic calming policies.
Additionally, considering that 60% of pedestrian travels are school trips, pedestrian connections to school should be provided.

Road network and intersections

- High proportion of pedestrian travel originating from compact form of Ankara will reduce as a result of urban sprawl then motorized travel will increase. Transportation demand along several main transportation corridors which connect city center to outer parts can be met by rail transit systems. However, new routes should be formed as an alternative to these corridors to increase road network capacity and main distributer road network which connects outer parts of city without passing through city center should be designed.

- There are problems about road hierarchy of Ankara. Road hierarchy standarts should be defined for roads.

- In city center, it is obvious that grade separated intersections which encourage auto travel will not solve the traffic problems. In this section of city, auto travel will be restricted, giving priority to transit vehicles and pedestrians. Solutions based on comprehensive surveys and censuses should be prepared in other parts of the city.

Parking Policies

A comprehensive solution should be proposed for parking problems in CBD. Particularly, in the entry of the city center, in where traffic congestion is high, parking demand and auto travel should be restricted.

Parking areas should be formed for rail stations around city center and in residential areas. These areas should be connected to station entrances and exits.

Car parks should be operated without subsidy, in this context, at grade car parks will not economically feasible, however multistorey car parks and high capacity car parks which are economically acceptable should be evaluated in terms of land use. Areas around city center are seen reasonable considering land prices, acceptable parking prices and feasible multistorey car park height. Those areas in where traffic congestion and density are relatively low are prefereable places.

Because of reason mentioned above, building multistorey car parks at least one rail station far from the core of Kızılay and Ulus and integrating those with rail stations and bus stops are proposed. Additionally, forming these car parks as a mixed use center will relieve burden of city center.

Freight transportation

Problems such as lack of service roads and uncertainity of storage and redistribution areas, load additional difficulty to urban traffic. Storage areas and parking areas should be defined at urban fringe for storage and redistribution purpose.

Interurban passenger terminal

- Renewing existing airport or building new one will questioned.
- Ankara Gar is thought as a main terminal and its connection to rail system is taken into consideration.
- AŞTİ remains within the city because of urban sprawl. Therefore, new interurban bus terminals should be formed at the main entry of the city.

Road standards

There is no standart to apply about road hierarchy, so continuity could not be achieved in road hierarchy.

In road section;

- Traffic lane and width
- Median, sidewalk, parking lane width
- Transverse slope
- Longitudinal slope
- Curve radius
- Drainage conditions
- Surface properties
- And other facilities

should be designed relative to predefined speed, road hierarchy, traffic volume, and qualification in land use planning.

3.3.3 Analysis of land use – transportation interaction of Ankara with planning context

3.3.3.1 Historical development of density of Ankara

When the density of Ankara is examined in historical period, it is seen that there has been a decreasing tendency. (Table 3.1).

Table 3.1: Historical transformation of the density measure of Ankara urban form in relation with area coverage and population increases (Çalışkan, 2004).

	Urban Area (hectares)	Population	Increase rate of area (%)	Increase rate of population	Gross Density (people per
1927	300	74,553	-	-	248
1932	710	110,000	136	47.5	154
1945	1,900	220,000	167	100	115
1956	3,650	455,000	92.1	106.8	124
1970	14,000	1,236,152	283.5	171.6	88
1985	27,000	2,304,166	92.8	86.3	85
1990	56,000	2,584,594	107.4	12.1	46
1997	62,000	2,949,771	10,7	14.1	47
2000	66,000	3,237,679	6.4	9.7	49

As depicted in Table 3.1 population of Ankara is 74 553 and population density is 248 per/ha in 1927. In the year of 1932, population reach 110 000 but declined density of 154 p/ha. Reason behind this fall is Jansen Plan which suggests low density development. Western development of city was started in that year along İstanbul Highway and around AOÇ. In 1945, the population rises to 220 000 resulting density of 115 p/ha. During 1945-1956, developments continued through east-west axis (Bahçelievler-Cebeci axis) and north-south axis (Keçiören-Çankaya). In this period middle income groups located along axis which have high accessibility to center. Also, unauthorized housing raised in extensive area during 1945-1956. In 1956, the density of population rose to 124 p/ha dispersing urban area of 3,650 hectares. The demand for height increment due to increase in land values was effective for increasing the density of population. In this period air pollution became one of fundamental problems of city. By the year 1970, the density trend again started decreasing with density of 88 p/ha in an area of 14,000 hectares. In the mid 70s, redevelopment process stopped in inner areas and devlopment splashed out to urban fringe. Batıkent and Sincan development areas were expropriated and Housing organizations were developed on Eskişehir Highway. And also public and educational buildings were located on Eskişehir and İstanbul Highway in this period (Altaban, 1987). In 1985, density decreases to 85 p/ha with slight change. Then, in 1990, it reduces sharply to 46 p/ha. In this period, western corridor development change the density pattern creating large vacant lands and green areas included within urban form, while the built-up areas had not been changed significantly. After that there was not a considerable change in amount of urban coverage area. However, population has continued to increase. At year of 2000, the population of Ankara has increased to 3.2 million covering an area of 66,000 hectares. In this period, new developments remain within the current radius of urban macro form. It can be said for near future that, density level will be increase provided that infill developments are taken place in the vacant part of southwest sub-region and increase in population continues (Çalışkan, 2004).

In world classification, the density of Ankara, 49 p/ha, is very near to European average with effects of outgrowth after 1990 (Table 3.2). However, it is important to note that the density measures given are calculated by using overall coverage area which includes large amount of vacant and green lands, thus, in the case of usage of built up area of Ankara, which is 21 300 hectares, in calculation, the density runs up to 152 p/ha. (Çalışkan, 2004).

3.3.3.2 Compactness

Having the same density level with European cities does not mean that compactness degree is same. General urban pattern of European cities quite different from pattern of Ankara, in such a way that European cities had spread over wider area with medium to high-density urban pattern whereas development of Ankara realized in limited area with high density apartment blocks. The measure of annual travel distances per capita given in Table 3.3 supports this determination[1]. As seen from Table 3.3 values of passenger km per capita for year of 1992 is higher in European cities than in Ankara. But after 1990, because of accelerating outgrowth of Ankara which is relatively auto dependent and has lower density urban development, ratio of auto trips increases rapidly. Even though, it is still lower than all. (Çalışkan, 2004).

Average journey to work trip lengths given in Table 3.4 are another indicator of compactness. From 1980 to 1990, there is a slight change in journey to work trip lengths, but in twenty years, it reaches from 6.1 to 10.22 due to decentralization of residential areas without establishing jobs-housing balance (Çalışkan, 2004).

Additionally, the measure of job density is far lower than world cities given in Table 3.2 and there is not any increment during 1970-2000. However, eliminating vacant land results that the job density value runs up to 3.4 businesses per hectare for year of 2000 (Çalışkan, 2004).

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[1] It is important to note that if mobility levels (average number of daily trips per person) of cities are considered, more objective comparison can be obtained.

Table 3.2: Intensity of land use in global cities. (Newman et. al, 1999: 94-95, 1970 Yılı Ankara Konut Dışı Kullanışlarda Toplam Alan /İşyeri /Ciro (Ankara Metropoliten Alan Nazım Plan Bürosu - 1970 Yılı Ankara Çalışması, ATO işyeri istatistikleri, 2000) (as cited in Çalışkan, 2004).

City	**Metropolitan Density**	
	persons/ hectare	**Jobs/hectare**
San Francisco	16.0	8.5
Los Angeles	23.9	12.4
Detroit	12.8	6.1
Boston	12.0	7.1
New York	19.2	8.7
AMERICAN AVG.	14.2	8.1
Canberra	9.5	5.0
Melbourne	14.9	5.9
Sydney	16.8	7.2
AUSTRALIAN AVG.	12.2	5.3
Vancouver	20.8	10.5
Toronto	41.5	23.2
CANADIAN AVG.	28.5	14.4
Brussels	74.9	46.8
Stockholm	53.1	39.3
Copenhagen	28.6	16.0
Paris	46.1	22.1
Munich	53.6	37.2
Amsterdam	48.8	22.2
London	42.3	23.6
EUROPEAN AVG.	49.9	31.5
Kuala Lumpur	58.7	22.4
Singapore	86.8	49.3
Tokyo	71.0	73.1
Bangkok	149.3	62.4
Hong Kong	300.5	140.0
ASIAN AVG.	161.9	72.6
Ankara 1970	88	1.2
Ankara 1985	85	-[1]
Ankara 2000	49	1.1

[1] The dataset on the number of work places is based on the year of 2000. In that database the businesses, which have been closed since 1985 is disregarded by the year 2000

Table 3.3: Annual travel by private and public transportation in world cities, 1990.(Newman et al., 1999: 84-85) (as cited in Çalışkan, 2004).

City	**Annual Travel in Passenger Cars (passenger km per capita)**	**Annual Travel in Public Transportation (passenger km per capita)**	**Total Annual Travel (passenger km per capita)**
San Francisco	16,229	899	17,129
Los Angeles	16,686	352	17,037
Detroit	15,846	171	16,018
Boston	17,373	627	16,018
New York	11,062	1,334	12,396
AMERICAN AVG.	16,045	474	16,519
Canberra	11,195	660	11,855
Melbourne	9,782	844	10,626
Sydney	9,417	1,769	11,186
AUSTRALIAN AVG.	10,797	882	11,679
Vancouver	12,541	871	13,412
Toronto	7,027	2,173	9,200
CANADIAN AVG.	9,290	998	10,288
Brussels	6,809	1,428	8,237
Stockholm	6,261	2,351	8,612
Copenhagen	7,749	1,607	9,356
Paris	4,842	2,121	6,963
Munich	5,925	2,463	8,388
Amsterdam	6,522	1,061	7,583
London	5,644	2,405	8,049
EUROPEAN AVG.	6,601	1,895	8,496
Kuala Lumpur	6,299	1,577	7,875
Singapore	3,169	2,775	5,944
Tokyo	3,175	5,501	8,676
Bangkok	4,634	2,313	6,947
Hong Kong	813	3,784	4,597
ASIAN AVG.	2,772	2,587	5,359
Ankara 1985	411	1980	2,391
Ankara 1992	860	2288	3,148
Ankara 2003	2203	3338	5,541

Table 3.4: Journey-to-work trip lengths in World cities, 1980-1990 (Newman et al., 1999) (as cited in Çalışkan, 2004).

Cities	**Journey-to-work length (km, 1980)**	**Journey-to-work length (km, 1990)**
American	13.0	15.0
Australian	12.0	12.6
Metro Toronto	10.5	11.2
European	**8.1**	10.0
Asian (Wealthy)	**NA**	NA
Ankara	6.17	7.08

3.3.3.3 Modal Split of Ankara

Modal split of transportation system is directly related with urban form, so, it can represent the features of urban form. From Table 3.5, it is seen that there is a descending behaviour in total passenger km in transit, work trips done by transit and non motorized work trips in between 1985 and 2003 in Ankara[1]. From 1985 to 1992, there is a decrease in transit trips and an increase in walking/cycling trips. The reason behind increase of non-motorized trip is the expansion of CBD and spawn of sub-centers such as Maltepe, Bahçelievler which are examples of mixed use (Çalışkan, 2004). But this increase is temporary effect, after 1992 tendency of auto dependeny in Ankara results a high decrease in non-motorized work trips.

Similarly for transit trips, it is seen in modal split tables of Ankara for years of 1990, 1992, 2003 and 2005 that percentage of transit decline whereas percentage of private transport increases (Table 3.6, Table 3.7, Table 3.8, Table 3.9). Modal split of motorized trip during 1990-2005 and change in ridership of public and private transportation during 1990-2005 are given in Table 3.10 and Table 3.11 respectively.

[1] In spite of descending behaviour, Ankara has third best value for % of total passenger km on transit and fourth best value on % of work trips on transit in world cities included in Table 3.5.

Table 3.5:Relative performance and provision for transportation modes in world cities, 1990. (Newman et al, 1999) (as cited in Çalışkan, 2004).

City	**% of Total Passenger km on Transit**	**% of Work Trips on Transit**	**% of Work Trips by Walking and Cycling**
San Francisco	5.3	14.5	5.5
Los Angeles	2.1	6.7	4.0
Detroit	1.1	2.6	2.0
Boston	3.5	14.7	7.4
New York	10.8	26.6	6.7
AMERICAN AVG.	3.1	9.0	4.6
Canberra	5.6	10.0	6.0
Melbourne	7.9	15.9	4.7
Sydney	15.8	25 2	5.5
AUSTRALIAN AVG.	7.7	14.5	5.1
Vancouver	6.5	12.4	5.7
Toronto	23.6	30.1	5.3
CANADIAN AVG.	10.2	19.7	6.2
Brussels	17.3	35.3	19.1
Stockholm	27.3	55.0	14.0
Copenhagen	17.2	25.0	32.0
Paris	30.5	36.2	14.9
Munich	29.4	46.0	16.0
Amsterdam	14.0	25.0	35.0
London	29.9	40.0	14.0
EUROPEAN AVG.	22.6	38.8	18.4
Kuala Lumpur	20.0	25.5	16.9
Singapore	46.7	56.0	22.2
Tokyo	63.4	48.9	21.7
Bangkok	33.3	30.0	10.0
Hong Kong	82.3	74.0	16.9
ASIAN AVG.	48.7	45.1	19.0
Ankara 1985	77	68	21
Ankara 1992	66	52	32
Ankara 2003	58	54	18

Table 3.6: Modal split in Ankara including nonmotorized trips, 1990, (ABB, 1998)

MODES	**NUMBER OF VEHICLES**	**NUMBER OF PASSENGERS CARRIED**	**% OF PUBLIC TRANSPORT PASSENGERS**	**% OF MOTORIZED TRANSPORT PASSENGERS**
EGO BUSES	973	875281	37,18	28,9
PUBLIC PRIVATE BUSES	200	182985	7,77	6,0
DOLMUS	1884	878331	37,31	29,0
PRIVATE PARATRANSIT	3200	365971	15,54	12,1
SUBURBAN RAIL	0	51846	2,20	1,7
TOTAL PUBLIC TRANSPORT		**2354414**	**100,00**	**77,7**
TAXI	8000	152488		5,0
PRIVATE-OFFICIAL AUTO	140000	515410		17,0
OTHER		9149		
TOTAL PRIVATE TRANSPORT		**677047**		**22,3**
TOTAL MOTORIZED		**3031461**		**100,0**

Table 3.7: Modal split in Ankara including nonmotorized trips, 1992 (EGO, 1995c)

