Efficiency Analysis of İzmir Metro in Its Current State

By

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ABSTRACT

This thesis analyzes the efficiency of the current state of İzmir Metro System by using the Method of Comparative Benchmarking. In the theoretical framework, the need and emerge of each transit mode is discussed, and the importance of mass transit concept is pointed out. The development of urban transit and the need for metro systems are examined. The characteristics of the prevailing mass transit systems modes are described and compared.

Efficiency concept, as the quality of well and effective service, without wasting time, money, or energy, is analyzed. Different approaches to efficiency are described. In the view of efficiency; right mode choice, right travel demand estimation, right choice of routes and stations are discussed and efficiency criteria for public transport are determined.

The Method of Comparative Benchmarking Analysis is examined for the measurement of efficiency. Applications and the uses of this method in public transportation and in metro systems are evaluated.

Specifically, performance measurement stages of that performance increaser method are employed to measure the performance of İzmir Metro. İzmir Metro is analyzed and then compared with similar systems worldwide.

Key Words: İzmir Metro, Efficiency, Urban Mass Transit, Comparative Benchmarking Analysis

ÖZ

Bu tez, İzmir Metro Sisteminin mevcut durumunun verimliliğini, Karşılaştırmalı Standart Belirleme Yöntemini ile analiz etmektedir. Teorik çerçeve içerisinde toplu ulaşım türlerinin gereği ve ortaya çıkışı tartışılmış ve toplu ulaşımın önemine değinilmiştir. Toplu ulaşım türlerinin gelişimi ve günümüzde, dünya çapında yaygın olarak kullanılan toplu ulaşım türleri incelenmiştir. Türlerin maliyet ve kapasite karşılaştırlması yapılmıştır.

En etkin ve kaliteli hizmetin; zaman, para ve enerji kaybetmeden sunulması olarak tanımlanan verimlilik kavramı analiz edilmiştir. Farklı verimlilik yaklaşımları açıklanmıştır. Çerçeve olarak da ulaşım karar ve eylemlerine, doğru yolculuk tahmini sonucunda, yerinde mod seçimi ve güzergah tayini gibi kriterler tartışılarak toplu ulaşım için verimlilik kriterleri belirlenmiştir.

Verimlilik ölçümü için Karşılaştırmalı Standart Belirleme Yöntemi incelenmiş, bu yöntemin uygulamaları ve toplu ulaşım alanındaki ve metrolardaki kullanımı yorumlanmıştır.

Performans artırıcı olan bu yöntemin, performans ölçüm aşaması özel olarak İzmir metrosuna uygulanmıştır. İzmir Metro analiz edilmiş ve dünyadaki benzerleri ile karşılaştırılmıştır.

Anahtar Sözcükler: İzmir Metro, Verimlilik, Kentsel Toplu Ulaşım, Karşılaştırmalı Standart Belirleme Analizi.

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INTRODUCTION

Public transport is essential for the city, especially for the poverty groups of the society. In the developing countries due to the lack of adequate money for public investments, efficiency concept becomes more critical. That is, more efficient public transport service provides more public service.

Urban transportation has become essential especially with Industrialization. The separation of workplaces and homes created the travel to work. The increase of population and expansion of cities required transportation of hundred thousands of workers between the dispersed land uses. Therefore early metros emerged in such crowded and dense cities at the end of the 19^{th} century and first quarter of the 20^{th} century. Then the dominant mode of urban transport was mass transit and the macroform of cities evolved as integrated with the metro systems.

Cities, which industrialized after the widespread use of automobile and bus (in 1930s), have different urban development characteristics because of the change of transport activity. These cities were sparser than the early industrialized ones.

Urban transit systems -especially the fixed, permanent and expensive ones- must be planned together with land use plan and other transportation systems, through the appropriate account of travel demand. Transport investments must comprise the major part of the society. High-density dwellings, offices, health facilities and commercial centers must be planned along the transit corridors. Transit should offer greater accessibility, speed, and convenience. These perspectives will make the decided system more efficient.

Efficiency can be defined roughly as maximizing the benefits at minimum cost. Efficiency has a major importance in urban transit because transit is a public service to citizens and if the supplied service is not consumed in time, it cannot be stored for the next time.

In Turkey, transport planning has not developed sufficiently; there is not a defined and systematic frame. This has led to a disorder in Transport applications. Transit systems of the cities are also affected from that disorder. Decisions have been made by guess and without being built on any measurement or analysis in the field of public transport. Unfortunately transport studies are often done after the mass transit decisions that the authorities gave as the outcome political considerations. Consequently, this situation causes building mass transit systems that are inefficient and working under their capacity.

Rail systems in urban transit are the modes, which have the most investment cost and the operating cost, so they should be employed in their feasible capacity. A rail transit system decision for a city is required a healthy transport study. Such an expensive public investment decision cannot be taken with political anxieties.

If we consider Izmir Metro, it needs to be evaluated through this point of view. İzmir Metro System is decided according to the report of Heusch und Boesefeldt Company "Transportation Master Plan for Greater City of İzmir, for the year 2010". The study started in 1989 and concluded in 1992 and the first stage of the metro line is finished in 2000. This line is the unique mass rapid transit system of İzmir running between Üçyol and Bornova. It is 11.6 km long and has 10 stations. It carries average 70,000 passengers per day.

İzmir metro seems inefficient in its current state. The sources of this intuition are:

- Its route is not so attractive and appropriate for travel demand.
- The frequency of the trips is lower than the metros worldwide.
- While its feasible capacity is declared as 400,000 passengers per day, it carries about 70,000 passengers per day

Different methods can be applied to measure efficiency. The efficiency evaluations of the metro will be made from today's perspective not the long-term future. However the results of the study aims to give ideas to improve the performance of the İzmir Metro. In this study, İzmir Metro's efficiency will be measured by using an interpretation of the method of Comparative Benchmarking Analysis. This method is defined as "*a tool for improving performance by learning from best practices and understanding processes by which they are achieved*"(EQUIP, 2000). It is a good method to measure efficiency of a system with limited data. It has many different usage areas from manufacturing industry to public service management. It is a method directly relevant with the practice.

Comparative Benchmarking includes the steps of self-assessment to understand your own processes and performance in detail; analyzing others' successful process and performance; comparing your performance with that of others; implementing the necessary changes to close the performance gap (EQUIP).

Efficiency will be evaluated from the operator’s viewpoint. To apply the method, a virtual benchmarking group will be set up with the metro systems similar to İzmir Metro. The method of benchmarking will be applied only to measure the performance of İzmir Metro System. The last stage of the method, which is improving the performance of the system, will be left to the operator’s initiative. Because this method -especially the last stage- requires a real benchmarking group and this group should share their data with each other.

A brief discussion of the historical development of transit systems and the need of subway systems will be held in Chapter 2. Prevailing and current used transit modes will be searched and the characteristics of the modes will be compared.

In Chapter 3, “Efficiency Concept” and the decision making process of the transportation planning will be discussed. The method of Comparative Benchmarking Analysis will be explained.

