DESIGN CRITERIA of HIGH CAPACITY BUS TRANSPORTATION SYSTEMS

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ABSTRACT

This thesis proposes to figure out a new model of public bus transportation mode in Turkey which is more competitive and effective among the conventional public transportation modes.

In theoretical framework, the focus is on the new concepts and implementations developed in the urban transportation sector. The effective transportation systems regarding lower expenditures were handled according to the travel demands they serve. However, in general, the effectiveness of the modes is determined according to the economic parameters; mainly the conventional modes are discussed and the effectiveness of BRT systems and LRT systems are compared.

A brief survey of the BRT (Bus Rapid Transportation) systems is handled to some extent. The design considerations and the results of the implemented examples are handled to constitute a guideline. The major public transportation modes of Izmir are discussed. A reserved bus-transportation system is designed in the case study stage. Meanwhile the reserved bus concept along the Inönü Street is not designed according to the existing proposals. A distinctive model is concluded regarding the local conditions of Izmir. At final stage, the energy consumption rates of the systems are calculated and the economic comparison of the systems is based on this parameter.

Key words: Urban transport, BRT, LRT, Reserved Bus Transport at Inönü Street

ÖZ

Bu tez, otobüs toplu taşımacılığının Türkiye'de geliştirilmesine ve daha etkin olarak kullanılmasına yönelik yeni bir model önermektedir. Hızlı kentsel gelişimin ihtiyaçları doğrultusunda üzerinde yoğun olarak çalışılan toplu taşımacılık hizmetleri ve bu konudaki birtakım yeni çalışmalar, uygulamalar konunun altyapısını oluşturmak amacıyla incelenmiştir.

Etkin ve verimli ulaşımın daha az harcamalarla karşılanması yönünde önerilen sistemler yolcu taşıma kapasite parametresi doğrultusunda irdelenmiştir. Bu analizler doğrultusunda dünya genelinde uygulanmış olan yüksek kapasiteli otobüs taşımacılık sistemlerinin tasarım kriterleri ve uygulanmış örneklerin sonuçları ele alınmıştır.

İzmir genelindeki toplu taşıma sistemleri hakkında genel bilgiler verilmiştir. Tasarım aşamasında karşılaşılabilinecek kısıtlamalar belirlenmeye çalışılmıştır.

İnönü Caddesi'ndeki mevcut yol genişlikleri böyle bir sistemin dünya genelinde uygulanmış örneklerine birebir benzemesi noktasında engelleyici olmuştur. Ama önerilen sistem de ülkemiz koşullarına uyum sağlayabilme olasılığı olan ve araçların işlemesi açısından da bazı yenilikler getiren yeni bir öneri olmuştur. Önerilen sistemin işletme maliyetlerinde gerçekleşecek kazanımlar da hesaplanmıştır. Sistemin yapılacak metro sistemiyle ekonomik karşılaştırması da buna dayandırılmış sadece yakıt harcamalarından kaynaklanacak işletme giderleri kıyaslanmıştır. Bunun başlıca sebebi de önerilecek otobüs sisteminin geleneksel otobüs sistemlerinin işletme maliyetlerine göre yakıt harcama miktarlarında büyük farklılıklar göstermesidir.

Anahtar Sözcükler: Kentiçi ulaşım, Yüksek kapasiteli otobüs taşımacılığı, Hafif Raylı ulaşım sistemleri**,** İzmir-İnönü Caddesi Tercihli Otobüs Modeli

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CHAPTER 1

INTRODUCTION

The interpretations about transportation systems increased after the Industrialization Age. As a consequence, the objective of the Industrialization Age transformed the classical planning discipline of civilized areas.

During the development of urbanized areas the transportation disciplines divided into two kinds of logic as horizontal and vertical. Land, water transportation and pipelines are the examples of horizontal logic of transportation. Meanwhile air transportation mode is the example of vertical one. As an intercity and international transportation mode, the air transportation is not the subject of urban transportation in the present time technology. It is still a utopia to develop a vehicle that operates on the streets of a city at the same time uses the air corridors. However, the vertical logic of transportation system does not consist of only air transportation. Viaducts, multi-layer junctions, pedestrian crossings, pass ways, underpasses, subway crossings are the examples of vertical logic of transportation. Unfortunately these kinds of implementations do not reach the adequate number in Turkey.

Nevertheless, there still exists a preference on the highway transportation mode across the world. The table below depicts the situation. The passenger percentages of railway and air transportation modes are in the lowest rate in Turkey. As a consequence, the situation in the urban transportation shows similar conditions as that of the international transportation.

Table 1.1 The Passenger Distribution Rates of Transportation Modes (Aybar 1992)

Countries	**Railway %**	**Highway %**	**Air Transport %**
Japan	35	60	4
Germany	6	92	2
England	6	93	1
France	8.7	88	13
USA	1	82	17
Turkey	4	94	2

This situation results in metropolitan areas as congestion in streets of cities and high level of air pollution.

Certainly, in this situation, public buses in traffic take place among the facts of congestion. On the contrary, the problems of bus transportation systems are pretended not to be seen by public authorities. This results in a viewpoint of undesirable situation in bus transportation systems in the public.

The major reason in this point of view is the delays of bus trips. The determinants of the delays of trips are 56% congestion in the traffic, 20 % stops in the traffic, 24 % the extension of stop time in the bus stops. (Chriss 1998)

Through this point of view bus ways, bus on HOV lanes, bus on arterials evaluated to solve the problems. As a result this constitutes the backbone of BRT systems across the world.

However, preliminary studies were conducted in the metropolitan cities of Latin American Countries. The best example Curitiba (the capital of the Brazilian state Parana) relied on public transportation through a different approach. Instead of monorails or subways the city turned to the poor stepsister of public transportation. –BUS SYSTEMS-

In order to fulfill the goals of the master plan, the main transport arteries were modified over time by devoting one two-way lane exclusively to buses. As a result, 28 percent decrease in the automobile travel is only one of the successful results after the implementation of BRT systems while the city population tripled.

The facts of this successful implementation also deserve attention. The cost effectiveness and time saving are regarded as effective results for BRT systems against LRT systems. On the contrary, Los Angeles Transportation Authority declares that 70 percent of the operating budget for transportation systems was used on 6 percent of its passengers. This is a contradictory situation according to the theories of economic efficiency. It is obvious that passengers of bus transportation systems deserve much more attention.

Similar troubles also exist for the travelers of the public transportation modes in Izmir. As a consequence in the frame of the study a unique example of BRT systems is designed regarding the local conditions. Reserved bus mode operation along reserved one way lane is developed regarding the physical restrictions in the Inönü Street. A distinctive variant of BRT mode is developed to the extent and the economic comparison of the system against the LRT project is dealt with.

The comparison of the systems is handled through the economic parameters as the portion of the operation cost of a transportation mode's passengers have to commit is crucial in determining the economic efficiency. Although the more passenger capacities mean the less operation costs, there exists a disadvantageous situation for the rail transportation mode passengers of Izmir. The results of the economic comparison will be discussed in the case study stage.

Thus a brief explanation of transportation modes regarding the traveler capacities will be held in Chapter 2. A classification of the modes and a comparison regarding capacities between all will be focused on. Current urban transportation systems and future projections will be discussed.

In chapter 3, the essential urban transportation systems will be handled through the economic parameters and this phase of the comparison will constitute the backbone of the study in the case study stage.

In chapter 4, relying on the effectiveness fact the design guidelines of BRT systems will be handled.

In the chapter 5, a survey for selecting the best destination for a unique BRT system for Izmir will be completed and a project for designing the system will be drafted and the comparison of the modes regarding operation costs will be concluded.

In the last chapter, some final decisions will be outlined for urban transportation.

CHAPTER 2

URBAN TRANSPORTATION SYSTEMS

2.1. Definition of Transportation

The basic and the main definition of transport, or transportation, is the movement of people and goods from one place to another. "The term is derived from the Latin *trans,* meaning across, and *portare,* meaning to carry."(Wikipedia, the free encyclopedia)

Michael Meyer and Eric Miller's detailed statement determines that transportation is a trip from an origin to a destination taken primarily at the level of the individual traveler or the movement of goods, to accomplish some purpose. At the level of a metropolitan region, transportation is the aggregate of thousands or, in many cases, millions of individual trip-making decisions.

Meanwhile, several types of transportation systems which provide connectivity with other societal functions have common components. Bovy determines these components as follows;

- the infrastructure (the roads, stations and terminals),
- vehicles (wheeled, flying, floating, operating single or in a row),
- order of the flows (dependent of the vehicle or the infrastructure),
- the operation system (control of the traffic, management, organization, security).

A distinct determination held by Morlok identifies those components like;

- terminals,
- transportation network,
- roadway interchanges,
- vehicles,
- control systems.

However the functional components of transportation can be summarized as;

- **fixed facilities;** The physical component of the system constitute the network of links (roadway segments, railway track, pipes), nodes (intersections, interchanges, transit terminals)
- **flow entities;** The units that traverse the fixed facilities (vehicles, railroad cars, large tractor-trailer combinations)
- **control system;** Consists of **vehicular control** and **flow control**. Vehicular control depends on individually guided vehicles, which is controlled manually or automated. Flow control organizes the operation of streams of vehicles and reduces the conflicts between vehicles. This system consists of signing, marking, and signal systems. (Papacostas and Prevedouros 1993)

The components classified above are complementary of each through the transportation planning process. As in the city planning process, the land allocation and the transportation planning processes are depending on each other. From this view point, the functional components of transportation planning become the major concern of city planner. It is clear that an eight-lane roadway would be implemented when 40% of transportation demand is served by bus transportation modes, and a four-lane roadway would be implemented when 80 % of the demand is served by buses.

2.2. The Impacts of Transportation Systems on the Development of Urban Settlements

Throughout the history of urban settlements the need to maintain good accessibility has been important. From the historical viewpoint of the development of urban areas, a density of population was first seen beside harbors, lakes, canals and rivers. However, the transformation of settlement pattern and the city structure accelerated with the innovations in transportation technology by the Industrialization Age.

In the 19th century, the railways opened up new areas to human settlement and facilitated the rapid growth of cities but the most widespread changes have been brought about the motor vehicle.

In short, the development of city planning processes is deeply related with transportation systems. The tram city, the train city, the automobile city concepts are the ways of classifying cities distinctively through the discipline of transportation planning. The distance to tram and train stations, and the rate of accessibility of cars affect the planning process of the settlements.

Table 2.1 The Distances Covered by Transportation Modes Proceed in 30 minutes (Keskin1975)

Modes of transport	the distance passed in 30 min intervals
on foot	2 km
tram or trolleybus	3.8 - km
bicycle	9 – km
bus	10 – km
automobile	14 – km stop time included
subway	15.5 – km stop time included
train	12.5 – km stop time included
express train	20.5 – km stop time included

In fact the problem of getting to work has always been the main concern. Even before the Industrialization Age that kind of need existed. However, in an agricultural society, the only concern with transportation occurred when the farmer had a surplus to sell at a nearby market.

The demarcation line in transportation systems and city planning processes is drawn by the result of the invention of machine. However, in early industrial towns the number of workers was not large. Enough houses were built within walking distance. The necessity of increasing numbers of employees arose with the invention of the belt-line production which formed the mass production. As a result of the realization of the advantages of the factory systems, expansion in the amount of paid workers came into being. The result was the appearance of suburbs, metropolitan centers, and finally the metropolitan areas.

In the 19th century the steam locomotive extended its rails between raw products, the factory, and the cities of consumers. The railroad also penetrated the town with a network of tracks. The factory with its tentacles of railroads and shipping was the heart of the city. (Kılınçaslan 1994)

When Daimler invented the internal combustion engine in 1885, transportation was beginning another step into the tangle of urban traffic. In land transport the automobile become to the 20th century what the railroad had been to the 19th the heart of the system and the most attractive to public. (Kılınçaslan 1994)

At about the same time, changes in freight transportation, made possible by expressways and improvements in the trucking industry, reduced the necessity of locating plant sites near port facilities in water oriented cities or terminals of railroads. This movement of industry from center city to outlying industrial park locations created a new phenomenon –out-commuting. (Kılınçaslan 1994)

This stage of evolution brought cities close to shape recognized today. “The city core became an exclusive business center (CBD), often including high-rise office buildings. Meanwhile pollution and efficiency concerns pushed industrial zones in the outskirts of the city. The major trend at this stage was the exodus to the suburbs, which were viewed as quiet bedroom communities, providing a socially proper setting for raising a family. The transportation network followed as well as fostered this trend. ***Radial corridors*** of public transit and highways were developed to bring the suburban workers to their work places in the central city where most employers were located. Downtown areas began experiencing traffic congestion problems, pollution problems, and lack of adequate parking space. (Papacostas and Prevedouros 1993)

The next stage represents worsened levels of pollution, density, services, and safety of central cities further encouraged people to move to the suburbs.

An outer ring of suburbs growing at high rates started developing in the 1980’s. At this stage, businesses and employers followed the residents in the exodus to the suburbs. As a result, satellite business districts were developed in the outer suburban ring. (Papacostas and Prevedouros 1993)

2.3. The Classification of Transportation Systems

Several ways of classification can be hold for transportation systems. According to types of technology they employ, the type of service they provide, the ownership and so forth. Each of these is the viewpoints of different perspectives.

Through the view point of Bovy, transportation systems have been classified through technical and functional criteria. The technical classification in major determines the physical independency of the system. The concept of independency depended on being effected by other modes of transportation or not. The air and water transportation types are the best examples of systems that operate uninterruptedly by other modes. The systems operating on physically separated routes like trains and some highway transportation modes also operate uninterruptedly. The criteria of the classification consist of;

- **type of the route** determines whether the operation route is natural or implemented (the examples of air and water transportation systems operate on natural operation routes),
- **flexibility** determines whether the operation route is suitable for flexible operation or it is fixed (most of the public transportation modes operate on fixed guide ways, schedules),
- **type of the operation** determines whether the operation is continuous or not (moving staircases, moving platforms are only examples of continuous operating transportation modes),
- **position of the vehicle** determines whether the vehicle is suspended or not and whether it operates in air or water. (Elker 1981)

Meanwhile the classification held through the functional criteria consists of;

- whether the system operates by motorized vehicles or not,
- whether the system is suitable for individual or mass transportation,
- whether the system operates on routes with other types of transportation or uses a reserved operation track. (Elker 1981)

The transportation system is further categorized into four major subsystems according to the medium by which the flow elements are supported. These subsystems are commonly referred to as modes, but it should be understood that this term is also used to make finer distinctions between the various means of travel.

1. Land transportation
   - Highway
   - Rail
2. Air transportation
   - Domestic
   - International
3. Water transportation
   - Inland
   - Coastal
   - Ocean
4. Pipelines
   - Oil
   - Gas
   - Water

2.4. The Classification of Public Transportation

The aggregation of diversities of functional components in transportation systems constitutes the features of transportation systems. The classification schemes generally concluded through these features. Meanwhile these features can be summarized into three sub-systems like;

- **Technologic features**; passenger capacities, the hour capacity, the physical independence, flexibility, the speed, energy consumption, comfort of the system, geologic-geographic-geometric standards,
- **Economic features;** infrastructure and management costs, the expenditures of the system subsidized by public, administrator or consumer, the labor force consumed,
- **Environmental features;** the effects of the system on the environment, probability of accidents, adaptation to the environment, etc…(Elker 1981)

In this chapter, the classification process will be held in terms of the technologic features. Variation of the transportation systems resulting from technological features draw attention as the result of technological developments and some futuristic solutions as proposed. To that extent, the classification held below, which were taken through major features like the capacity comparisons, speed up comparisons and technological developments of the modes.

The comparisons through the economic features between the conventional modes will be dealt with in the next chapter. The aim to limit the amount of modes resulted from the distribution rates of public transportation as the great amount of the passengers is still transported with land based modes.

- **Demand Classification**

The most important feature of transportation is its capacity. The capacity of a transportation system is normally expressed in terms of the maximum number of passengers per hour that can be carried to any point in the system. Consequently, to determine the appropriate transportation mode, the travel demand forecasting process - classifications – has always been held according to the quantitative data.

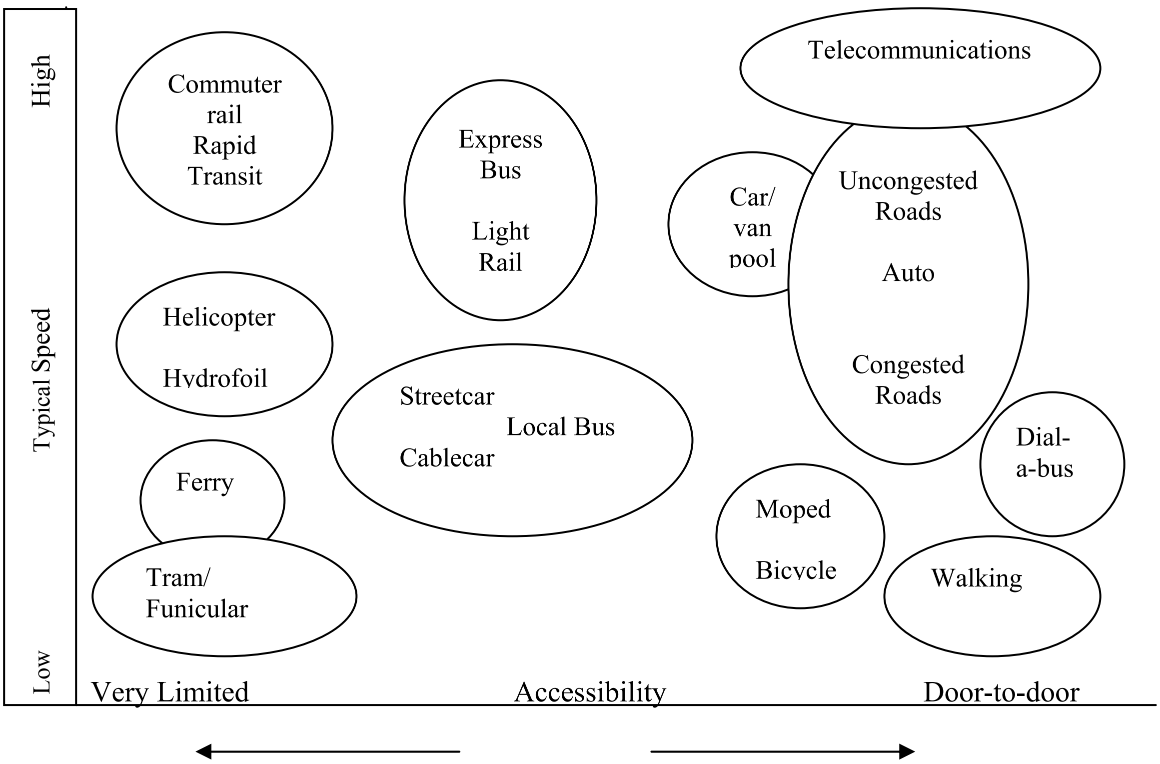


Figure 2.1 Typical Urban Transportation Modes (Hutchinson1974)

1. **Type 1A**- demand volumes greater than 20.000 person per hour
2. **Type 1B-** demand volumes from 8.000 to 20.000 person per hour
3. **Type 1C**- demand volumes less than 8.000 person per hour

Table 2.2 Travel Demand Type (Hutchinson 1974)

Travel-demand type	Transport technology			
	Mass rapid transit	Personal rapid transit	Bus systems	Dual-mode systems
Type 1-radial travel > 20.000 person/hr 8.000-20.000 persons/hr <8.000 persons/hr	 x x x	 x x	 x x	 x x
Type 2-circumferential travel		x	x	x
Type 3-residential Area travel			x	
Type 4-travel within CBD		x	x	
Type 5-travel to non-Central activities	x		x	

- **Functional Classification**

1. Mass Rapid-Transit Systems: transport technologies that operate on fixed guideways, have fixed on-line station locations, fixed vehicle routings, and operate on fixed schedules.
2. Personal Rapid-Transit Systems: transport technologies that operate on fixed guideways, have fixed off-line station locations, and may have flexible vehicle routings. This systems offer ***on-demand non-stop transportation between any two points*** on a specially built network. Developers aim to provide more convenient service than cars, with the social advantages of rail transit, and with per-passenger trip costs between $0.02 and $0.06/km, somewhere between the cost of a bicycle and a moped.
3. Bus systems: transport systems that use buses may have a range of passenger capacities and performance characteristics, and may operate on fixed routes with fixed schedules, or may be flexibly routed and demand scheduled.
4. Dual-mode systems: transport systems that use individual small vehicles may be operated under manual control on a street system but also provide for automatic control of the vehicles on the guideway.(Peter R. White,1982)

2.4.1. Mass Rapid –Transit Systems

Mass rapid-transit modes can be divided in three modes regard to three dimensions: technology, right of way, and type of service. Suburban railroad service for commuters, also called commuter rail or regional rail was started by the intercity railroads. This system is characterized by heavy equipment, high maximum speeds, and slow acceleration and deceleration. One distinctive aspect of this mode is that the service is often high quality. Trains run at speeds up to 120 km per hour, and are enough seats so that normally every passenger gets one. This is the only transit mode with average speeds that compete with driving on freeways.

The term heavy rail came into use to distinguish it from light rail, but the equipment is actually lighter than that of suburban railroads. This mode used to be referred to as subway-elevated because most tracks were located either underground or on structures elevated over streets and alleys. Many transport planning agencies have established that these ***high-capacity mass-transit*** systems are most appropriate for travel demand corridors in which the peak hour demands exceed ***20.000 persons per hour***.

Light rail transit, the most popular form of rail transit is really a modern version of the electric streetcar. Often the track is laid in the street in places, but much of it is located underground, on elevated guideway, or within a freeway right-of-way.

Various tramway and streetcar systems operate in cities throughout the world and tend to serve travel-demand corridors with peak hour travel-demands of less than 10.000 persons per hour. In recent years, increasing attention has been directed toward the development of technologies capable of serving travel demands within the ***8.000-15.000*** *persons per hour range*. Many of the European developments of this type are usually referred to by the term ***light rapid transit***. (White 1982)

Some of the advantages claimed for light rail are as follows:

1. It is safer than heavy rail because the electricity come from an overhead wire instead of a third rail. So, there is no need to fence the track, and it can operate in the street.
2. It offers more flexibility of location than heavy rail. Where land is expensive, it can be put in a street and passengers can board and alight from sidewalk.
3. It is viable in situations with lower level of demand than the need to justify costly heavy rail projects.
4. If most of a route is on separate right-of-way, average speeds are higher than for buses in mixed traffic. (Black 1995)

The principal service features of mass transit technologies may be summarized as shown in Fig. 2.2. This diagram shows the relationship between average travel speed, station spacing, and top speed of vehicle. This relationship based on acceleration and deceleration rates at stations of 5 km per hour second. It is interesting to note that the average speed of travel is not influenced greatly by increases in the top speed of a vehicle above about 80 km per hour. Stated in another way, the average speed of travel by urban mass transit is governed essentially by the station spacing.

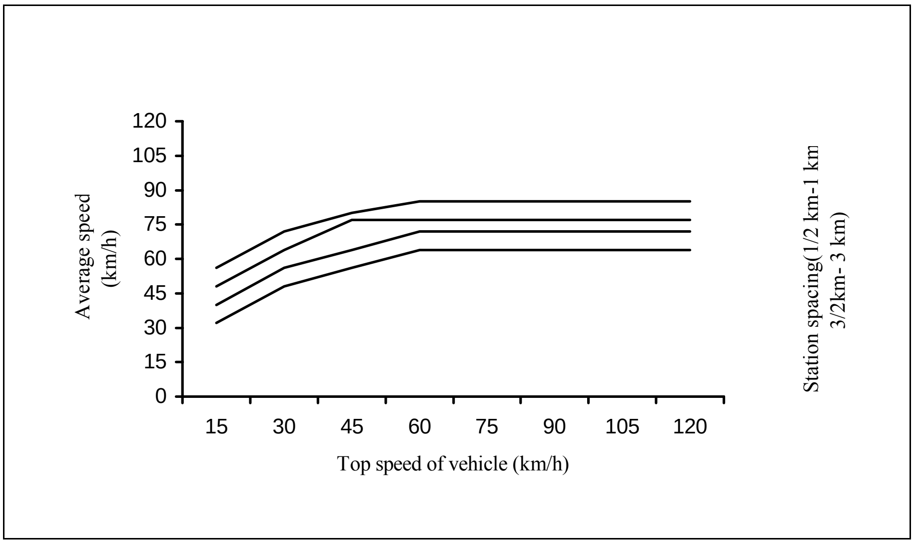


Figure 2.2 Average Speed of Travel by Mass Transit vs. Top Vehicle Speed, Station Spacing (Hutchinson1974)

2.4.1.1. High Capacity Systems:

The high-capacity mass-rapid transit system most commonly used and in use to date has been the steel-wheeled ***duo rail*** system. Examples of duo rail systems installed recently are the BART system in the San Francisco region, the Victoria Line of the London Transport underground system and the Toronto Transit Commission Subway System.

A second type of high-capacity mass-rapid transit system which has been used to a limited extent is the ***monorail***. Three types of monorail have been developed and these are: (1) ***The top-supported*** or suspended vehicle, (2) ***the bottom supported*** vehicle, and (3) ***the side supported*** vehicle. One of the earliest monorail systems is that in Wuppertal, Germany, where vehicles are suspended from double-flanged wheels rolling along a single rail above the car body.

Figure 2.3 Wuppertal Monorail System

Figure 2.4 Wuppertal Monorail System

Major disadvantages of suspended monorail systems include the relatively high cost of the supporting structure, difficulties with vehicle switching, and oscillations of the vehicle at high speeds in high winds and noise. (White 1982)

2.4.1.2. Medium Capacity Systems:

Several medium-capacity rapid-transit systems are under active development. One of the most-developed systems is the Westinghouse Skybus system. The carriages are lightweight buslike vehicles of variable size that move on an elevated concrete guideway. The vehicle guidance is achieved by rubber wheels running along a central I-beam with the vehicles being controlled automatically from a central computer.