MODES	**NUMBER OF PASSENGERS CARRIED**	**% OF PUBLIC TRANSPORT PASSENGERS**	**% OF MOTORIZED TRANSPORT PASSENGERS**	**% OF TOTAL PASSENGERS**
EGO BUSES	845516	33,77	25,6	17,5
PUBLIC PRIVATE BUSES	153494	6,13	4,7	3,2
DOLMUS	811218	32,40	24,6	16,7
PRIVATE PARATRANSIT (BUS)	397613	15,88	12,1	8,2
PRIVATE PARATRANSIT(MINIBUS)	226446	9,04	6,9	4,7
SUBURBAN RAIL	69575	2,78	2,1	1,4
TOTAL PUBLIC TRANSPORT	**2503862**	**100,00**	**75,9**	**51,7**
TAXI	626048		19,0	12,9
PRIVATE AUTO	168696		5,1	3,5
TOTAL PRIVATE TRANSPORT	**794744**		**24,1**	**16,4**
TOTAL MOTORIZED	**3298606**		**100,0**	**68,1**
NON-MOTORIZED	**1545109**			**31,9**
TOTAL	**4843715**			**100,00**

Table 3.8: Modal split in Ankara for motorized trips, 2003 (Akar, 2004)

MODES	NUMBER OF VEHICLES	NUMBER OF PASSENGERS CARRIED	%OF PASSENGERS (TOTAL)	% OF PASSENGERS (PUBLIC TRANSPORT)
EGO BUSES	1190	800000	19.3	25.6
ANKARAY	11 series (3 vehicles per series)	160000	3.9	5.1
METRO	18 series (6 vehicles per series)	185000	4.5	5.9
SUBURBAN RAIL	-	110000	2.7	3.5
DOLMUS	2230	780000	18.8	24.9
PRIVATE PARATRANSIT	6500	600000	14.5	19.2
PRIVATE PUBLIC BUSES: BLUE	200	200000	4.8	6.4
GREEN	372	200000	4.8	6.4
TWO FLAT	95	95000	2.3	3.0
TAXI	7660	260000	6.3	-
AUTOMOBILES (PRIVATE + OFFICIAL)	600000	750000	18.1	-
TOTAL PUBLIC TRANSPORT		3130000	75.6	100.0
TOTAL PRIVATE TRANSPORT		1010000	24.4	
TOTAL		4140000	100.0	

Table 3.9: Modal split in Ankara for motorized trips, 2005 (EGO, 2005a)

MODES	NUMBER OF VEHICLES	NUMBER OF PASSENGERS CARRIED	% OF TOTAL PASSENGERS	% OF PUBLIC TRANSPORT PASSENGERS
EGO BUSES	1234	630000	14,8	20,9
ANKARAY	11 Series (3 vehicles per series)	135000	3,2	4,5
METRO	18 Series (6 vehicles per series)	185000	4,4	6,1
SUBURBAN RAIL		56000	1,3	1,9
DOLMUS	2230	970000	22,8	32,1
PRIVATE PARATRANSIT	6183	550000	12,9	18,2
PUBLIC PRIVATE BUSES	200	160000	3,8	5,3
OTHER PUBLIC PRIVATE VEHICLES	358	250000	5,9	8,3
GREEN TWO FLAT PRIVATE BUSES	93	85000	2,0	2,8
TOTAL PUBLIC TRANSPORT		**3021000**	**71,1**	**100,0**
TAXI	7800	280000	6,6	
PRIVATE AUTO	683 082	950000	22,3	
TOTAL PRIVATE TRANSPORT	690 882	**1230000**	**28,9**	
TOTAL		**4251000**	**100,00**	

Table 3.10: Modal split of motorized trip during 1990-2005

	% OF MOTORIZED TRANSPORT PASSENGERS (1990)	% OF MOTORIZED TRANSPORT PASSENGERS (1992)	% OF MOTORIZED TRANSPORT PASSENGERS (2003)	% OF MOTORIZED TRANSPORT PASSENGERS (2005)
TOTAL PUBLIC TRANSPORT	77,7	75,9	75,6	71,1
TOTAL PRIVATE TRANSPORT	22,3	24,1	24,4	28,9

Table 3.11: Change in ridership of public and private transportation during 1990-2005

	1990	**1992**		**2003**		**2005**	
	NUMBER OF PASS. CARRIED	**NUMBER OF PASS. CARRIED**	**% increase (1990-1992)**	**NUMBER OF PASS. CARRIED**	**% increase (1992-2003)**	**NUMBER OF PASS. CARRIED**	**% increase (2003-2005)**
TOTAL PUBLIC TRANSPORT	2354414	2503862	**6,35**	3130000	**25,01**	3021000	**-3,48**
TOTAL PRIVATE TRANSPORT	677047	794744	**17,38**	1010000	**27,08**	1230000	**21,78**

3.3.3.4 Factors that enhanced transit and nonmotorized travel in Ankara

In spite of decresing trend in transit and walking/cycling, Ankara has highest level in work trips on transit among world cities given in Table 3.5. Also level of work trips by walking/cycling is higher in Ankara than world cities other than Asian and European cities given in Table 3.5. Because, Ankara has three prerequisites of cost effective and sustainable transit service which are mentioned by Pushkarev & Zupan (1977).

1. **A large dominant center:** CBD of Ankara still maintains its feature of being unique strong center. In Ankara, high proportion of jobs is clustered in the CBD, since decentralization process is not realized as aimed in Ankara Transportation Master Plan. So high proportion of work trips are directed toward city center through public transportation system. Existing of limited parking areas in CBD due to high density is another factor for enhancing transit use.

2. **Dense residential developments:** As mentioned before, the density of Ankara runs up from 49 p/ha to 152 p/ha for the year of 2000, if built up area is used in calculation instead of overall area which includes green zone and vacant lands. Thus, residential areas along radial corridors have high density by means of which efficient public transportation is ensured.

3. **Long radial corridors:** Ankara has star shape radial corridors connecting in city center. This provides direct access to high density CBD, which has most of job opportunities, through radial corridor.

As for walking behavior, one of the main factors behind high walking trip rates is compact form again. Although dispersed, single-use residential areas have developed in urban fringe, Ankara has very compact urban form in CBD and along radial transit corridor.

For both high transit and walking trip rates, low income level and high gasoline price have very significant supportive effect. In spite of all these conditions, share of walking trips are reducing day by day due to unconcerned behaviour of authorities. Table 3.12 shows this fall clearly.

Table 3.12: Share of motorized and nonmotorized trips in transportation from 1930 to 1985 (Tekeli, 1987)

YEAR	TOTAL MOTORIZED TRANSPORT	% OF TOTAL MOTORIZED TRANSPORT	TOTAL NON-MOTORIZED TRANSPORT	% OF TOTAL NON-MOTORIZED TRANSPORT	TOTAL TRANSPORT
1930	19200	**13**	124800	**87**	144000
1935	43100	**22**	153400	**78**	196500
1940	68650	**27**	183350	**73**	252000
1945	91550	**25**	271450	**75**	363000
1950	160700	**35**	301300	**65**	462000
1955	361000	**50**	361000	**50**	722000
1960	542000	**52**	498000	**48**	1040000
1965	807000	**56**	642000	**44**	1449000
1970	1378000	**70**	600000	**30**	1978000
1975	1904000	**70**	818000	**30**	2722000
1980	2433000	**80**	609000	**20**	3042000
1985	2928000	**81**	674000	**19**	3602000

3.3.3.5 Reasons behind the increasing auto travel

In Ankara, limiting auto use can be achieved easier than in cities having higher income level and lower gasoline price such as Canadian and American cities (Table 3.13). In spite of these advantages, Ankara is proceeding in the way of being auto dependent city. From this point, it can be said that current policies and implementations about land use and transportation are not sufficient to direct travel behavior in Ankara.

Table 3.13: GNP in world cities 1990. (Newman, 1999) (as cited in Çalışkan, 2004).

Cities	GNP per Capita ($US, 1990 per person)
American	26,822
Australian	19,761
Canadian	22,572
European	31,721
Asian	9,018
Ankara 1985	2728
Ankara 1992	2664
Ankara 2000	2989

Factors behind auto dependency

1. Lack of coordination between transportation and land use planning

In recent years importance of land use-transportation coordination is realized by countries which suffer from lack of coordination. In Ankara, this concept is emphasized in Transportation Master Plan as a main policy. But, it is seen that this objective could not be realized considering evolution of travel behavior of Ankara in recent years. As a result, effects of the uncoordinated development burden transportation system of Ankara. For example unplanned, auto oriented, single land use developments i.e. Çayyolu, Bilkent, İncek, Temelli, Beysukent etc. are entirely against Transportation Master Plan of Ankara (TMPA) as they increase travel distances, congestion problems, air pollution etc. Also it is very difficult to supply efficient transit service to such type of developments. As a result, auto travel becomes dominant mode.

Nevertheless, there are also successful applications in terms of land use-transportation coordination. One of these examples is commuter rail between Sincan and Kayaş. This rail system serves development of western corridor which includes Sincan Organized Industry Area, Sincan, Elvankent, Etimesgut (Figure 3.1).

These developments are not mixed use communities; however they have strong connection between city center via commuter rail

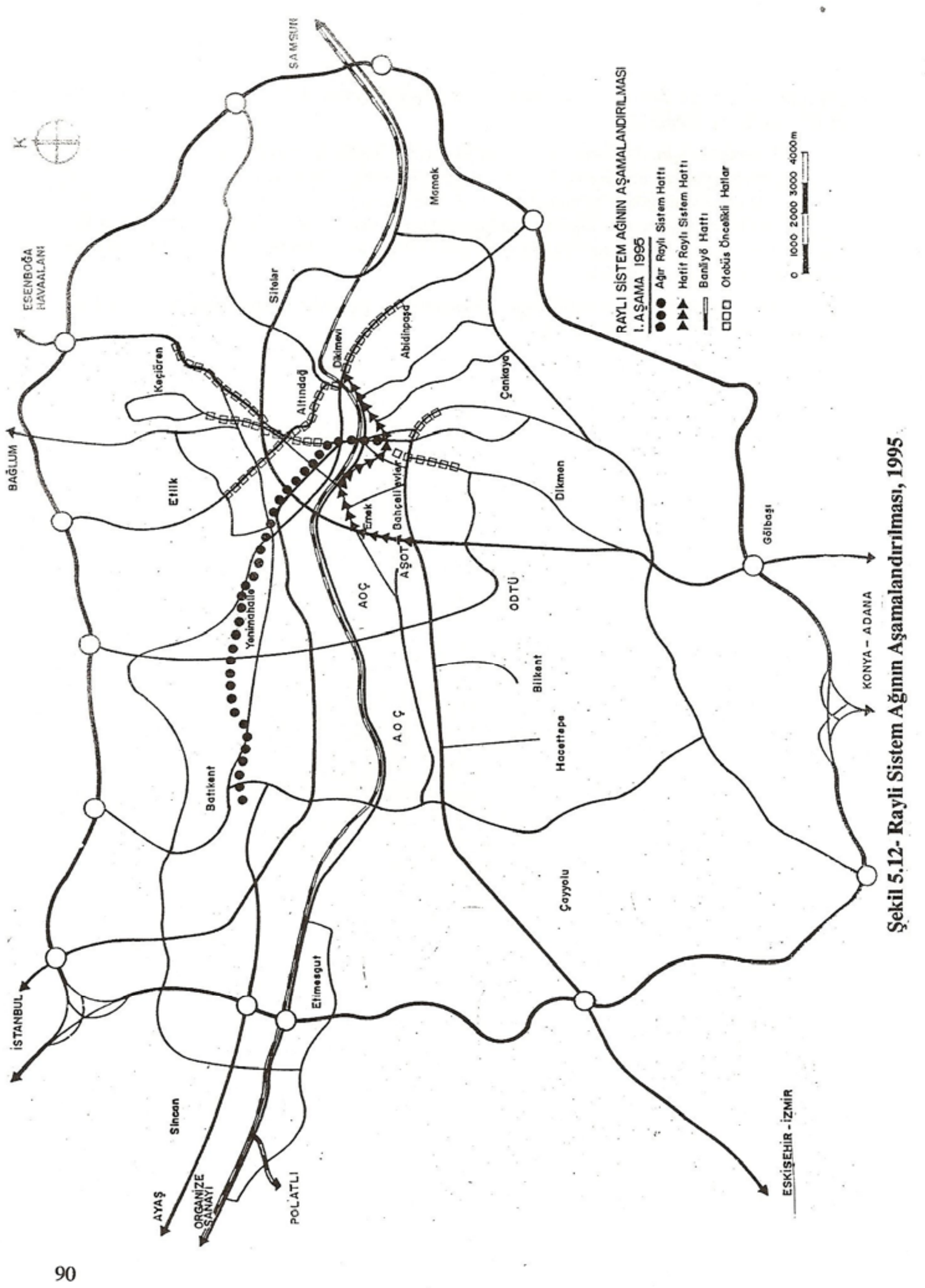

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Figure 3.1: Commuter rail between Sincan and Kayaş, (EGO, 1995a).

2. *Giving priority to vehicles*

Regardless of main principle of Transportation Master Plan of Ankara which is giving priority to people, recent applications in Ankara mostly based on auto priority.

Grade separated intersections and road widening

Grade separated intersections are prominent examples of such applications. Although grade separated intersections reduce congestion and dependently environmental impacts of congestion; it is obvious that they can not solve the traffic problems in city center. Additionally, they do not only encourage auto travel but also cause unnecessary expenditure with their high cost.

Recently Greater Ankara Municipality has started new grade separated intersection projects at Atatürk Boulevard near Kuğulu Park (Figure 3.2-3.3).