In Chapter 4, current transport supply system of İzmir will be handled. The method of comparative benchmarking analysis will be applied to measure the efficiency of İzmir Metro System. The data of İzmir Metro System and worldwide similar metro systems will be listed. The systems will be compared through the decided indicators. The results will be evaluated.

In the last chapter, results of the study will be discussed and some proposals will be added, for both the operator of İzmir Metro and the municipality of other cities to have more efficient transit systems.

Chapter 2

DEVELOPMENT OF URBAN TRANSPORT

1. First People Movers of the Urban Life

Public transportation was first used by the Romans. They established a system of vehicles for hire during the reigns of Emperors Augustus and Tiberius. They used two or four-wheel wagons that were stationed at inns every 5 or 6 miles along their famous highways. In the 16th century Coaches that ran on regular schedules between major towns appeared in Europe. (Black, 1995)

The first form of public transportation to operate only within cities was the hackney carriage, the forerunner of the taxi, which appeared in Paris and London shortly after 1600. By 1700 there were about 600 hackneys operating in London. (Black, 1995)

At the beginning of the 19th century, the cities were dense and compact and the geographical area of a city was limited to the radius of walking distance from the center, so average person walked to work. Also there were some rich families lived on outskirts and traveled by horseback or carriage.

The modern era of urban transit began in 1819 with a coach line in Paris. It used an existing type of stagecoach called a ***diligence***. The first transit service in the USA was started by Abraham Brower on Broadway in New York City in 1827. It was a private enterprise that designed a special stagecoach with the seating 12 passengers. It was named the ***accommodation***, and two years later they designed a new model and named it the ***sociable***. (Black, 1995) Figure 2.1 shows typical stagecoaches:

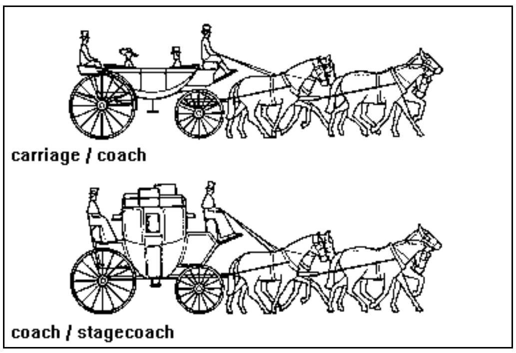

Figure 2. 1 Typical Stagecoaches (http://www.perfectpresence.com, 2001)

2. Urban Transport in the 19th Century

In 1825 the vehicle named ***Omnibus*** was designed for use in Paris. It was drawn by three horses and could seat 18 passengers. In 1829 an omnibus line started also in London. It was seen in New York and Philadelphia in 1831. Boston got them in 1835 and Baltimore in 1844. Each vehicle was individually owned and operated. So they were the first private enterprises that earned money from the public transit sector. The first large transit firm was the London General Omnibus Company, formed in 1856. In the first year it had 580 omnibuses and 6400 horses. Although the omnibus was designed to operate in cities, it was slow and uncomfortable. They were used in New York City until they were replaced by motorbuses between 1905 and 1908. (Black, 1995)

At the same period the emerging mode was the ***Horse-Drawn Street Railway*** or the popular name ***horsecar***. It was first seen in New York & Harlem Railroad in 1832. In this mode, the use of horses was first considered temporary. They considered using them until the steam railroad could be extended from Albany to New York, but the performance of the horses were well and never replaced by steam engines. There were many size and shapes of horsecars. There were short cars drawn by a single horse and large cars capable of 50 seats and pulled by three or four horses. It was a great improvement that ran on iron rails. The friction was reduced so horses could pull more load and the speed was also double that of the omnibus.

Figure 2. 2 Omnibus

Figure 2. 3 Horsecar

(http://mdhsimage.mdhs.org/Library/Images/Mellon, 2001)

The next technology is the ***cable car***, which began its first service in 1873. In this system a cable is laid in a small trough between the rails. It is kept in continuous motion by a steam engine located at the end of the line. The car has no motor. The cable cars represented a major advance: They reached speeds of 7 to 9 miles per hour in business districts and 12 to 13 miles per hour elsewhere.

In the 1890s cable cars started to be replaced by ***electric streetcars***. It is also called electric railway, trolley, or tram. This technology was found by Werner von Siemens in 1879. It was an important invention but to supply electricity to the vehicles was still a major problem. Both Siemens and Edison used the two rails to carry the rails, but it was dangerous. Even the horses and the careless pedestrians were shocked by the rails. In 1884 a 1-mile electric street railway line was built in East Cleveland. It was the first commercial electric street railway in the United States. Leo Daft electrified a line of the Baltimore Union Passenger Railway in 1885. Power came from the third rail on the ground, which caused a danger. By 1902 more than 90 percent of the street railway in United States was electrified. A few horsecars continued to run on Bleecker Street in New York City until 1917. Just after World War I, the streetcar industry suffered a major crisis. Between 1916 and 1923, more than one-third of U.S. transit companies went bankrupt. Thus the streetcar industry entered a period of stability. (Black, 1995)

Figure 2. 4 Cable Car
(http://www.perfectpresence.com, 2001)

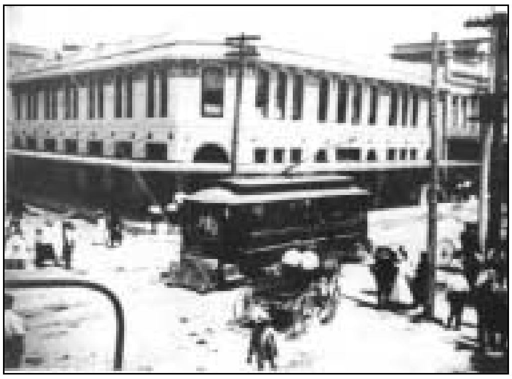

Figure 2. 5 Electric Street Car
(http://www.library.ci.corpus-christi, 2001)

Another mode of 19th century was the ***steam railroads***. In 1830 in England, the first intercity railroad service began between Liverpool and Manchester. Like today's automotive industry the railroad industry formed a major part of the economy in the 19th century. The first suburban line opened in 1838 in London. London reached a large network of suburban tracks between 1840 and 1875 and is still used. The United States had first commuter train in 1843 between Worcester and Boston. Other European cities Paris, Berlin, Hamburg, Liverpool and Glasgow and the U.S. cities Washington, Pittsburgh, and San Francisco also built suburban routes in the 19th century. U.S. began to use steam railroads in 1843, between Worcester and Boston. (Black 1995)

Another important mode in the past was the ***interurban railway***. This mode was midway between a street railway and an intercity train. The vehicles were heavier than streetcars and they can travel at 60 miles per hour. Routes began at the city center and ran into the other cities in the country. The first interurban electric railway in the world began its service in Northern Ireland in 1883. This mode was especially used by the farmers to deliver their products and by the stores to deliver their packages. They also carried mails. (Black 1995)