In many European cities ***older tram systems*** have been upgraded in recent years. New equipment has been introduced and in many cities the tram systems operate on separate right-of-way. ***These modernized tram systems are usually referred to as light rapid transit.*** A principle argument advanced in support of the use of light rapid-transit systems is that their capacities may be increased as the passenger demand increases. The number of carriages in a train may be expanded to increase the capacity and the system may be automated gradually. (White 1982)

Figure 2.5 The Vehicle on the Route

Figure 2.6 The Vehicle at Station

Figure 2.7 The Units at the Station

Figure 2.8 The Elevated Concrete Guideway

2.4.2. Personal Rapid –Transit Systems:

The idea of personal rapid transit developed to obtain transit services competitive as private automobile. The service characteristics of the mode reach to the quality of private automobiles with some regulations like;

1. It goes anywhere in the city.
2. It leaves at any time; there is no fixed schedule.
3. There are no intermediate stops or transfers.
4. The average door-to-door speed is high. (Black1995)

This system is designed by extensive route network, small vehicles and automatic control systems which mean that they need no human operators. Figure 2.9,10,11,12 illustrate the major functional features of a number of personal rapid-transit systems. Anderson and associates identify the following features as the most important characteristics of personal-rapid (PRT) systems.

The use of off-line stations permits adequate capacity to be obtained on a line with smaller vehicles instead of large trains. Passenger trips may be nonstop, personal, and on-demand. During peak periods of demand, vehicles may be operated with trains and fixed schedules. Since trips may be nonstop between stations, the average travel speed is close to the line haul speed. This means that the maximum vehicle speed can be achieved more easily .than the maximum speeds required for mass rapid-transit systems. (Black1995)

Table 2.3 Comparison of Transport System Capacities (Hutchinson1974)

System	Headway (sec)	Capacity (vehicles/hr)	Capacity (passengers/hr)
Automobile			
City street	1-2	600-800	900-1.200
Freeway		1.500-2.000	2.250-3000
Bus transit			
City street	60	60	3.000
Freeway	15	240	12.000
Theoretical max.	4	850	40.000
Subway			
10-car train	90	40	40.000-72.000
PRT system	2-10	360-1800	1.000-20.000

Mass rapid-transit systems achieve high capacities by employing relatively large trains operating at minimum headways of about 90 seconds. The principle underlying PRT systems is that high capacities may be achieved with the small vehicles if headways between vehicles are reduced.

Figure 2.9A Proposal for PRT Systems-Sky Web Express

Figure 2.10 Station Designed for PRT

Figure 2.11 Prototype in Various Uses

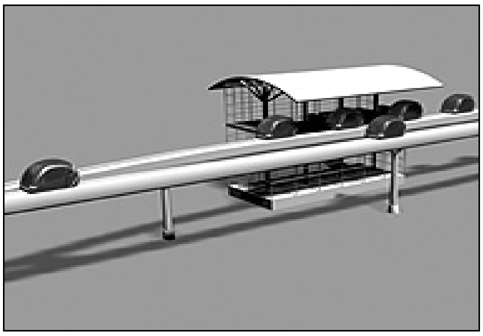


Figure 2.12 Off line Stations on the Route

Figure 2.13 System Prototype

Figure 2.14 System Component

Figure 2.15 The System under-
Construction

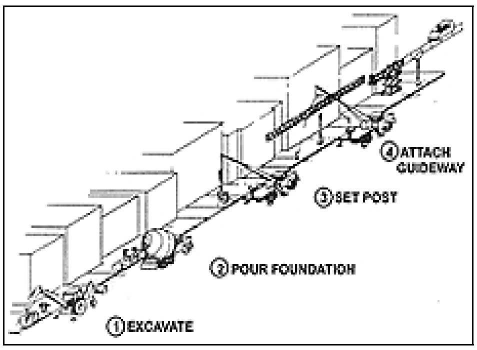


Figure 2.16 The Construction Scheme

2.4.3. Bus Systems:

Bus transit is well known since it is the most common form of urban public transportation across the world. About 90% of all transit passenger trips are realized by bus in Izmir. This indicator clarifies the concentration of highway-based public transportation. Meanwhile the distribution rates of transit passengers of developing countries show resemblance.

The modes of the system can be distinguished in three dimensions: the seat configuration of the buses, the type of the operation route, and the service alternatives. The seat configuration and the service alternative features are major conjunctive elements in developing countries.

The **type of the operation route** can be classified as four types:

- High-occupancy vehicle (HOV) lanes,
- Concurrent flow lane (Diamond lanes),
- Contra-flow lanes,
- Transit ways.

The high occupancy vehicles **(HOV) lanes** are built as designated special lanes for buses to raise their speed in order not to suffer from traffic congestion in mixed traffic. Meanwhile as the result of the low capacities of buses, van pools and car pools use the lanes. It is constructed as a separate lane on freeways separated from other traffic by a railing or concrete barrier.

A different design that requires minimal investment is a **concurrent flow lane**. Here a freeway lane is designated as an HOV lane but is not physically separated. It is usually marked with a wide paint stripe. In some cases large diamonds are painted on the pavement, in which case it is popularly called a diamond lane.

Another arrangement is a **contra-flow lane**, in which buses run in the opposite direction from other vehicles on the same side of the median strip. The lane is separated by plastic posts. Normally it is used during peak periods. The posts are removed and the lane is opened to all traffic other times.

Another way to improve bus service is to turn an entire city street over to buses, excluding cars and trucks. This may be called a **transitway**. It is done only in the downtown areas.

Meanwhile the seat configuration appears at the head of the three dimensions. Buses that exist in various sizes operate according to a variety of schedules. They may range in size from 10-12-passenger buses which are called as **minibuses** to buses with 60-90 passenger capacities. There are also larger buses, which have long been common in Europe. **Double-decker** buses are still predominant in Great Britain. They are not antiques; double-decker buses are still being manufactured. In our metropolitan cities like Istanbul and Izmir similar kinds also are in the use of public transportation. More popular worldwide are **articulated buses** which have a hinge and bend to go around corners. Besides bus systems may operate as fixed schedule systems or as demand responsive systems, serving as a feeder mode.

The term paratransit was improvised in the 1970's to cover the concept of demand responsive systems. It is a midway between conventional transit and the private automobile. In other words, it is a lower level of personal rapid transit systems at the level of individual traveler. They are similar to transit in that they are services available to the public. They are similar to the private automobile in that they operate on demand. In Turkey **dolmus** and **minibus systems** are the examples to the second degree of the system's service pattern (many-to-few). Meanwhile the degree of the service pattern will be held under the demand-responsive-bus title.

However, the distinction of service concentration in several countries using this system attracts attention. The paratransit services in developed countries appear to serve in low-density and suburban settings. In reverse it serves in downtown areas, in central business districts and in high concentrated areas in developing countries like Turkey. They appear to penetrate parallel through the conventional public transportation routes. In order to serve as a feeder service the minibuses are the competitors of bus transportation systems in Turkey. This situation of course is the result of the inefficiency in the service degree of public transportation.

The service alternative will be held below to make better explanations. Two distinctive types will be discussed: The express bus systems and demand-responsive bus services. The comparison between those alternatives and conventional bus services will be held according to the average speed, stop distances, operation schedules and types of destination.

2.4.3.1. Express bus systems:

Express bus service is used for long lines, usually with higher quality service than regular bus lines. Operated for commuter services or, sometimes, throughout the day, express bus service has one or more of the following characteristics:

- Long stop spacing, resulting in higher travel speed;
- Portions of the line use reserved buses of HOV lanes, or operate on freeways;
- Offer higher comfort-usually provide seating for all passengers;
- Have higher-than-regular fares.

Express bus services can be offered as a special service, such as peak hour commuter lines; or, they may be used as a higher quality/higher fare service paralleling regular bus lines, but more competitive with private cars. Express bus often serves on the lines to airport or between city centers and major regional activity centers. At the outer end, there may be a series of stops for collection and distribution or one stop at a park-and-ride lot. There may be a single stop in the CBD or an area where buses make several stops.

2.4.3.2 Demand –responsive bus systems

Demand-responsive bus systems have been implemented in a number of cities in the United States, Canada, and Europe. Buses stop only on demand, when a passenger signals to get off or someone is waiting at a bus stop to get on. In the low-demand system, buses skip many of the stops, but during rush hour they must stop at most of the designated points which reduces speed. Another alternative is limited-stop service with stops spaced much farther apart. The limited stop-buses were 50 to 100 percent faster than other buses in light traffic, but there was little difference in heavy traffic.

Guenther has provided a convenient scheme for classifying the spectrum of demand-responsive bus services that have been developed and for comparing them with existing systems. Figure2.19 shows this scheme. The horizontal scale identifies the types of routing while the vertical scale identifies the frequency of service.

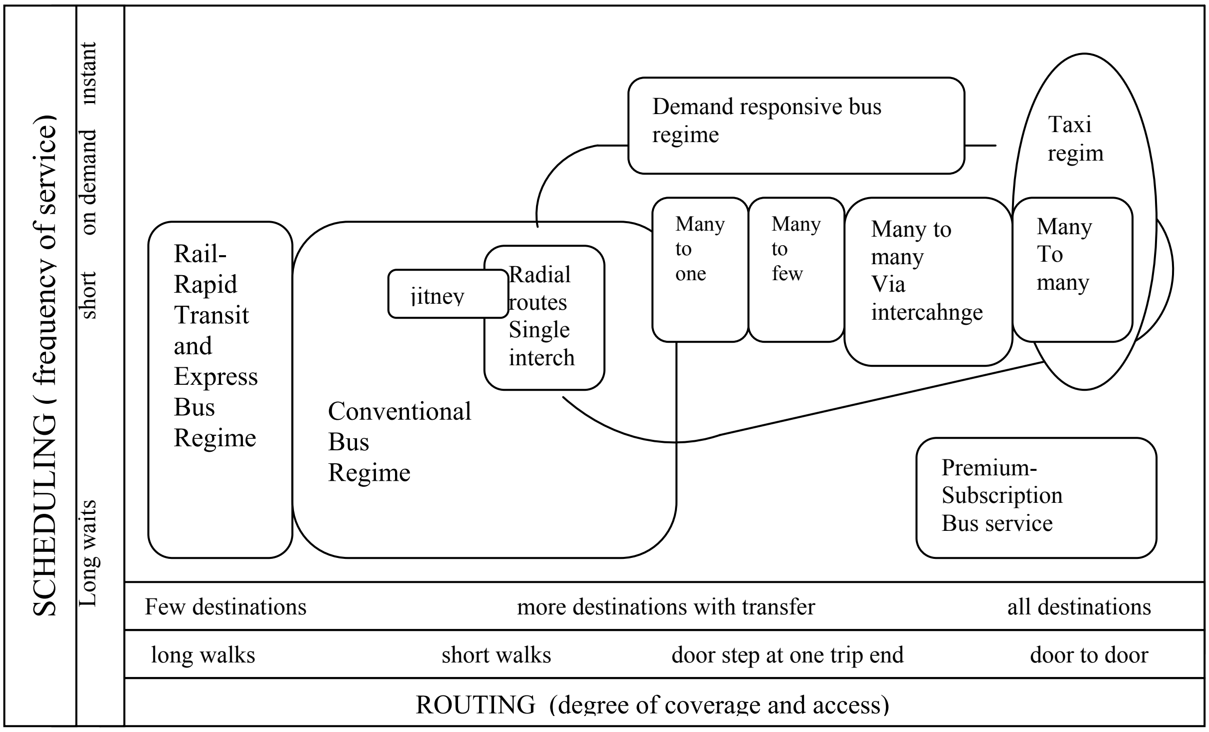


Figure 2.17 Public Transport Systems Classified by Routing and Scheduling (Hutchinson 1974)

Four major public transport regimes are identified in the diagram; the taxi is identified as the concept that has the best response to passenger demand. ***The diagram suggests that demand-responsive bus systems approach the service characteristics of taxi systems.*** The diagram identifies four versions of demand-responsive systems and these are;

1. many home origins to one destination
2. many home origins to a few destinations
3. many home origins to many destinations via a central interchange point
4. many home origins to many destinations

The many-to-one version has been the demand-responsive bus concept used most commonly. A focal point exists for the service which might be a town center, a commuter rail station, an express bus stop, shopping center, or other major activity center. The many-to-few version is similar, but more focal points within an area are served. Each activity center may be served by a specific set of vehicles, or a given set of vehicles may serve several adjacent activity centers. The version with a central interchange point or points is an extension of the many-to-few version, where passengers may transfer between service areas. The fourth version is simply a modified version of the taxi which provides for pooled riding. (White 1982)

2.4.3.3. Bus rapid transit systems:

BRT is a broad term given to a variety of different transportation solutions that operate through the usage of buses. It can come in a variety of different forms, from dedicated *busways* that have their own right-of-ways (e.g., Ottawa's Transitway) to bus services that utilize HOV lanes and dedicated freeway lanes (e.g., Honolulu's City Express) to limited stop buses on conventional routes. In addition, bus rapid transit is often linked with intelligent transportation systems (ITS), and can involve special buses that control traffic signals, smart card systems, AVL bus tracking, dynamic message signs, and automatically guide buses. An ideal BRT service would be expected to include some or all of the following features:

- **Bus lanes:** A lane on an urban arterial or city street is reserved for the exclusive or near-exclusive use of buses.
- **Bus streets and busways:** A bus street or transit mall can be created in an urban center by dedicating all lanes of a city street to exclusive use of buses.
- **Bus signal preference and preemption:** Preferential treatment of buses at intersections can involve the extension of green time or actuation of the green light at signalized intersections upon detection of an approaching bus. Intersection priority can be particularly helpful when implemented in conjunction with bus lanes or streets, because general-purpose traffic does not intervene between buses and traffic signals.
- **Traffic management improvements:** Low-cost infrastructure elements that can increase the speed and reliability of bus service include bus turnouts, bus boarding islands, and curb realignments.
- **Faster boarding:** Conventional on board collection of fares slows the boarding process, particularly when a variety of fares is collected for different destinations and/or classes of passengers. An alternative would be the collection of fares upon entering an enclosed bus station or shelter area prior to bus arrivals (similar to how fares are collected at a kiosk before entering a subway system). This system would allow passengers to board through all doors of a stopped bus." (From Wikipedia, The Free Encyclopedia)

BRT investments are considerably higher than regular buses involve because they require construction of special lanes or roadways, stations and other equipment. Their ***investments are lower than LRT*** because they do not need electrification and tracks. Correspondingly, BRT performance and service, including speed, reliability and capacity, is also better than what regular buses can offer.
(http:// www.homestead.com/ brtc/files/2001)

2.4.4. Dual-mode systems:

The automated highways concepts allow us to develop driverless vehicles operating on elegant guideways. The vehicles thought to be controlled through a wire buried in the pavement according to electronic highway project. The concept also called as smart streets in major had an aim to increase the capacity of a freeway. However, all the projections thought to be developed to limited sizes? Essentially it would be more suitable to develop those as it is in dual uses.

Dual mode systems can be defined as those transport technologies which use individual small vehicles that may be operated under manual control on the street system, but which provide for the automatic control of the vehicles on the guideway. (White 1982)

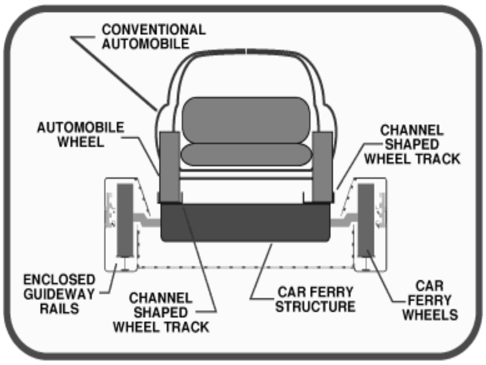


Figure 2.18 The Cross-Section of a Ferry

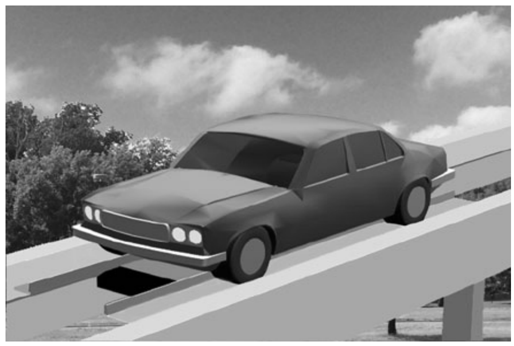


Figure 2.19 The Car on the Car-ferry

Among these, efforts to improve the bus operations performance through technological devices constituted the dual-mode bus projects. The long-recognized problems of bus transportation which preclude rapid and efficient bus operations considered to be solved by the German O-Bahn concept.

The principal aim of this concept is to remove bus operations from the public highway where the traffic is concentrated. It is an off road technology that involves a special trackway physically separated from the highway similar to the other automated highway concepts. While the known name in English is ***Kerb Guided Busway*** the special track consists of two parallel sets of 10 meter long 'L' shaped prefabricated concrete panels laid 2.60 meter between inside vertical faces. Bent rails are laid in curved sections as required. These were supported at every 1.35 meters by sleepers by which they are fixed by means of fishplates and clamps. The sleepers are wide enough for both directions and are mounted on concrete bore piles which act as foundation. To make it easier for buses to enter the trackage, the entry points are fitted with steel box girders which funnel in from 3.50 meters down to 2.60 meters.

Figure2.20 Close up View of a Guide Wheel

Figure2.21 Busway Trackage

Figure 2.22 Bus at a Junction

Figure 2.23 Bus Stop Reached from Roads

The system which requires the driver to speed up the vehicle is justified in the opinion of local officials by the following factors: construction costs have been less than those for an LRT alignment; buses provide greater service flexibility and closer access to origin and destination points than rail bound operations; high speeds (100 km/h) can be maintained on the channel; the ride is very smooth on the carefully constructed guideway; and a vary narrow strip of land is required (7.3 meters).

There is no doubt that the guided busway has operational benefits which can not be attained by a conventional, 10 m-wide busway-lane on which drivers remain in full control at all times.

However, the negative impacts of the system such as higher costs, greater mechanical complexities and the problem of removing disabled vehicles that may block the guideway prevents the system from becoming a widespread mode. Only few experiments and tests were completed in Germany (Mannheim, Essen), Great Britain (the Millennium Dome, Leeds, Ipswich). Even in Essen there weren't any plans to extend the system further.

2.5. Evaluation of Public Transportation Systems:

The principal criteria in the classification schemes mentioned above are the capacity criteria. In fact, the capacity classification schemes above were dealt with in ideal situations of the systems. In other words, systems for the induced demand or the theoretical capacities of systems were described. With a realistic approach it is clear that the systems at most of their operation times serve for the demand, which is both over the limits of the system and under the efficient capacities. However, it is useful to know the proportions of the user rates in conventional modes to make a better distinction between transportation modes. To an extent, a classification scheme was discussed below.

The major aim in the table below which depicts conventional public transportation modes in cities with populations over one million is to make easy and better conclusions about the transportation modes in Izmir.

Table 2.4 The Annual Passengers of Public Transportation in Metropolitan Cities (Evren and Öğüt 1995)

	Country	City	Population	Bus Transport passengers	Tram passenger	LRT passenger	Metro-Heavy Rail passenger
1	Austria	Vienna	1.500.000	123.900.000	45.200.000	40.700.000	256.500.000
2	Belgium	Brussels	1.100.000	56.700.000	62.600.000	0	87.800.000
3	Bulgaria	Sofia	1.100.000	195.000.000	234.000.000	0	0
4	Canada	Montreal	1.800.000	115.300.000	0	0	197.000.000
5		Toronto	2.200.000	199.800.000	0	46.100.000	153.000.000
6	Czech Republic	Prague	1.200.000	482.000.000	408.000.000	0	555.000.000
7	France	Lille	1.100.000	42.400.000	7.600.000	0	54.000.000
8		Lyon	1.200.000	42.100.000	0	0	98.600.000
9	Germany	Berlin	3.500.000	778.700.000	156.800.000	0	480.400.000
10	Hungary	Budapest	2.100.000	769.000.000	0	348.600.000	280.000.000
11	Italy	Milano	4.000.000	401.100.000	205.400.000	0	343.800.000
12	Japan	Fukuoka	1.300.000	150.000	0	0	111.000.000
13		Kobe	1.500.000	121.300.000	0	0	92.500.000
14		Kyoto	1.500.000	170.600.000	0	34.700.000	73.700.000
15		Osaka	2.600.000	434.200.000	16.700.000	0	1.379.800.000
16		Yokohama	3.200.000	239.300.000	0	0	113.000.000
17	Poland	Lodz	1.100.000	204.000.000	183.000.000	0	0
18	Portugal	Lisbon	2.700.000	363.000.000	31.900.000	0	146.700.000
19	Romania	Bucharest	2.300.000	300.200.000	281.900.000	0	256.700.000
20	Russia	Novosibirsk	1.500.000	211.200.000	119.400.000	0	90.900.000
21		Samara	1.300.000	81.000.000	127.000.000	0	0
22	Spain	Barcelona	2.600.000	197.700.000	0	0	265.100.000
23		Madrid	3.100.000	512.000.000	0	0	391.000.000
24	Ukrania	Kharkov	1.600.000	469.000.000	291.000.000	0	250.000.000

Using the above data, the proportion between bus transport users and the rail transport users has been obtained. According to the proportion of bus transport users to rail transport users, a rate about 0,783 was obtained. This means that about 44% of public transportation capacity is covered by bus transportation modes. The rest 56% is covered by rail transportation modes.

However, the distribution rates of passengers in public transportation modes in Izmir can not be handled in that measure. According to the ESHOT (the public enterprise of bus transportation in Izmir) data for the year 2003 the total number of passengers in public transportation in Izmir is as follows;

ESHOT---209.125.045 (the bus transportation mode)

IZULAS---73.992.419 (the bus transportation mode)

METRO---26.897.611 (the rail transportation mode)

IZDENIZ---12.603.788 (the ferry transportation mode)

The situation of public transportation in Izmir shows a concentration in bus transportation mode. It is obvious that rail and ferry transportation modes in Izmir can still not cover the major demand in public transportation. On contrary, this is another matter in transportation planning in Izmir.

However, the capacity analysis could not be made through all its aspects. As the capacities of systems affect the costs of transportation systems, the classification through the economic features will be discussed in the next chapter in order to make better conclusions about the systems.

CHAPTER 3

THE CONVENTIONAL PUBLIC TRANSPORTATION MODES

3.1. The Economic Features of Transportation Systems

The travel demand which covered by distinctive transportation modes with various capacities is a definite determinant of the economic features of systems. The transportation modes in major are economically dependant of the passenger demands. The basic classification which determines the costs of a transportation system constituted through three dimensions. These are the costs according to the passenger, vehicle, and the public. However the systematic classification is concluded according to the investment costs and the management costs.

The expropriation costs, the construction costs of infrastructure, upper structures, stops, stations, purchase of vehicles and other costs (the signalization, communication systems development costs) constitute the investment costs. Meanwhile energy consumption, service staff salaries, repair expenses and other costs (the ticket printing and office expenses of the enterprise) constitute the management costs of a system.

However the total costs of a system generally calculated according to the effective operation capacities of the system. In fact the realistic determinations about the total costs calculated regard revenues through passenger-km parameter. A distinction according to the investment and management costs will be obtained through the passenger-km parameter.

The private vehicle can be accepted as the most expensive transport mode as the purchases of the vehicles are admitted in the investment costs. The heavy rail transport mode which also called as metro will be the second expensive mode as it requires specific infrastructures and tracks construction. On the contrary the tram and bus systems are the cheapest modes. While the roadway construction expenses accepted as the costs related to public on which various types of transportation modes operate they are not included to the investment costs.

Similarly the management cost classifications through the passenger per km parameter generally predict the private transport mode as the most expensive mode. The minibus and dolmus systems are the secondary ones. The heavy rail transportation modes, tram and bus systems are the cheapest modes according to the management costs through this perspective. There is no doubt that the costs of energy consumption rate regarding passenger per km is the main fact in this arrangement.

Table 3.1 The Energy Consumption Rates of Modes through per Passenger-Km Parameter (Japan Railway Technical Service)

Transportation modes	Volume of traffic (100 million passenger-km)	Energy consumption (10 billion kcal)	The rate of energy consumption (kcal/passenger-km)
Rail Transport	3.215	3.365	*104*
JNR(Japanese National Rail)	(1.929)	(2.058)	*(106)*
Private Rail	(1.286)	(1.307)	*(101)*
Bus Transport	1.304	1.544	*149*
Private vehicle	3.607	25.432	*705*

3.1.1. Efficiency in Urban Transportation

Efficiency has a major importance in urban transport, because transportation is a service industry and if the supplied service is not consumed in right time and place, it can not be stored for the next time. Transport planning should estimate the exact amount of the resources.

Efficiency in transportation should consider the relationship of resource use and costs on the one hand, and productivity on the other. Efficiency concept in the urban transport is relevant with various factors. (European Commission Transport RTD Programme 2001)

- **Capital**, operating and maintenance (including energy) costs
- **Costs** to the user and related topics: journey speed, delays, congestion, price for the use of road space, fare.
- **Benefits** to the users (surplus) and the operator (revenues minus costs).
- **Productivity** (expressed e.g. as operating cost per passenger trip or passenger revenue per vehicle hour).
- **Capacity** (vehicle and service) offered.
- **Utilization by mode**, including shift of passenger trips from single occupancy vehicles.
- **Load factor** for freight and public transport.
- **Incremental costs or travel time** per addition to capacity.
- **Accessibility** in terms of service area coverage capability.