Figure 3.2: Existing situation of Kuğulu Intersection (Ankara Büyükşehir Belediyesi, 2006)

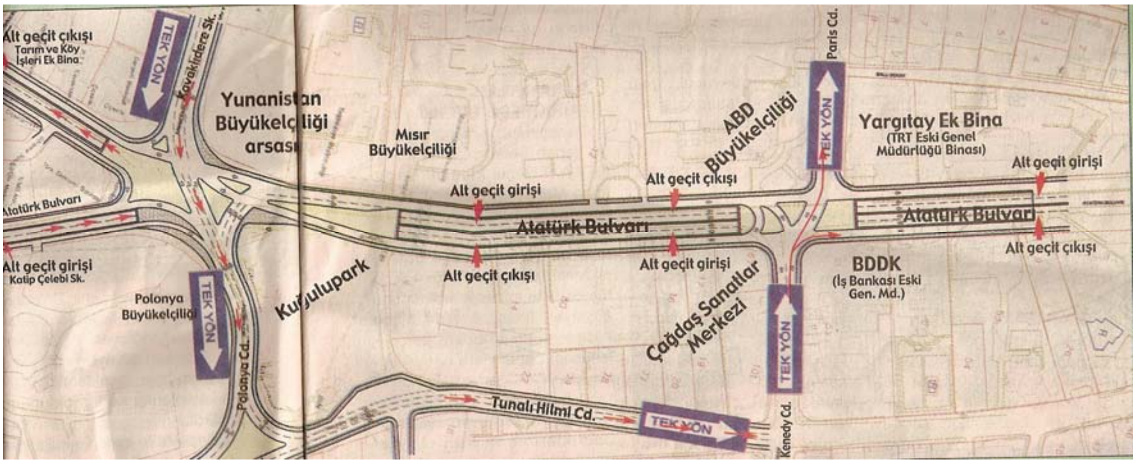


Figure 3.3: Planned project for Kuğulu intersection and other intersection between Akay and Kuğulu (Ankara Büyükşehir Belediyesi, 2006)

Besides encouraging auto travel and having high cost, these projects will also reduce transit and pedestrian accessibility. Up to now pedestrians use at grade intersection to cross over the Atatürk Boulevard. But after this project, pedestrians will be subjected to high risk of dead or injury, because of high speed through traffic or they have to use pedestrian bridge which is not a contemporary solution.

After completion of project, vehicles coming from Kuğulu Intersection will accumulate at signallized intersection at Kızılay as expected. That is to say, every newly constructed grade separated intersection necessitates another one, which means that these types of applications only provide temporary relieves.

Another recent application which encouraging auto travel has made at Eskişehir Highway. Although existing rail transit project being constructed which required to encourage public transportation, road widenings have been done in some section of Eskişehir Highway, Beytepe and Bilkent Highway Bridges.

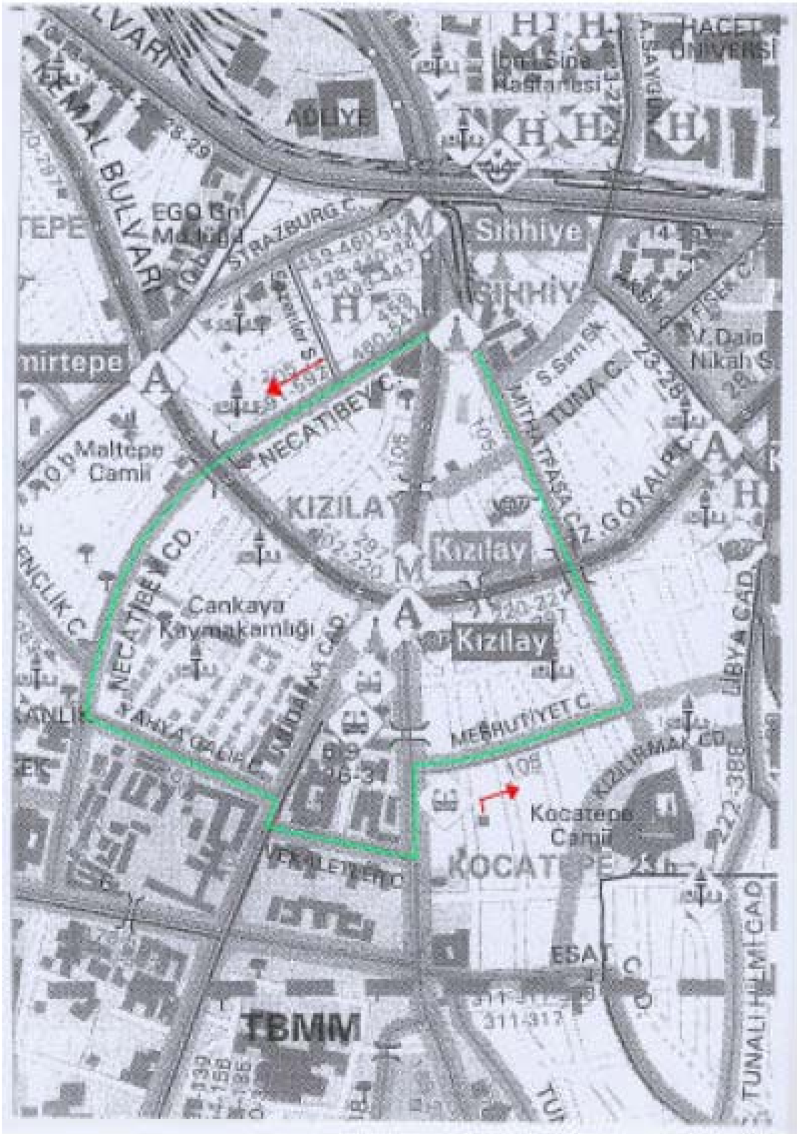
However, for handling transportation problems, it is necessary to look at entire picture. Whereas, partial solutions only provide temporary relieve, proposing comprehensive solutions such as efficient transit system, bus priority, access management applications, land use mix, which keeps drivers from joining through traffic offering on site job opportunities, retail services etc., help to overcome problems for long term.

Auto priority at city center

Traffic congestion which is main reason to offer grade separated intersections is main problem of cities which have road network intersecting in the core. If successful transit metropolises are examined, it is seen that they solve congestion problem in inner city by means of alternative road which provide cross connection without going through center and auto travel restriction policies (Cervero, 1998).

The solution for Ankara is ring roads and restrictions of auto travel while giving priority to buses or other public transportation vehicles in core arterials as aimed in Transportation Master Plan of Ankara. Conversely in Ankara direct opposite applications are realized in such a way that core arterial is dedicated to auto travel and roads carrying potential of alternative roads are dedicated to buses and autos. As an alternative approach to handle this problem, Atatürk Boulevard, which is a main arterial of CBD, may be closed to auto travel and may be dedicated to public transportation and pedestrians. In that case core circular arterials suggested by Akar (2004) functions as an alternative to Atatürk Boulevard. The road sections which flow in the counterclockwise direction are given below (Map 3.9).

- Necatibey Street
- Yahya Galip Street
- Milli Müdafa Street
- Vekaletler Street
- Atatürk Boulevard
- Meşrutiyet Street
- Mithatpaşa Street



Map 3.9: The core circular Arterials.

3. Single land use

In Ankara economic activities are generally collected in city center and in some limited subcenters such as Ulus, Bahçelievler, Tunalı, Maltepe etc. So, people do not find job opportunities in residential areas, which resulted commuting between home and work. Single land use versus mixed land use comparison will be done in detail in “3.3.3.6 Land use mix in Ankara” with examples.

4. ***Random decision of large shopping*** **centers:**

Large shopping centers should be located near transit station instead of locating at urban fringe on the intercity highways. In Ankara, there are lots of examples of auto dependent shopping centers such as Carrefour, Millenium, Metro Gross Market and other outlet stores on the Istanbul Highway and Real Complex in Bilkent. These shopping centers attract auto owners with their large parking areas. People choose to go these types of shopping centers with their autos instead of going city center using public transportation vehicles. It is one of the prominent examples of conflict between policies of Transportation Master Plan and recent applications. However, large shopping centers should be located integrated with public transportation system to avoid people using automobiles. Akköprü Migros which provide opportunity to access with metro system is a successful example in terms of land use-transportation integration.

5. Lack of pedestrianization

In Transportation Master Plan of Ankara, it is emphasized that priority should be given to people and pedesrian facilities should be enhanced. However, Ankara is very far from having a pedestrian friendly environment. In lots of road section, pedestrian have to share roads with high speed vehicle traffic. Figure 3.4 , Figure 3.5., Figure 3.6, shows some examples of this situation.

Figure 3.4: Pedestrian crossing at Sıhhiye, (TMMOB, 2004a)

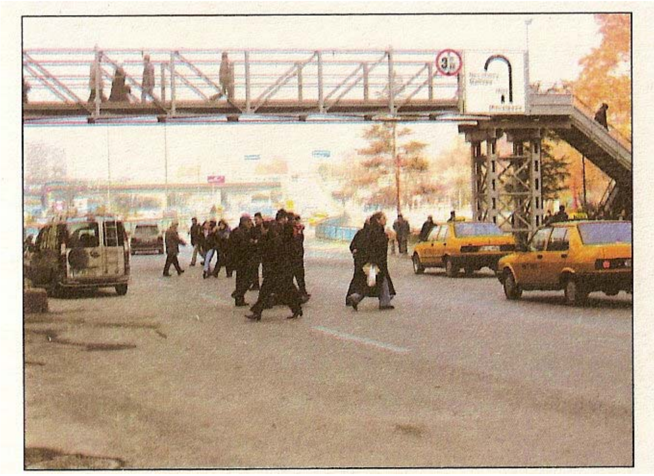


Figure 3.5: Pedestrian crossing at Sıhhıye, (TMMOB, 2004a)

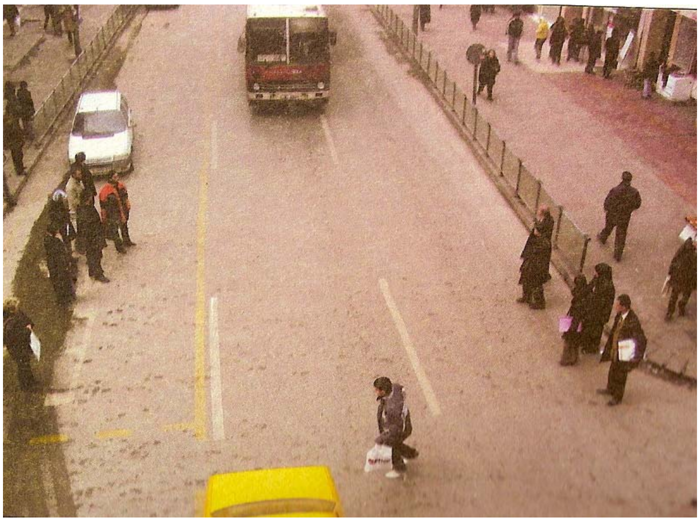


Figure 3.6: Pedestrian crossing at Meşrutiyet Street, (TMMOB, 2004a)

As seen from above Figure 3.4-3.5-3.6, people do not choose to cross over the street using pedestrian bridge in spite of accident risk. This shows that pedestrian bridges cannot be a solution for pedestrian crossings.

Although, it is clear that pedestrians prefer at grade crossings, lots of pedestrian bridge were constructed in Ankara. Especially in Meşrutiyet Street, several pedestrian bridges exist with short spacing. These pedestrian bridges not only inactive facilities but also occupy pedestrian sidewalks (Figure 3.7-3.8-3.9).

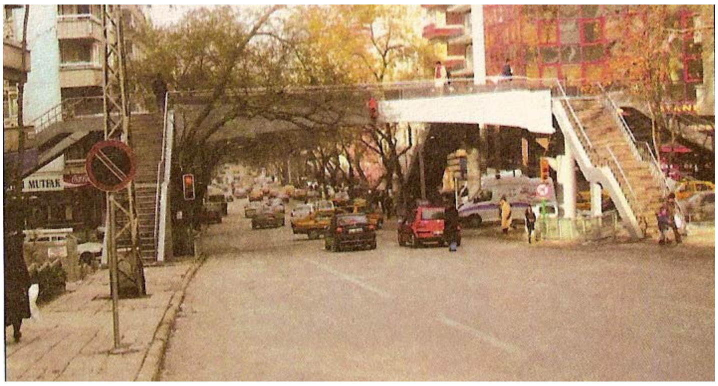


Figure 3.7: Pedestrian Bridge occupying sidewalk, in Meşrutiyet Street (TMMOB, 2004a)

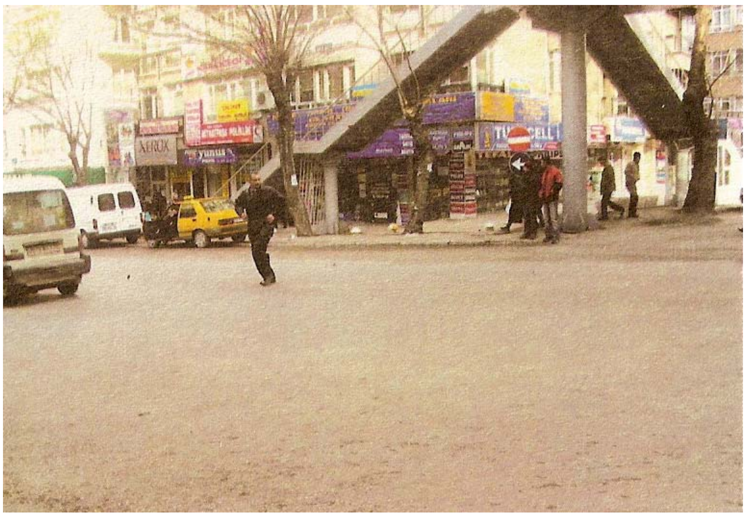


Figure 3.8: Pedestrian Bridge occupying sidewalk, in Meşrutiyet Street (TMMOB, 2004a)

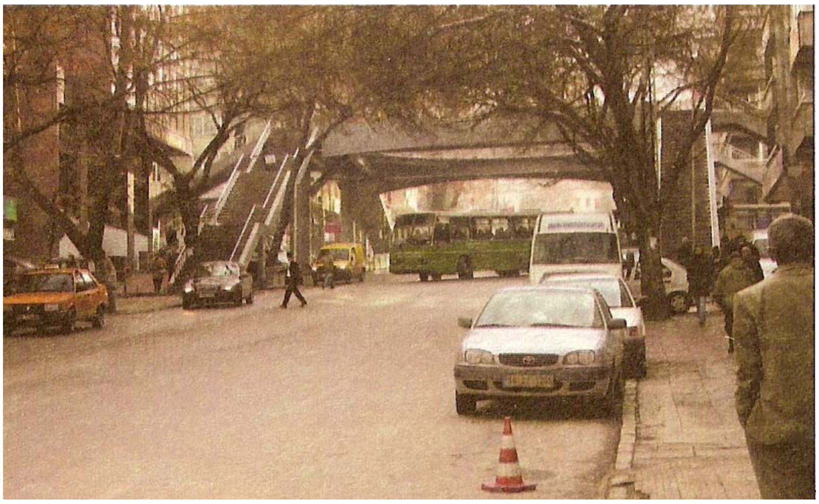


Figure 3.9: Pedestrian Bridge occupying sidewalk, in Meşrutiyet Street (TMMOB, 2004a)

Sidewalks are not only occupied by pedestrian bridge but also with vehicles as shown in Figure 3.10.