2. 1. Subway and Elevated Systems

The early form of the subways and the elevated systems were powered by the steam engines. The first subway in the world was opened in London in 1863. It was 3.7 miles long. The trains were pulled by the steam locomotives, and to expel the smoke from the tunnels special efforts were made. The line was popularly called ***sewer railway***. It was operated for many years and then electrified. Elevated steam trains were used in New York, Manhattan, Brooklyn, Queens, Kansas City, Sioux City and Iowa until the end of the 19^{th} century. (Black 1995)

The first subway, which was using electricity from the third rail, opened in London in 1890. In 1896 Budapest and Glasgow started their underground transit services. Metropolitan West Side Elevated Railroad was the first electric elevated line that began service in 1895. It used a locomotive equipped with motors and able to pull unpowered trailer cars. It was not an efficient design so in 1897 they invented the multi-unit system in which every car has motors. It was an important invention because cars could be added to the train when you need to increase the capacity of the system. (Black 1995)

Before World War II several European cities especially the dense ones had subways. The first metro line in Paris was completed in 1900, Berlin's subway began service in 1902, and Hamburg opened one in 1912, Madrid in 1919, Barcelona in 1924, Stockholm in 1933. (Black 1995)

The historical survey shows that the first subways or the elevated systems were built in the cities, which had high population (See Table 2.1). Undoubtedly the forms of those cities were compact and they were dense in the 1900s.

Table 2. 1 A Historical Comparison (http://www.azrail.org/azrail/metropopulations.htm, 2001)

CITY	City Population When Built	The Year Rail Transit System Entered Service	Current City and Metro* Populations	2002 City/Urban Population Density (persons per square mile)
Chicago	2,200,000	1913 (Chicago Elevated Transit: CTA)	City: 2,900,000 Met: 9,100,000	4,285
London	5,500,000	1890 (London Transport Underground)	City: 7,100,000 Met: 12,500,000	7,645
Moscow	2,500,000	1935 (Moscow METRO Subway)	City: 8,400,000 Met: 15,000,000	8,450
New York	3,400,000	1900 (NYC-MTA Subway)	City: 8,000,000 Met: 21,200,000	5,407
Paris	2,700,000	1900 (RATP: Metro)	City: 2,100,000 Met: 9,000,000	9,181
Tokyo	3,700,000	1927 (Teito Rapid Transit Subway)	City: 8,000,000 Met: 28,000,000	18,401

* "City" is the population inside the incorporated area of the city.
"Metro" is the total population of the City plus all the outlying suburbs.

Also the number of passengers carried by one of these early metros is unreachable by several metros even today. The New York City subway was carried average 400,000 passengers a day in 1904 (Black 1995). However İzmir Metro carries about 70,000 passengers a day in the year 2001. This shows the need of metro systems in 1900s for the dense industrialized cities like New York. Figure below gives ideas about the densities of the dwellings close to the early subways.

Figure 2. 6 City Hall Park 1903 (http://wt.mit.edu/Subway/Archives, 2001)

Construction of the early station of the first line of New York Subway. The wooden framework can be seen where the entrance and exits would eventually be.

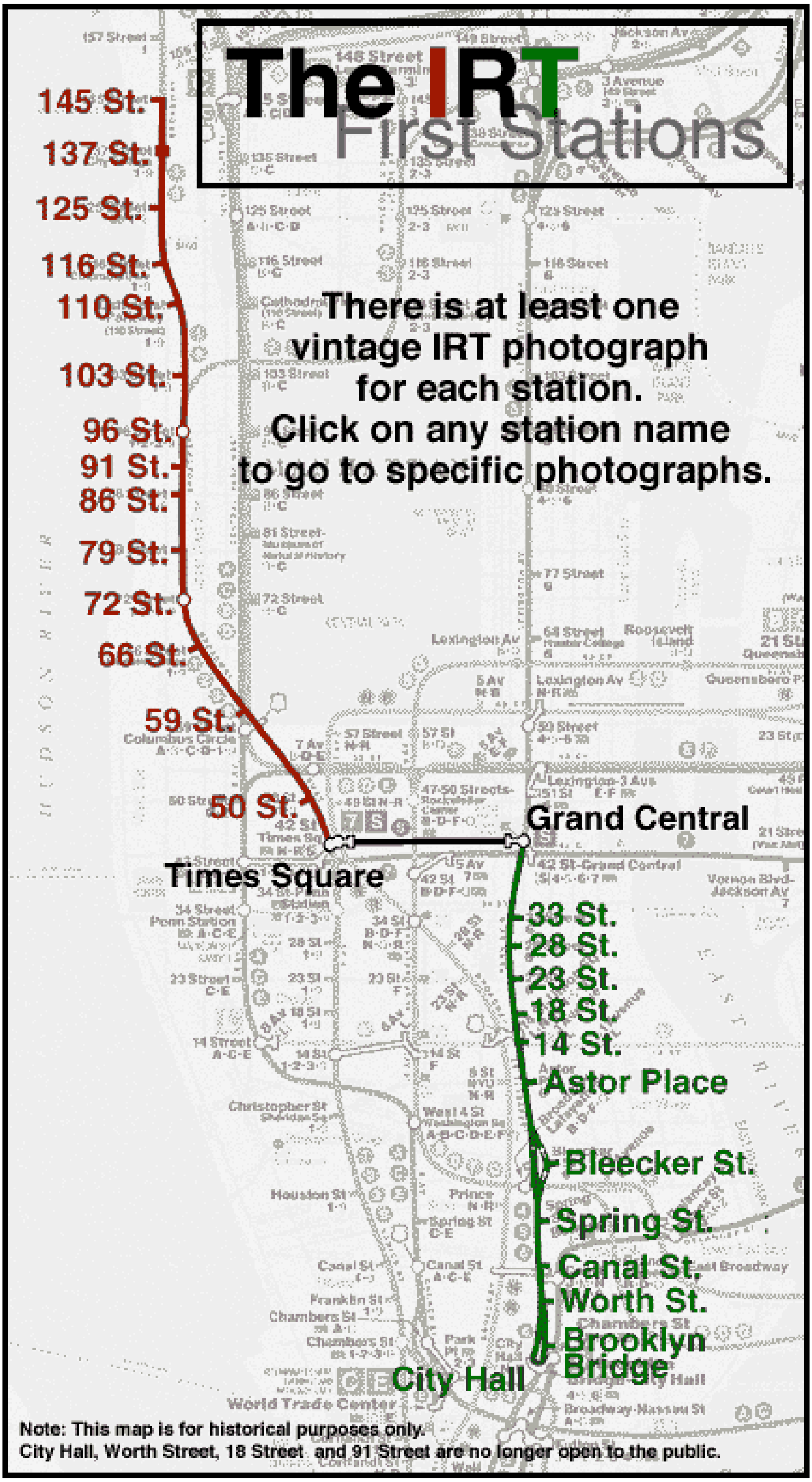

Figure 2. 7 Historical Map of the New York First Line (http://wt.mit.edu/Subway/Archives)