3.1.2. Economic Efficiency in Urban Transportation

Efficiency is defined as “the quality of doing something well and effectively, without wasting time, money, or energy” in the Longman Dictionary. Inevitably, to make clear the discriminations between economic scales is useful while trying to achieve the economic efficiency for transportation. To that extent the total costs of owning and operating a company, including transportation companies, are usually broken into fixed and variable costs.

Fixed costs do not relate to production or utilization of equipment. Aircraft, trucks, trains, computers, and offices cost a fixed amount of money no matter what the degree of utilization. **Variable costs,** on the other hand**,** tend to be proportional to the degree of utilization. The more the equipment is utilized, the more labor that is necessary to operate them, the more fuel that is necessary to produce propulsion, and the more maintenance that is required. All costs tend to become variable in the long term as corporations expand or reduce their activities. (Papacostas and Prevedouros 1993)

In simple terms, when economies of scale are present, production increases lower the cost per unit and increase the profit per unit. ***Economies of scale*** exist when first, ***the fixed cost is high*** (thus the more the units over which it is spread, the lower the cost per unit), and second, ***the variable cost is small*** compared with the fixed cost. The existence of economies of scale (EOS) is depicted in the **Fig 3.1 and 3.2.**

When EOS is not present, the cost per unit does not change substantially as the number of units produced (or transported) increases. In contrast, when EOS are present, the cost per unit decreases substantially as the number of units produced (or transported) increases. (Papacostas and Prevedouros 1993)

100 units transported: 10 / 100 = \$0.10 cost per unit

200 units transported: 18 / 200 = \$0.09 cost per unit

A 10% decrease in the cost per unit is observed.

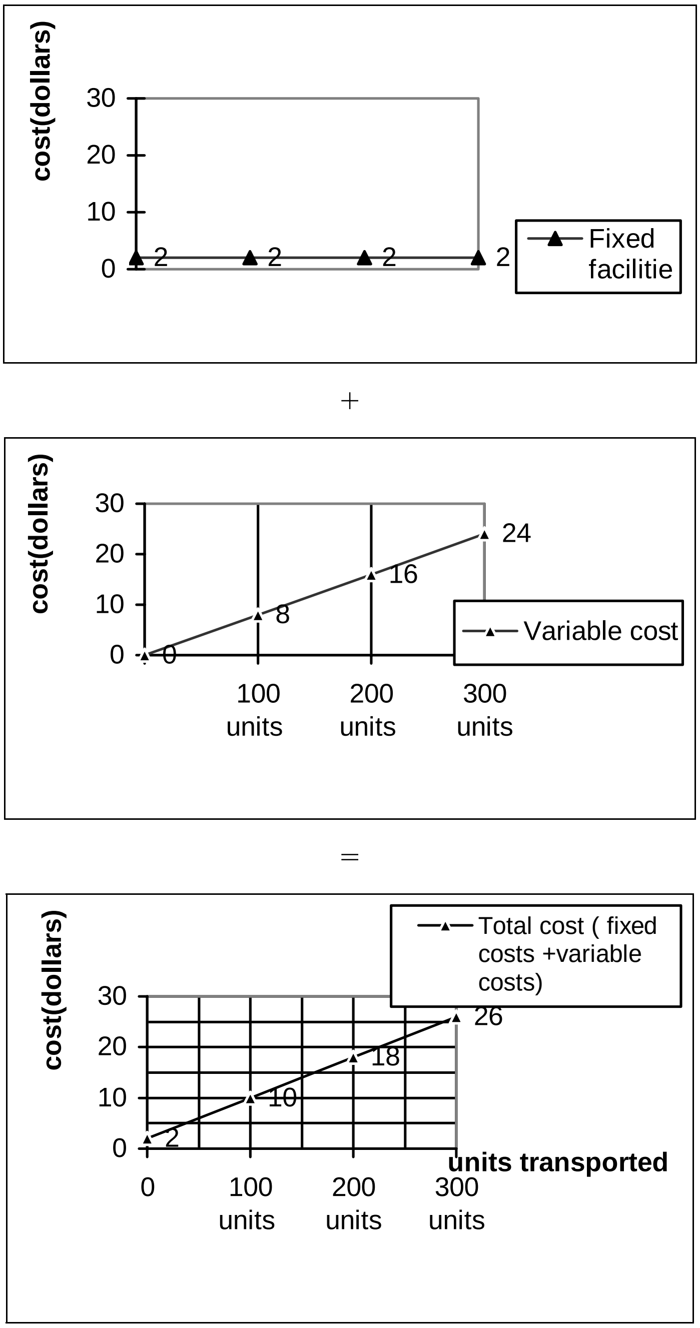


Figure 3.1 No Economies of Scale (Papacostas and Prevedouros 1993)

100 units transported: 20 / 100 = $0.20 cost per unit

200 units transported: 22 / 200 = $0.11 cost per unit

A 45% decrease in the cost per unit is observed.

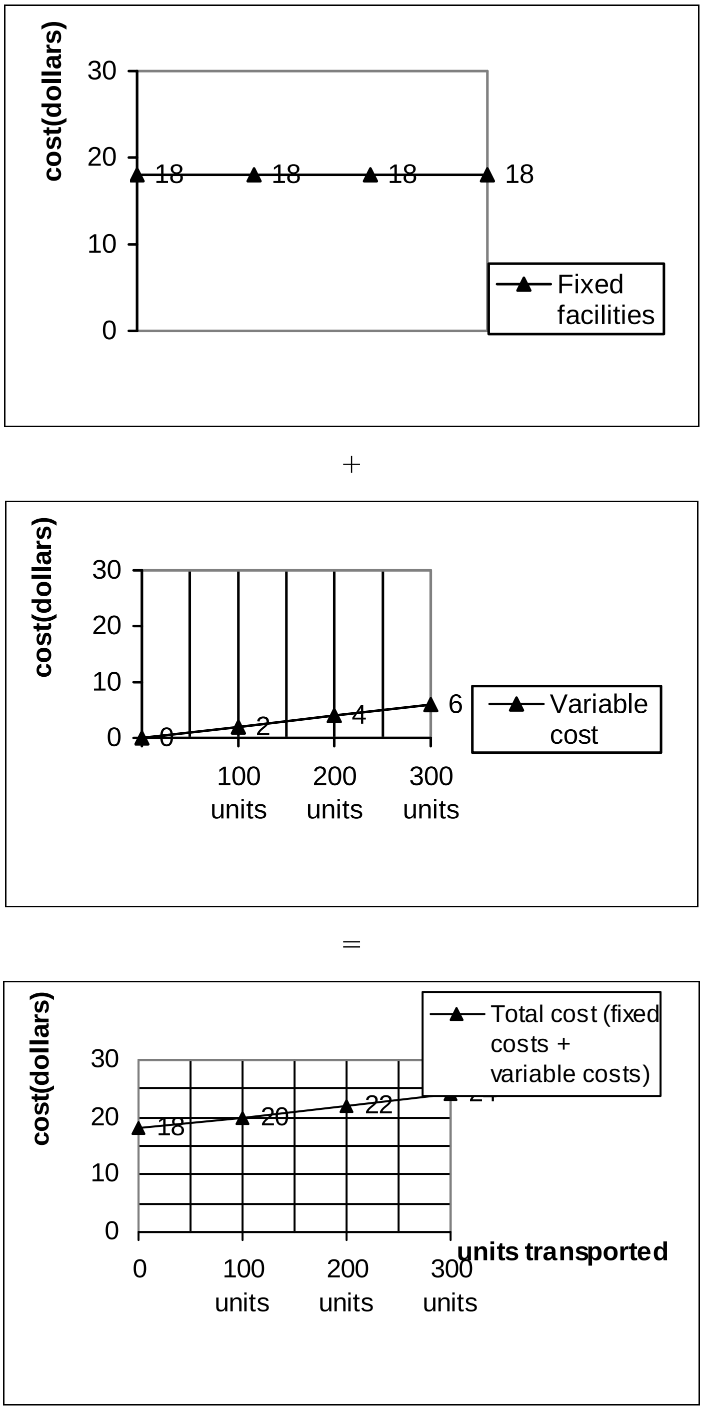


Figure 3.2 Substantial Economies of Scale (Papacostas and Prevedouros 1993)

3.2. The Comparison of BRT & LRT

There have been many studies to make objective comparisons of rail and bus modes. According to these researches the common assertions are;

- Driving an automobile all the way is the cheapest with volumes up to 5.000 passengers per hour
- Taking a bus all the way is generally cheapest when volumes are 10.000 passengers per hour
- Rail with feeder buses or residential collection and with a downtown subway for distribution is cheapest with high population density and volumes of at least 40.000 persons per hour

Deen and James compared busway and rail alternatives in Atlanta. They found that rail is superior for any volume higher than 12.000 passengers. In 1973 Miller compared busway and rail alternatives for Los Angeles. Rail was superior for any volume above 5.000.Several analyses claimed that the bus is best in all conditions. In 1969 Stover and Glennon advocated a freeway flyer system in which buses operate in mixed traffic on freeways. In 1973 Smith compared this scheme with a subway and found the bus option to be better in all respects. He suggested that some rail lines should be torn up and replaced with motorways. (Black 1995)

The difficulty of drawing a demarcation line between BRT and LRT depended on the surveys which have been undertaken by public authorities is obvious. Because public choice involves many values, and some of them are immeasurable. However the research of the United States General Office gives ideas about the two modes BRT and LRT.

3.2.1. The Economic Comparison of Bus and Rail Modes

The capital cost of LRT systems is twice of the capital cost of Busway systems.

Average cost of Busway systems is per km $ 21,610,000

Average cost of the Bus on HOV lanes is per km $ 14,370,000

Average cost of the Bus on Arterial is per km $ 1,090,000

Average cost of the LRT is per km $55,730,000

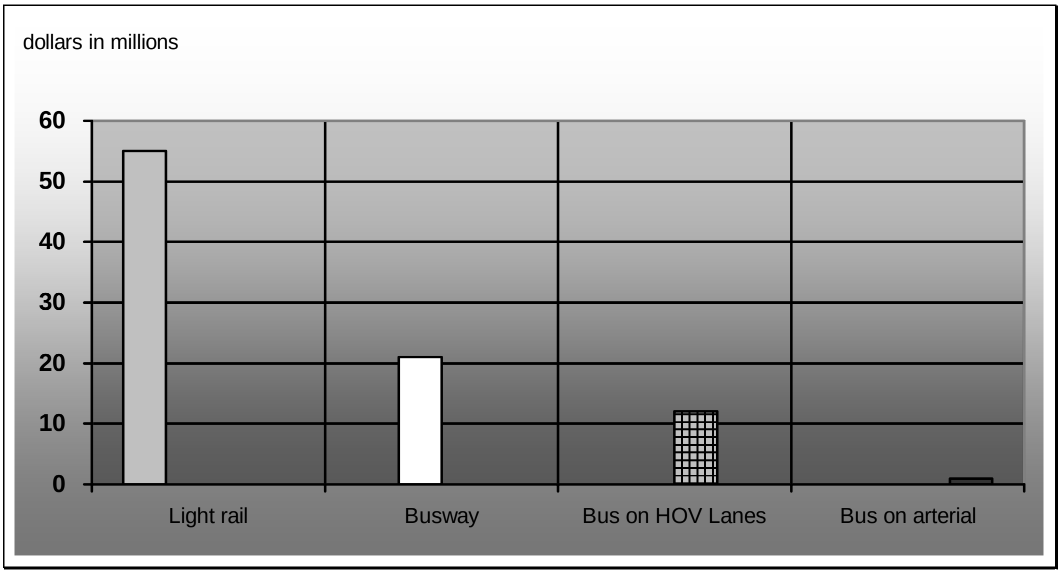


Figure 3.3 Capital Cost per Kilometers for the Different Modes of Transit
(US General Accounting Office 2001)

3.2.2. Analysis of Speed Comparison

The figure 3.4 shows the speed comparison of the two modes in USA. Average speed of LRT is higher only in Los Angeles.

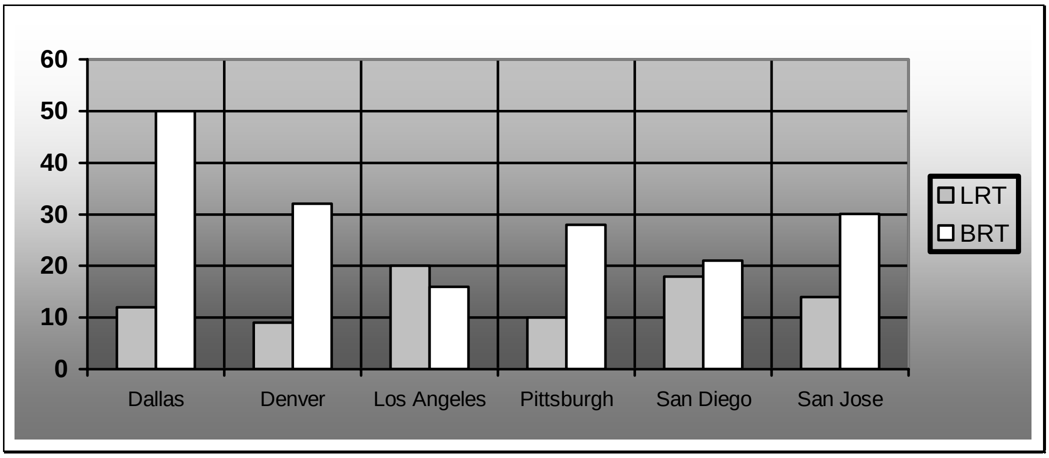


Figure 3.4 Average Speeds of BRT and LRT Service, 1999
(US General Accounting Office 2001)

3.2.3. Analysis of Operating Costs per Vehicle Revenue Hour

Operating cost of LRT systems is higher than BRT systems in all cities except San Diego due to the vehicle revenue hour.

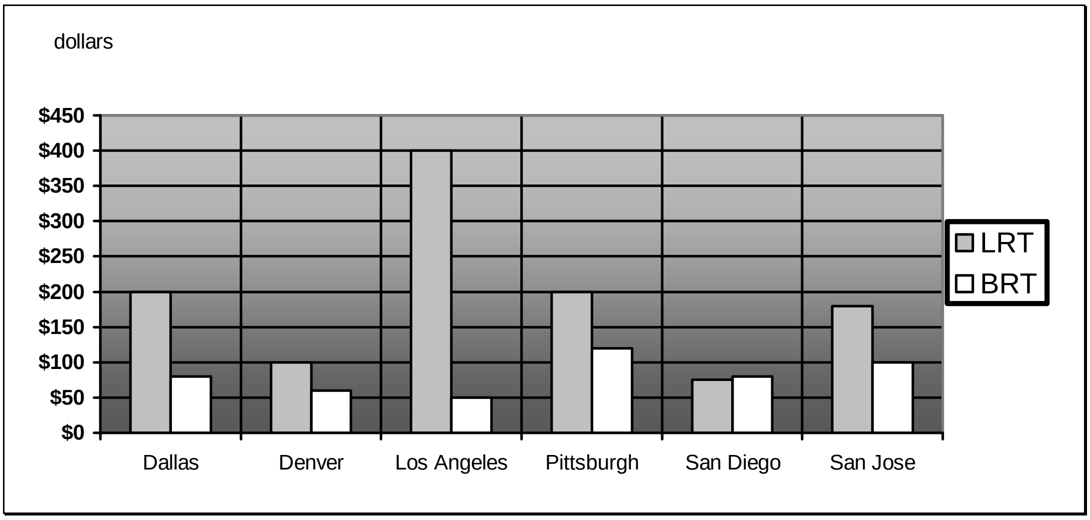


Figure 3.5 Operating Cost Per Vehicle Revenue Hour

(US General Accounting Office 2001)

3.2.4. Analysis of Operating Costs per Vehicle Revenue Km

Operating cost of LRT systems per vehicle revenue km is higher than BRT systems in all cities. Through these charts it can be declared that BRT systems are more efficient mass transit modes than the LRT systems in all conditions according to the operators' viewpoint.

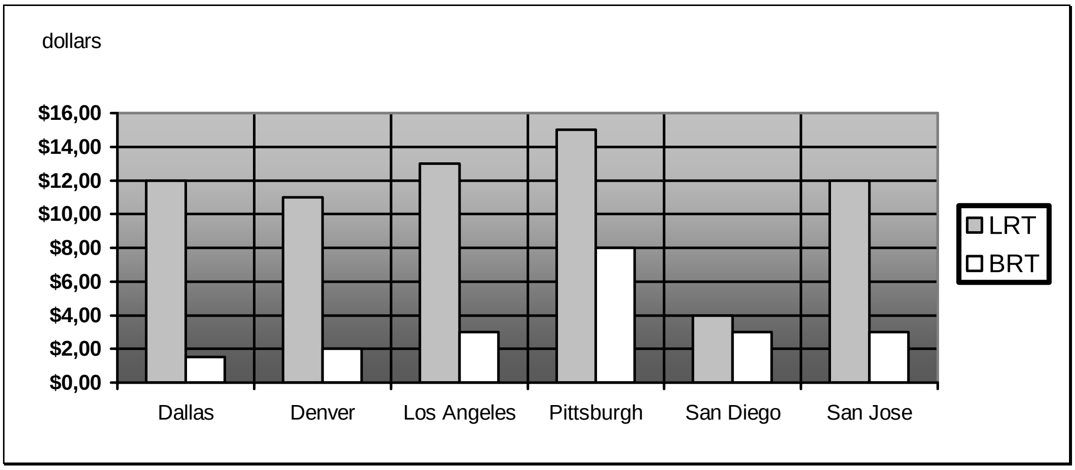


Figure 3.6 Operating Cost Per Vehicle Revenue Km
(US General accounting Office 2001)

3.3. Advantages of BRT:

Besides costs and performance characteristics discussed Bus Rapid Transit has many variety of advantages according to the Light Rail Transit. As being more flexible than LRT the system can start service during the construction of the entire systems' other phases. As an interim system it can be used until Light Rail is built.

On the contrary, Bus Rapid Transit system cannot easily overcome the negative expressions which stated for buses like the high level of noise, environmental contamination and low degree of quality in facilities.

3.3.1. Bus Rapid Transit More Flexible Than Light Rail

Bus Rapid Transit systems operate more flexibly than Light Rail systems. Can respond to changes like;

1. increasing or decreasing capacity in community patterns
2. routes can be adjusted over time to serve new developments, and developments of urban sprawl

3. Can use park & ride lots like the ones exist on rail transit routes. By the result of these arrangements collect riders in neighborhoods and provide rapid distance travel by entering a busway or HOV facility.
4. As transit riders most significant incentive to use mass transit is the less transfer between vehicles serve without requiring a transfer.
5. On the contrary, Light Rail systems frequently require a transfer of some type, from either a bus or a private automobile.
6. Operate both on and off busway or bus lanes.
7. Can pass disabled vehicle as light rail train had to match the delay time caused by a stalled train.

3.3.2. Bus Rapid Transit Operation Suitable for Phasing

Bus Rapid Transit systems differ from Light Rail systems in how they can implement and operate. There is not a necessity to build up the entire system for beginning operations. Improvements can develop incrementally. Such as signal prioritization and low-floor buses which improve capacity and bus speed, can be added incrementally.

3.3.3. Bus Rapid Transit as an Interim System

Bus Rapid Transit has the advantage of establishing a mass transit corridor. The development of a busway secures a transit right-of-way for the future. Some cities have identified Bus rapid Transit as a means of building transit ridership in a travel corridor to the point where investment in a rail alternative becomes a cost-effective choice.

CHAPTER 4

BRT: THE EFFICIENT TRANSPORTATION MODE

The petroleum crisis in the beginning of 1970's led public authorities to re-consider economic efficiency concepts in public transportation. The main concern in transportation discipline had become the development of the capacities. The result is the re-development of bus transportation systems which required low investment costs according to the rail transportation modes. Thus rapid transportation systems which give priorities and privileges to buses in traffic had been constructed. The various implications which called as BRT systems developed to the extent had different impacts. According to those;

- The systems which are continuous and have no stops along the route reach to the 72.500 passenger capacities and 1450 vehicles per hour.
- The systems with stops reached to 20.000 passenger capacities and 400 vehicles per hour.
- The systems in urban areas operating along the bus lanes reached to 10.000 passenger capacities and 200 vehicles per hour.

In addition to these in developing countries paratransit services use the reserved roadways with bus systems together. The 145 km reserved bus lane in Bangkok is used by 150 minibuses which reached to 18.000 passenger capacities in peak hours.

Meanwhile some implementations in Turkey developed at the end of the second half of 1970's. The first implementation had been constructed at Ankara along the Dikimevi-Besevler route by October 1978. The operation in the two directions provided at 5.3 km long median bus lanes which were separated by curbstones and metal railings. The Dikmen-Meclis route constructed at the same time period provided one way direction operation at curb bus lane. Third example constructed in Ankara was another type of the mode which operated at Demetevler minibus-bus lane. Vehicles penetrated through residential districts at contra-flow lanes.

Besides The Taksim-Zincirlikuyu route which constructed in Istanbul in1979 was the most important example. Vehicles operate partially at median bus lanes and partially at curb bus lanes along the route. The operation on this reserved lane reached to 200 vehicles per hour per direction at peak periods. In other words the capacity per hour per direction reached about 12.800 passengers. During the normal period of day the average amount reach to 150-160 vehicles per hour.

Somehow those examples of implementations had not reached to adequate numbers and by time some of them had been abandoned in Turkey. The vital point of the situation in Turkey had been the attitude toward the public transportation concept.

On the contrary the developments in the city planning process regarding economically efficient public transportation services to the extent can be best seen in Brazilian city Curitiba.

4.1. The Pioneer for the Bus Rapid Transportation

Curitiba the capital city of the Brazilian state Parana had developed a non subsidized; private owned, public transportation system which had been a pioneer for the Bus Rapid Transportation.

The system developed between the late 1960's and 1982. Today it stands as a model recognized internationally. The results of the system regarding several innovative solutions had provided the citizens giving priority to public instead of private transport. The city at the time has the highest user rates of all Brazilian state capitals, 75 percent of all weekday commuters. The key features of the widespread use and popularity of the system connects with the master plan for the city which developed by several architect firms in cooperation with city planners.

This master plan had five key principles;

- Changing the urban radial growth to a linear one by integrated land use, road network and transport strategy
- Decongest the city center
- Demographic control and management
- Economic support to urban development
- Infrastructure development

The planners recognized that the transportation systems can serve as the backbone for the development and growth of the city in the future. In coordination with the master plan the planning department had constructed five arterial structural roads that would form the structural growth corridors. These structural corridors are composed of a triple road system with the central road having two restricted lanes dedicated to express buses. Parallel to the express bus lanes were two local roads running in opposite directions. They allowed local traffic to pass through the city. (Friberg 2003)

In 1982 all five structural corridors were completed with inter-district and feeder lines. In other words the 60 km bus way routes along these axes are fed by 300 km of feeder routes which concentrate passenger demand on strategically placed terminals. On these terminals, but only here, the passengers can change between different lines on the same fare with extending public transport access to 90 % of the city area. (Friberg 2003)

The tube stations were constructed to speed up the system. Passengers now enter from the tube station at an even level to the bus floor and passengers pay their fares by tokens or in cash to an attendant at a turnstile while entering the tube station. Boarding times are thus reduced, approaching those of subway passengers. (Friberg 2003)

The latest improvement to the system is bi-articulated buses that were specially designed for the Curitiba system. These huge buses operate in the special lanes and have capacity of 270 passengers. Due to the system design with special lanes, pre-paid passenger boarding and the priority the buses receive in road hierarchy, the bus system can operate with a much higher capacity than traditional city bus system. (Friberg 2003)

4.2. The Scope of Implementing BRT

The BRT system concept is based on dedicated rights of way as in rapid transit. The system components as utilization of existing streets, development of required street furniture are needed for implementation of the system. As it provided a high quality of service similar to LRT the capital investments are relatively lower. Beyond these conclusions it could be situated that BRT is more affordable, flexible in scale than LRT for medium areas. ***The system could also operate at existing bus lines in most areas, but would enter a special lane on an existing highway, or a dedicated right-of-way to bypass mixed traffic to reach the Central Business District.***

Insofar as BRT can utilize dedicated rights-of-way it offers advantages over regular bus service, including service frequency, increased capacity, and speed.

4.3. Locations of Specific Samples Implemented

The locations, urban populations, rail transit availability, and development status of the ***26 cities*** are shown in Table4.1. They include ***12 urban areas in the United States*** (Boston, Charlotte, Cleveland, Eugene, Hartford, Honolulu, Houston, Los Angeles-three systems, Miami, New York- two systems, Pittsburgh, and Seattle); ***2 cities in Canada*** (Ottawa and Vancouver); ***3 cities in Australia*** (Adelaide, Brisbane, and Sydney); ***3 in Europe*** (Leeds, Runcorn, and Rouen); and ***6 in South America*** (Belo Horizonte, Bogota, Porto Alegre, Curitiba, Quito, and Sao Paulo).

Most of the BRT systems are found in urban areas with over 700.000 in population. Many of these urban areas also have rail rapid transit either.