Figure 3.10: Vehicle occupying sidewalk (TMMOB, 2004a)

For Meşrutiyet Street a signallized crossing can be a better solution. So that, people can cross over the street safely and at the same time, sidewalks can be wholly devoted to pedestrians (TMMOB, 2004a).

Nevertheless, pedestrian bridges are necessary on arterial road in where movement function is essential. An example of pedestrian bridge on arterial has been constructing on Eskişehir Highway at Ümitköy entrance near transit station. Because of the transit station, very risky crossing has been made especially by commuters in peak periods, but after completion of the pedestrian bridge, probable traffic accidents will be prevented.

6 . Lack of traffic calming applications

- Because of speed limitation in urban areas the maximum road width should be 3.2 m. However, there are road widths which are greater than 3.5 m in Ankara. This makes people to think that the numbers of lanes are more than they are (TMMOB, 2004a).(Figure 3.11)

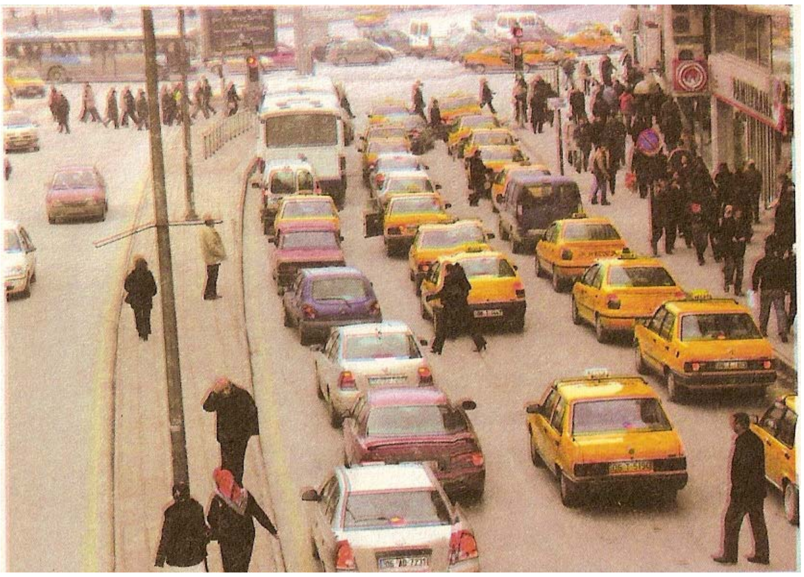


Figure 3.11: Road widths in Ankara, (TMMOB, 2004a)

- Curb radius should be selected so as to decrease the speed of turning vehicles. However in Ankara, this criteria is not considered in the design of roads. Figures 3.12 and 3.13 represent the examples of improper right turning radius.

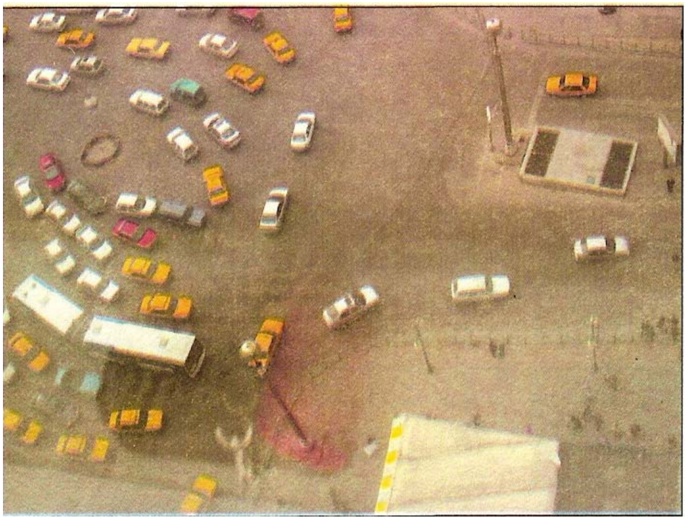


Figure 3.12: Turning radius at Kızılay, (TMMOB, 2004a)

Figure 3.13: Turning radius at Kuğulu (TMMOB, 2004a)

7. Hybrid form of Ankara

Ankara has an urban form which is partially transit oriented and partially auto oriented. In Cervero (1998), these types of urban forms are defined as hybrids. (Appendix B) As in other hybrid form examples, providing public transportation service to auto oriented parts of the city is a problem for Ankara.

In Transportation Master Plan of Ankara, transportation service is defined as public utility and it is stated that public transportation service should be met entirely by the local government. But, lots of private public buses and dolmuses, public transportation vehicles operated by private entrepreneurs, have provided transportation service in where EGO buses and rail transit services provided by Greater Municipality of Ankara are inadequate.

3.3.3.6 Land use mix in Ankara

Mixed land uses are essential to achievie places in which people can live, work, and meet daily need without being dependent on automobile travel. By means of mixed land use, trip distances between activities and number of trips reduce whereas numbers of non-motorized trips increase (Vernez-Moudon et al., 2003).

In Ankara, residential, industrial, retail and public uses and green zones are dispersed in the form of large parcel and development of subcenters and dependently jobs-housing balance could not be achieved (EGO, 1994). In Ankara, city center or CBD have most part of employment in its body and residential areas developed around the CBD. So, most people have to commute between their home and workplace creating high transportation demand directed to downtown.

Jobs-housing imbalance in Ankara

As mentioned above, Ankara does not seem to be successful about creating mixed use, self-contained communities. The Table 3.14, which shows employment and workforce values and jobs to housing ratios associated with numbered district, supports this statement. Hereby, the workforce refers housing unit and employment refers available jobs in the district. Then, dividing employment by workforce, jobs to housing ratio is obtained.

Margolis (1973) suggest that when jobs to housing ratio units lay within interval of 0.75 to 1.25, communities have acceptable balance ratio. From this point, to achieve general idea in terms of jobs-housing balance, values which are within the interval of 0.75 to 1.25 are identified with bold box in Table 3.14 and district number versus jobs to housing ratios is plotted. As seen from graph, only several districts are in the acceptable level[1] (Figure 3.14). Map 3.10 depicts the numbered districts given in Table 3.14.

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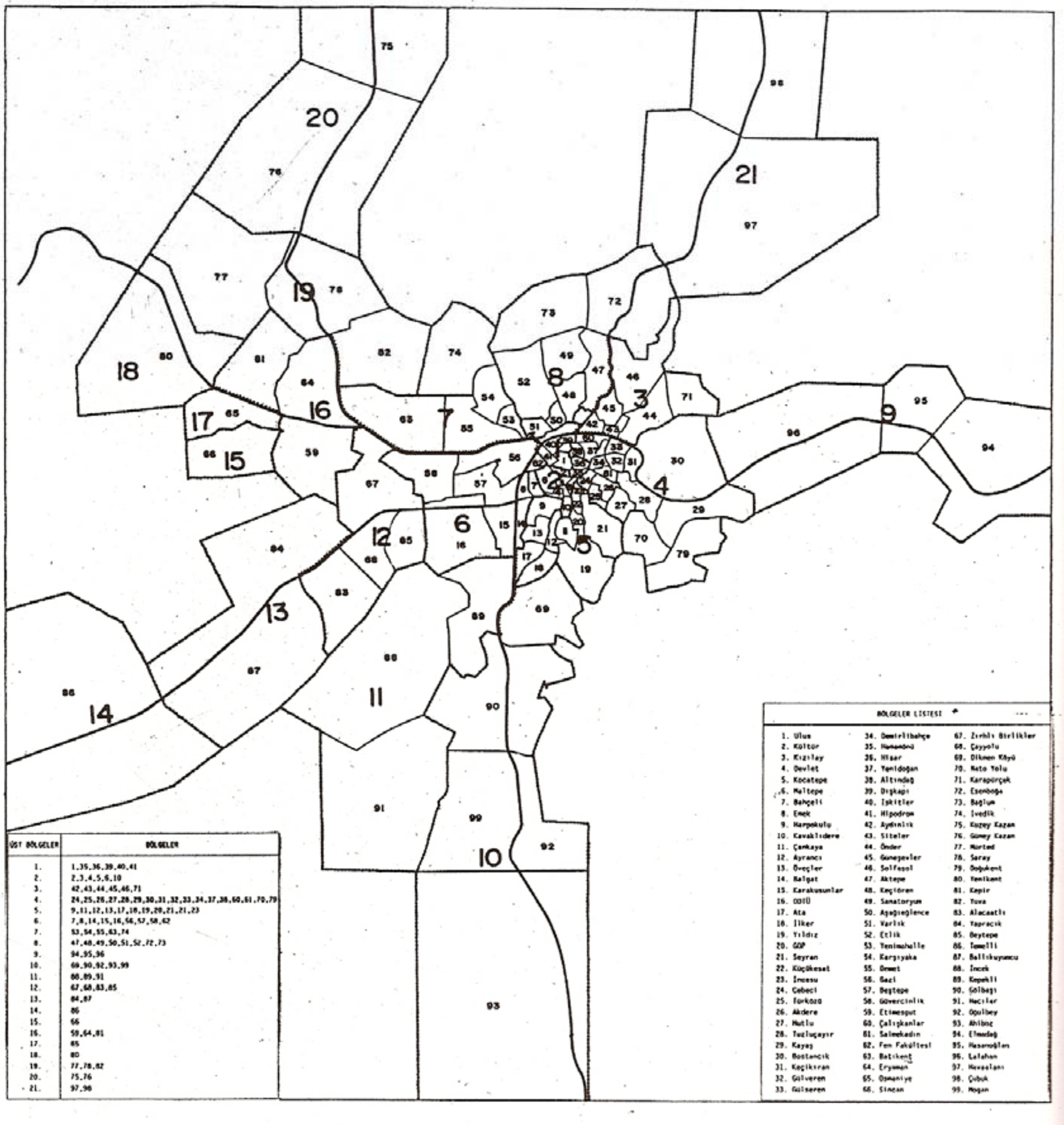
[1] The area selected to calculate jobs-housing ratios should be determined so as to reflect features of region. Because too large or too small areas may not feature the properties of the region in terms of land use. Considering this note, jobs-housing ratios given in the Table 3.14 only give an idea about jobs-housing balance of the 99 districts of Ankara.



Map 3.10: District boundaries (EGO, 1995a).

Table 3.14: Employment, workforce and jobs/housing ratios, 1995 (EGO, 1995a).

		EMPLOYMENT	WORKFORCE	JOBS/HOUSING
1	ULUS	99000	1825	54,25
2	KÜLTÜR	17500	152	115,13
3	KIZILAY	70800	2038	34,74
4	DEVLET	36200	517	70,02
5	KOCATEPE	7750	2130	3,64
6	MALTEPE	18900	8623	2,19
7	BAHÇELİ	7820	10952	0,71
8	EMEK	7700	9127	0,84
9	HARPOKULU	2288	243	9,42
10	KAVAKLIDERE	14430	5172	2,79
11	ÇANKAYA	9200	10648	0,86
12	AYRANCI	9030	13082	0,69
13	ÖVEÇLER	5300	14603	0,36
14	BALGAT	5002	8579	0,58
15	KARAKUSUNLAR	9550	16733	0,57
16	ODTÜ	14528	1460	9,95
17	ATA	4000	12169	0,33
18	İLKER	3993	11470	0,35
19	YILDIZ	5100	15212	0,34
20	G.O.P	6600	9127	0,72
21	SEYRAN	6190	18558	0,33
22	KÜÇÜKESAT	4500	10648	0,42
23	İNCESU	4700	6693	0,70
24	CEBECİ	8150	10648	0,77
25	TURKÖZÜ	2696	7423	0,36
26	AKDERE	5100	12474	0,41
27	MUTLU	3710	11885	0,31
28	TUZLUÇAYIR	9350	28902	0,32
29	KAYAŞ	4650	10648	0,44
30	BOSTANCIK	6050	19775	0,31
31	KEÇİKIRAN	2700	6693	0,40
32	GÜLVEREN	3840	7728	0,50
33	GÜLSEREN	3030	5872	0,52
34	DEMİRLİBAHÇE	4700	6085	0,77
35	HAMAMÖNÜ	8300	1521	5,46
36	HİSAR	7112	6876	1,03
37	YENİDOĞAN	6000	11865	0,51
38	ALTINDAĞ	5000	9127	0,55
39	DIŞKAPI	27000	769	35,11
40	İSKİTLER	32100	3266	9,83
41	HİPODROM	10000	76	131,58
42	AYDINLIK	9090	14907	0,61
43	SİTELER	68900	3651	18,87
44	ÖNDER	15015	32401	0,46
45	GÜNEŞEVLER	7500	17341	0,43
46	SOLFASOL	2440	7910	0,31
47	AKTEPE	9255	27229	0,34
48	KEÇİÖREN	16000	43201	0,37
49	SANATORYUM	11050	28802	0,38
50	AŞAĞI EĞLENCE	7050	6987	1,01

Table 3.14 continued : Employment, workforce and jobs/housing ratios, 1995[1], (EGO, 1995a).