2.2. Automobile and Bus

Road locomotive or the steam carriage was the first private motor vehicle of the man. It was like railroad locomotive but it has flat surfaced wheels to run on highways. The first one was built by Richard Trevitchnick in England in 1801, but the road locomotive could not become a major mode of urban transport. The important invention was the internal-combustion engine, fueled by gasoline. In 1878 this engine was perfected by the German Nicholas Otto. (Black 1995)

At the end of the 19^{th} century there were many small automobile manufacturers but the products were very expensive and they were mechanical toys for the rich people or used for car race. Automobile has become a transportation mode for the large numbers of people by Henry Ford. In 1908 he achieved to build the Model T Ford for a price of $850. He aimed to discount the price every year. In 1914 he attained full assembly-line production and reduced the time for chassis building from 12 hours 28 minutes to 1 hour 30 minutes. Thus the price of the Model T reached to $360 in 1914 and $290 in 1926. Certainly with the other companies such as General Motors, Chevrolet the use of automobile spread in 1920s. (Black 1995)

At the same period the truck the tractor and the bus were also designed and produced by the companies. The first motor bus service in the world began in London in 1899, and by 1911 London General Omnibus Company completely replaced horse-drawn omnibuses with motor buses. New York City began to use motorbuses in 1905. But the widespread use of buses began after the invention of the diesel engine in buses.
Two diesel buses began service in New Jersey in 1929 and 27 diesel buses began service in Newark in 1937. (Black 1995)

Arrival of the motor vehicle changed the transportation habits of the people and the transportation and land use decisions of the authorities. The new movers of the urban life were more flexible, so they were more accessible to any geography. This changed development characteristics of the cities. Cities became sparser than the earlier ones.

3. Prevailing Mass Transit Modes

Urban transportation is a widespread action that consists walking, bicycles, urban freeways, metro and regional rail systems. Transit systems can be classified basically in three categories.

- Private Transportation
- Paratransit or For-hire Transportation
- Urban Transit, Mass Transit or Public Transportation

In private transportation the passengers are the owners and the operators of the vehicles. Pedestrian, bicycle and private car are the common modes of this system. Paratransit system is provided by operators for individual or multiple trips. Taxi, dial-a-bus and jitney are the samples of this system. Mass transit system, which is the most essential for transport planning, includes the modes operate on fixed routes and with fixed schedules. Bus, light rail transit, metro, regional rail and several other systems are all the modes of mass transit system.

In this section especially the characteristics of the mass transit systems will be defined. Vuchic distinguishes the transit modes on three dimensions:

- Technology,
- Type of service,
- Right of way,

"***Technology*** of transit systems refers to the mechanical features of their vehicles and travel ways. The four most important features are:
· Support: rubber tires on roadways, steel wheels on rails, boats on water, etc.
· Guidance: vehicles may be steered by the driver, or guided by the guideway; on rail, AGT and monorail systems drivers do not steer vehicles/trains, because they are mechanically guided.
· Propulsion: most common in transit systems are internal combustion engine - ICE (diesel or gasoline) and electric motor, but some special systems use magnetic forces (linear induction motor - LIM), cable traction from a stationary motor, propeller or rotor, and others.
· Control: the means of regulating travel of one or all vehicles in the system. The most important control is for longitudinal spacing of vehicles, which may be manual/visual by the driver, manual/signal by the driver assisted by signals, fully automatic with driver initiation and supervision, or without any driver at all.

Type of Service includes several classifications:
· By types of routes and trips served: Short-haul, City transit and Regional transit.
· By stopping schedule: Local, Accelerated (Skip-stop, Zonal) and Express service.
· By time of operation and purpose: All-day, regular service, Peak-hour service or Commuter transit, and Special service for irregular events (public meetings, sport events, etc.).
***Right-of-way (ROW) Categor*y**, or type of way on which transit vehicles operate, is the most important characteristic of transit modes. There are three ROW categories:
· **ROW Category C** are public streets with general traffic.
· **ROW Category B** represents transit ways that are partially separated from other traffic. Typically they are street medians with rail tracks, which are longitudinally separated, but cross street intersections at grade. Bus lanes physically separated from other traffic also represent ROW category B. This ROW requires a separate strip of land and certain investment for construction.
· **ROW Category A** is fully separated physically protected ROW on which only transit vehicles operate. This category includes tunnels, aerial (elevated) structures or fully protected at-grade tracks or roadways. Thus, vertical position of the ROW is not as important as its separation from other traffic, because total independence of Transit units allows many physical and operational features that are not possible to use on ROW categories B and C. Therefore, the modes with ROW category A are guided (rail, exceptionally rubber-tired) systems with trains, electric traction and signal control which offer very high capacity, speed, reliability and safety."(Vuchic, 2002)

Vuchic's right of way categorization seems to be the best way for the transport planners in their decisions. This categorization points out the planners, to make their decision based on the capacity of the corridor.

Mass transit systems are usually categorized according to the vehicle types. To consider the capital and operating cost of transit modes it is better to categorize them according to the vehicle types.

3.1. Suburban Railroad

Suburban railroad service was started by the intercity railroads for commuters. It is also called ***commuter rail*** or ***regional rail***. There are suburban railroads in many foreign cities; London and Paris have large networks. Suburban railroads also operate in Canada, Asia, Australia, and other parts of Europe. This system is characterized by heavy equipment, high maximum speeds, and slow acceleration and deceleration. The routes are typically 25 to 50 miles long and lead to a stub-end terminal in the central business district. Most other stations are in the suburbs and are several miles apart. Usually ridership is highly concentrated in the peak periods. The service is often high quality. Trains run at speeds up to 80 miles per hour, and there are enough seats so every passenger gets one.

New York City has the largest system, carrying over 500,000 passenger trips each weekday. Today all the systems are under government control in United States, although a few private railroads operate them under contract to public bodies (Black, 1995). In Turkey, TCDD, which is a governmental cooperation, is the controller of all suburban railroads.

3.2. Heavy Rail

The term ***rapid rail*** is also used, and in foreign countries. Heavy rail refers to traditional high platform subway and elevated rapid transit lines so it is also called as ***subway-elevated***. Principal characteristics are operation over rights of way that are completely segregated from other uses. Tracks are placed in subway tunnels, on elevated structures, or on fenced surface rights of way. The popular term, which is also used in Turkey, is ***Metro***.

Metro trains consist anywhere from 2 to 12 cars. Each car has its own motors, and gets power from a third rail (or in some cases from overhead wire). Because of the danger of the electricity boarding is from high platforms, and tracks put at ground level. Stations are designed to allow large numbers of people to enter and leave rapidly.

Heavy rail is intended primarily to serve travel within the central city, although the newer systems often have lines extending into the suburbs. The average spacing is about a mile. New York City has some stops that are only one-quarter mile apart, but this is considered inefficient by modern standards (Black 1995). Rail vehicles are long living capital goods that have to fulfill exactly defined safety and quality requirements. Planned rail vehicle economic life takes about 30 years. Some modernization and maintenance works are necessary during the product‘s life (Fleischer 2001).