Table 4.1 Sample Cities and Locations (Chrisholm 2003)

LOCATIONS NORTH AMERICA	**URBANIZED AREA POPULATION** (MILLIONS)	**RAIL TRANSIT IN METROPOLIS AREA**
Boston, MA	3.0	√
Charlotte, NC	1.4	
Cleveland, OH	2.0	√
Eugene, OR (Lane Transit District)	0.2	
Hartford, CT	0.8	
Honolulu, HI	0.9	
Houston, TX	1.8	
Los Angeles County, CA	9.6[a]	√
Miami, FL	2.3	√
New York, NY	16.0	√
Ottawa, ON	0.7[b]	√
Pittsburgh, PA	1.7	√
Seattle, WA	1.8	
Vancouver, BC	2.1	√
AUSTRALIA		
Adelaide	1.1	√
Brisbane	1.5	√
Sydney	1.7	√
EUROPE		
Leeds, United Kingdom	0.7	
Rouen, France	0.4	√
Runcorn, United Kingdom	0.1	
SOUTH AMERİCA		
Belo Horizonte, Brazil	2.2	√
Bogotá, Colombia	5.0	
Curitiba, Brazil	2.6	
Porto Alegre, Brazil	1.3	√
Quito, Ecuador	1.5	
Sao Paulo, Brazil	8.5	√

[a] Los Angeles County Only
[b] Excludes Hull, Quebec

Source: TransMilenio S.A., and Hidalgo (2002)

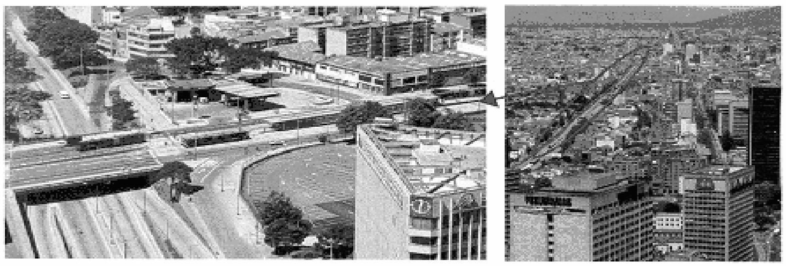


Figure 4.1 Trans Milenio Busway Systems

4.4. The Features of the System:

- Dedicated bus corridors with strong physical separation from other traffic lanes.
- Modern bus stops that are more like bus 'stations' with pre-board ticketing and comfortable waiting areas.
- Multi-door buses that 'dock' with bus stations to allow rapid boarding and alighting.
- Large, high capacity, comfortable buses that are preferably low-emission vehicles.
- Differentiated services such as local and express buses.
- Bus prioritization at intersections either through signal priority or physical avoidance (e.g., underpasses).
- Co-ordination with operators of smaller buses and paratransit vehicles to create new feeder services to BRT stations.
- Integrated ticketing that allows free transfers, if possible, across transit companies and modes (bus, tram, metro).
- Use of GPS or other locater technologies with a central control area that manages bus location at all times and facilitates rapid reaction to problems.
- Real-time information displays on expected bus arrival times.
- Good station access for taxis, pedestrians and cyclists, and adequate storage facilities for bicycles.
- New regimes for bus licensing, regulation and compensation of operators.
- Land-use reform to encourage higher densities close to BRT stations.

- Park and ride lots for stations outside the urban core.

- Well-designed handicap access, including the ability for wheelchair passengers to quickly board buses.
- A sophisticated marketing strategy that encompasses branding, positioning and advertising. (Targa 2003)

4.4.1. Specific Features of the System:

The specific features of the system are the indispensable features. It is not possible to construct a BRT system without dedicated runnigways, off-vehicle fare collection and distinctive stations that will integrate with the conventional bus system. However the features below listed are required for a system that will operate physically independently along the whole route.

Table 4.2 Number of Facilities with Specific Features (Chrisholm 2003)

FEATURE	US / CANADA	AUSTRALIA & EUROPE	SOUTH AMERICA	TOTAL SYSTEMS	PERCENT OF TOTAL
Running Way	13	5	6	24	83
Stations	12	4	3	19	66
Distinctive Vehicles	7	1	3	11	38
Off-Vehicle Fare Collection	2	0	3	5	17
ITS	7	1	3	11	38
Frequent All-Day Service	11	5	6	22	76
Total Systems	17	6	6	29	100

4.4.1.1. Running Ways

Running ways of BRT includes ***mixed traffic lanes***, ***curb bus lanes***, and ***median busways*** on city streets; reserved lanes on freeways; and bus-only roads, tunnels, and bridges. Table4.3 summarizes the various running ways found in the BRT case. Examination of the data shows that ***b***usways dominate North American practice, whereas ***median arterial busways*** are widely used in South America. Reversible high occupancy vehicle ***(HOV) lanes*** in freeway medians are found only in the United States. Bus tunnels that exist in Seattle, Brisbane, and Boston bring a major feature of rail transit to BRT. In most of the case studies, the running ways are radial, extending to or through the city center.

Figure 4.2 Trolleybus Station, Quito

Figure 4.3 Bi-articulated Bus Median, Curitiba

Figure 4.4 Busway in Charlotte, NC

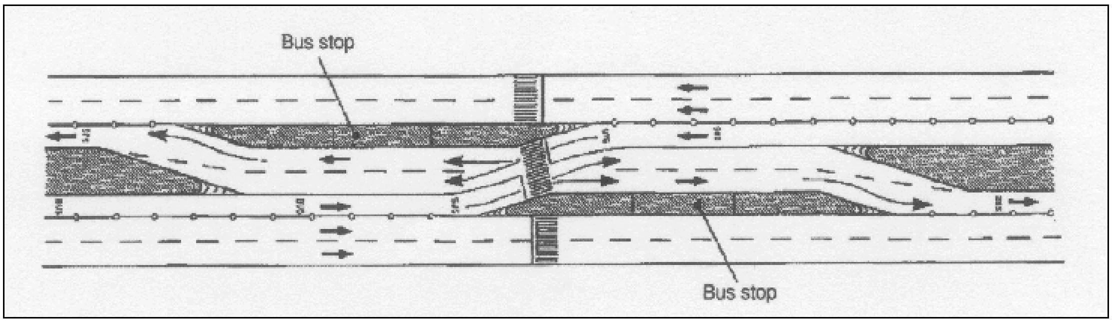


Figure 4.5 Typical Median Busway Design, South America
(Chrisholm 2003)

Table 4.3 Running Way Characteristics (Chrisholm 2003)

LOCATION	BUS TUNNEL	BUSWAY (SEPARATE RIGHT-OF-WAY)	FREEWAY BUS LANES	ARTERIAL MEDIAN BUSWAY	BUS LANES	MIXED TRAFFIC
North America	Boston Seattle	Charlotte New Britain-Hartford Miami Ottawa Pittsburgh	Houston Los Angeles New York	Cleveland Eugene	Ottawa Pittsburgh Vancouver	Honolulu Los- Angeles Vancouver
Australia	Brisbane	Adelaide [a] Brisbane Sydney				
Europe		Runcorn			Rouen [c]	Leeds [b]
South America				Belo Horizonte Bogotá [d] Curitiba [d] Porto- Alegre [d] Quito [d] Sao Paulo		

(a) O-Bahn technology
(b) Guided bus with queue bypass
(c) Optically guided bus
(d) High-platform stations

4.4.1.2. Stations

The spacing of stations ***along freeways*** and busways ranges from ***600 to almost 2100 meters***, enabling buses to operate at high speeds. Spacing ***along arterial streets*** ranges upward ***from about 300 meters*** (e.g., Cleveland and Porto Alegre) ***to over 1200 meters*** (e.g., Vancouver and Los Angeles).

Most stations are located curbside or on the outside of bus-only roads and arterial median busways. However the Bogotá system, a section of Quito's Trolebus, and Curitiba's 'direct' service has center island platforms and vehicles with left side doors.

Busways widen to three or four lanes at stations to enable express buses to pass stopped buses. Stations and passing lanes can be offset to minimize the busway envelope.

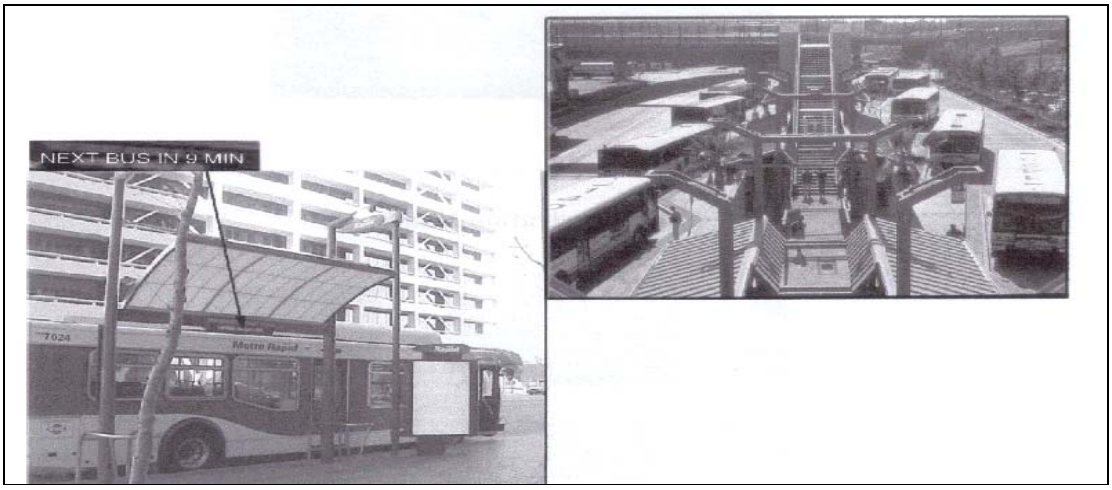


Figure 4.6 Examples of Bus Rapid Transit Facilities in Los Angeles and San Diego

4.4.1.3. Vehicles

Solo and standard articulated diesel buses are widely used for BRT operations. There is however, a trend toward innovations in vehicle design. These innovations include (1) 'clean' vehicles (e.g., low-sulfur diesel fuel, diesel electric hybrids, compressed natural gas (CNG), and possibly fuel cells in the future); (2) dual-mode (diesel-electric) operations through tunnels; (3) low-floor buses; (4) more doors and wider doors; and (5) use of distinctive, dedicated BRT vehicles.

Figure 4.7 Vehicle Used in Rouen

Figure 4.8 Busway Station

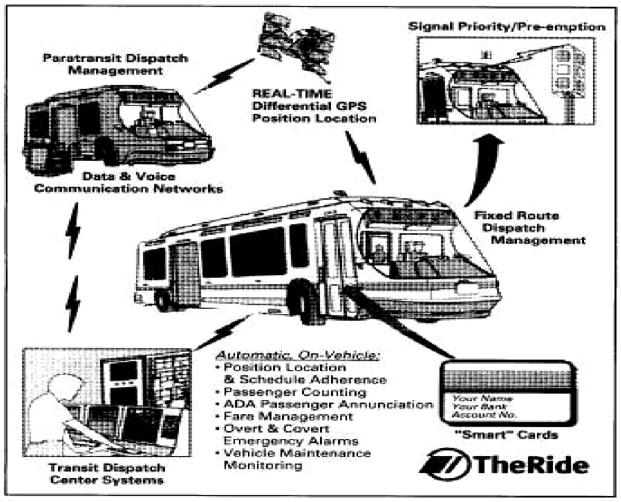
4.4.1.4. ITS

Applications of ITS technologies include automatic vehicle location systems; passenger information systems; and transit preferential treatment systems at signalized intersections, controlled tunnel or bridge approaches, toll plazas, and freeway ramps.

The Metro Rapid routes in Los Angeles can get up to 10 seconds additional green time when buses arrive at signalized intersections. ITS can also help provide priorities for buses at freeway ramps, toll plazas, and bridge or tunnel approaches. (Chrisholm 2003)

The GPS (Global Positioning System) which determines the location of the bus in the traffic also preserves other features;

- Provides input whether the bus is on time, behind or ahead schedule.
- The system implemented in Iowa by Rockwell International includes an on-board emergency system which the driver can activate on life threatening situations. The dispatcher can see the vehicle tracked on the map and can dial the emergency agent.
- An open database system permits access of external sources from internet and customer kiosks will enable passengers to regularly access real time information.



The Advanced Operating System incorporates many elements of technology to maximize efficiency and better serve the public.

Figure 4.9 Schematic Uses of GPS (Siuru 1996)

4.5. The Major Elements of Operating Plan:

There are six major elements of a bus rapid transit operating plan- ***route structure***, ***service frequency***, ***stop/station spacing***, ***service span***, ***network structure***, and ***the degree of integration with other transit modes***. While these operating plan elements are common to the definition of all transit modes, it is particularly important to define them rigorously for bus transit service due to the fact that the flexibility of buses allows each element of the operating plan to be defined over a wider range of possibilities.

4.5.1. Route Structure

The structure of a route is the core element of the bus rapid transit service design. It defines where a route operates, what locations are served on that route, and what patterns of service operate on that particular route.

Two major variables define the route structure- ***the alignment of the corridor*** and ***the alignment of the routes*** that serve that corridor. The route structure thus defines which locations are served and how those locations are linked together. (Diaz-Schneck 2002)

In the case of Quito, the capital city of Ecuador operates a successful bus rapid transit line using electrically powered trolley buses in an exclusive lane. Figure 4.2 depicts a trolley bus in the station. The trolleybus operates between the main activity centers and business districts in the center of the city. ***The route is bound on both ends by terminals*** where feeder lines converge to serve the Trolleybus.

4.5.2. Service Frequency

The service frequency defines how often customers along a particular bus transit route are served. ***Higher frequencies generally lead to low waiting times*** for customers whose trips begin and end along a particular trunk line service.

In the case of Porto Alegre, in order to expedite the boarding and queuing process, buses are organized at the downtown terminal to follow ***an ordered convoy***.

As a modal bus routes have the chance to be assigned into three different families of routes, each assigned by a separate letter (A, B, C). Buses thus organize into queues at the downtown terminal according to the assigned designation. A signal at the downtown terminal directs buses in the each of the three queues into ordered convoys of six buses (2 from route family A, 2 from the route family B, and 2 from the route family C). Buses follow each other in this order in platoons of up to six buses mimicking the multiple cars of a train. Since buses in each route family fall in the same order in the bus convoys, passengers can organize themselves at designated locations on platforms at stations along the route in order to meet their specific buses. (Diaz-Schneck 2002)

Meanwhile the operator can explore different combinations of convoys. For example, the six bus convoy could, in theory, present the following combinations: A-B-C-D-E-F, A-A-B-B-C-C, and A-A-A-B-B-B.

Convoys are generated throughout a probabilistic function that takes into account previous allocations. Headways between successive bus arrivals at the convoy setting location are obtained from a shifted negative exponential function; their general time depends on user specified conditions. The user can select one of the following conditions for vehicle insertion:

Option 0- vehicles are generated according to FIPO (first in, first out) practice at the stop line of the upstream-most traffic signal. Real generation time takes into account the duration of the green display.

Option 1- buses are generated in convoys that may or may not be complete. Vehicles are inserted at the stop line of the upstream-most traffic signal. If the convoy is complete by the onset of the green, a

complete convoy is generated; otherwise a fictitious controller waits until remaining green time is just sufficient to generate waiting buses, i.e., an incomplete convoy.
Option 2- buses are generated only when complete convoys have been assembled and light display of the upstream-most traffic signal is green. One or more convoys can be generated during a green phase, all depending on the size of them.
Option 3- vehicles are generated according to FIPO practice. Real generation time is identical to original time proposed by vehicle inserting routines of the model.
Option 4- buses are only generated when complete convoys are assembled.
Option 5-buses are generated in convoys that may or may not be complete, since they enter the system when queues reach a maximum length or when a maximum waiting time since the release of the previous convoy has elapsed; maximum values are set by the user. When maximum values are very high, option 5 produces identical results to option 4. (Lindau 1998)

4.5.3. Stop / Station Spacing

The spacing of the stops or stations along a particular route defines where customers can access a particular route. Typically, ***stop spacing on a bus rapid transit route is much longer than conventional transit*** routes allowing for faster running speeds between stops / stations and shorter times spent dwelling at stops due to the banding together of customers at stops / stations.

The experience of Vancouver reveals that a simple improvement, such as changing the spacing of stops, can dramatically improve service to effectively serve established passengers in the corridor and to effectively bring additional passengers to transit. The Coast Mountain Buslink operates on one of its heaviest bus routes along Broadway, an east to west cross-town route (route 9) that serve the University of British Columbia, several commercial districts, and the Sky Train terminal. Route 9 serves the corridor with standard length electric ***trolley*** buses with ***stops spaced*** typically spaced at intervals of approximately ***400 meters.*** The operations division of the bus company launched an experiment to provide an overlay of service in the Broadway corridor that serves only major activity centers and major transfer points. ***The diesel buses*** that serve the new route (99 B-Line) stop ***an average interval of close to 1200 meters***, roughly three times the distance of the stop spacing on the local route. ***The diesel buses on the route are able to overtake local buses to achieve higher speeds***. (Diaz-Schneck 2002)

4.5.4. Service Span

The service span defines what period of the day a particular service operates. While most of the bus rapid transit services surveyed operated their respective bus rapid transit services during the entire service day, an operating plan can be often take advantage of travel market characteristics to meet service needs with bus rapid transit where physical conditions may constrain the operation.

The Montreal experience demonstrates how bus rapid transit service can benefit patrons even when the service is not fixed throughout the day. The STCUM, Montreal transit provider, operates a bus lane along Boulevard Pie IX in the eastern section of Montreal between the Pie IX Metro station and the neighborhoods of North Montreal. ***In each peak hour, the STCUM operates the R-Bus (Reserved Bus) route in the peak direction of travel demand*** along Boulevard Pie IX. ***The buses travel in a lane that opposes the general flow of traffic*** serving designated stations along the route that are spaced at intervals between 400 and 1200 meters. The contra-flow bus lane is regulated by a specialized signal system, operation managers, and police patrols along the corridor. (Diaz-Schneck 2002)

4.5.5. Network Structure

The structure of the bus rapid transit network defines the coverage of the bus rapid transit system over a metropolitan area and the spatial relationship of bus rapid transit routes to each other and to the other routes within the system. Several variables define a network structure such as the number of lines, the orientation of lines with respect to one another and the proportional of conventional lines that meet bus rapid transit route.

4.5.6. Degree of Integration with Other Transit Services

The degree of integration of the bus rapid transit services with other transit services defines the ability of customers to transfer between routes in the service network. A high degree of integration between routes spreads travel benefits to those customers whose travel needs are only partially satisfied by bus rapid transit routes to experience the same benefits as those who travel exclusively along the route. For example, ease of transfer between local circulator buses and high speed, high capacity bus rapid transit service can reduce total travel time and can enhance the user friendliness of the system and the comfort for passenger.

4.6. Performance:

The performance of the BRT systems evaluate because of the configuration of each system. Performance can be measured in terms of passengers carried, travel speeds, and land development changes.

4.6.1. Rider ship

The number of weekday bus riders reported for the systems in North America and Australia ranges upward from 1.000 in Charlotte to 40.000 or more in Los Angeles, Seattle, Adelaide and Brisbane. Daily ridership of BRT in Ottawa and South American cities is substantially higher and usually exceeds 150.000 per day at total.

Examples of heavier peak-hour, peak direction passenger flows at the maximum load points are shown in table 4.4. ***These flows equal or exceed the number of LRT transit passengers carried per hour in most U.S and Canadian cities and approach metro (rail rapid transit) volumes.***

The progress in usage of bus rapid transportation depended on the features of the system. Expanded service, reduced travel times, improved facility identity are just the some of these features.

- 18% to 30% of riders were new riders in Houston;
- Los Angeles had a 26% to 33% gain in riders, one third of which was new riders;
- Vancouver had 8.000 new riders, 20% of whom previously used automobiles and 5% of whom were taking new trips;
- Adelaide had a 76% gain in ridership;
- Brisbane had a 42% gain in ridership;
- Leeds had a 50% gain in ridership; and
- Pittsburgh had a 38% gain in ridership.

Table 4.4 Peak-Hour, Peak-Direction Passenger Flows (Chrisholm 2003)

Over 20.000 per hour	New York; approach to Lincoln Tunnel
	Bogotá's Trans Milenio
	Porto Alegre
	Sao Paulo
8.000-20.000 per hour	Belo Horizonte
	Ottawa
	Quito
	Curitiba
	Brisbane

4.6.2. Speeds

Operating speeds reflect the type of running way, station spacing, and service pattern. Typical speeds are shown in Table 4.5.

Table 4.5 Typical Operating Speeds (Chrisholm 2003)

Freeway-Busway	
• Nonstop	65-80 km/h
• All-stop	40-55 km/h
Arterial Streets	
• Express, Bogotá, Curitiba	30 km/h
• Metro Rapid bus, Ventura Blvd., Los Angeles	30 km/h
• Metro Rapid bus, Wilshire Blvd., Los Angeles	22 km/h
• All-stop-Median Busways, south America	18-22 km/h
• Limited-Stop-New York City	12-22 km/h

4.6.3. Travel Time Savings

Busways on dedicated rights-of-way generally ***save to 1 to 2 minutes per km*** compared to pre-BRT conditions, including time for stops. ***Bus lanes on arterial streets typically save 1 minute per km***. The time savings are greatest where the bus routes previously experienced major congestion. Pittsburgh, for example, has reported travel time savings up to 3 minutes per km during peak hours.

Table 4.6 Examples of Travel Time Savings (Chrisholm 2003)

Busways, Freeway Lanes	32%-47%
Bus Tunnel-Seattle	33%
Bogotá	32%
Porto Alegre	29%
Los Angeles Metro Rapid Bus	23%-28%

4.6.4. Land Development Benefits

Reported land development benefits with full-featured BRT are similar to those experienced along rail transit lines.

Studies have indicated that construction of the Ottawa Transitway has led up to $ 675 million (U.S. dollars) in new construction around transit stations; a study completed by the Port Authority of Allegheny County reported $ 302 million in new and improved development along the East Busway, 80% of which was clustered at stations. Property values near Brisbane's South East Busway grew 20%, which is largely attributed to the busway construction. (Chrisholm 2003)

4.7. Design Guidelines for At-Grade Busways

This section discusses the at-grade busway infrastructure components in detail including; right-of-way, bus stops, shelters, bus bays, intersection layout, traffic signal priority, and the above-mentioned busway operational measures. ***A typical at-grade busway should include two through exclusive bus only lanes with an optional two extra lanes at the station areas to allow express buses to bypass other buses boarding and alighting passengers.*** Deciding whether to install a median or a side-aligned busway mainly depends on the existing right-of-way configuration, as well as, the characteristics of the corridor on which the busway will be installed.

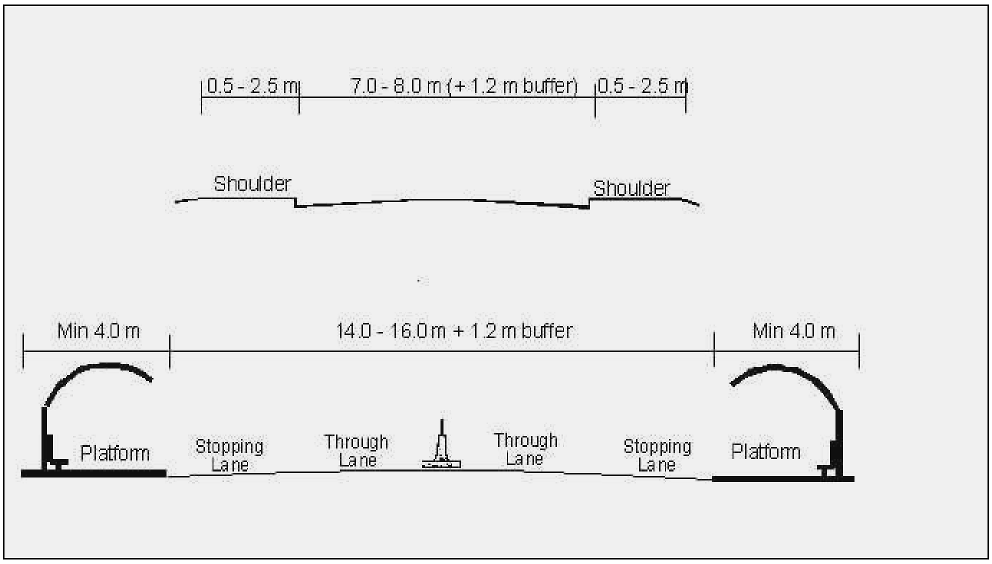


Figure 4.10 Typical Busway Cross-sections in New Roadways or Abandoned Right-of-Way. (Shen 1998)

4.7.1 Right-of-Way Characteristics

At-grade busways can be introduced along existing roads, using abandoned or sharing railway right-of-way, or they can be purpose-built. ***Along an existing road, a busway can run in the middle of the roadway (median busway) or along the curb*** (lateral busway or curbside busway). **Figure 4.11** presents different busway alignments.

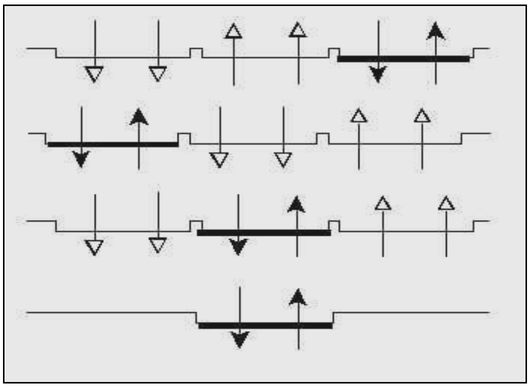


Figure 4.11 Typical Busway Configurations (Shen 1998)

A purpose-built busway can accommodate dedicated at-grade bus only roads (e.g., Runcorn New Town, UK); an abandoned railway right-of-way can be modified for the busway operation (e.g., Miami, FL).

A busway can also share the right-of-way with other modes of transit in part of its alignment (South Busway, Pittsburgh), and a dedicated right-of-way along a new road (e.g., Avenida Cristiano Machado, Belo Horizonte, Brazil).