		EMPLOYMENT	WORKFORCE	JOBS/HOUSING
51	VARLIK	6900	913	7,56
52	ETLİK	19700	50807	0,39
53	YENİMAHALLE	7920	12776	0,62
54	KARŞIYAKA	15240	35109	0,43
55	DEMET	23924	35900	0,67
56	GAZİ	12800	3985	3,21
57	BEŞTEPE	15200	5081	2,99
58	GÜVERCİNLİK	3100	852	3,64
59	ETİMESGUT	12800	22818	0,56
60	ÇALIŞKANLAR	3800	7606	0,50
61	SAİMEKADIN	7120	10040	0,71
62	FEN FAKÜLTESİ	17400	0	-
63	BATIKENT	12840	32248	0,40
64	ERYAMAN	12140	35900	0,34
65	OSMANIYE	6750	7606	0,89
66	SİNCAN	9800	21296	0,46
67	ZIRHLI BİRLİKLER	5100	1947	2,62
68	ÇAYYOLU	5150	13691	0,38
69	DİKMEN YOLU	3422	7849	0,44
70	NATO YOLU	23	456	0,05
71	KARAPÜRÇEK	650	1521	0,43
72	ESENBOĞA	2300	4564	0,50
73	BAĞLUM	1500	4564	0,33
74	İVEDİK	800	1521	0,53
75	KUZEYKAZAN	4900	3042	1,61
76	GÜNEYKAZAN	3400	3042	1,12
77	MÜRTED	5250	456	11,51
78	SARAY	6400	1521	4,21
79	DOĞUKENT	1835	456	4,02
80	YENİKENT	1850	4564	0,41
81	KEPİR	6500	24339	0,27
82	YUVA	225	761	0,30
83	ALACAATLI	550	1521	0,36
84	YAPRACIK	340	608	0,56
85	BEYTEPE	2950	4564	0,65
86	TEMELLİ	6504	4077	1,60
87	BALLIKUYUMCU	2086	4198	0,50
88	İNCEK	2900	9127	0,32
89	KEPEKLI	612	426	1,44
90	GÖLBAŞI	12302	20627	0,60
91	HACILAR	1616	5720	0,28
92	OĞULBEY	2320	1065	2,18
93	AHİBOZ	2470	2890	0,85
94	ELMADAĞ	7985	7756	1,03
95	HASANOĞLAN	8240	5476	1,50
96	LALAHAN	2440	1095	2,23
97	HAVAALANI	5124	2373	2,16
98	ÇUBUK	2088	2981	0,70
99	MOGAN	3200	152	21,05

[1] Employment workforce values proposed for 1995, are taken from Ankara Transportation Master Plan EGO, (1995a)

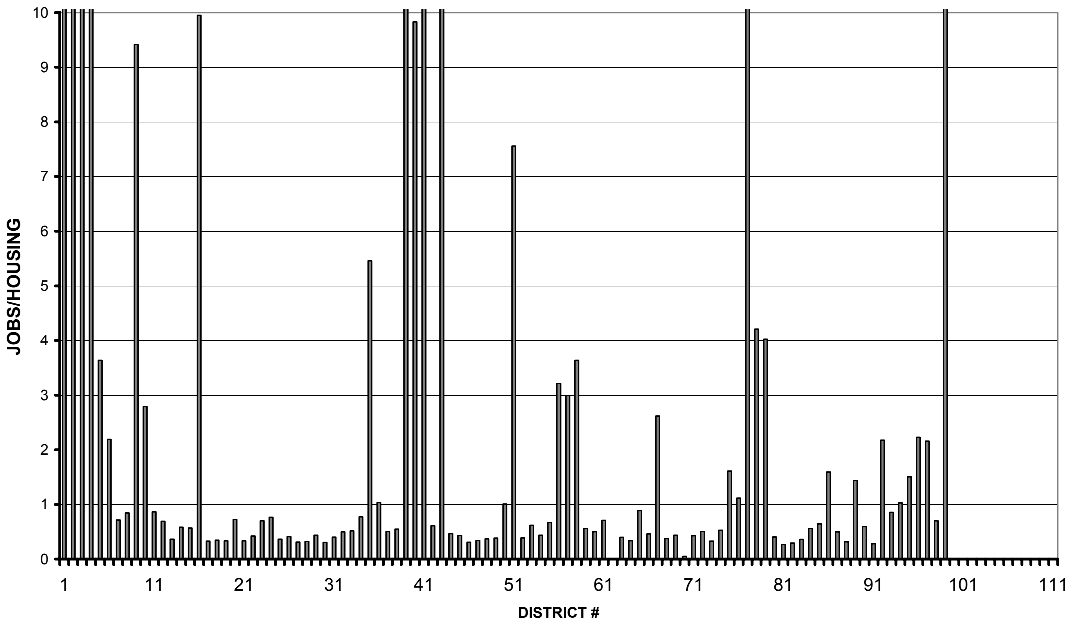


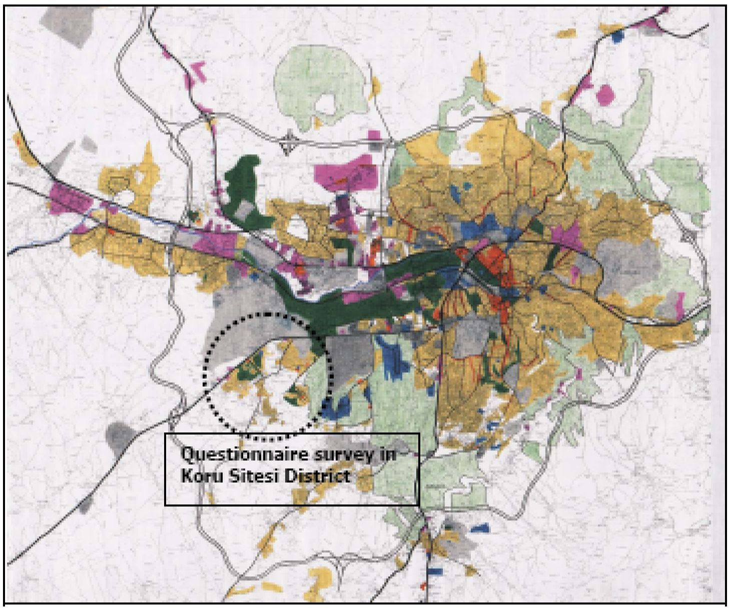
Figure 3.14: Graph of jobs to housing ratio[1] versus district number according to Table 3.14

1.Jobs-housing imbalance in Çayyolu

Çayyolu area is composed of a newly developed low density[2], auto oriented neighborhoods which are Konutkent, Ümitköy, Beysukent and Koru Sitesi, located along Eskişehir Highway at southwestern part of Ankara (Map 3.11). These developments do not feature properties of self-confident, mixed land use communities. In the area both detached houses and multistory houses exist in a low density pattern. There are limited shopping centers and limited work places in the neighborhood. Mostly high income families live in this area, this result high auto ownership ratio.

[1] High jobs to housing ratios are not shown in graph to ensure clearance

[2] Density of Çayyolu is given as 60 p/ha in unpublished MS thesis study done by Çalışkan (2004). It is far lower than 152 p/ha, the average density of Ankara. (152 p/ha is calculated taking only built up areas into account)



Map 3.11: Location of survey area in Ankara (Zorlu, 2006)

A recent study which contains a household questionnaire[1] about travel behaviour of this area in 2004 was conducted by Zorlu (2006). Results of the survey support above statements. According to study; auto ownership is 399 autos per 1000 population. It is very far from average auto ownership level of Ankara which is 182 autos per 1000 population (Akar, 2004). And as a result of lack of job opportunities, almost all of the work places of the residents are out of neighborhood (Figure 3.15).

In this condition, as expected, the auto travel becomes major mode with the share of 55%. For motorized trip, its percentage runs up to 61% which overs excessively percentage of average auto travel of Ankara in motorized trips, %25.9 in 2004[2](Figure 3.16).

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[1] Questionnaire is conducted for sample size of 628 person.
[2] This value is interpolated using modal split data of 2003 (Table 3.8) and 2005 (Table 3.9).

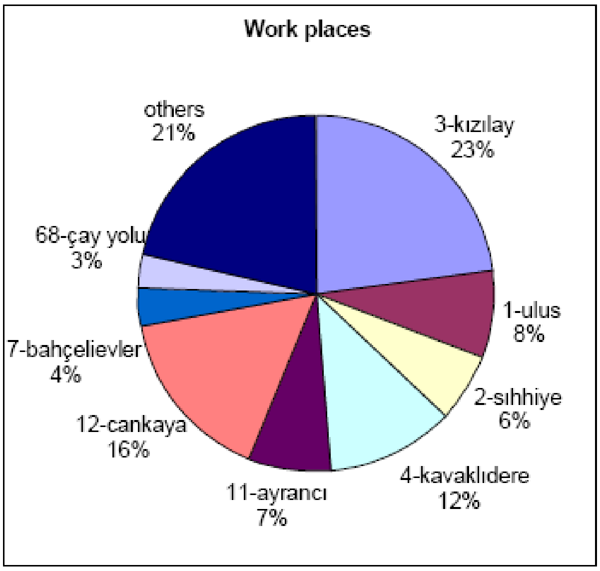


Figure 3.15: Work place of residents of survey area, (Zorlu, 2006).

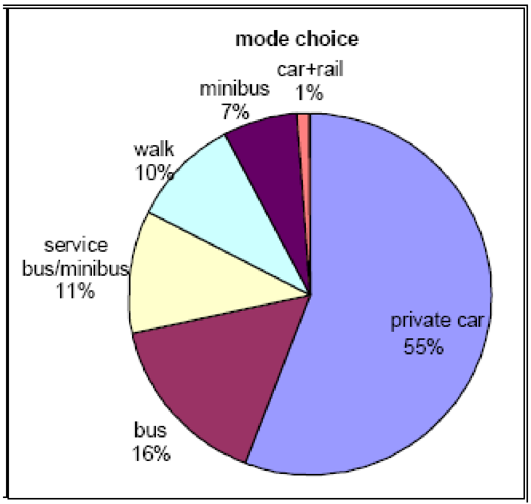
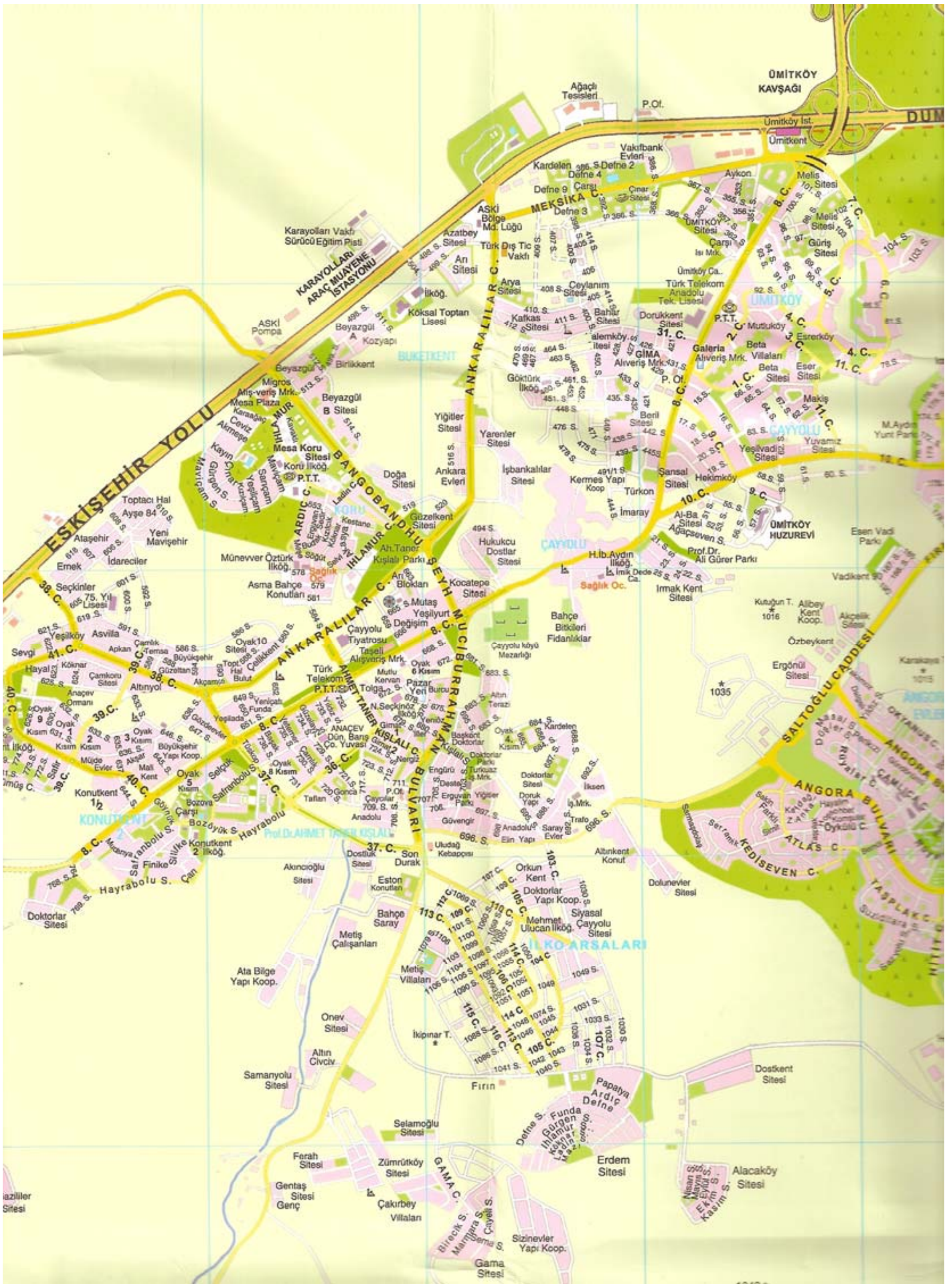


Figure 3.16: Mode choice in survey area, (Zorlu, 2006).

Çayyolu is very typical example for auto oriented developments with its low density, single land use, curvilinear and cul de sac streets. Additionally, in the neighborhood, there are not any sidewalk systems or bikeway systems or any other pedestrian friendly application. (Map 3.12)



Map 3.12: Curvilinear and cul de sac street pattern of Çayyolu Area (Ankara Büyükşehir Belediyesi, n.d)

Besides, there is not a reliable bus service meeting needs in the area. Also, dispersed pattern of housing do not allow establishing a bus route which ensure easy walking distance for residents to reach bus stops. Another reason is long travel distances with uncomfortable buses. As a result people choose to travel with their own autos instead of suffer from inefficient transit system.

Thus, it is inevitable to have such a low percentage of pedestrian travel, 10%, and high percentage of auto travel, 55%, for that area with combination effect of dispersed housing, curvilinear street pattern, shopping centers which are not within the easy walking distance, jobs-housing imbalance, high auto ownership and low quality transit service.

To solve transportation problem of Eskişehir Highway, heavy rail system has been designed and constructing recently.

- Kızılay-Çayyolu Heavy Rail (Metro) Transit System

With the construction of the rail system, it is expected that Çayyolu will have comfortable and fast transportation system and became transit adaptive neighborhood which means to transfering auto oriented development to *adaptive transit* neighbourhood by constructing heavy rail system (Cervero, 1998). Schematic scheme of Kızılay-Çayyolu Metro System is given in Figure 3.17.