Heavy rail systems are extremely expensive modes to build. Because of the need of tunnels, elevated structures, or other fully segregated rights of way and to accommodate more gentle curves and grades. Both costs and performance vary from location to location according to stop spacing, vehicle and system design, etc. However according to the World Bank Reports; the capital cost of a full metro system is between $30 and $180 million per kilometer (the most expensive is being fully automatic, fully underground systems). For example, a dedicated underground rail system cost $40 million per kilometer in Santiago, Chile, $64 million in Osaka, Japan, and $117 million in Caracas, Venezuela. The capital cost of İzmir Metro is $52 million per kilometer.

Most heavy rail systems use the standard gauge of intercity railroads, with tracks 4 feet 8 ½ inches apart. But in Russia the gauge is 5 feet. Most systems use steel wheels, but French pioneered a design in which vehicles have rubber tires. It is used in Paris, Montreal and Mexico City where the French did the engineering. This system is quieter and comfortable, but energy consumption is higher. One of the most famous subways is in Moscow, where the first line is opened in 1935. The older stations were decorated with statues, chandeliers, and marble walls. The tunnels are usually deep. The system has grown continually and now carries more passengers than any other in the world.

Figure 2. 8 New York Metro
(Photo by David Pirmann 1996)
(www.nycsubway.org, 2001)

Figure 2. 9 Hong Kong Metro
(Photo by Rob Neutelling)

3.3. Light Rail

“Light rail transit is a metropolitan electric railway system characterized by its ability to operate single cars or short trains along exclusive rights-of-way at ground level, on aerial structures, in subways or, occasionally, in streets, and to board and discharge passengers at track or car-floor level.”(Transportation Research Board definition)

“An electric railway with a "light volume" traffic capacity compared to heavy rail Light rail may use shared or exclusive rights-of-way, high or low platform loading and multi-car trains or single cars. Also known as streetcar, trolley car or tramway”(APTA Glossary of Transit Terminology definition)

Some other definitions and thoughts about LRT Systems:

- "Light Rail is the child of a streetcar mother and a rapid transit father It is a nephew to an interurban line, a cousin to commuter rail, and a step-brother to a bus." (Jim Seamon - St Louis Mo)
- "On heavy rail, you board the train from a platform. On light rail, you board the train from the ground." (Harry H Conover)

Actually it is a modern version of the electric streetcar. It is safer than heavy rail because the electricity comes from an overhead wire instead of a third rail. There is no need to fence the track, and it can operate in the street. 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 the sidewalk. Right-of-way acquisition and construction can be much cheaper than heavy rail. Therefore it is viable in situations with a lower level of demand than that need to justify costly heavy rail projects. If most of a route is on separate right-of-way, average speeds are higher than for buses in mixed traffic. The technology is well known and has been proved by experience. There is little risk of having mechanical problems or big cost overruns. ROW category is usually B.

Light Rail trains may operate either single or multiple cars. Passenger capacity of each car in a multiple car consist can be about 250 passengers (standees included). The number of cars that can be operated in any one consist are limited by several factors. One of the major factors is station platform length. Other minor factors include traffic logistics within the city and the ability of the control cab to operate more than a certain numbers of cars.

Depending upon the specific system, the distance between light rail stations is shorter than within heavy rail systems, which lends some major advantages to urban settings within a light rail system, trains may operate in mixed street traffic (urban areas), downtown malls, on dedicated rights of way, or in the middle of major thoroughfares, where trains cross intersections, in the same manner as other vehicles Due to these factors, the average speed of light rail systems is significantly lower than heavy rail systems.

Well-planned and well-used light rail systems can move more people than can buses. Light rail systems also consume less energy than buses and, depending on the power source, emit fewer pollutants. Light rail systems can carry 6,000 people per hour in mixed traffic and up to 36,000 people per hour with five- or six-car trains, exclusive rights-of-way, and grade-separated intersections. Light rail systems have certain drawbacks, including system inflexibility and expensive track maintenance. However, in the dense cities of Asia, light rail is becoming increasingly attractive and viable.

Source: San Diego Metropolitan Transit Development Board.

Figure 2. 10 LRT in San Diego
(United States General Accounting Office, 2001)

Figure 2. 11 LRT of Montpellier (France)
(Light Rail tour de France, 2001)

Dallas built a 185-mile light rail system that cost $828 million. Pittsburgh spent $542 million to convert 105 miles of streetcar lines to an LRT system entirely on separate right-of-way, including a new downtown subway.

3.4. Bus

Bus vehicles vary according to their size, capacity and body type. Each type was of course built for certain needs. Main types are defined below;

Minibus is a 6-8 meters long vehicle, which has a capacity of 15-40 seats and standing spaces. It is used for lightly traveled lines, short shuttle lines, services in residential neighborhoods, etc.

Regular bus is 10-12 m long, 2.50 m wide. It has 30-50 seats and 60-20 standing spaces (minimum number of seats corresponds to the maximum number of standing spaces).

Double-decker buses have two decks, the upper being for seated passengers only. Like articulated buses, double-deckers have a greater capacity than regular buses, but take less street space. They involve passengers climbing stairs, which is inconvenient.

Riding on the upper deck, however, offers nice views for passengers. They are used extensively in the cities of the United Kingdom and many British Commonwealth countries, as well as in Berlin and a few other cities.

Articulated bus is a vehicle with the main body on two axles and an articulated section with the third axle. These buses are 16-18 m long and have a capacity approximately 50 percent greater than regular bus. With their greater capacity, articulated buses are suited for heavily traveled lines. In a few cities with very heavy ridership double-articulated buses, with three body sections and four axles, are used.

Figure 2. 12 80-foot bi-articulated vehicles (36-40 additional seats) (http://www.fta.dot.gov/brt/lamrdp/mrp2.html, 2001)

Low-floor buses, perfected during the 1990's, have become standard in several industrialized countries. These buses have floors 35-40 cm above ground, so that entry from a curb is nearly flat, or a plate is provided for wheelchairs. Low-floor buses offer considerably greater comfort for passengers and speed up their boarding-alighting. Mechanical equipment on these buses is stored mostly on the roof, while the motor is in a compartment in the rear, where the floor is ramped up. Most buses are powered by 4-, 6- or 8-cylinder diesel engines. To reduce air pollution, a number of new propulsion systems have been developed: "clean diesel," ethanol, methanol, propane and other propulsion is used. Some new engine designs, such as propane, are rather quiet, but noise and odor do remain disadvantages of diesel buses.