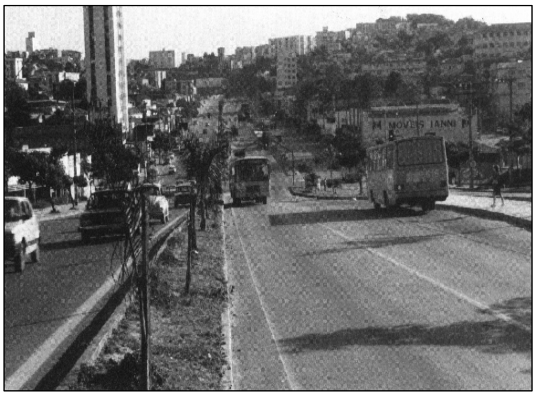


Figure 4.12 Median Busway

Figure 4.13 Median Busway

4.7.1.1. Median At-grade Busway Cross-section

The insertion of a new busway in an existing roadway is a difficult issue that arises over the allocation of road space between the conflicting demands of different road users. In many cases, there are insufficient right-of-ways to add two more exclusive busway lanes. Thus, a median at-grade busway usually consists of an exclusive two-lane roadway, one lane in each direction, reserved for the use of buses. Unless, there is enough right-of-ways near the intersections, two extra lanes (one each direction) can be added as an overtaking facility at the station area. Otherwise, the buses on the busway have to operate in the same order from beginning to the end of the busway. The total width of the busway is a function of its design speed. **Table 4.7** represents some of the recommended lane width and different separation dimensions.

Table 4.7 Recommended Cross-section Widths for Median At-Grade Busways with No Overtaking Facilities Carrying More Than 60 Buses/Hour. (Shen 1998)

Design Speed (km/h)	Width (m)			
	Bus Lane	**Central Separator**	**Outer Separator**	**Total Width**
100	4.00	0.40	0.75	10.30
80	3.75	0.40	0.50	9.30
60	3.25	0.40	0.30	7.90
40	3.00	0.40	0.20	7.20

Figure 4.14 Median At-Grade Busway, Curitiba-Brazil

Figure 4.15 Median Busway in Curitiba

Figure 4.16 Median Busway

4.7.1.2. Side-Aligned At-Grade Busway Cross-Section

A Side-aligned at-grade busway is usually planned and installed in newly constructed corridors where the right-of-way needed is reserved and driveways for businesses are permitted at the busway side. Typically, a side aligned busway consists of an exclusive two lane roadway, one lane each direction, reserved for the use of buses as shown in Figure 4.20.

For high speed operation of 80 km/hr lane width may vary from 3 to 4 m depending on the space available. If the right-of-way permits, an extra 1.2 m separation distance (buffer) between the two directions may be placed. Shoulders may also vary from 0.5 m to 2.5 m. At stations, two extra lanes (one each direction) are placed. This will result in one stopping lane and one through lane. This cross-section will allow non-stop or express buses to pass by other buses loading and unloading passengers at stations as shown in Figure 4.21 (South Miami-Dade Busway in Miami, Florida). A fence is usually installed at the station area to separate the two direction of traffic and to prevent passengers from crossing the busway within the station area. Typically, the cross-section at the station area varies from 23 m to 26 including a 4-m station platform for each direction.

Figure 4.17 Side-Aligned At-Grade Busway Miami, FL

Figure 4.18 Side-Aligned At-Grade Busway Miami, FL

4.7.2. Bus Stop Characteristics

The spacing of bus stops is dependent on the purpose and the design speed of the busway. If the busway is to serve as a rapid transit corridor between a remote residential zone and a central business district (CBD), few stops would be provided. If however the busway travels through passenger catchments areas, stop spacing is considered to be

- close (500 to 1000 meters) where passengers would walk to stops;
- intermediate (1000 to 1500 meters) where passengers would ride other buses to stops;
- long (1500 to 4500 meters) where passengers would drive private vehicles to stops. (Held 1990)

These distances compared to standard on-road stop spacing usually in the order of 250-300 m. It should be noted that close and possibly intermediate stop spacing would prevent buses from attending Class A busway design speeds in the order of 100 km/hr.

The design of bus stops should be such that delays associated with loading and unloading affects only the bus in question. Thus, ideally either bus bays or overtaking facilities should be provided into the bus stop design if the right-of-way permits.

Passenger security is a major issue in bus stop design and location, because the design and location of the bus stop can positively or negatively influence a bus patron's perception of that bus stop. Landscaping, walls, billboards, and solid structures can restrict sight lines and provide spaces to hide. Thus, transit agencies should carefully review which amenities are to be included at a bus stop and consider any factors that may influence security. (Held 1990)

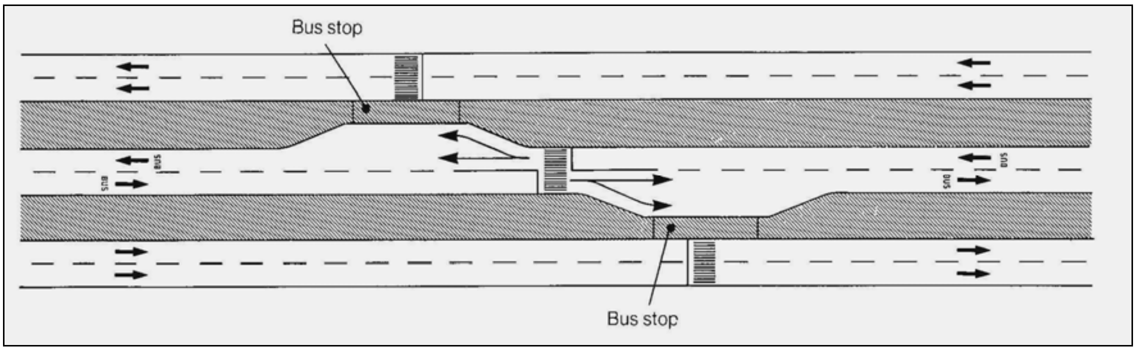


Figure 4.19 Typical Bus Stop Layouts, Avenida Cristiano Machado, and Belo Horizonte Brazil

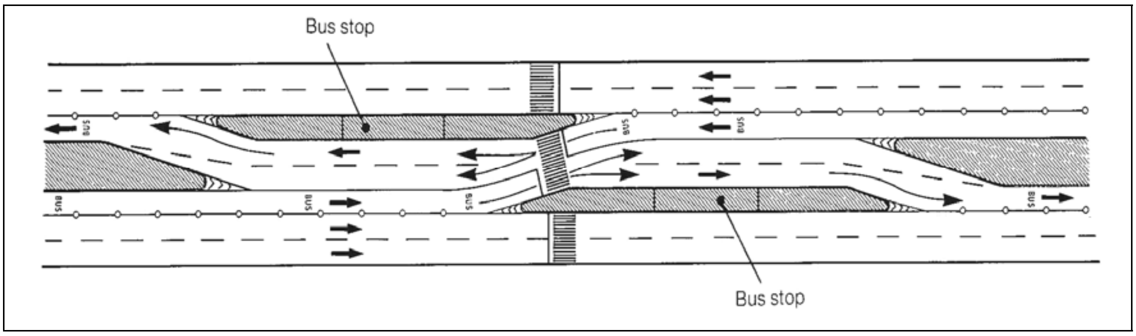


Figure 4.20 Typical Bus Stop Layout, Avenida 9 de Julho, Sao Paulo, Brazil (Shen 1998)

CHAPTER 5

RESERVED BUS TRANSPORTATION SYSTEM OPERATING ON ONE LANE

The aim of this chapter is to design a bus rapid transportation mode in an existing arterial as an alternative transportation mode in Izmir. Beyond the basic explanation of this assertion, the necessity for depicting the conceptual framework of the claim is inevitable.

In the first stage the general projections for the traffic of Izmir will be handled. A brief explanation of the expected problems and the current ones would also take place. A survey that shows the frequencies of public bus transport on the major arterials will be the backbone of the route preference stage. In short the debate and choice stage. In the implementation stage an operating plan and the design of the chosen route will be handled. The correlation with the previous chapters will be shown through a survey which determines the economic comparisons of the projected systems for the traffic in Izmir. The principal parameter of the economic comparison will be costs related to passenger/km parameter as the economic efficiencies of systems generally depend on it. However, this will be last stage during the correlation phase. The preceding stage will be, of course, the determination of the efficient level of service of bus transportation. As the feedback stage consists of different approaches which can be manipulate by the operator by time, this stage would be handled out of the content.

5.1. The State of Public Transportation in Izmir

The transport network of Izmir constitutes of bus, ferry, railway and other private modes. The distribution rates of mass transit modes surveyed by UKOME (Center for Coordination of Transportation) reveal that bus transportation mode is the most preferred mode; within the 89.3% usage. The Heusch-Boesfeld report which was written for İBŞB in 1992 also indicates the bus frequency on the major arterials of Izmir would be concentrated. According to that report;

- public transportation demand along Inönü Street per day will rise to 180.000 passenger per direction
- public transportation demand along Eşrefpaşa Street per day will rise to 210.000 passenger per direction
- public transportation demand along Varyant Street per day will rise to 300.00 passengers per direction by the year 2010.

It becomes clear that Izmir needs some innovative implementations to solve the potential increase in congested roadways. According to the studies concluded by Heusch Boesfeld two types of transportation plans suggested.

In the scenario A, great amount of transportation demand will be met by only bus transportation mode across Izmir. In the scenario B, networks of light rail transportation mode was suggested. The decision which would give an end to the situation of public transportation in Izmir was as taken a part of the second scenario. The decision was reached that the insufficiency for bus transportation to cover the estimated transportation demand would continue.

The first stage of metro system of Izmir was to the extent constructed in the year 2000. It is 11.6 km long and starts from Bornova and ends at Ücyol. By the year 2010 the second stage, which extends to Üçkuyular, will have been completed.

However, the system is not as feasible as it is expected because the system is operated for 70.000 passenger/day while similar systems handle 400.000 passenger/day. (Selvi 2002)

The feasibility survey of the metro system is out of the field of the current study, while it is indispensable to know the inefficiency of metro to propose a BRT system on its potential destination by the economic efficiency criterion. Beyond this, it is necessary to know the situation of congestion in the current state and the projected increase to make better conclusions.

5.1.1. Reasons of the Rising Congestion in Izmir

From the viewpoint of people who experience the traffic jam, crawling along at congestion times instead of moving at normal driving speeds causes frustration. It is a situation in which there are so many cars on a road at any one time that average speed has to drop and then the number of cars traversing the road in any given time period falls below its possible maximum. The congestion also consumes scarce resources and causes economic inefficiency. The reason of this situation can be explained by two factors: the immediate and the long term factors.

- Rapid growth of population and job
- More intensive use of automotive vehicle
- Failure to build new road

The above mentioned immediate-term factors, which increase the congestion level on the streets of cities are also common for the congestion in Izmir. A continuous growth in the population of the city is obvious. The increase in population from 1.750.000 people to 2.500.000 people in the last fifteen years strengthens the idea of growth. According to the Heusch Boesfeld's report, a growth in the ownership of private cars is also a factor. The number of private vehicles was 77.634 in 1985 and 135.393 in1990. The growth rate is about 13% for a year. On the other hand, the rapid urbanization without any projections about the city also causes failure to enhance the degree of roadway quality. There have always been expropriation problems to an extent during the construction stage of new roads.

The long term factors which depend on the immediate term factors have the chance to be reconsidered with respect to the time factor.

The indicators below support the rate of increase in the situation of congestion through the long term factors.

- Concentration of work trips
- Desire to choose where to live and work
- Desire to travel in private vehicles

The demographic data completed in 1990 depicts that 49% of the population of Izmir lives in the Konak district. Simply, Konak is the most concentrated district of the city. According to the census; the percentage of the concentration being working people 34% , students 9.2% , housewives 25%, and children under the age of twelve 24%. Approximately half of the population in the district at that time developed the travel demand at the peak hours of the day. It is clear that the concentration at the time did not have the chance to reduce. In general, the distribution rates of professions indicate that the travel demand consists mainly of work trips.

The above mentioned information clarified the case for the two long term factors regarding congestion. The necessity to declare the volume of transportation modes is obvious. Comparison of the population growth between the volumes of transportation modes will explains the desire to travel in private vehicles. It is the most significant long term factor which affects the level of congestion in the streets. According to the report concluded_for the municipality of Izmir 697.693 passenger/day demand was covered by buses in 1984. On the other hand, 700.000 passenger/day demand was covered by buses in 1990. The number of passengers carried by minibus transportation increased from 373.050 to 459.159. This situation indicates a reduction in the bus transportation modes while the number of bus transportation passengers increases. Based on the population growth, a contradictory situation will also be experienced through 1984 to 1990.

The number of the vehicles in the report shows that buses make up about 10 % of the total vehicles. It is also a contradictory situation for buses while they cover the 50 percent of the transportation volume at that time. This condition is of course was valid for the year 1990 when the population was about 1.750.000. The number of transported passengers with buses reached to 770.000 passengers per day when the population of Izmir is about 2.500.000. Even this indicator is enough to depict the continuity in the reduction of the volumes of bus transportation. Thus the result is the well known congestion.

5.2. The Appropriate Route and Transportation Mode

The destination of the second stage of metro, which is between Üçyol and Üçkuyular, is connecting a residential district, Üçkuyular, to a commercial district, Konak. This is the most important part of the project. As a public transportation system, bus transportation systems compensate the public necessity on two major arterials at the moment. If Üçkuyular is assumed to be the starting point, there will exist two major arterials. The subject of this research is Inönü and Mustafa Kemal+Mithatpaşa Streets. Surveys which figure out the concentration of the arterials were carried out to find out the bus flow characteristics of the streets during the work hours of the week days.

The process of counting vehicles operating along those arterials was carried out through different time periods. The concentration of urban traffic motion which is considered as the concentrated flow of traffic will be towards business district from residential areas at morning hours and to opposite directions on the reverse lane at evening hours. As a result, the morning peak-hour counting was done at Fahrettin Altay Square. Reversely, the evening peak-hour counting process was carried out at Konak Bahribaba bus stations. The reversal in the direction of concentrated traffic flow depended on the spread of traffic flow from business district to residential district at the end of the day. In addition, noon hours were chosen as the day-time period to find out the adequate number of vehicles going in both directions.

Table 5.1 Traffic Flow on Mustafa Kemal and Mithatpasa Streets

13:00-14:00	**ÜÇKUYULAR-KONAK**		**KONAK-ÜÇKUYULAR**	
Identification numbers	Flow quantities	Measured	Flow quantities	Measured
169	**8**	**7.5 min**	**6**	**10 min**
245	**4**	**15 min**	**5**	**12 min**
216	**3**	**20 min**	**3**	**20 min**
311	**2**	**30 min**	**2**	**30 min**
8	**3**	**20 min**	**3**	**20 min**
300	**3**	**20 min**	**3**	**20 min**
554	**2**	**30 min**	**3**	**20 min**
209	**1**		**2**	**30 min**
371	**1**		**2**	**30 min**
305	**1**		**2**	**30 min**
271	**1**		**2**	**30 min**
7	**1**		**2**	**30 min**
6	**2**	**30 min**	**1**	
480	_	_	1	
404	_	_	*1*	
167	_	_	1	
TOTAL CAP/HOUR	32		39	

Table 5.2 Traffic Flow on Mustafa Kemal and Mithatpasa Streets at Peak Hour

17:00-18:00	**ÜÇKUYULAR-KONAK**		**KONAK-ÜÇKUYULAR**	
Identification numbers	Flow quantities	Measured	Flow quantities	Measured
169	**4**	**15 min**	**6**	**10 min**
245	**2**	**30 min**	**3**	**20 min**
216	**1**		**2**	**30 min**
311	**1**		**2**	**30 min**
8	**3**	**20 min**	**2**	**30 min**
300	**2**	**30 min**	**2**	**30 min**
554	**2**	**30 min**	**2**	**30 min**
209	**2**	**30 min**	**2**	**30 min**
371	**2**	**30 min**	**1**	
305	**2**	**30 min**	**2**	**30 min**
271	**1**		**1**	
7	**2**	**30 min**	**2**	**30 min**
86	3	20 min	2	30 min
269	1		1	
502	1		_	_
54	_	_	2	30 min
361	_	_	5	12 min
64	_	_	3	20 min
121	_	_	4	15 min
404	_	_	2	*30 min*
120	_	_	4	15 min
244	_	_	1	
TOTAL CAP/HOUR	29		51	

In the tables the buses identified with italic numbers and underlined ones are the examples of delayed buses. Those vehicles usually operate by 45 minutes or 60 minutes intervals. Some sort of delays on their destination usually happens in mixed traffic. The vehicles identified with italic and underlined numbers are not observed on the contra lanes after an hour observation has been completed. The numbers with bold characters are the vehicles which operate along the street on both lanes. As a result, the other identified vehicles operate along those streets only on one lane for once during their trips.

Table 5.3 Traffic Flow on Inönü Street

13:00-14:00	ÜÇKUYULAR-ÜÇYOL		ÜÇYOL-ÜÇKUYULAR	
Identification numbers	Flow quantities	Measured	Flow quantities	Measured
86	**7**	**8.5 min**	**7**	**8.5 min**
605	**4**	**15 min**	**4**	**15 min**
670	**2**	**30 min**	**4**	**15 min**
486	**1**		**1**	
370	**2**	**30 min**	**3**	**20 min**
5	**3**	**20 min**	**3**	**20 min**
379	**1**		**1**	
270	**3**	**20 min**	**4**	**15 min**
81	**2**	**30 min**	**3**	**20 min**
600	**4**	**15 min**	**3**	**20 min**
509	**1**		**2**	**30 min**
217	**3**	**20 min**	**1**	
586	**5**	**12 min**	**4**	**15 min**
519	**2**	**30 min**	**2**	**30 min**
82	**3**	**20 min**	**2**	**30 min**
375	*1*		_	_
320	*1*		_	_
479	_	_	*1*	
319	_	_	*1*	
TOTAL CAP/HOUR	45		46	

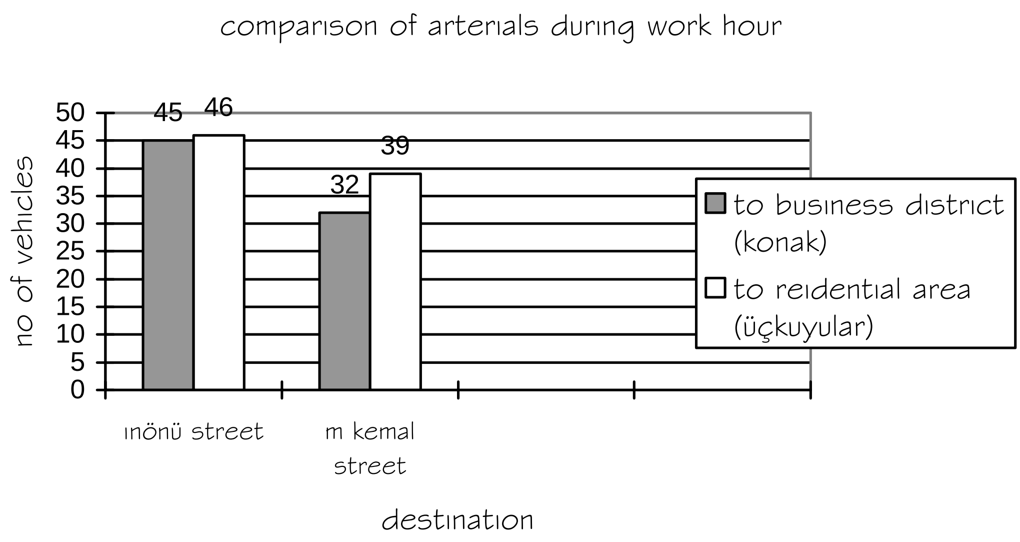
Table 5.4 Traffic Flow on Inonü Street at Peak Hour

07:00-08:00	**ÜÇKUYULAR-ÜÇYOL**		**ÜÇYOL-ÜÇKUYULAR**	
Identification numbers	Flow quantities	Measured	Flow quantities	Measured
86	**12**	**5 min**	**7**	**8.5 min**
605	**5**	**12 min**	**4**	**15 min**
670	**4**	**15 min**	**3**	**20 min**
486	**2**	**30 min**	**2**	**30 min**
370	**2**	**30 min**	**1**	
5	**2**	**30 min**	**3**	**20 min**
379	**1**		**1**	
270	**4**	**15 min**	**4**	**15 min**
81	**5**	**12 min**	**2**	**30 min**
600	**4**	**15 min**	**4**	**15 min**
509	**3**	**20 min**	**1**	
217	**2**	**30 min**	**_**	
586	**5**	**12 min**	**5**	**12 min**
519	**2**	**30 min**	**2**	**30 min**
82	**3**	**20 min**	**4**	**15 min**
375	*1*		*1*	
320	*3*	*20 min*	*1*	
479	*1*		*1*	
319	*1*		*2*	*30 min*
11	*2*	*30 min*	*1*	
183	*1*		*1*	
281	1		_	
370	**-**	**-**	1	
TOTAL CAP/HOUR	66		51	

The tables above indicate that the total number of public transport vehicles operating on Inönü street during work hours is 91 (45+46) while the total number of vehicles operating on Mustafa Kemal Street is 71(32+39). Beyond the peak hour, the indicator is 117(66+51) to 80(51+29). Inönü Street can be said to be more concentrated than Mustafa Kemal Street during all the daily trips. Based on the quantitative data, İNÖNÜ STREET can clearly be chosen as a bus route on which arrangements will be held.

5.2.1. The Flow Concentration between Üçyol and Üçkuyular

The concentration of flows on the same street changes according to the state of the daily rush. At morning hours the concentration of the flow moving toward to business districts becomes denser. On the contrary, by the end of the day the concentration of the flow moving toward to residential areas increases. The figure below also is a kind of proof of this assertion. There exists a 66-vehicle flow penetrating toward Üçyol and a 51 vehicle flow on the reverse lane at morning rush.



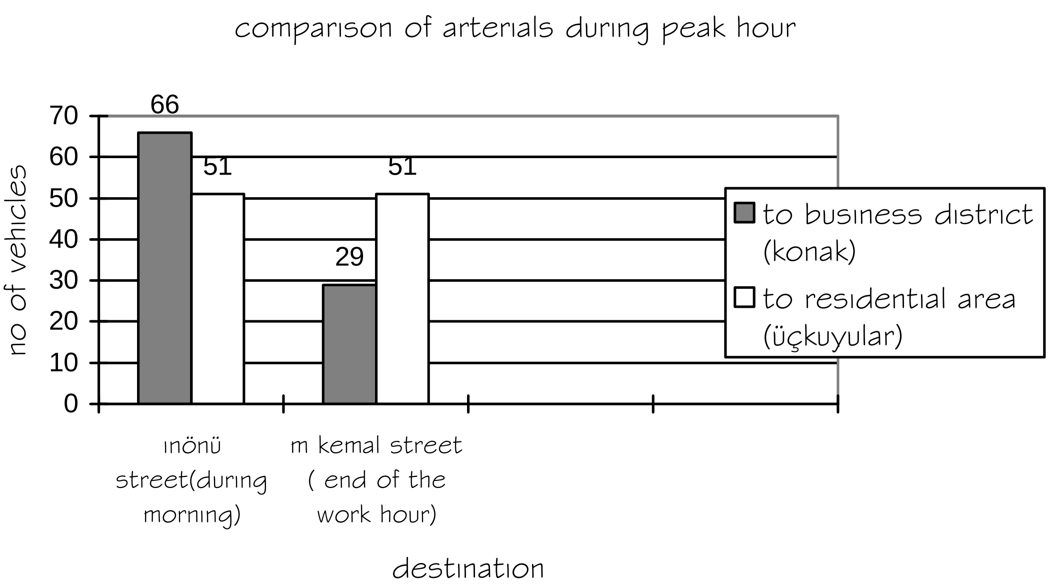


Figure 5.1A Comparison of Traffic Flows

5.2.2. The Physical Features of Inönü Street

The width of the fragments of the street, number of squares, bus stops, traffic lights, pass ways are the physical components which have major impacts on the transport system.

The interruption of the route is not a requisite for the effectiveness of a system. Since the 5 km route between Üçyol and Fahrettin Altay is the İzmir Metro's second stage route, it will also be accepted as the route of the BRT system, which will be a special proposal for public transport. The route has been divided into 6 fragments according to the 6 new metro stations on the Metro plan (F.Altay, Poligon, Hıfzısıhha, İslam Enstitüsü, Hakimevleri, Bahçelievler). This will be adopted in this study because it enables us to measure the street simply and systematically.

Table 5.5 The Measurements of the Fragments of Inönü Street

destination	ÜÇYOL-ÜÇKUYULAR					
fragment	**F.Altay -** Poligon	**Poligon -** Hıfzısıhha	**Hıfzısıhha-** İslam Enstitüsü	**İslam Enstitüsü-** Hakimevleri	**Hakimevleri -** Bahçelievler	**Bahçelievler -** Üçyol
cross-section width measurement	19.50 - 18.50m	18.50 - 18.50m	18.50 - 12.50m	12.50 - 12.50m	12.50 - 14.50m	17.50 - 20.00m

It is obvious that the width of the street has several variations. The street gets narrow approximately 40 % along the route. As stated in previous chapters, the recommended width of the cross-section varies between 7.20-10.30 meters with no overtaking when BRT systems operated at median-grade busways. Beyond this, two extra lanes are needed at stations for effective usage. In most cases on the side aligned busways has not been installed. This type of implementation is suitable usually in newly constructed corridors where the right side of the way is reserved and driveways for businesses are permitted. As a result both type of implementation is not suitable for Inönü Street.

At this point a new concept of bus rapid transport should be handled through the vision of the direction of the flow and the cross section's width.

As a result an implementation according to the day hour would be the solution. In the morning hours the flow of vehicles from Üçkuyular to Konak should operate along the separated track until the midday. At the end of the work hours the separated track should be reserved for the opposite direction. This is the operation plan affected by the physical restrictions and the characteristic of traffic in which direction the concentrated flow occurs. The design process of the plan put forward in the implementation stage.

5.2.3. Characteristics of Operation Direction along Inönü Street

The feasibility and the aim of simple use of the route have the possibility to occur with traffic squares bounding the starting and the end points of the route. It is suitable to select the F.Altay and Üçyol stops as the start and the stop points of the destination to reach this goal. As the continuity of the route is the unique feature of the system, there exist two types of classification.