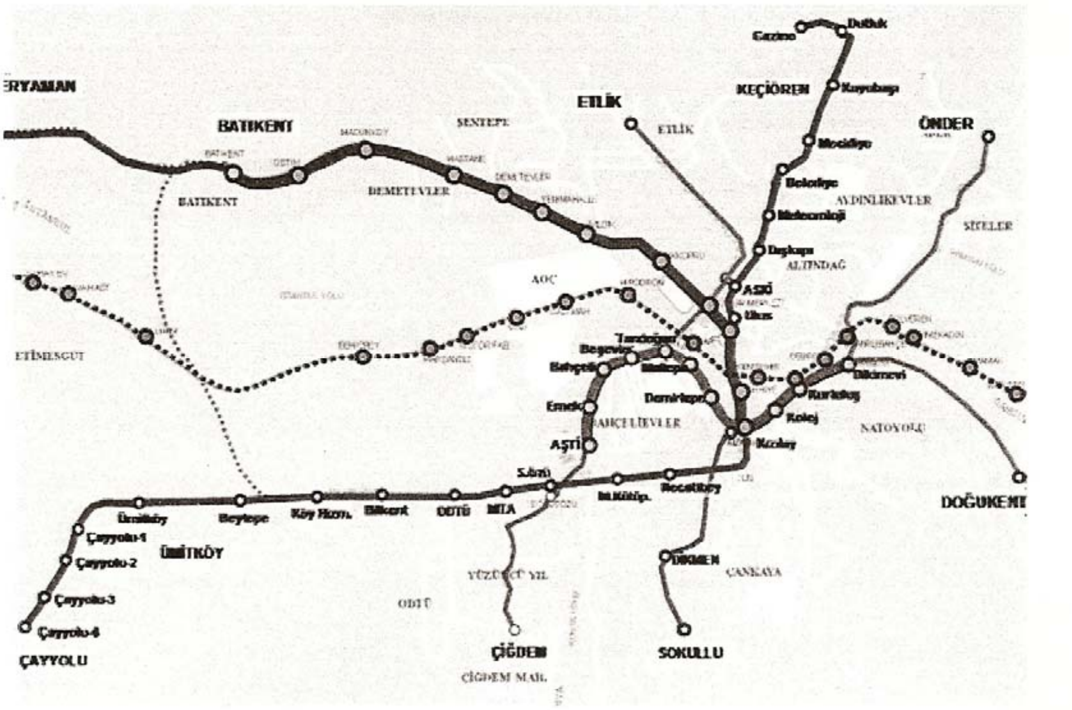


Figure 3.17: Planned rail system lines of Ankara, 2005 (EGO, 2004)

Examining Transportation Survey of Kızılay-Çayyolu Metro Project (EGO, 2004) below results are obtained;

- Cordon count result of stations, shown in Figure 3.18, gives an idea about traffic generated from and attracted to Çayyolu.
- Difference of number of passengers value for Konutkent (1861 passenger) and Ümitköy (8355 passenger) determines the passengers added at Çayyolu count station (including Koru Sitesi, Konutkent, Ümitköy) in the direction of CBD. So the difference is 6494 passenger (Table 3.15).
- Whereas for opposite direction (trips from CBD), difference of number of passengers value for Konutkent (2021 passenger) and Ümitköy (4201 passenger) is 2180 (Table 3.16). The large difference between 6494 and 2180 show as Ümitköy could not attract trip as much as it generates.
- As a result, we reach same conclusion from above results that Çayyolu is not succesfull about being a mixed use subcenter and balancing jobs-housing ratios.

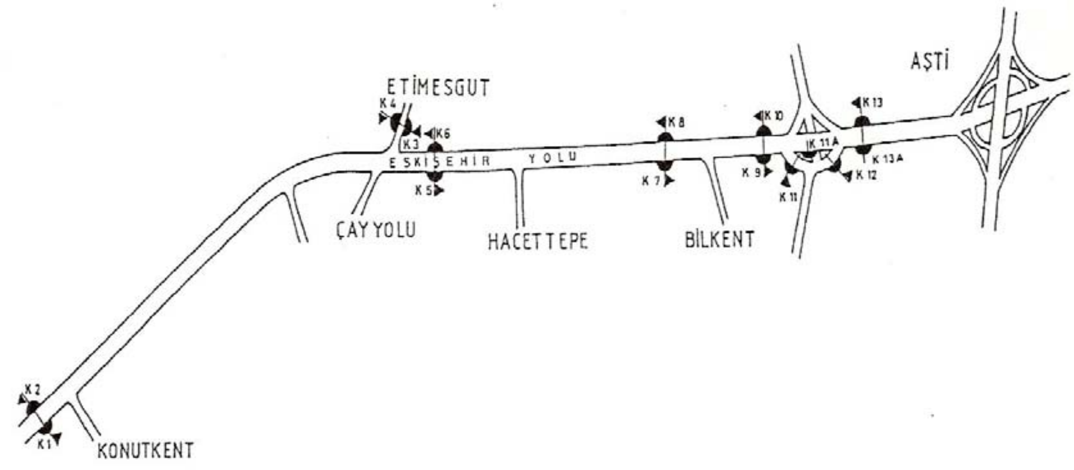


Figure 3.18: Traffic cordon count stations of Eskişehir Highway. (ATTIS, 1998 as cited in EGO, 2003)

Table 3.15: Eskişehir Highway Cordon Counts – Number of Passenger Traveled by Public Transportation and Number of Passenger Traveled by Private Transportation to CBD, (EGO, 2004).

	NUMBER of PASS. (PUBLIC TRANSPORTATION	%of PUBLIC TRANSP.	NUMBER of PASS. PRIVATE TRANSPORTATION	% of PRIVATE TRANSP.	TOTAL
	To CBD				
K1-Konutkent	549	**30%**	1312	**70%**	**1861**
K5-Ümitköy	5000	**60%**	3355	**40%**	**8355**
K7- Beytepe	5132	**54%**	4428	**46%**	9560
K9-Bilkent	5997	**57%**	4604	**43%**	10601
K11A-ODTÜ	5367	**68%**	2583	**32%**	7950
K13A-MTA	13401	**73%**	4834	**27%**	18235

Table 3.16: Eskişehir Highway Cordon Counts – Number of Passenger Traveled by Public Transportation and Number of Passenger Traveled by Private Transportation from CBD (EGO, 2004).

	NUMBER of PASS. (PUBLIC TRANSPORTATION)	%of PUBLIC TRANSP.	NUMBER of PASS. (PRIVATE TRANSPORTATION)	%of PRIVATE TRANSP.	TOTAL
	From CBD				
K1-Konutkent	542	**27%**	1479	**73%**	**2021**
K5-Ümitköy	1728	**41%**	2473	**59%**	**4201**
K7- Beytepe	5482	**72%**	2133	**28%**	7615
K9-Bilkent	7006	**72%**	2740	**28%**	9746
K13A-MTA	8344	**65%**	4500	**35%**	12844

Additionally, expected passenger volumes are determined by using IBIMOD transportation model. This model which is developed by Canadian IBI Firm was used also for 1985 Ankara Urban Transportation Study and 1994 Ankara Transportation Master Plan. According to IBIMOD model, passenger volumes are obtained for associated stations for 2015 (EGO, 2004) (Table 3.17 and Figure 3.19). As seen from Figure 3.19, passenger volumes directing toward Kızılay direction are relatively higher than passenger volumes directing toward Çayyolu-4 direction. This difference appears very high between ODTÜ and Çayyolu-4 station.

This evidence again indicate that in Çayyolu region in where residential land use is dominant, land use mix or jobs-housing balance could not applied successfully. Because of lack of job opportunities, people have to commute between their home and jobs. As a result, in peak period very high differences occur between generated and attracted trips.

Table 3.17: Kızılay-Çayyolu Metro System Expected Peak Period Passenger Volume, 2015 (EGO, 2004).

Expected Peak Period Passenger Volume of Kızılay-Çayyolu Metro Line (2015)		
Station (East Section)	**To West**	**To East**
Çayyolu-4	10691	543
Çayyolu-3	14231	1347
Çayyolu-2	23644	2012
Çayyolu-1	24774	2335
Ümitköy	25255	2982
Beytepe	25264	4920
Köy Hizmetleri	25563	5378
Bilkent	25595	8469
ODTÜ	24140	13230
MTA	24550	13813
Söğütözü	30313	12486
M. Kütüphane	32051	11232
Necatibey	31130	12462
Kızılay		

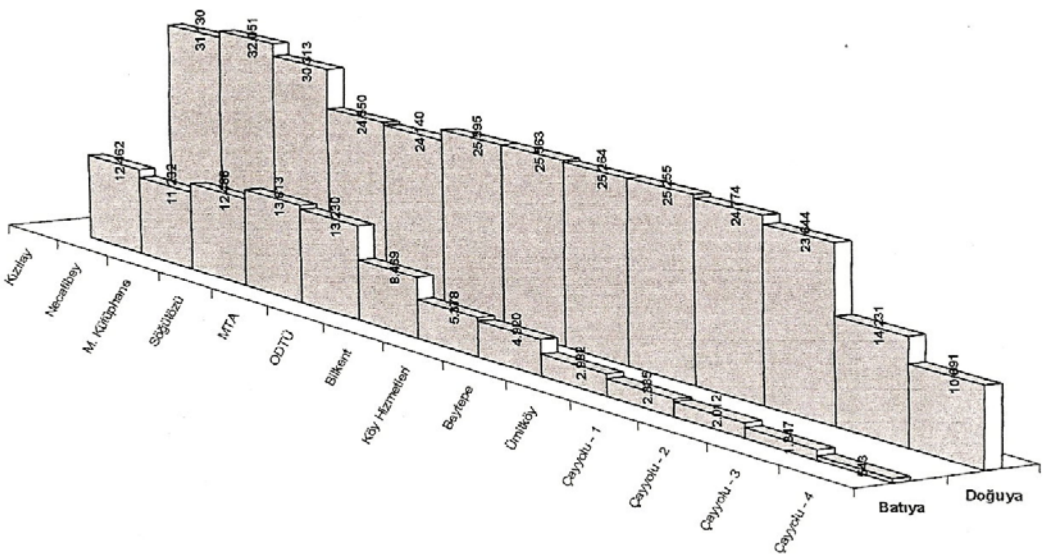


Figure 3.19: Passenger volumes of Kızılay-Çayyolu Metro System at peak period for 2015 (EGO, 2004).

Suggestions for Çayyolu Area

In Çayyolu area, job opportunities should be provided to create jobs-housing balance by means of which travel distances reduce and also balanced passenger volumes can be obtained in metro system attracting trips to area. Retail shops should be provided within easy walking distance as many as possible to decrease auto travel.

Furthermore, pedestrian conditions should be improved providing sidewalk system and applying traffic calming to discourage auto travel. A bikeway is also required in Çayyolu especially after completion of metro project, cycling can be a reasonable mode for students to access rail station.

2. Jobs-housing imbalance at Keçiören

Keçiören is a compact, high density residential area and it reachs satisfaction point in terms of density. In the Keçiören, there are a few small scale public organization and some retail activities. Large production plants or large scale public organizations do not exist in the area. So, Keçiören could not achieve being mixed use subcenter. As a result of this features, in peak periods high amount of work travel demand occur to CBD, whereas low amount of trips directed to Keçiören in morning peak, therefore unbalanced traffic volumes come out in peak periods (EGO, 2005b).

In peak period, high percentage of travel demand is met by public transportation, but existing public transportation system which is provided by bus, dolmus, public services etc. is not sufficient for such a high demand (Table 3.18). For instance, EGO buses carries 87.7 passenger in average to CBD, in spite of the fact that maximum passenger for standart buses is determined as 75 passenger /bus in Transportation Master Plan (EGO, 1995a; EGO, 2005b).

For solving transportation problems, heavy rail system (metro) has been designed and constructing recently between Tandoğan-Keçiören (Figure 3.17).

Keçiören will have comfortable, fast and reliable transportation system after completion of the metro system. Table 3.18 and Table 3.19 include results of cordon counts in 2003 which performed for the purpose of obtaining required data to design metro system. Obtained results confirm unbalanced travel demand, in such a way that at Fatih Köprüsü count station, traffic directing toward Keçiören is about 29% (=18301/62590) of traffic directing toward Kızılay. Locations of count stations are given in Figure 3.20.

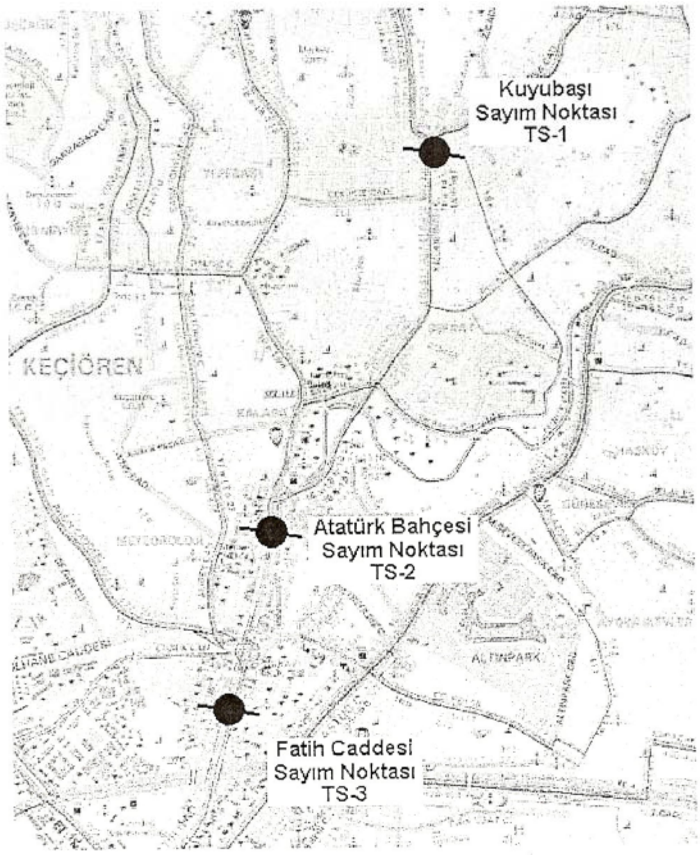


Figure 3.20: Keçiören Metro Corridor cordon count stations, (EGO, 2005b).

Table 3.18: Keçiören Cordon Counts – Number of Passenger Traveled by Public Transportation and Number of Passenger Traveled by Private Transportation to CBD, (EGO, 2005b).

	NUMBER of PASS. (PUBLIC TRANSPORTATION)	%of PUBLIC TRANSP.	NUMBER of PASS. (PRIVATE TRANSPORTATION)	%of PRIVATE TRANSP.	TOTAL
	To CBD				
Kuyubaşı	17880	**78%**	5112	**22%**	22992
Atatürk B.	27759	**72%**	10750	**28%**	38509
Fatih Köprüsü	47863	**76%**	14727	**24%**	62590

Table 3.19: Keçiören Cordon Counts – Number of Passenger Traveled by Public Transportation and Number of Passenger Traveled by Private Transportation from CBD, (EGO, 2005b).