In selecting buses for a specific service, expected passenger volume is critical for vehicle design. Maneuverability and riding comfort are also considered. Thus, for lightly traveled bus lines in suburban areas with many narrow residential streets, or on hilly terrain, minibus may be best suited because it is least expensive per vehicle-km, its small capacity is adequate and it can negotiate such alignments better than large buses. On the other hand, heavy passenger loads make regular or high-capacity buses more economical and superior in offering the required capacity. Average trip lengths influence the number and width of doors, as well as seating arrangement. Relatively short trips and intensive exchange of passengers at stops requires two double channel doors on regular, 3-4 double channel doors on articulated buses, and single rows of seats on each side.

3.4.1. Bus Travel Ways

The vast majority of buses operate on regular streets, ROW category C. Being in mixed traffic, and their speed and reliability of service depend on traffic conditions. Their average speed is lower than average speed of cars because they stop to pick up and drop off passengers. Buses are therefore not very competitive with car travel in the same corridor with respect to speed and reliability. Their advantage is much lower cost and convenience of not having to drive and park. To make buses more efficient and attractive to passengers, bus preferential measures can be introduced. These include the following:

Preferential signals: buses in a separate approach lane at intersections get the green signal before other lanes, so that they can proceed through the intersection ahead of other traffic.

Alternating stop locations at near- and far-side of intersections (before or after cross street) so that buses clearing one intersection on green signal use the green at the following intersection before they make the next stop. Also, spacing between bus stops should typically be about 250-400 m.

Exclusive bus lanes, which may be curb lanes or lanes in the median - ROW category B. This is the most significant improvement measure because it makes buses independent of traffic conditions on the same street.

Buses on high-occupancy vehicle (HOV) lanes or roadways are used when bus lines with frequent service follow freeway alignment for a rather long distance. HOV facilities usually have traffic control that prevents congestion, but they do not provide the image of an exclusive, independent transit facility. 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***. HOV lane restrictions are prone to violation because the lanes move at a higher speed than adjacent lanes open to all traffic.

The direction is reversed in the middle of the day. Sometimes the lanes are restricted only in peak periods; others operate 24 hours a day Some HOV lanes require car pools to have at least two persons, others at least three The first bus lane of US is the Shirley Busway, which opened in 1969 It is 11 miles long and runs through the Virginia suburbs of Washington, DC, ending near the Pentagon Houston now has the largest system, totaling 465 miles as of 1990.

Busway - special roadways reserved for buses only (ROW category B or A). Since busways require very high investment costs, they are used for some sections of lines. If ROW category A is required for a large section of line, it is usually better to introduce rail system, so that the investment in high quality ROW is better used for electrically powered trains, rather than single bus vehicles.

Figure 2. 13 Busway in Charlotte (United States General Accounting Office, 2001)

As seen in the figure, Busway is located in the middle of the highway. This line can be used as HOV lane for the private cars at nights, or when there is no need for express buses.

3.4.2. Bus Stops and Stations

As mentioned, spacing between bus stops along urban streets is usually 250 to 400 m long. In suburban, lightly traveled areas, stops can be closer if they are on-call, so that buses stop only on passenger demand. Bus stops should have a shelter for weather protection, a bench and complete information about the lines serving that stop and their schedules. With advanced electronics, it will be possible to display the time of arrival of the next bus.

At major bus stations where many lines converge and terminate, a set of islands can be used for parallel bus stop locations. Pedestrians can either cross bus roadways at grade, because buses are stopped at those locations, or there can be stairways from each island to a cross-pedestrian corridor above the station or underneath, in a tunnel. The latter design is common when bus lines feed a rail line, which is placed above or under the station area.

For major bus-rail transfer stations the most efficient layout is an island to which stairs or escalators from the rail station arrive. Bus access roadways are brought to a circular drive, which goes clockwise (in countries with driving on the left, the circular roadway must have counter-clockwise driving). Bus stops are located around the island, and they may have a straight curb or “saw-tooth” pattern, which facilitates bus access and departure, maneuvers.

3.4.3. Express Bus

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 bus or HOV lanes, or operate on freeways;
- Offer higher comfort - usually 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 car. Express bus often serves lines to airport or between center city and major regional activity centers.

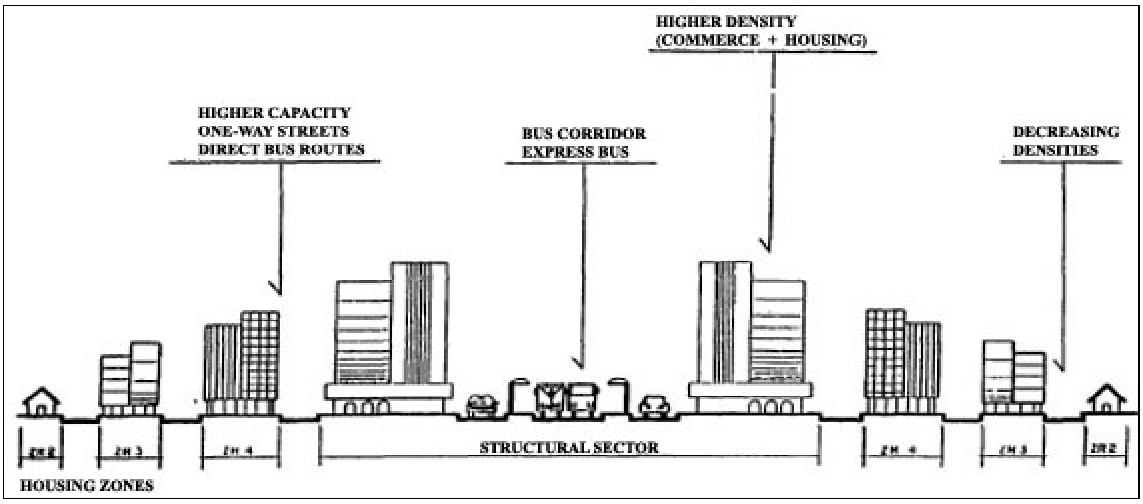

Figure 2. 14 Hypothetical cross section of Curitiba's trinary road system.
(United States General Accounting Office, 2001)

The figure points out that express bus lanes should be designed on the street where the commerce and housing have high density.

3.4.4. Bus Semirapid Transit

On major urban corridors, which require faster, more reliable and higher capacity services than regular buses can offer, but there is no rail service, bus lines can be upgraded to offer higher level-of-service and higher capacity than regular bus lines. This type of service, designated Bus Semirapid Transit (BST) or Bus Rapid Transit (BRT), represents a mode between regular bus and LRT system.

BST 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 for LRT because they do not need electrification and tracks. Correspondingly, BST performance and service, including speed, reliability and capacity, is also better than regular buses can offer. It does not match performance and level-of-service of LRT because rail vehicles are more spacious, more comfortable, have better performance and considerably lower noise due to electric traction.

Moreover, their permanent tracks, rights-of-way and stations also give rail systems a much stronger image. BST are obtained by provision of reserved lanes or roadways (ROW category B), preferential treatment at intersections, stops with multiple births (stopping locations) which allow overtaking and simultaneous boarding of several buses, fare collection prior to boarding and other elements which increase speed and reliability of service. To increase line capacity, articulated and, in some cases with mostly straight corridors, double-articulated buses are used.