5.2.3.1. The F.Altay-Üçyol Route

There are also two sub-classification systems as depicted below.

- The vehicles that operate along the two directions of the street through all their trips; from the starting point to the end point and from the end point to the starting point those vehicles use the lanes and the reverse lanes.

375-320-82-217-586-605-370-5-270-81-600

- The vehicles that operate along the whole route during their trips in only one direction; those vehicles use the whole route only for one time while completing their trips. They do not use the reverse lane completely while back on their trips to the starting point. All of those vehicles enter into Inönü Street from Üçyol stop and leave the street from F.Altay point.

519-509-379

5.2.3.2. The F.Altay- Izmirspor Route

Şoförler Lokali stop and Izmirspor stop are located next to each other. From these stations a junction bounds to Bozyaka SSK stop and to Şirinyer district of Izmir. Naturally some vehicles of bus transport system give service to that district and those vehicles leave the route from that junction.

479-319-670-486

Due to the lack of space in the physical plan, there will be difficulties in designation process. This will result from the fact that identified vehicles will not be put into service at the stage of operation plan.

5.2.4. The Service Degree of the Districts Connected Through Inönü Street

The vehicles operating along Inönü Street have various destinations that combine various districts to each other. The quantitative survey handled above does not figure out the identified vehicles with their start and end points of their destinations. The density in the service is stated in the tables below. The most heavily served districts will be assumed as the starting points. In short, the left side of the table shows starting points to figure out the concentration degree. The identification numbers take place at the right side in the table.

The supposition in the tables below is that a great deal of the vehicles operates toward to Balçova, Konak districts. The major part of the flow serves the two destinations at the same time. From this point of view, the operator will have an obligation to give priorities to the vehicles running in those destinations while constituting the operation plan.

Table 5.6 The Service Concentration of the Districts

start point of destination	end point of destination	*identified vehicles*
Balçova (8)	Şirinyer	375
	Ayakkabıcılar Sitesi	605
	Cennetçeşme	379
	Karabağlar	509
	Üçyol	586
	Gaziemir	519
	Limontepe	319
	Uzundere	479
Konak (5)	Menderes	508
	Bademler	320
	Siteler	82
	Narbel	370
	Narlıdere	5
Buca (2)	Narlıdere	670
	İnciraltı	270
Üçkuyular (1)	Bozyaka SSK	486
Esentepe(1)	Montrö	81
Karşıyaka (1)	F.Altay	600
Halkapınar (1)	Oyak	217

5.2.5. Visual Survey of the Traffic along Inönü Street

Various types of violations exist along the arterials of cities which generally result in accidents. Some impede the flows even though there are some legal prohibitions. In most cases, violations prevent the public transportation vehicles from moving during the hours even when the traffic is not concentrated. Those events are the results of the individuals' attitudes in the traffic. In the study, identification of the street would also be useful from this view point. Thus some photos depicting the troubles of the traffic along Inönü Street were taken. Meanwhile the violations and troubles are classified as follows;

- Private cars park at the bus stop, preventing buses from approaching bus stop,
- Private cars park in front of the bus stops, preventing buses from leaving the bus stop,
- The traffic gets jammed while buses overtake the other vehicles,
- Buses have to wait at the stations while passengers get on other buses,
- The absence of pedestrian crossings results in risky street crossings.

Figure 5.2 Private Cars at the Bus Stop

Figure 5.3 Private Cars in front of the Bus Stop

Figure 5.4 Taxi Forces to Keep on Moving

Figure 5.5 The Congestion on the Bus Stop

Figure 5.6 The Lack of Pass ways

Figure 5.7 The congestion along one Lane

5.3. The Appropriate Fleet of the Reserved Bus System

As depicted below, the concentration of intervals especially at the beginning of a period, leads to accumulation. Depending on the table below, it can be said that there will be a convoy 17 vehicles for both of the operation directions without arrangements for the time table. This can cause a blockage at the starting and the end points of the route.

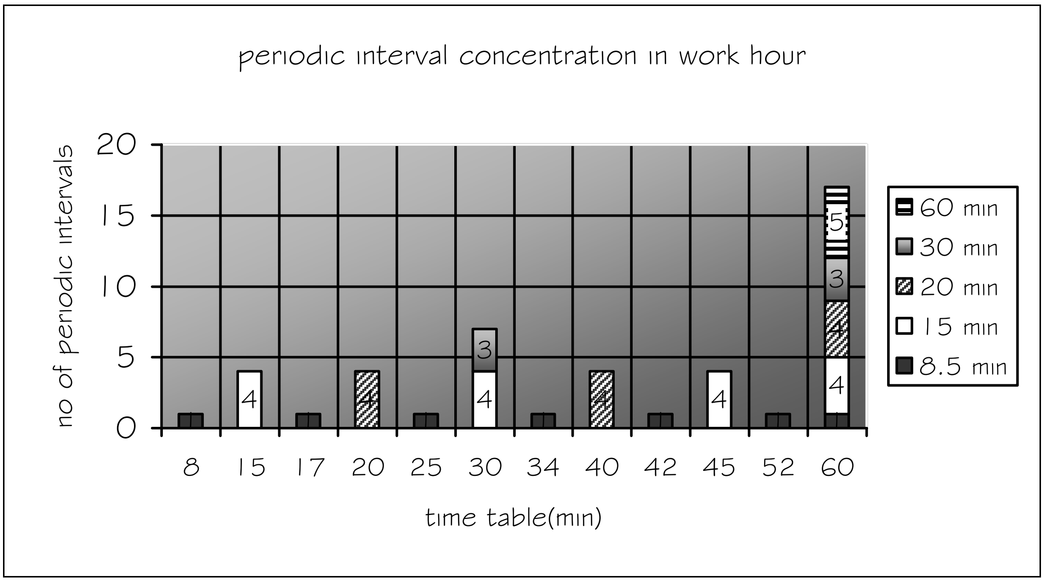


Figure 5.8 Time Table of Identified Buses

The time table has various intervals of service depicted below.

- The vehicles identified by the number 86 operate through 8.5-minute intervals.
- The vehicles identified by the numbers 605-670-270 and 586 operate through 15-minute intervals. The vehicle identified by the number 670 does not use the whole route. As a result, it will not be dealt with in the operation plan. *The 15 minute intervals of service will include the vehicles identified by numbers 605-270-586.*
- The vehicles operate through 20-minute intervals identified by the numbers 370-5-81-600.
- The vehicles operate through 30-minute intervals identified by the numbers 519-82-509.
- The vehicles operate through 60-minute intervals identified by the numbers 486-379-217-319-479-375 and 320. The vehicles identified by the numbers 486-479-319 do not use the whole road either. As a result, those vehicles will not be included in the operation plan, too. *The 60-minute intervals of service will include numbers 379-217-375-320.*

The operation plan constituted above is available during the flow operates from Üçyol to F.Altay. The maximum numbers of vehicles reach to 14 at the beginning of the period.

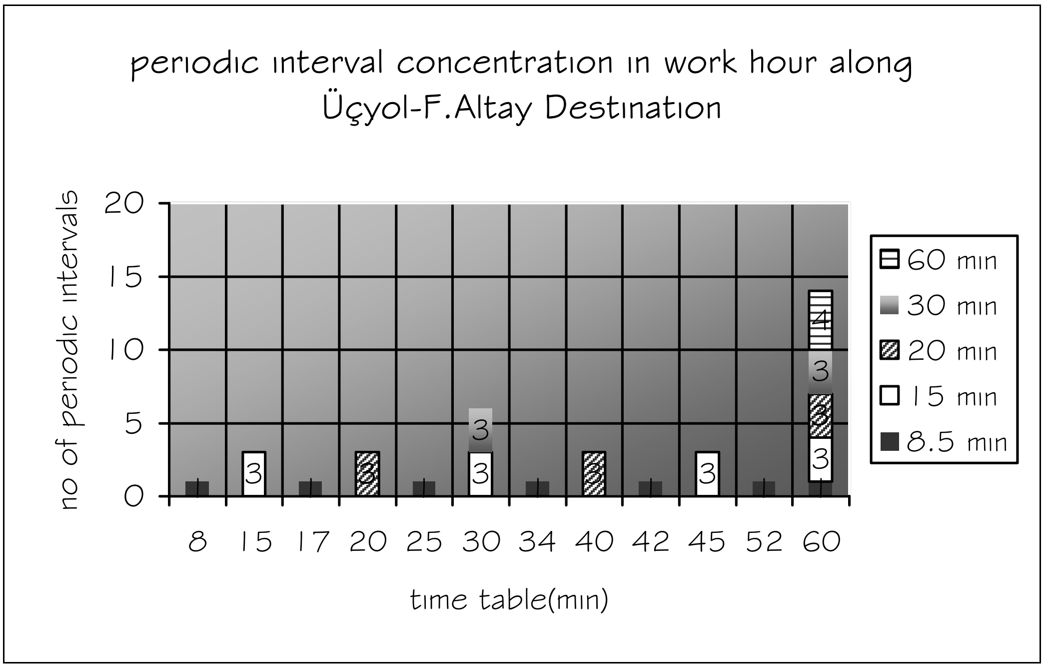


Figure 5.9 The Time Table of the Operation Plan of the BRT System

As the operation direction reverses the number of vehicles decreases depending on their routes. Those vehicles are identified by the numbers 519-509-379.

Meanwhile those vehicles have various intervals of service. The vehicles 509 and 519 operate by 30 minutes of intervals. The vehicle 379 operates by 60 minutes of interval. To an extent, the operation from F.Altay to Üçyol will not be as concentrated as the one on the reverse lane.

The time table for F.Altay-Üçyol destination is like;

- The **8.5-minute** interval covered by the numbers **86**
- The **12-minute** interval covered by the numbers **586**
- The **15-minute** interval covered by the numbers **605-600**
- The **20-minute** interval covered by the numbers **5-270-217-82**
- The **30-minute** interval covered by the numbers **81-370.** *The numbers 519- 670 will not be included by the reason of leaving the route.*
- The **60-minute** interval operated by the numbers **375-320.** *The numbers 379-509- 486 will not also be included.* The maximum number of vehicles reaches to 12 at the beginning of a period.

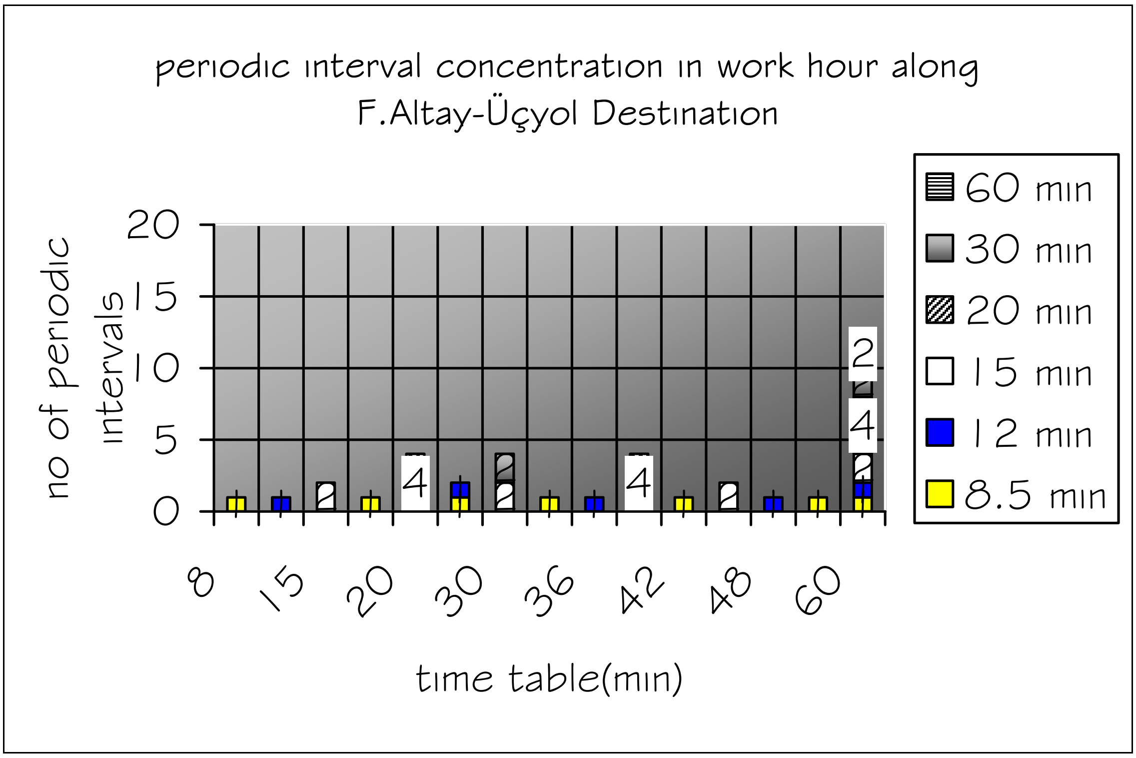


Figure 5.10 The Time Table of the Operation Plan of the BRT System

5.3.1. Reserved Bus Transportation Systems' Stations

The locations of the stations of the system will be determined from the second phase project of the Metro Line so that the service level intended will match condition of the rail system.

Table 5.7 The Station Locations of the Transportation System

<table>
<tr><td rowspan="2"></td><th colspan="3">Type of Transport</th></tr>
<tr><td>Bus Transport
(the current transportation type)</td><td>Metro Line
(projected)</td><td>BRT Line
(proposed)</td></tr>
<tr><td rowspan="16">The Station Points</td><td>İzmirspor</td><td rowspan="2"></td><td rowspan="2"></td></tr>
<tr><td>Şoförler lokali</td></tr>
<tr><td>Askeri Hastane</td><td>Bahçelievler Station</td><td>Bahçelievler Station</td></tr>
<tr><td>Çeşme</td><td rowspan="2"></td><td rowspan="2"></td></tr>
<tr><td>Nokta</td></tr>
<tr><td>Renkli</td><td>Hakimevleri Station</td><td>Hakimevleri Station</td></tr>
<tr><td>Hakimevleri</td><td rowspan="2"></td><td rowspan="2"></td></tr>
<tr><td>Dönmezler</td></tr>
<tr><td>Susuzdede</td><td rowspan="2">İslam Enstitüsü Station</td><td rowspan="2">İslam Enstitüsü Station</td></tr>
<tr><td>Okul</td></tr>
<tr><td>Hıfzısıhha</td><td>Hıfzısıhha</td><td>Hıfzısıhha</td></tr>
<tr><td>Poligon</td><td rowspan="2"></td><td rowspan="2"></td></tr>
<tr><td>Denizmen</td></tr>
<tr><td>Güzelyalı</td><td>Poligon Station</td><td>Poligon Station</td></tr>
<tr><td>Fahrettin Altay</td><td>Fahrettin Altay Station</td><td>Fahrettin Altay Station</td></tr>
</table>

5.4. Determination of the Service Frequency of Reserved Bus

The frequency which is among the variables of level-of-service determines the waiting times of modes. It is also assumed that high demand levels constitute frequent intervals of service for transportation modes. On the other hand, the measure of the trip time also determines the degree of service and affects the mode choice of passengers in transportation. Congestion in the traffic is the main factor that extends the trip time of public transportation and the reasons of the situation handled above.

As the delays come about in bus public transportation are generally the results of the congestion, the amount of the extended time comes about during peak hours is depicted below in table **5.18**. While the reserved bus mode is perceived as a kind of BRT system, the vehicles will be considered to operate through the ordinary trip times. In short, buses will not experience delays. As the vehicles are considered to be operating through free flows in BRT systems, the fleet size of vehicles will be different from the current conditions, as well. The efficient frequency will also be calculated according to the situation that the vehicles operate along separated tracks during free flows. First, the fleet size will be calculated according to the formula given below.

$$\boldsymbol{q} = \frac{dp}{v_c \times o}$$

$$\boldsymbol{f_i} = q \times T_{rt}$$

$\boldsymbol{q}$ = vehicles pass per hour

$\boldsymbol{dp}$ = passenger passed per peak hour – current data of ESHOT

$\boldsymbol{C_v}$ = vehicle capacity (seat capacity + number of standing passengers) – estimated data in general conditions

$\boldsymbol{O}$ = occupancy degree of vehicles – estimated data in general conditions (0-1)

$\boldsymbol{F_i}$ = fleet size

$\boldsymbol{T_{rt}}$ = round trip time – current data of ESHOT

(Papacostas and Prevedouros 1993)

Table 5.8 The Capacities per day and Trip Times of Bus Lines in the Year 2003 (Derived from ESHOT data)

Identification numbers	average passenger/day	average passenger/peak hour	trip time(minutes)	trip time (minutes) at peak hour	no of vehicles operating along the lines in peak hours
375	460	105	60 min	75 min	2
605	3.775	868	75 min	90 min	16
379	331	76	60 min	65 min	2
509	1.923	442	80 min	90 min	6
586	5.822	1339	35 min	40 min	8
519	1.507	346	65 min	75 min	5
319	274	63	45 min	60 min	2
479	362	83	60 min	65 min	2
508	1.932	444	55 min	60 min	10
320	1.260	290	90 min	100 min	4
82	2.915	670	70 min	80 min	8
370	2.460	566	50 min	55 min	4
5	2.412	555	45 min	55 min	5
670	5.125	1178	75 min	90 min	12
270	4.602	1059	90 min	100 min	12
486	975	224	60 min	70 min	3
81	2.556	588	45 min	50 min	6
600	3.382	778	60 min	70 min	6
217	1.146	264	60 min	65 min	4
total capacity		43.219	fleet size		117

The total fleet size regarding the peak period and the ordinary period trip times calculated by putting the formula into practice shows a distinction. Meanwhile the process is handled for each bus line but it is not handled here widely. The results will be displayed below. As an example, the results of the buses identified by the numbers 375 and 605 for each time period are given below.

$$\boldsymbol{q} = \frac{105}{100 \times 1} = 1.05 \cong 1 \; vehicle/hour$$
$$\boldsymbol{f_i} = 1 \times 1 = 1 \; vehicle$$

$$\boldsymbol{q} = \frac{105}{100 \times 1} = 1.05 \cong 1 \; vehicle/hour$$
$$\boldsymbol{f_i} = 1 \times 1.25 = 1.25 \; vehicle$$

$$q = \frac{868}{100 \times 1} \cong 9 \text{ vehicle/hour}$$

$$f_i = 9 \times 1.25 = 11.25 \text{ vehicle}$$

$$q = \frac{868}{100 \times 1} \cong 9 \text{ vehicle/hour}$$

$$f_i = 9 \times 1.5 = 13.5 \text{ vehicle}$$

Consequently, calculations were for a total of total 107 vehicles per hour regarding the ordinary period trip time and 124 vehicles per hour regarding the peak period trip time. Removal of delays in the reserved bus mode concept helps develop the fleet size according to results calculated for ordinary period. It is obvious that an aim to decrease the numbers of vehicles operating along the street will result in an economic benefit while the current number of the buses operates along street are 117 during peak hours. However this is possible with some developments and the designation process will be dealt with in the next parts of the chapter. The benefits of the implementation will be measured either in the next parts.

Among these, a contradictory situation comes about when the ideal number is calculated for 124 operating vehicles during peak periods within the mixed traffic. This fleet size has to be valid in current conditions. In other words, this number in the fleet size calculated is the required number of vehicles that have to operate to develop efficient and comfortable service during peak periods. It is possible to declare that the buses in the current state operate with capacities exceed the efficient fullness conditions. This situation also results in economic inefficiency in the public transportation.

Distinctive results in the frequency determination process will also be obtained from the calculated fleets. Without any doubts the service frequency of the reserved bus transportation mode will not be as frequent as the current state. However, the comparison will be made for ordinary period and peak period fleets because the current state of fleet is considered operating as in inefficient conditions.

$$f = \frac{t}{F_i}$$

f = frequency of the bus transportation service

t = an hour-60 minutes

F_i = fleet size of ordinary period – 107 vehicles

F'_i = fleet size of peak period – 124 vehicle

$$f = \frac{60}{107} = 0.56 \text{ vehicles per minute}$$

The interpretation of the formula exposes an interval of 34(0.56x60) seconds for the service frequencies of the concept mode. In other words the interval for the operation time of the haulage could exceed half minute for one vehicle operation along the route.

$$f = \frac{60}{124} = 0.48 \text{ vehicles per minute}$$

In this case, there is an obligation for vehicles to operate by 29(0.48x60) seconds of intervals. This constitutes more restrictive conditions for the operation. As if the current fleet size were adopted in the calculations, 31 seconds of intervals would be calculated. The reason of the over crowded vehicles become clear from this point of view. It is difficult to operate vehicles in mixed traffic according to the data of the ideal state. The situation is preferred rather than operating more vehicles in the current state.

5.4.1. Required Surface Area of the Stations

The calculations handled above help to determine the required station areas for the passengers waiting for boarding. The necessity to operate a vehicle in every half a minute requires multiple bus stops designed in consecutive order. This means that during the boarding action, other buses should have the opportunity to reach the station area. Thus it is necessary here to determine the boarding periods of passengers according to the concept.

The system which will be developed has to be efficient according to the alighting and boarding periods of the conventional modes. Meanwhile the passenger boarding periods of reserved bus transportation mode has to be evaluated from the conventional modes alighting and boarding periods.

Table 5.9 The Alighting and Boarding Periods (Gür2003)

	second/passenger
alighting	1.5-2.5 seconds
boarding	2.0-4.0 seconds

The reserved lane designation for the system enables to design distinctive bus stops. Thus there is a possibility to hold the fare collection process of the passengers at the entrance of the station. However, it is difficult to measure the affects of this implementation here. Thereby the boarding periods of passengers here are accepted as the average of alighting period of the conventional bus transportation systems. Two seconds will be accepted as boarding period during the calculation process.

The other major factor which defines the boarding period is the estimation of the travel demand. Probability of a demand which is about the limit of fullness is highly possible in each stop. A size up to 100 passengers in the stops might appear for each bus line. This situation can result in about 200 seconds of boarding time without collecting fares at the bus. However, the fare collection concept at the entrance of the station with turnstiles enables the passengers to step on the vehicle through all doors. It is obvious that the possibility to shorten the boarding time of the vehicles in respect to two-third of the conventional mode is available according to this condition. The resulting boarding period will be approximately about 60-65 seconds.

The boarding period of 60 seconds causes other buses to stop while the process is continued. This means the second vehicle and then the third one can approach to the stop when there is a concentrated level of demand. This means at least 36-meter long bus bays for three buses have to be designed. Among this the acceleration and deceleration lanes have to be at least 20 meters long. According to the variables above, at least 75-m long bus bays are required.

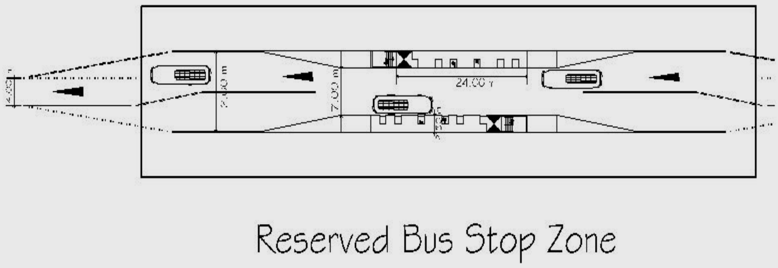
With the data above, a demand degree about 200 passengers, at least in a minute in peak periods, has to be covered for the reserved bus service. This means 50 m^{2} - 65 m^2 of surface is needed in the station area for passengers because the standard is 3-4 standing people for each m^2. However, the required surface can be extended by developing seats and overpasses. The upper limits for the required station areas can change according to the designer's viewpoint but the minimum required area has to be developed for an efficient service under the current conditions. Consequently, reserved areas for the potential expansions in the demand levels will doubtlessly supply some advantages.

5.5. The Station & Bus Lane Design of the Reserved Bus Service

The variables and data stated above help to constitute an idea of a dedicated one-way reserved-bus lane concept which is possible as the direction of the operating flow along the route changes according to peak hour concentrations. The crucial point of the design process is the construction of flexible separators which enable the system to switch the direction of operation in each direction according to the concentrated periods of times. In this point of view the concentrated operation flow will use the whole route. The flow in the reverse direction will operate along the lanes of the roadway. In the course of time, the concentrated flow direction reverses the flexible railings, reversing positions as well.

However, there is also an arrangement for the buses operating in the mixed traffic. The vehicles have to operate along the left lanes of the roadway. Those buses operating on the reverse lane will also be able to use the joint stations during boarding and alighting process. As a result, the buses on the reverse lane which has lighter traffic concentration can operate at the approximate level of service as the buses operate along the dedicated lane during that time period. On the other hand, the situation constituted for the buses operate through mixed traffic will also affect the traffic as a regulator.

Therefore the concept of joint bus station will constitute a reduction in the number of the bus stops. The problems arising as results of the bus bays along the right lanes of roadways will no longer occur.