	NUMBER of PASS. (PUBLIC TRANSPORTATION)	%of PUBLIC TRANSP.	NUMBER of PASS. (PRIVATE TRANSPORTATION)	%of PRIVATE TRANSP.	TOTAL
	From CBD				
Kuyubaşı	10285	**83%**	2070	**17%**	12355
Atatürk B.	9084	**73%**	3399	**27%**	12483
Fatih Köprüsü	14237	**78%**	4064	**22%**	18301

Expected passenger volumes are determined by using IBIMOD transportation model as in the case of Kızılay-Çayyolu Metro. According to IBIMOD model, passenger volumes are obtained associated with stations for 2015 (EGO, 2005b). (Table 3.20 and Figure 3.21). As seen from Figure 3.21, passenger volumes are extremely higher for trips directing toward Tandoğan than trips directing toward Gazino. This unbalanced directional distribution is result of a single land use.

Since, in Keçiören, job opportunities are very limited as mentioned above, people have to commute between their homes and their works.

Table 3.20: Tandoğan-Keçiören Metro System Expected Peak Period Passenger Volume, 2015 (EGO, 2005b)

Expected Peak Period Passenger Volume of Tandoğan-Keçiören Metro Line (2015)		
Station (East Section)	**To South**	**To North**
Gazino	8959	1173
Dutluk	13711	2806
Kuyubaşı	23968	7413
Mecidiye	28359	8418
Belediye	39499	9457
Meteoroloji	43979	7238
Dışkapı	34612	7875
ASKİ	31990	9949
AKM	21934	9021
EGO	19125	6327
Tandoğan	-	-

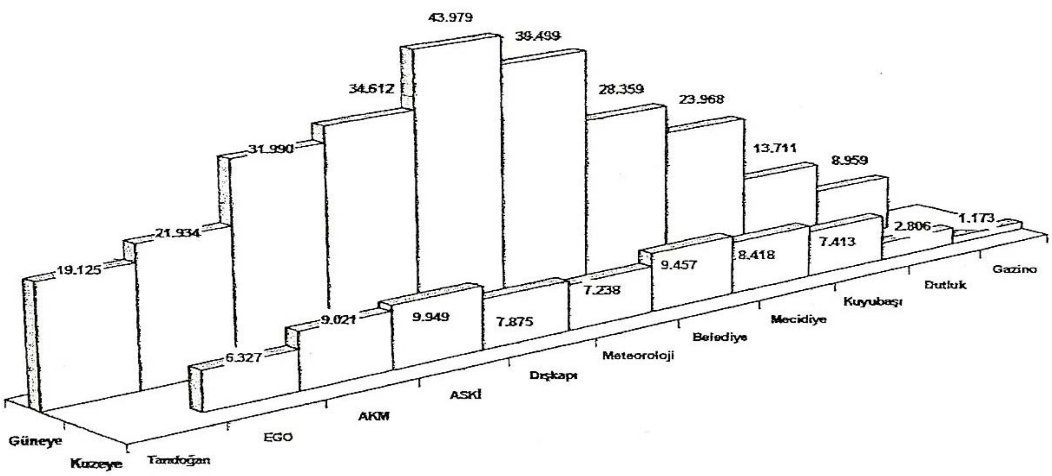


Figure 3.21: Passenger volumes of Tandoğan-Keçiören Metro System at peak period for 2015 (EGO, 2005b).

Suggestions for Keçiören

Creating new job opportunities in the Keçiören is compulsory to reduce passenger volume directing toward CBD. Considering compact form of Keçiören, arranging parking areas near rail station is difficult, so feeder bus system and pedestrian travel will be dominant to access rail station. To encourage pedestrian travel, a pedestrian friendly environment should be ensured applying traffic calming, designing pedestrian crossings, creating pedestrian only zones and integrating these zones with rail stations.

CHAPTER 4

SUMMARY AND CONCLUSIONS

The link between land use and transportation

Transportation need comes out as a result of need to join activities of people. So, locational arrangements of activities, namely land use determines the travel patterns. At the same time, transportation facilities can direct or change land use. This interaction between land use and transportation creates a continious cyclic process. In such a way that first land use create transportation demand, after that transportation facilities are added to the system, then this system increase accessibility and dependently stimulate more transportation demand. So transportation facilities become insufficient and needs to develope.

Land use factors affecting transportation system

This study aims to determine land use impacts on transportation so as to identify which land use pattern causes which result. Investigating literature about land use impacts on transportation from various perspectives, which are density, land use mix, jobs-housing balance, street design, transit accessibility, general findings are obtained.

Density

Density or compactness which means number of person or employment in a particular area is one of the basic determinants of travel behaviour. High density minimizes travel distances and consequently increases accessibility of area. In addition, high density is essential for efficient urban public transportation because required high level of ridership is provided by means of densely populated areas. Besides these advantages, in dense areas, auto ownership levels are lower than in relatively low density areas because of scarcity of areas devoted parking.

Dependently, short travel distances cause an increase in share of nonmotorized modes in modal split and also ability to supply efficient transit system increases usage of public transportation modes such as buses and rail systems in high density areas. As a result of higher usage of nonauto modes, energy consumption and vehicle miles of travel decreases for compact areas.

Land use mix

Another determinant of travel behavior is land use mix which means clustering different land uses such as residential, office, retail etc. within an area. Land use mix can occur vertically or horizontally. Vertical land use mix is applied in buildings devoting floors of building to different land uses, for instance, first floors are generally used for retail activities and upper floors are used as a residential units or office. Horizontal land use mix clusters different land uses horizontally different from vertical land use mix.

Land use mix gives opportunity to people for making different activities in short distances. So, travel distances decrease and nonmotorized modes become convenient or prevailing mode. This result a decrese in number of vehicular trips, total vehicle miles traveled and travel time.

Studies about mixed land use effect on travel behavior in suburban workplaces also indicates that mixed land uses encourages transit trips and reduces auto trips providing nearby opportunities for lunch time activities. Single land use creates high trip demands in peak periods, whereas mixed land use spreads trips more evenly throughout the day and creates bidirectional flow of traffic in peak periods facilitating efficient usage of infrastructure. Mixed land use also enables shared parking and ridesharing.

Jobs-housing balance

Creating jobs-housing balance in communities is one of the main purposes of mixed land uses. Jobs-housing balance keeps drivers from joining through traffic providing job opportunities near residential areas.

Shortened trip distances encourage people to use nonmotorized trips. Consequently, congestion, vehicle kilometers traveled, energy consumption and the emission of vehicle pollutants decrease.

Street patterns

Street pattern is one another factor affecting travel behavior. If historical period is investigated, it is seen that there is an evolution of street pattern from gridiron to cul de sac. In traditional or neotraditional developments grid patterns which are highly connected, dense, street patterns are used whereas in conventional suburban developments poorly connected hierarchical road system is used with many cul de sacs. This increases the travel distances, creates higher traffic volumes channeling traffic onto arterials, and does not offer pedestrian friendly environment because of larger block size and indirect routes.

However, grid pattern offer more direct routes with small block size and shorter travel distances. As a result of small block size the number of intersection increases, more frequent intersections offer more left turn opportunity and also cause drivers to slow down. All of these features, lower speed, shorter travel distances, more direct routes create pedestrian friendly environment.

Besides these, grid pattern gives opportunity to driver not to go enter arterial traffic providing alternative routes and increase capacity of system with dense street pattern.

Additionally, grid pattern is more convenient for transit use because transit stops are more accessible from neighborhoods and for town center development; grid pattern is more suitable than strip developments along arterial roads.

Access management

Access management is a tool to increase performance of street networks. It is defined as an effort which ensures efficient and safe flow of traffic while providing access to desired land. Access management tries to limit number of conflict points,

to seperate conflict points, to seperate turning vehicles from through traffic, to ensure hierarchy of road network and to limit direct access to arterial roads. Shortly, access management causes an increase in capacity and safety.

Transit accessibility

Last item of literature survey is transit accessibility. Transit oriented development or transit villages are examined to define transit accessibility. Transit oriented development means facilitating public transportation through transit supportive design. Outcoming problems of auto travel such as traffic congestion, air pollution and high energy consumption etc. strengthen the tendency of using mass transit.

According to examined studies, compact and high density land uses are essential to achieve transit supportive urban form. As origins and destinations spread over wide area, possibility to access transit station or bus stops reduces; consequently ridership level reduces, then establishing accessible and efficient transit system becomes more difficult. As a result people choose car instead of using transit vehicles in low density areas.

Residential density, nonresidential density and distance from downtown are identified as determinants of effective public transportation. Hereby, residential density and non residential density are considered as trip generator and trip attractor respectively. Therefore, for both high residential and high nonresidential density indicates a high transportation demand which ensure efficient public transportation. Moreover, shorter distances between residential and nonresidential areas result in high transit demand. Because of these reasons, compact form is desired to create transit supportive developments. Additionaly, studies shows that an economically strong CBD[1] is essential to reach required transportation demand.

Besides high density, mixed land use is indispensable part of transit oriented development. Mixed land use encourages people to walk instead of to drive providing various activities together. Locating retail shops, restaurants etc. near workplaces eliminates requirement of auto use to reach lunch time activities. Therefore people choose public transportation because they do not need their autos anymore.

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[1] Besides having high amount of non-residential floorspace, strong CBD concept also means redeveloped and pedestrianized CBD which have high travel activity in terms of transit and pedestrian travel.

Locating workplaces near residential units, namely creating jobs-housing balance also degenerates auto travel and ensures bidirectional flow which offers efficient transit service instead of one directional flow as in the case of single use regions. Beyond being mixed and compact, form of developments affect the performance of transportation system. Basic principle of transit oriented design is concentrating development around bus or rail station or along transit corridors. From this point of view, it is emphasized that compact developments with a limited number of subcenters which are connected to strong core and each other via transit network supports high transit ridership. Grid like street pattern is preferred for transit oriented developments, because grid pattern increases accessibility of transit riders minimizing distance from stations and provides efficient routes for bus travel.

Lastly, pedestrian friendly environment is essential for high transit ridership. Provision of continuous sidewalk network, street furniture, safe pedestrian crossings, pedestrian only zones integrated with rail stations is necessary to support public transportation and to reach livable environment standard.

Other factors

After emphasizing that land use has very significant impact on transportation system performance through above statements, it is necessary to indicate other factors such as income level, gasoline price, parking prices which can support or distort land use policies. High income level, low gasoline price and low parking cost encourage automobile use inevitably. Consequently, it is very difficult to keep drivers away from their cars. Because of this reason land use and transportation policies should be implemented with reasonable pricing policies.

Another fundamental issue comes out in the planning process. Coordination between land use planning and urban transportation planning is crucial to achieve community in where transportation and urban form complement each other and create efficient transportation system. Evidences from successful transit metropolis show that integration between land use and transportation is key point to reach high performance transit system. However, it is very difficult to ensure coordination between parties, generally for transportation and land use, independent decision are taken regardless of their interactive nature. So, auto oriented, low density, single use communities are developed as in the case of many auto dependent countries.

Case study: Ankara

Being capital city of Türkiye, Ankara still continues to develop. However, development of city could not be directed entirely by planning decisions in historical period. Consequently, hybrid form of Ankara has come out. High density radial corridors connecting at urban core represent features of adaptive city which is a type of transit-oriented metropolises, whereas, low density, dispersed developments represent features of adaptive transit cities which try to adapt their transit system to serve low density dispersed areas.

When the density of Ankara is examined in historical period, it is seen that there has been a decreasing tendency due to partial planning and unplanned development. In world classification, the density of Ankara is very near to European average with effects of outgrowth after 1990. As a result of urban sprawl of Ankara, an increase in automobile travel has come out while nonmotorized travel reduces day by day due to unconcerned behaviors of authorities.

It is worthwhile to note that Ankara has the highest level in work trips on transit among world cities and level of work trips by walking/cycling is higher in Ankara than many world cities by the year of 1990. Because, Ankara has three prerequisites of cost effective and sustainable transit service which are a large dominant center, dense residential developments and long radial corridors. Furthermore, low income level and high gasoline price have very significant supportive effect on high transit and walking trip rates for work trips.

In spite of these advantages, Ankara is proceeding in the way of being auto dependent city. Although, principles of transportation master plan of Ankara includes most of the key factors for success such as land use-transportation integration, jobs-housing balance, creating mixed land use subcenters, CBD redevelopment, priority to people, social equity, integration of transit systems,pedestrianization, bus priority and so on, implementations do not support the defined objectives or are not parallel to the plans.

Unplanned, auto oriented, low density, single land use developments i.e. Çayyolu, Bilkent, İncek, Temelli, Beysukent etc. are examples of lack of land use-transportation integration. Because, such type of developments do not allow efficient transportation system and create long travel distances, congestion problems, air pollution etc.

Besides these, recent applications of Greater Ankara Municipality in Ankara mostly come out as based on auto priority. Grade separated intersections are prominent examples of this policy. While construction of rail transit systems continues, grade separated intersections have been constructed. This creates conflict between goals and objectives of urban transportation planning and applications.

Another problem of Ankara which causes increase of auto travel is job-housing imbalance. Ankara does not seem to be successful about creating mixed use, self-contained communities considering the jobs to housing ratios associated with neighborhoods of Ankara. Therefore, people have to commute between their homes to CBD in where most of the job opportunities exist. Besides long commute distance and excessive travel demand directing toward CBD, one directional traffic flows occur during peak period along corridor connecting residential area to CBD.

Additionally, little or no effort has made for pedestrians. Some sidewalks are converted to roads or car park. Traffic calming is not applied in areas where pedestrian movements are high.

It can be concluded that increase in car travel seems to continue unless current applications which favor auto travel are stopped.

Proposals for Ankara

Below proposals are offered to contribute achievement of improved transportation system performance in Ankara.

- Land use-transportation integration must be ensured in planning and implementation stages. Coordination between authorities and groups dealing with urban transportation planning and urban planning is essential for integration process.