The best examples of BST systems are found in Ottawa, Canada, and Curitiba, Brazil. Sao Paolo and several other cities in Brazil, as well as Turkey, Ireland, France and other countries also have this mode. Several U.S. cities had upgraded bus systems, but then degraded them into HOV lanes and commuter, rather than regular lines. In the late 1990s, Federal Transit Administration initiated a program to develop several BST ("BRT") lines in a number of cities.

An effective way to increase bus ridership is to give buses priority in traffic. A dedicated bus lane (assuming high-occupancy rates and efficient operation) can move twice as many people per hour as buses operating in mixed traffic and 40 times as many people per hour as cars. By giving buses priority over car traffic, more people will turn to buses as a fast and efficient alternative. Many European cities, including Zurich and Helsinki, Finland, have designed systems that give priority to buses and trolleys at intersections. One of the most effective bus systems is in Curitiba, Brazil, where the integration of guided land development and a public transportation network created conditions that naturally promote bus use. (http://www.homestead.com/brtc/files, 2001)

Figure 2. 15 Curitiba Busway (http://www.homestead.com/brtc/files, 2001)

In Canada, the city of Ottawa, Ontario, is developing an extensive busway system rather than a subway system because of its comparatively low cost and flexibility in serving low- to medium-density urban areas. In addition to exclusive bus lanes, the city is considering a bus tunnel in part of the city center and will promote the use of alternative fuels, including compressed natural gas and electricity, to help alleviate related emissions problems. The system has been designed so that it could be converted to rail transit if needed. (World Resources Institute, 2001)

The first bus lane of US is the Shirley Busway, which opened in 1969 It is 11 miles long and runs through the Virginia suburbs of Washington, DC, ending near the Pentagon Houston now has the largest system, totaling 465 miles as of 1990.

Conventional bus service involves frequent stops along the entire route (8 to 10 designated stops per mile is typical) One alternative is *limited-stop service* with stops spaced much farther apart (usually 2 to 4 stops per mile) Chicago has operated such service for many years.

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 *transit mall* or *transitway*; it is done only in the downtown area. The sidewalks are widened, leaving one or two lanes for the buses When the volume of buses is low, people walk back and forth across the street.

Recent innovation is to give buses priority at traffic signals. Some buses are equipped with radio transmitters that send pulses that make traffic signals turn green as the bus approaches an intersection.

4. Comparison of Modes

There have been many studies to make objective comparisons of rail and bus modes. One of them was the study ordered by President Kennedy to construct a busway on the Shirley Highway (Black, 1995). According to this research:

- Driving an automobile all the way is cheapest with volumes up to 5,000 passengers per hour
- Taking a bus all the way is generally cheapest when volumes are 10,000 per hour or higher
- Rail with feeder busses 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 5000.

Several analyses claimed that the bus is best in all conditions. In 1969 Stover and Glennon advocated a *freeway flyer* system in which busses 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).

In 1990 Vuchic and Olanipekun after a study in southern New Jersey, they concluded that "*rail transit can in many cases represent the most effective and in the long run, most economical transit mode for both high-density cities and low density suburbs*".

Rapid rail transits, such as subways, often appear to be the ideal solution to clogged city streets. These rail systems promise high mobility, can be built under valuable urban land, and, they emit relatively few pollutants, so they are environmentally attractive alternatives. But, huge construction and operating costs damage the city budgets.

According to World Bank Report the capital cost of the modes below is as follows:

- At grade busway systems formed by conversion of existing roadway (including vehicles) cost between $1-5 million per route-kilometer,
- Elevated busways may cost as much as $15 million per route-kilometer,
- Light Rail Transit (LRT) between $10 and $30 million,

Compared to heavy rail, light rail can be very practical for urban applications, due to it's ability to operate in mixed traffic settings This ability can severely reduce construction costs of an urban rail system. However, within the same system, light rail has the ability of traveling at speed of up to 60 miles/hr (100 km/hr), when separated from these mixed traffic settings.

It is difficult to draw an exact conclusion from these studies. Perhaps none of them was really objective. In addition, 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 LRT and BRT.

United States General Office examined the mass transit systems of six cities in United States. They examined Dallas, Denver, Los Angeles, Pittsburgh, San Diego and San Jose and reached the following findings.

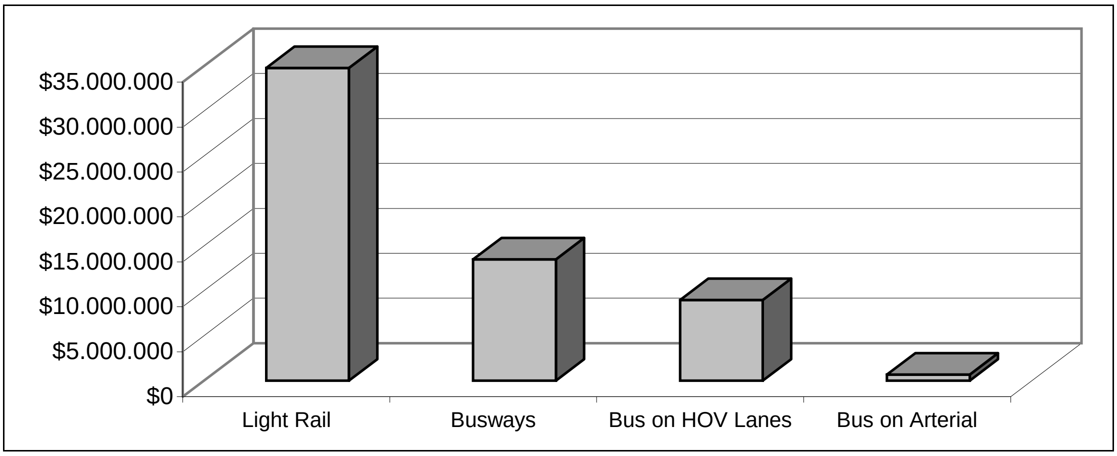

Figure 2. 16 Capital Cost Per Miles for the Different Modes of Transit
(Mass Transit, Bus Rapid Transit Shows Promise, US General Accounting Office, 2001)

The capital cost of LRT systems is twice of the capital cost of Busway systems. Average cost of the LRT systems is $34,790,000 per mile ($55,730,000 per km). Average cost of the Busway systems is $13,490,000 per mile ($21,610,000 per km). Average cost of the Bus on HOV lanes is $8,970,000 per mile ($14,370,000 per km). Average cost of the Bus on Arterial is $680,000 per mile ($1,090,000 per km).