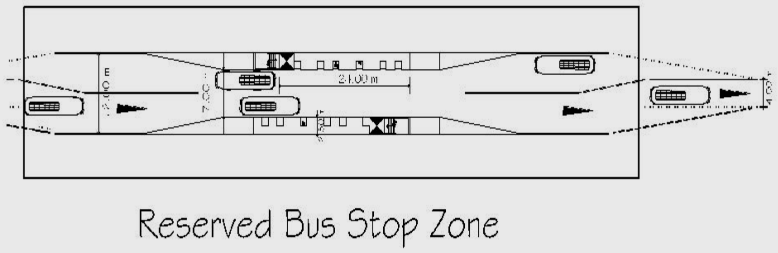


Figure 5.11 The Dedication Scheme of Reserved Bus Service

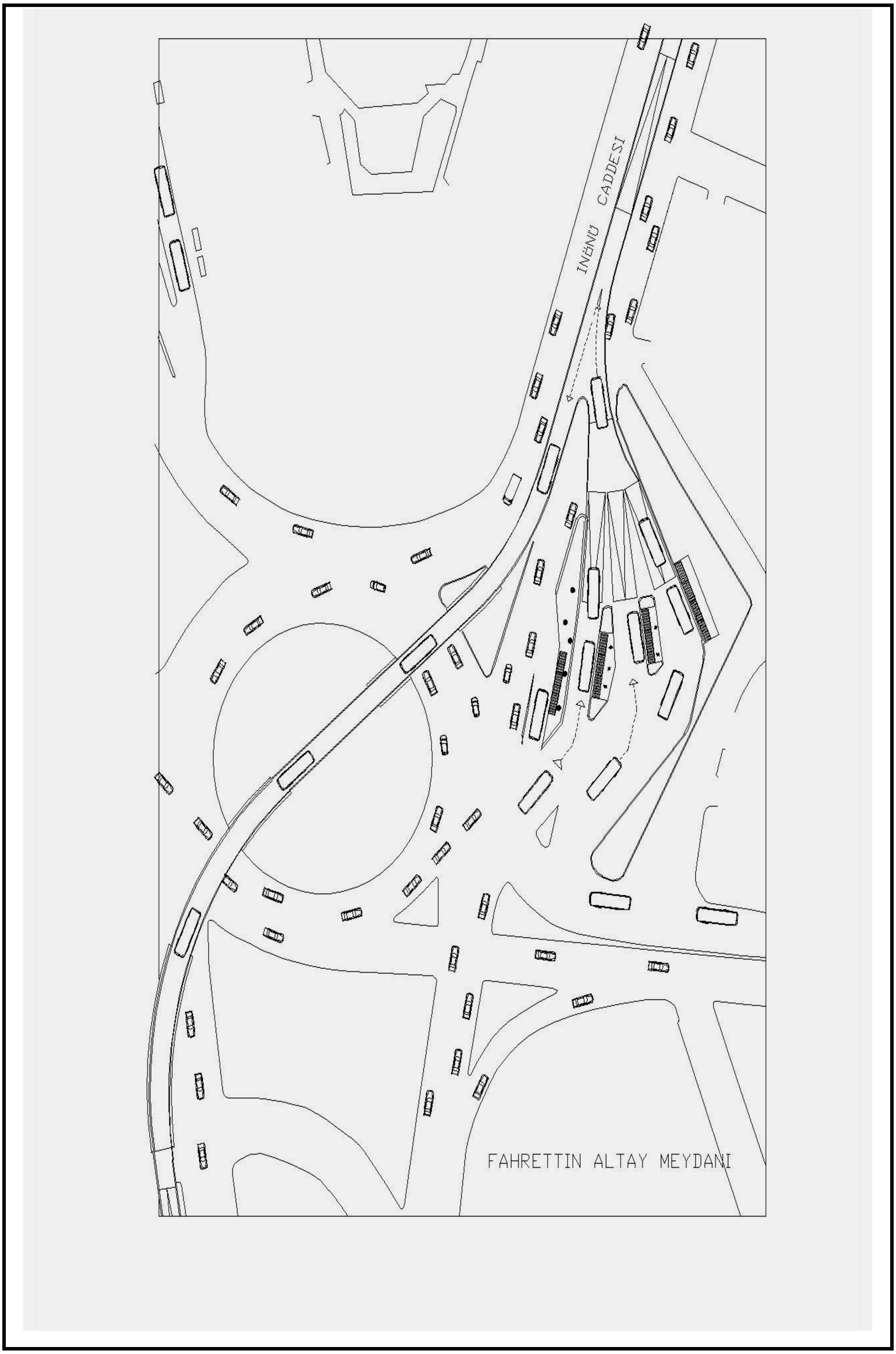


Figure 5.12 The F.Altay Station of Reserved Bus Service

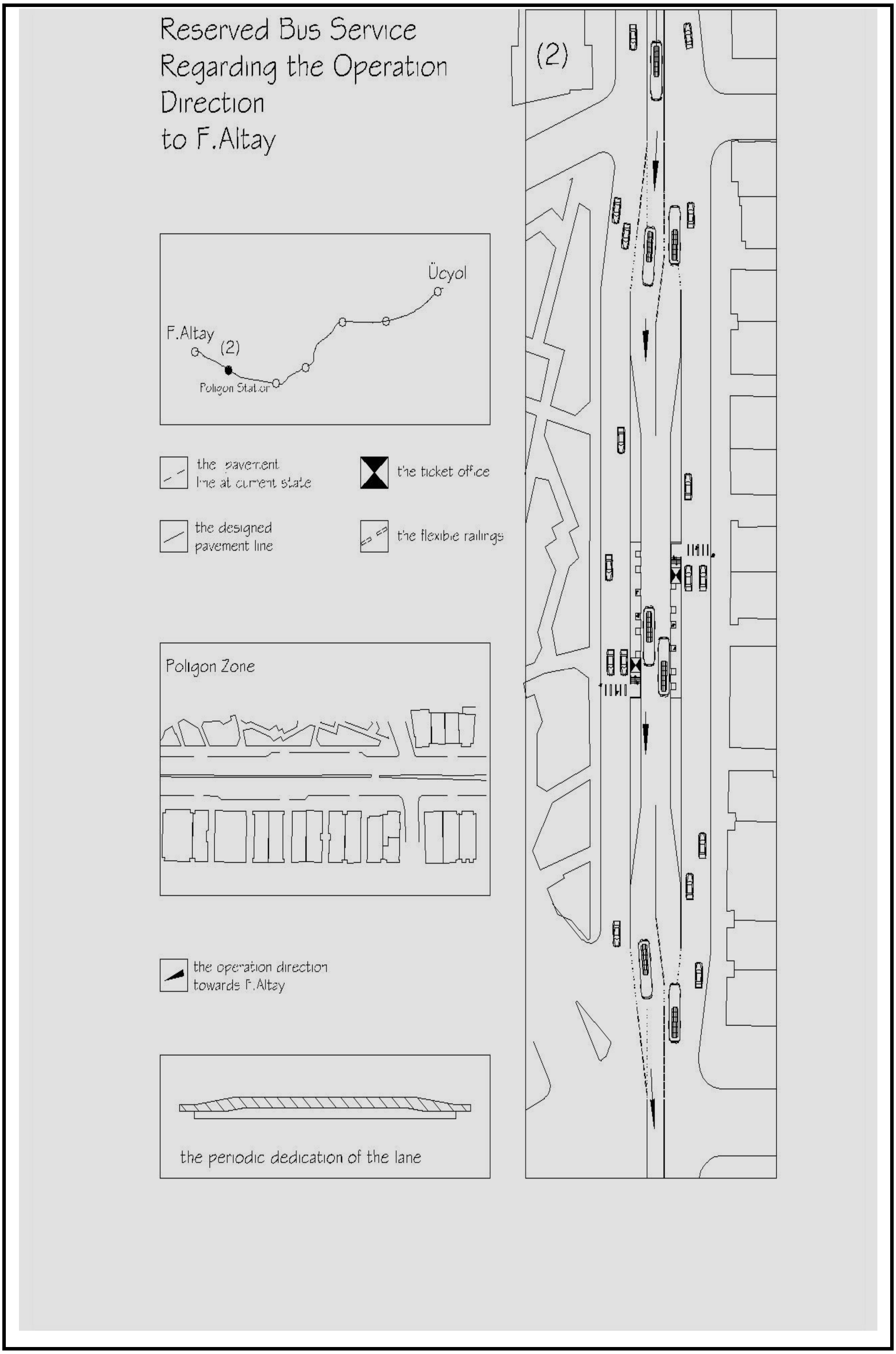


Figure 5.13 The Poligon Station of Reserved Bus Service- Direction toward F.Altay