- Jobs-housing balance should be tried to apply in single use, residential areas to prevent long commute distances and one directional traffic flow at peak periods.
- Vertical and horizontal mix of land use should be applied in new developments in where retail activities are not in the easy walking distance. This would decrease auto travel for shopping.
- Applications which favor auto travel such as construction of grade separated intersections and road widening should be stopped. Otherwise, people would prefer to use their cars instead of using transit systems available or being constructed.
- Random decision of large shopping centers leads to increase in auto usage. Because of this reason, they should be located near rail stations as in the case of Akköprü Migros.
- In Ankara, bus system is still carrying vast majority of passengers as a main bus or feeder bus. So, bus priorty regulation should be realized to encourage operators and people for public transportation.
- Share of pedestrian travel in modal split reduces day by day in Ankara. In city center, auto travel is supported by improper applications. However, city center should be devoted for pedestrian travel and public transportation.
- Pedestrian friendly environment should be ensured through traffic calming applications, reasonable pedestrian crossing, pedestrian only areas and sidewalk network.
- For new developments, transit supportive design should be planned considering probable extension of rail stations.
- In new developments, curvilinear and cul de sac type of street patterns should be avoided because of the reason that these patterns support auto travel and increase vehicle kilometers traveled. Grid street pattern should be used when topography is convenient.
- Block size should be formed as small as possible to minimize travel distances and to increase pedestrian travel. If small block is not possible, pedestrian paths can be created in large block to ensure pedestrian scale.

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APPENDIX A

Protected Only Left Turn Signals

Protected Only left turn signals allow vehicles to proceed during the display of the green left turn arrow only. No permissive green ball is displayed, therefore vehicles may not move during gaps in the opposing through traffic.

The considerations for installation of Protected Only left signals include:

- High left turn traffic volume
- High Opposing through volume
- An existing crash history
- The geometric design of the roadway is such that sight distance for left turn traffic is insufficient for safe completion of a left turn across opposing traffic
- High speed opposing through traffic
- Left turning vehicles must cross 3 or more lanes of opposing through traffic
- There are multiple left turn lanes

Protected Only left turn arrows that precede the through movements are referred to as leading left turns. Left turn arrows that follow the through movement are referred to as lagging left turns.

At some intersections, the protected only left turn may change from leading for both directions, to lagging for both directions, to leading for one direction and lagging for the other, during different times of the day. These adjustments allow for the maximum flow of through traffic in coordination with the other traffic signals along the roadway. This reduces the number of through vehicle stops and decreases the overall vehicle delay at the intersection.

Protected / Permissive Left Turn Signals

Protected / Permissive left turn signals will display a green left turn arrow allowing for a protected left turn movement, followed by a yellow left turn arrow indicating that the protected left turn is ending. A green permissive ball is then displayed which allows waiting left turn vehicles to proceed with the left turn during acceptable safe gaps in the opposing through traffic.

The considerations for installation of Protected / Permissive left turn signals include:

- High left turn traffic volume
- High opposing through volume
- An existing crash history
- The geometric design of the roadway allows sufficient sight distance to safely complete a left turn
- Lower speed opposing through traffic
- 1 or 2 opposing through lanes
- Only 1 left turn lane

At some intersections using protected / permissive left turn signals, the left turn arrow may not be displayed all times of the day or may be displayed only when 3 or more vehicles are waiting in the left turn lane. At these times, left turn volume is low and most left turning vehicles can proceed either during gaps in the opposing through traffic or during the yellow vehicle clearance period. Left turn arrows are a definite convenience for the lower volume left turning traffic, but since the allotted time for the arrow must be subtracted from the much heavier opposing through traffic, overall intersection delay is increased. Safety and crash history are always considered when determining this type of operation. (Official web site of City of Linclon and Lancster County,n.d)

Appendix B

Types of Transit Metropolises

Cervero (1998) define transit metropolis as “a region where a workable fit exists between transit services and urban form. In some cases this means compact, mixed-use development well suited to rail services, and in others it means flexible bus services well suited to spread out development”. Cervero (1998) defines four different types of transit metropolises explained in detail below.

Adaptive Cities

Adaptive city is a type of transit-oriented metropolises that have invested in rail systems to direct urban development for purposes of achieving larger societal objectives, such as preserving open space and producing affordable housing in rail-served communities. Adaptive cities have properties of compact, mixed-use suburban communities and new towns concentrated around rail nodes.

Figure B.1 shows the relationship between transit system and urban form for adaptive cities. The image below the graph presents form of radial rail lines that connect outlying communities to a CBD. Cities which have a strong and dominant CBD and subcenters connected to CBD through rail transit system, like pearls on a necklace are the model of adaptive cities. Concentrating development at nodes and resulting confinement of travel demand along the radial axis increase efficiency of system in terms of mobility. Adaptive city’s formula to success is the combination of a large CBD, high density, mixed-use development around rail stations at subcenters, and long-haul radial links that enable balanced, two way flows.

As implemented in Stockholm and Copenhagen, protective greenbelts are formed between rail nodes (Figure B.1). As seen in Figure B.1, densities and land prices are the highest in the CBDs and at suburban rail nodes. They decline rapidly with distance from the nodes and come to zero within the protective greenbelts.

Another point to build successful rail metropolis is giving care to pedestrians ad cyclists. In the case of Scandinavia's rail-served suburbs, there are public squares and outdoor marketplaces in town centers near rail stations. In several of Stockholm's rail-served suburbs, underground stations share space with supermarkets to provide daily shopping opportunity for commuters on the way home. As a result of implementation of above mentioned principles, although both Stockholm and Copenhagen have high per capita incomes and vehicle ownership rates in the world, 60 percent of commute trips are made by employed residents of rail-oriented new towns (Cervero, 1998).

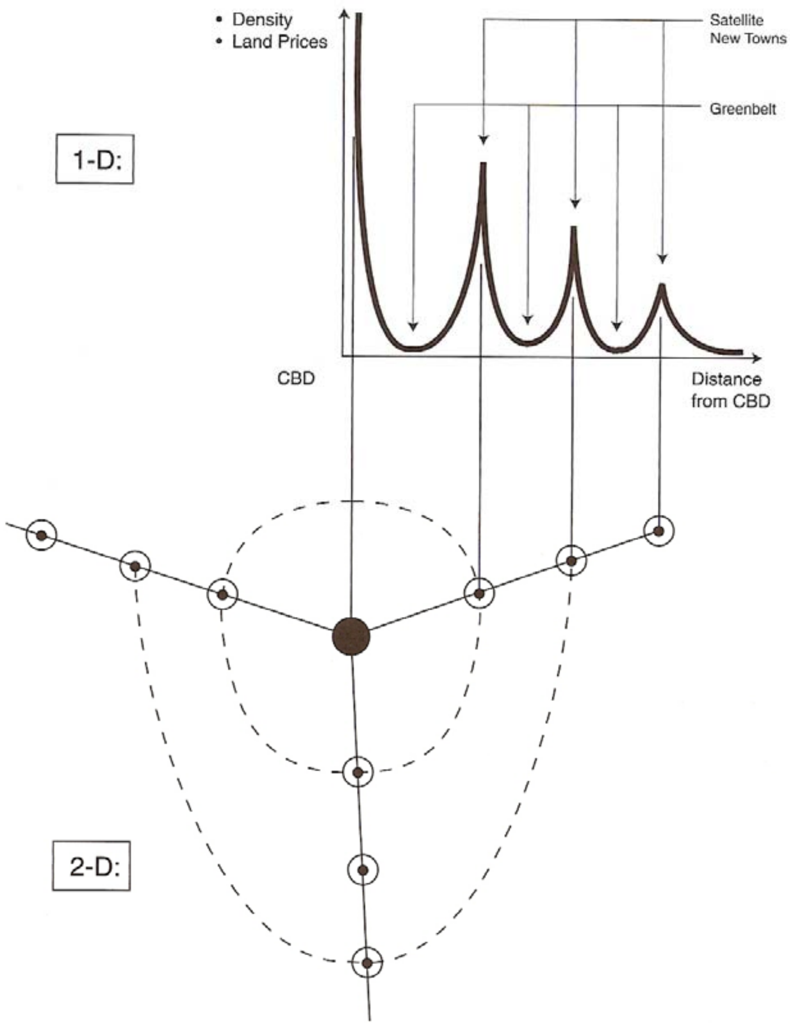

Figure B.1: Transit and urban relationship in adaptive cities (Cervero, 1998).

Adaptive Transit

Adaptive transit cities are dispersed, low density patterns of growth. They adapt transit services and new technologies to serve these areas. Adaptive transit cities can be classified into three groups. These are technology-based examples (e.g., dual-track systems in Karlsruhe, Germany), service innovations (e.g., track-guided buses in Adelaide, Australia), and small-vehicle, entrepreneurial services (e.g., colectivos in greater Mexico City).

Adaptive transit, represents a polar opposite response to decentralization, is accepted as an outcome of wealth and changing lifestyle. Transit systems are arranged to best serve this environment.

Figure B.2 represents the challenges of designing public transit system in the thinly spread development in which origins and destinations are distributed nearly homogeneous throughout a region. Naturally, such development produce almost random patterns of trip making, this means trips can go from anywhere to everywhere. The decentralization tendency has been largely responsible for the sharp growth in crosstown and lateral trip making. Instead of traveling along radial corridors between suburbs and CBD, commuters want to move tangentially and want to use facilities that were not designed to serve these purposes.

Adaptive transit generally falls into three groups.

- First group is technology-based responses and example of this is track-guided buses which are used in Essen, Germany and Adelaide, Australia. Also called O-Bahn, by means of this technology buses are able to move both along dedicated tracks and on roads. Thus, it is possible to achieve high speeds and efficiencies along mainline corridors. In the suburbs and CBD, vehicles exit the guide way and operate as ordinary street buses, so that, transfers are eliminated.
- A second type of adaptive transit involves service reforms which aims to reduce waits and transfers. An example is timed-transfer systems. This system was applied in the two largest cities of Canada, Edmonton and Calgary, and then adopted by many large bus transit systems in North

America, including Ottawa. In Edmonton, all services were reorganized around transit centers, in addition to the main downtown terminal, with routes covering the city in a combined crisscross and radial fashion. So, five to ten buses converge to every transit center in twenty to thirty minutes. Passengers scramble from one bus to another to make their connections and buses depart three to five minutes later. Many U.S. and Canadian cities have tried to reach Edmonton's successes.

- A third type of adaptive transit uses flexibly routed paratransit services, such as shuttle vans, jitneys, and microbuses, that enable door-to-door service. Paratransit vehicles fills the gaps of transportation system and provide feeder connections to rail system in developing countries. Paratransit sector of Mexico City is one of the examples.

As a result, adaptive transit is a system which tries to reduce the perceived burden of making connections. A criticism is that adaptive transit strategies reinforce and perpetuate sprawl and unsustainable patterns of growth by meeting need of low-density development, they reinforce and perhaps even perpetuate sprawl and unsustainable patterns of growth (Cervero, 1998).

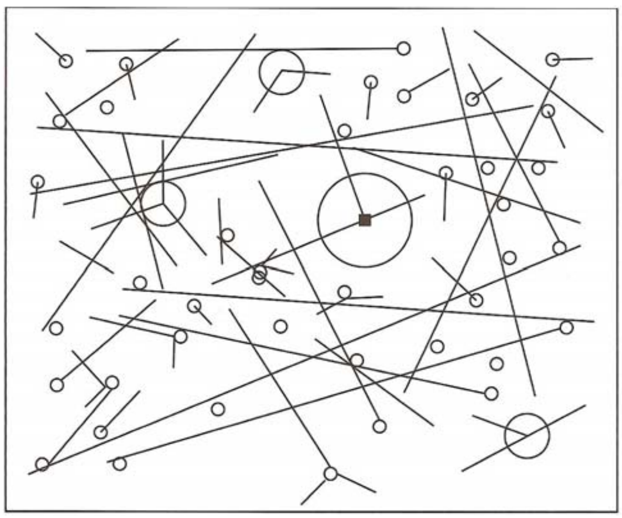

Figure B.2: Transit and the spread-out metropolis. a seemingly random pattem of movements (represented by lines) connected to a vast array of places (represented by circles) (Cervero, 1998).

The Hybrids

Regions development pattern of which are partly transit-oriented and their transit services are partly adapted to the lay of the land can be called as hybrids. Between the extremes of a strong-centered cities (Figure B.1) and a thinly spread, weak-centered cities (Figure x2), the development pattern of many hybrids tends toward polycentrism, as shown in Figure B.3. In hybrid development, there is a dominant center or CBD which have mixed land use, pedestrian-friendly design and subcenters. The centers have multiple land uses and pedestrian-friendly design. Railways and buses which connect subcenters are feeded by buses, trams, and vans that connect residents of outlying neighborhoods to the subcenters. The cases of Munich, Ottawa, and Curitiba are examples of such hybrids. They have formed a balance between concentrating development along mainline transit corridors and adapting transit to efficiently serve their spread-out suburbs and exurbs.

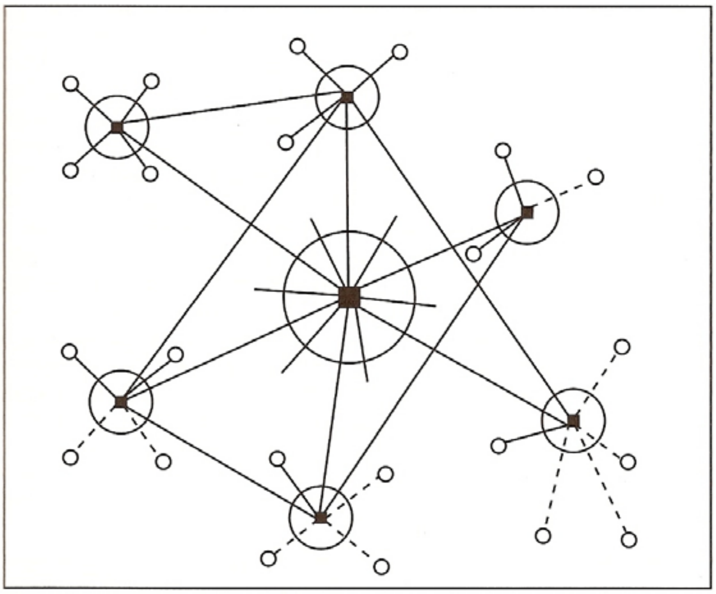

Figure B.3: Transit and the polycentric city. A hierarchy or urban centers (represented by circles) interconnected by main line (represented by long lines) and feeder (represented by short lines) services (Cervero, 1998).

Strong-Core Cities

Strong core cities tie rail improvements to central city revitalization efforts. These cities integrate transit and urban development within a more confined central city context. These cities have high shares of jobs and retail services in their cores.

Zurich and Melbourne are examples of this type. They use tramways to enrich the quality of urban living and to provide efficient forms of circulation in built-up areas. In these places, trams are designed so as to co-exist nicely with pedestrians and bicyclists. In both cases, tramways have been used to strengthen existing development patterns (i.e., adaptive transit) while inner-city revitalization has tried to achieve more compact, transit-oriented built forms (i.e., adaptive cities) (Cervero, 1998).