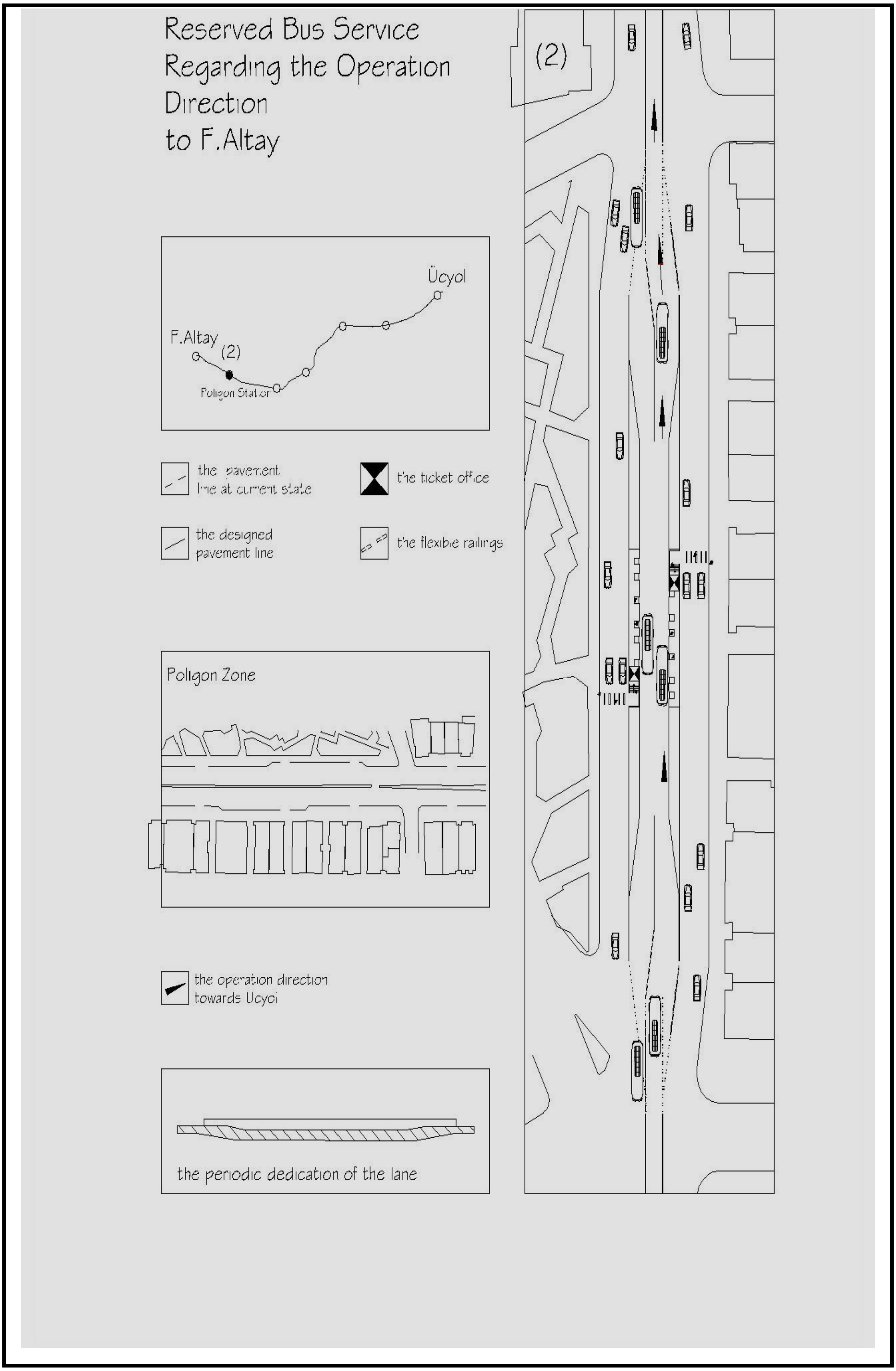


Figure 5.14 The Poligon Station of Reserved Bus Service- Direction toward Üçyol

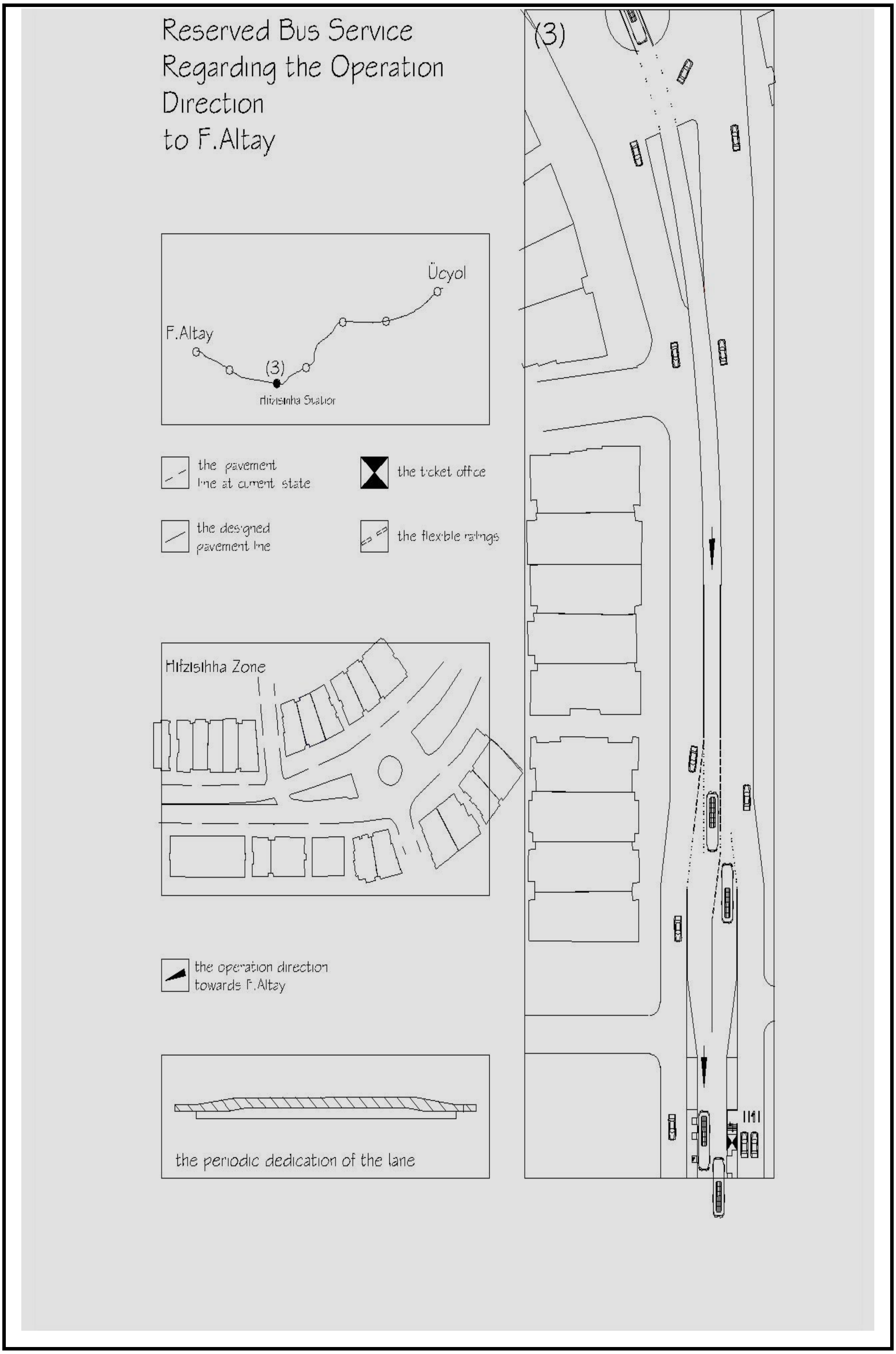


Figure 5.15 The Hifzisihha Station of Reserved Bus Service

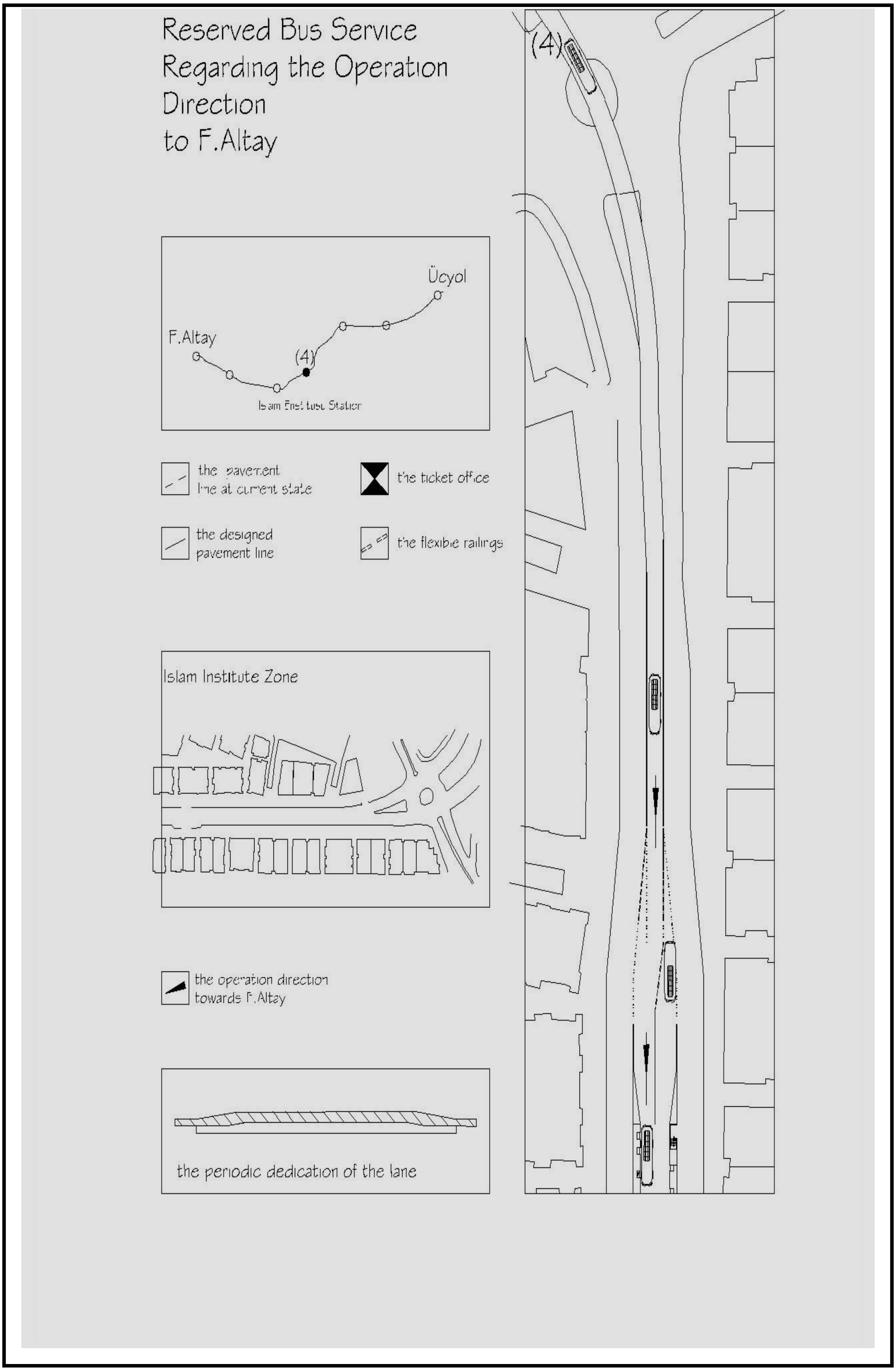


Figure 5.16 The Islam Institute Station of Reserved Bus Service

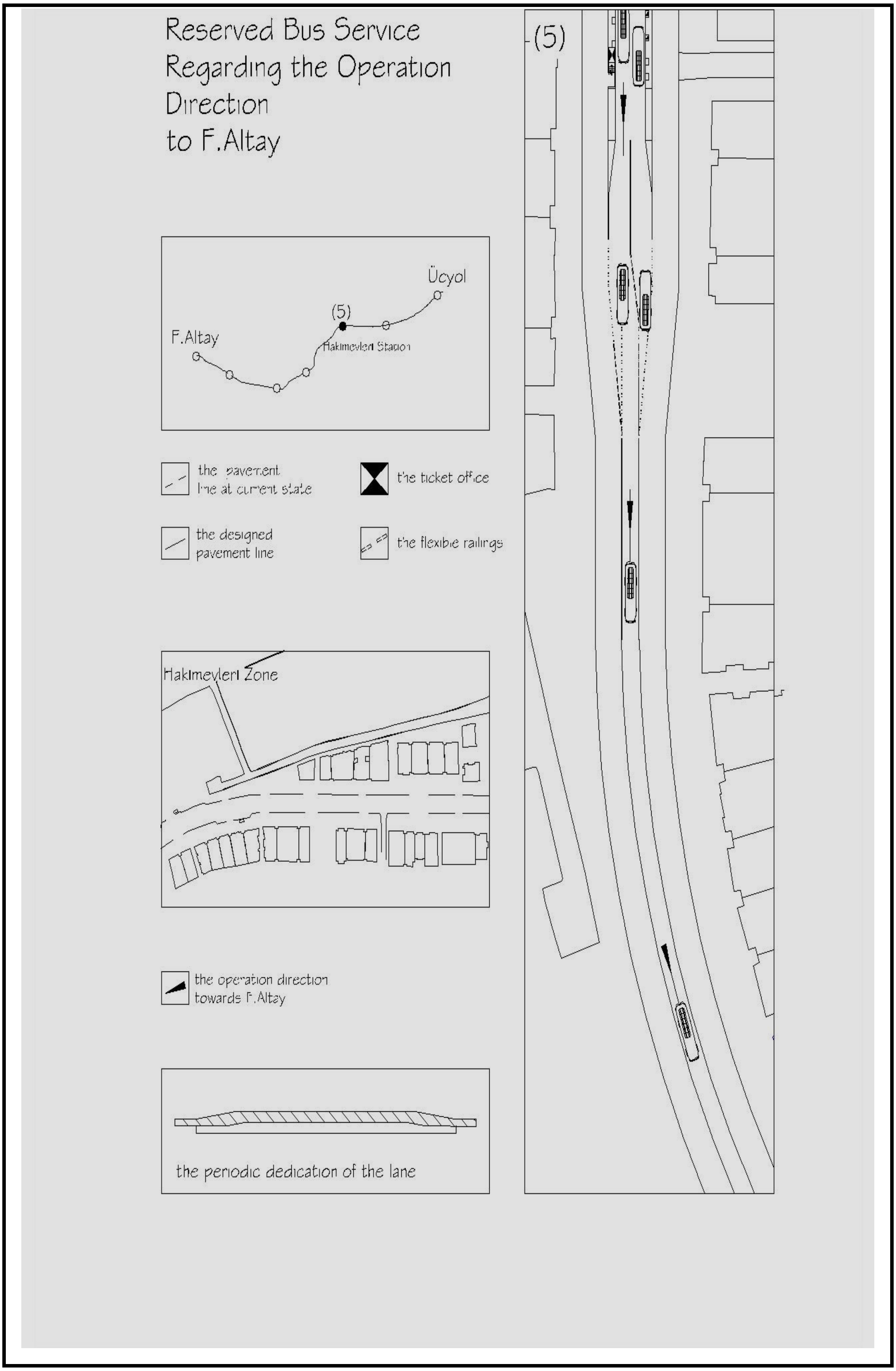


Figure 5.17 The Hakimevleri Station of Reserved Bus Service

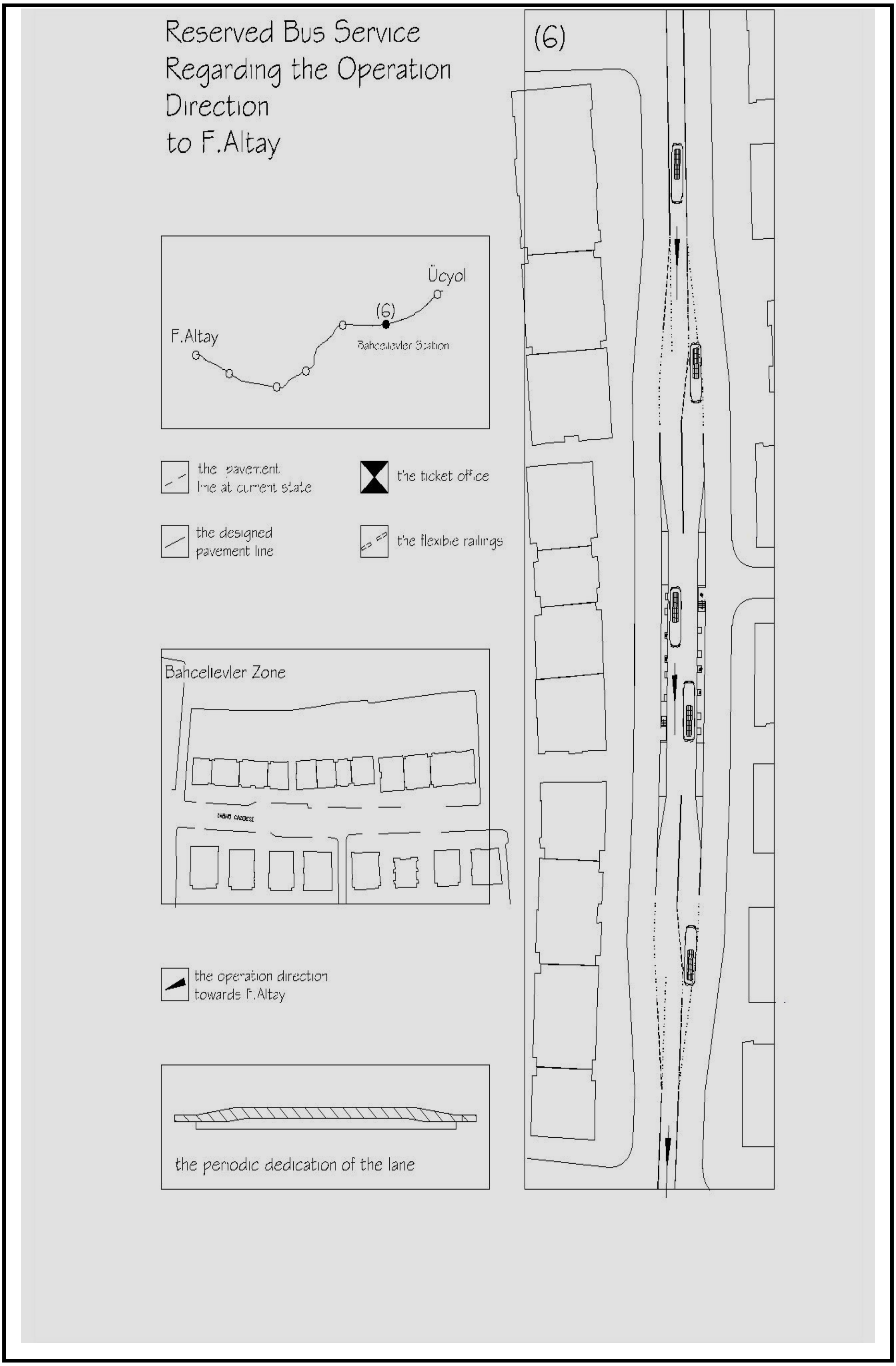


Figure 5.18.The Bahcelievler Station of Reserved Bus Service

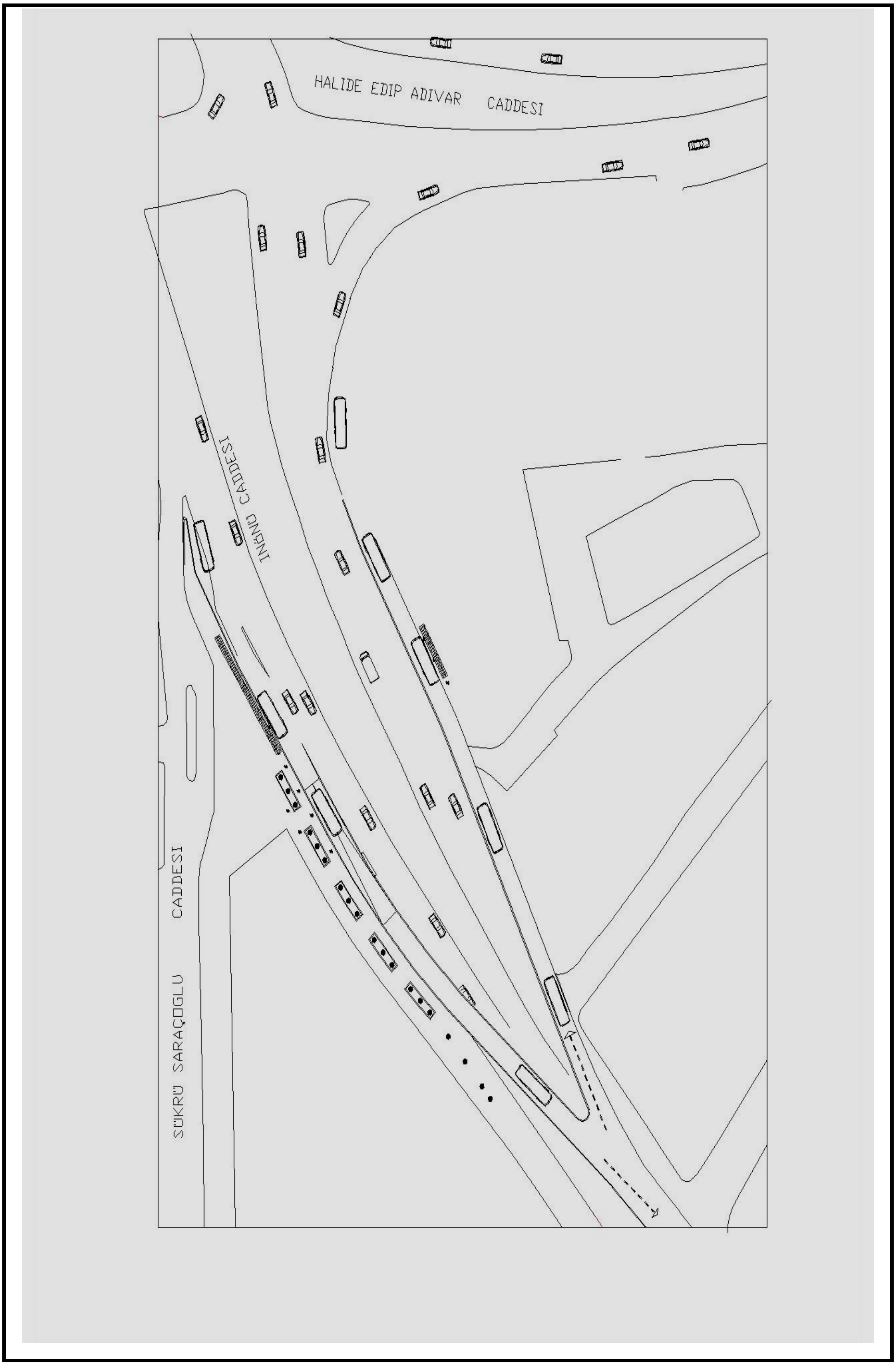


Figure 5.19.The Üçyol Station of Reserved Bus Service

Figure 5.20.The Inönü Street

5.6. The Calculation of the Energy Consumption of Reserved Bus

The reserved bus concept will be considered in relation with the economic view under this title. However the project designed above does not cover the whole routes of the conventional bus lines the reduction amount of fuel consumption of the operating buses will be calculated separately.

The calculation of the profits of the system among other things assists to develop the backbone of the study as it targets to conclude an economic comparison between BRT systems and LRT systems regarding management costs. To conclude this goal the length of the bus lines and the number of bus trips will be depicted below. Among this the fuel consumption rates of the vehicles according to Elker will be accepted as 0.04 liters per km operating through free flows and in mixed traffic as 0.08 liters per km.

Using these data, the peak hour energy consumption rates will be calculated according to the two situations. The initial stage will be the calculation of the fuel consumption rates of conventional bus mode. It will be obtained by the multiplication of three variables: whole route length, number of the peak hour trips and the fuel consumption rate within mixed traffic. On the other hand, the peak hour period is accepted to come about at morning hours: 7:00 between 9:00 and at evening hours: 16:00 between 20:00. This is accepted by ESHOT technicians as the unique characteristic of the Inönü Street and it will be adopted in the study as a fact.

The latter process will be the calculation of the consumption rates of the reserved bus mode. However, this process is not as simple as the calculation process of the conventional mode described above. The buses operating in peak hours will partially penetrate through free flows along their trips. Depending on this situation, the energy consumption rate will also be calculated partially. The consumption rates for Inönü Street and for the rest of the routes will be calculated comparably.

The result in the table below reveals an advantageous situation for the reserved bus lane operators as approximately 100 liters less fuel consumption. This, of course, is only one of the advantages that the system supplies for the operators. However, the economic analysis of the systems regarding management costs will be carried out according to the fuel consumptions of the modes as the variation of the management costs will occur for the energy consumption conditions only.

Table 5.10 The Energy Consumption Determination of the System

identified vehicles	no of operating vehicles	no of peak hour trips	total trips per day	length of the bus line	proportion of the reserved bus lane (5.2 km)	fuel consumption of the conventional bus mode in peak hour	fuel consumption of the bus mode operating along reserved bus lane in peak hour
A	B	C	D	E	F	CxEx0.08	CxExFx0.04 + CxEx(1-F)x0.08
375	2	10	22	23km	22%	18.4 liters	(2+14.4)16.4 liters
605	16	55	112	29km	17%	127.6 liters	(11+105.9)116.9liters
379	2	11	18	21.4km	23%	18.8 liters	(2.2+14.5)16.7liters
509	6	24	54	27.5km	18%	52.8 liters	(4.8+43.3)48.1liters
586	8	64	158	8.2km	60%	42 liters	(12.8+16.8)29.6liters
519	5	24	57	23km	22%	44liters	(4.8+34.4)37.2liters
319	2	12	19	17.5km	29%	16.8liters	(2.4+11.9)14.3liters
479	2	9	20	19.25km	26%	13.86liters	(1.8+10.26)12.06liters
508	10	50	112	21.6km	23%	86 liters	(10+66.4)76.4liters
320	4	16	38	41km	12%	53 liters	(3.2+46.1)49.3liters
82	8	31	85	32km	16%	79 liters	(6.2+67)73.2liters
370	4	26	72	15.3km	33%	32 liters	(5.2+21.4)26.6liters
5	5	34	87	17.4km	29%	47 liters	(6.8+33.7)40.5liters
670	12	49	121	25.5km	20%	100 liters	(9.8+80.3)90.1liters
270	12	52	110	25.9km	19%	108 liters	(10.4+87)97.4liters
486	3	18	40	14.25km	35%	21 liters	(3.6+13.3)16.9liters
81	6	41	96	12km	42%	39 liters	(8.2+23)31.2liters
600	6	24	70	23.5km	21%	45 liters	(4.8+35.5)40.3liters
217	4	23	52	16.35km	30%	30 liters	(4.6+20.8)25.4liters
Total						974.3 liters	858.6liters

The energy consumption of the bus mode during the ordinary period will also be calculated according to the table.

(D-C) xEx0.04liters

The application of the formula above results in 650liters fuel consumption during ordinary period at total. According to these data the energy consumption costs that have to be committed by one passenger can be calculated to accomplish the comparison process.

The overall number for conventional buses is (650+974.3) approximately 1625 liters and for the reserved bus modes is (650+858.6)1508 liters. The current cost of diesel fuel is 2.0 YTL per liter. The total costs are 3.250 YTL for conventional buses and 3.016 YTL for reserved buses. On the other hand, the energy consumption costs of Izmir metro in its current situation (the system that operates between Üçyol and Bornova) is 8.000 YTL per day.

5.6.1. The Travel Demand Level of the LRT Project along Inönü Street

The calculation of the energy consumption in major targets will present an economic comparison that passengers of the modes have to commit. In other words, the process is the determination of the main factor that affects the ticket fares of the modes. The requirement to make a new estimation about the passenger demand of the metro system along the Inönü Street is necessary as an inconsistency occurs between the current passenger demand levels and the estimated demand levels project.

Table 5.11 The Passenger Demand of the Year 2010 Regarding Scenario B of Heusch/Boesefeldt Report

LRT Station	No of Passengers boarding LRT at stations	LRT Station	No of Passengers boarding LRT at stations
The Central Division			
Üçyol	59.000	Basmane	62.000
Konak	120.000	Hilal	54.000
Çankaya	58.000	Halkapınar	115.000
The South-West Division			
Bahcelievler	23.000	Hıfzısıhha	39.000
Hakimevler	34.000	Poligon	36.000
Islam Enst.	28.000	F.Altay	62.000

The passenger demand of central division and the south-west division of the LRT project mentioned above as two segments will constitute the first stage of the master transportation plan regarding scenario B of Heusch/Boesefeldt Report. It is known that the scenario B has been preferred by the municipal authorities in order to cover the great amount of transportation demand by the rail transportation modes.

The metro of Izmir reached capacities of about at 73.692 passengers per day in year 2003. According to the data declared and the amount of the passenger demand targeted in the central division of metro, a troublesome situation could arise in the future. Criticism about the situation is out of question here, but the data above helps to estimate the travel demand of the south-west division here.

It is estimated that there will be a demand from 222.000 passengers on Inönü Street segment in the year 2010. In table 5.11 above, the sum of the estimated travel demand in South-West Division will amount to 222.000 passengers.

The data measured at the year 1991 is depicted below in the table 5.12. According to the report, 104.000 passengers will demand public transportation services. A linear equation will be set up and the travel demand of the year 2003 will be calculated as follows:

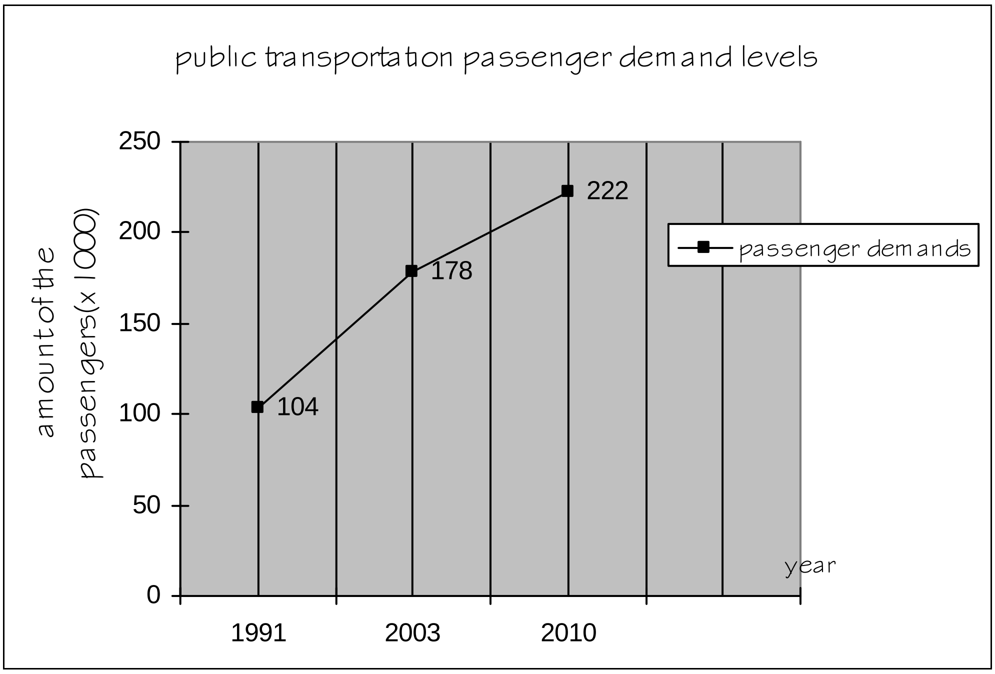


Figure 5.21.Estimation of the Passenger Demand Levels of the Year 2003 Regarding Heusch/Boesefeldt Report

The gap between the estimated level of passenger demand and the current passenger demand is great in amount. According to the data of ESHOT mentioned above in table 5.8 about 43.000 passengers of demand per day occurs. Besides the data derived from the Heusch/Boesefeldt Report, about 178.000 passenger demand per day is expected in Inönü Street. However, the passenger demand level of the year1991 exceeds the demand levels of the year 2003.

In this case, it becomes difficult to make comparisons between the energy consumption rates of the modes. In this respect, the comparisons between the modes will be made through the amounts declared by the municipal authorities below.

Table 5.12 Calculated Passenger Capacities of the Transportation Modes According to the Heusch/Boesefeldt Report by the Year 1991

INÖNÜ STREET										
DIRECTION	DATE	TIME PERIOD			ESHOT-BUS		MINIBUS		TAXI-DOLMUS	
					vehicle	passenger	vehicle	passenger	vehicle	passenger
F.ALTAY	27.12.1991	7.00	-	8.00	74	3240	147	824	91	508
		8.00	-	9.00	80	1880	260	640	178	500
		9.00	-	10.00	77	2310	169	918	187	516
		13.00	-	14.00	73	1140	220	1728	294	848
		17.00	-	18.00	80	4480	207	1736	414	616
		18.00	-	19.00	87	6160	247	2744	577	892
		19.00	-	20.00	120	3200	234	1680	380	420
KONAK	27.12.1991	7.00	-	8.00	172	8080	194	2116	79	288
		8.00	-	9.00	132	8100	230	3392	394	792
		9.00	-	10.00	124	7300	189	2110	217	640
		13.00	-	14.00	91	6880	180	2320	327	788
		17.00	-	18.00	84	4840	194	848	435	412
		18.00	-	19.00	67	4960	160	1904	336	728
		19.00	-	20.00	64	7760	180	2320	327	1044
						TOTAL 70.330		**TOTAL 25.280**		**TOTAL 8.992**
GENERAL TOTAL					**104.602**					

5.6.2. The Comparison of the Energy Consumption Costs of the Modes

The management cost of a transportation mode basically divided into three categories. The expenses of staff and the maintenance costs will not differ according to the concept. Thus the economic comparison of management costs of the modes was made within this framework. The overall costs of the systems depicted above will be calculated according to the current travel demand of the systems.

The energy consumption rate of the metro project along the Inönü Street is given below in the table according to the length of the track proportionally.
It is predicted that 3.600 YTL of expenditure will occur through the 5 km length of the projected track while 8.000 YTL of expenditure comes about on the 11.6 km length current track. According to the variables declared by the municipal authorities, the whole metro project will serve about 160.000 passengers per day.

Table 5.13 Determination of the Costs Regarding Passenger per Direction Parameter

mode of transportation	travel demand	overall energy consumption costs per day	costs regarding one passenger per direction
conventional bus service	43.000	3.250 YTL (3.250.000.000 TL)	7.5 YKr (75.000 TL)
reserved bus service	43.000	3.016 YTL (3.016.000.000 TL)	7.0 YKr (70.000 TL)
LRT service in the year 2003	73.692	8.000 YTL (8.000.000.000 TL)	18.5 YKr (185.000 TL)
LRT service in the year 2010	160.000	3.600 YTL+8.000 YTL (3.600.000.000 TL + 8.000.000.000 TL)	7.25 YKr (72.500 TL)

As seen above the rail transportation mode consumes much more energy than both of the bus modes. It is obvious that the rail system will be advantageous in economic scale when the results of the report are seen. However, the formation of the low passenger demand has the probability to come true.

CHAPTER 6

CONCLUSION

The necessity to revise the transportation plans by using the dynamic variables of a city is inevitable because the circulation characteristic of traffic differs from day to day. On the contrary, the arrangement of the roadways which affects the physical form of the cities does not have the probability to undergo several revisions. The process arranges roadways hierarchically and separates types and volumes of traffic, design speed and efficiency flow and requirements in general circumstances. However, in the course of time, the dynamic variables of a city cause some problematic situations for the transportation network. The accomplished plans can not succeed in covering the requirements by time and problems that have not been foreseen force the planners to re-arrange their decisions.

It is clear that in most cases the traffic along freeways occurs in ideal conditions or below the capacities of the roadways. Besides, the arterials, collectors and local streets become the problematic levels of the hierarchical classification scheme as the result of the fast urbanization. The rise of the congestion along those roadways develops inefficiency for all aspects of the all transportation modes and this situation leads the planners and the decision makers to develop new ideas or concepts for the transportation service.

Various projects aim to remove the disorder in traffic developed by the accumulation of all kinds of vehicles operating along shared roadways. These projects try to do by separating the public bus transportation modes from the private transportation modes.

Distinctive examples of reserved bus transportation modes operate, to an extent, along the allocated lanes, on HOV lanes and on express bus lanes constructed across the metropolitan cities of developed and developing countries. The reserved bus ways at medians or on side aligned bus ways were developed as the unique examples of the bus rapid transportation modes that operate along the arterials and collectors.

However, the bus transportation systems in Turkey has not been arranged to operate on a wide branch of these kinds of mode. The capacity arrangements provided by the variations of the system frequencies and usually buses operate with the exceeding capacities. As a result, buses always operated in mixed traffic and become one of the major reasons of the congestion in the traffic. In addition consumers of public transport have always suffered from the delays during their trips and waiting at the stations. Inefficiency and discomfort in public transport become a great problem which supports the negative thoughts. Ironically these conditions also become ordinary and people get used to those negative aspects of the transportation.

The development of rail transportation modes in Izmir claimed to solve the problems of the public transportation to an extent. However, it is highly possible that the metro project of the city grounded on the Heusch/Boesefeldt Report has not been reviewed after the approval process. The inconsistency between the estimated and the current travel demand also indicates the economic inefficiency of the system. This is the one side of the transportation problem of the city.

Another important situation is the restrictive conditions of the physical environment that prevent to construct effective rapid bus transportation systems-reserved bus systems-among the transportation networks of cities in Turkey. Beyond this situation, in most cases effective bus systems have not been considered, either.

This constitutes a contradictory situation against the economic conditions of the country. In spite of the preference of the bus systems that serve through equal level of LRT services with fewer expenses in all developed countries, the rail transportation mode was preferred or had to be preferred in Turkey in all conditions. The insufficient structural conditions of the roadways impede the construction of reserved lanes for the distinctive uses of the bus systems according to the current concepts.

In this case, it is necessary to develop new concepts according to the local conditions. The concept of adopting preferential operation direction along one reserved lane will have the chance to cover the requirements of a BRT system in a physically restricted street. The economic benefits and a reduction in the congestion situation in the traffic will be equal to the current implications. The buses of the mode could also reach to the service level of the LRT modes with the operations without any delays along the dedicated lane. Beyond the impacts, the system would be an original variation and will have a high chance of construction as it requires theoretically at least half of the construction costs of current reserved bus developments.

The results of the operation costs of the system regarding energy consumption rates calculated in the study also reveal an advantageous situation for the mode. At this point the study concluded constitutes an alternative transportation system for the responses of the decision makers of the public.

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APPENDIX

Table A.1 Capital costs of Bus Rapid Transit Systems operating on **Busways**

Location or system	Total cost (year of expenditure)0.000	Year system opened	Escalated total Cost (year 2000 dollars)0.000	System Length (km)	**Cost per km (year 2000 dollars)0.000**
Houston, TX					
Katy (I-10)	103.50	1984	154.16	24.6	16.20
North (I-45S)	138.90	1984	206.88	32	16.72
Northwest (US 290)	113.50	1988	150.87	21.72	17.98
Gulf (I-45)	98.90	1988	131.46	24.94	13.64
Los Angeles, CA					
El Monte Busway	58.00	1973	127.25	17.70	18.62
Miami, FL	60.00	1997	63.12	13.67	11.95
Pittsburgh, PA					
South Busway	27.00	1977	63.34	6.92	23.70
East Busway	113.00	1983	174.54	10.94	41.29
West Busway	275.00	2000	275.00	8.04	88.44
Total	**$987.80**		**$1.346.62**	**160.61**	
the average cost per km					**$21.61**

Table A.2 Capital Costs of Bus Rapid Transit Using **HOV Lanes**

Location of system	**Total cost (year Of expenditure)0.000**	**Year system opened**	**Escalated total Cost (year 2000 dollars)0.000**	**System length (km)**	**Cost per km (year 2000 dollars)0.000**
Dallas, TX					
I-30	18.90	1991	26.75	8.36	5.85
I-35E	11.60	1996	13.96	10.62	2.83
Denver, CO					
I-25	228.00	1995	248.34	10.62	60.55

Location of system	**Total cost (year Of expenditure)0.000**	**Year system opened**	**Escalated total Cost (year 2000 dollars)0.000**	**System length (km)**	**Cost per km (year 2000 dollars)0.000**
Houston, TX					
Southwest (US 59)	129.60	1993	147.21	23.01	16.55
Eastex (US 59)	146.80	1999	150.43	32.22	11.98
Seattle, WA					
I-5	7.60	1985	10.98	9.65	2.94
I-405	10.20	1986	14.42	9.65	3.86
San Diego, CA					
I-15	31.40	1988	41.74	12.87	8.39
Total	**$584.12**		**$653.82**	**117**	
the average cost per km					**$14.37**

Table A.3 Capital Costs of Bus Rapid Transit Systems operating on **Arterial Streets**

Location or system	Total cost (year of expenditure)0.000	Year system opened	Escalated total Cost (year 2000 dollars)0.000	System length (km)	**Cost per km (year 2000 dollars)0.000**
Los Angeles, CA					
Wilshire-Whittier	5.01	2000	5.01	41.36	0.30
Ventura	3.26	2000	3.26	26.87	0.32
Orlando, FL					
Lymmo	21.00	1997	22.09	3.7	15.44
Total	**$29.27**		**$30.36**	**71.94**	
the average cost per km					**$1.09**

Table A.4 Capital costs of **Light Rail Transit Systems**

Location or system	Total cost (year of expenditure)0.000	Year system opened	Escalated total Cost (year 2000 dollars)0.000	System length (km)	**Cost per km (year 2000 dollars) 0.000**
Baltimore, MD					
Central Line	364.00	1992	424.54	36.37	30.22
Three extensions	106.30	1997	111.82	10.94	26.45
Buffalo, NY	510.60	1984	760.50	10.3	191.24
Dallas, TX					
S&W Oak Cliff	280.70	1996	300.21	15.45	50.32
Park Lane	579.30	1997	609.40	16.74	94.32
Denver, CO					
Central Corridor	116.00	1994	129.05	8.53	39.18
Southwest Extension	176.30	2000	176.30	14.00	32.60
Los Angeles, CA					
Blue Line	775.00	1990	954.55	35.41	69.83
Green Line	900.00	1995	980.29	32.187	78.87
N. E. New Jersey					
Hudson Bergen	992.10	2000	992.1	16.09	159.62
Pittsburgh, PA	540.00	1985	780.01	40,555	49.80
Portland, OR					
Banfield	282.00	1986	398.64	24.14	42.77
Westside/Hillsboro	963.50	1998	1.001.77	28.48	91.07
Sacramento, CA					
Original Line	165.00	1987	226.71	29.45	19.93
Mather Field Road Extension	34.00	1998	35.35	3.70	24.72
Salt Lake City, UT					
South Rail Line	312.50	1999	320.22	24.14	34.35
San Diego, CA					
Blue Line	473.93	1981	788.52	40.55	50.34
Orange Line	302.46	1986	506.69	34.76	37.75
San Jose, CA					
Guadalupe	400.00	1987	549.60	33.79	42.10
Tasman West	325.00	1999	333.03	12.23	70.51
St. Louis, MO					
Metrolink	348.00	1993	395.27	30.57	33.46
Total	**$8.946.69**		**$10.774.58**	**498.41**	
the average cost per km					**55.73**