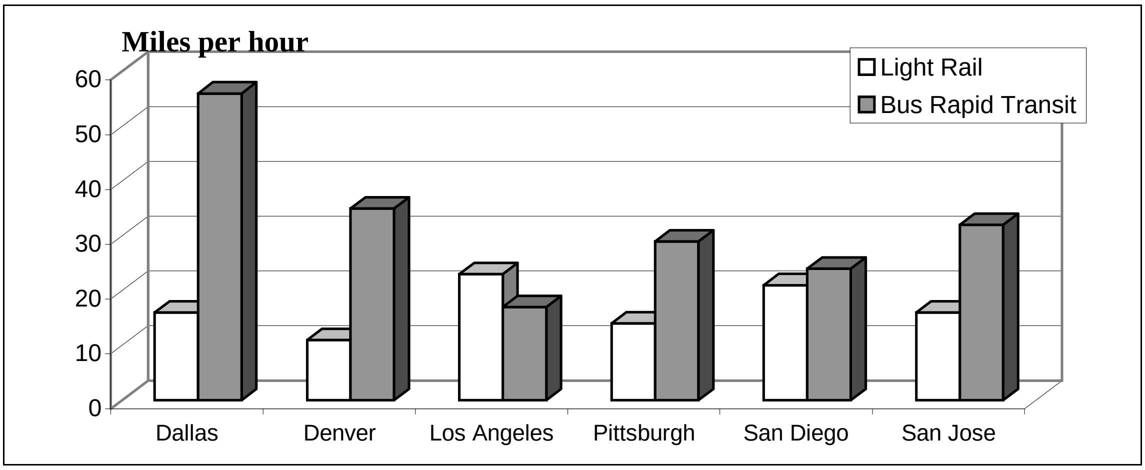

Figure 2. 17 Average Speed of BRT and LRT Service, 1999
(United States General Accounting Office, 2001)

The figure 2.17 shows the speed comparison of the two modes in USA. Average speed of LRT systems is higher only in Los Angeles.

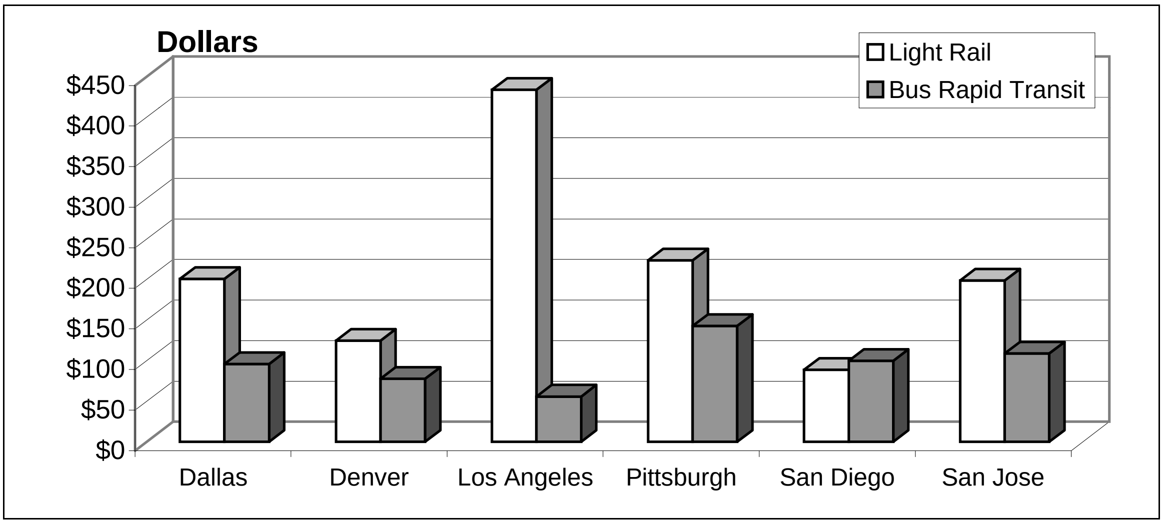

Figure 2. 18 Operating Cost Per Vehicle Revenue Hour, 1999
(United States General Accounting Office, 2001)

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

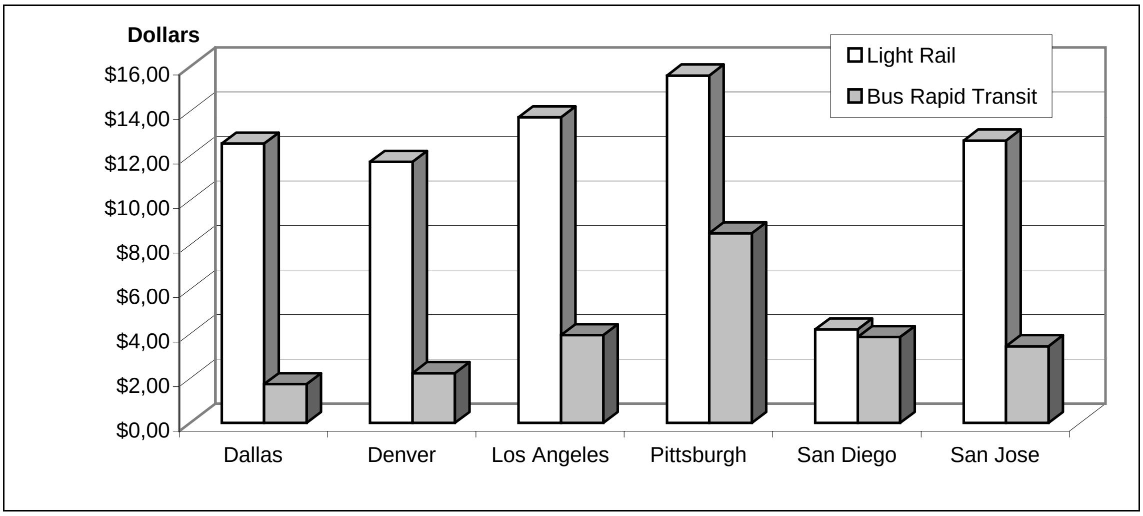

Figure 2. 19 Operating Cost Per Vehicle Revenue Mile, 1999
(United States General Accounting Office, 2001)

Operating cost of LRT systems per vehicle revenue mile 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 operator's viewpoint.

Chapter 3

EFFICIENCY CRITERIA AND THE METHODOLOGY

Efficiency is defined as "*the quality of doing something well and effectively, without wasting time, money, or energy*" in the Longman Dictionary*

Goods and services are inadequate to provide the whole needs of human in all over the world. There is gap between the resources and the needs. Undoubtedly this gap is more obvious in the developing countries. Therefore, the right allocation of the resources, and the right *choices* are necessary. The life quality of a society would increase with an efficient resource allocation.

If it is possible to provide the needs better than the existing situation, there is inefficiency in the system. Here, the difference of technical efficiency and economic efficiency should be underlined. Technical efficiency of a good or service could be provided, but if it is not demanded by the society, it is inefficient economically. Since, the limited resources to acquire this good or service could be used to produce a demanded one. (Üstünel, 1975)

For economists, efficiency is described with such phrase; *"the economy is producing just the right quantity of goods and services to satisfy society's wants at minimum cost."* (Renner, 2001). Neo classical economists defend the perfect competition in the market mechanism to provide economic efficiency. They assume the efficiency as the equilibrium of the benefits and the costs to society in any organization.

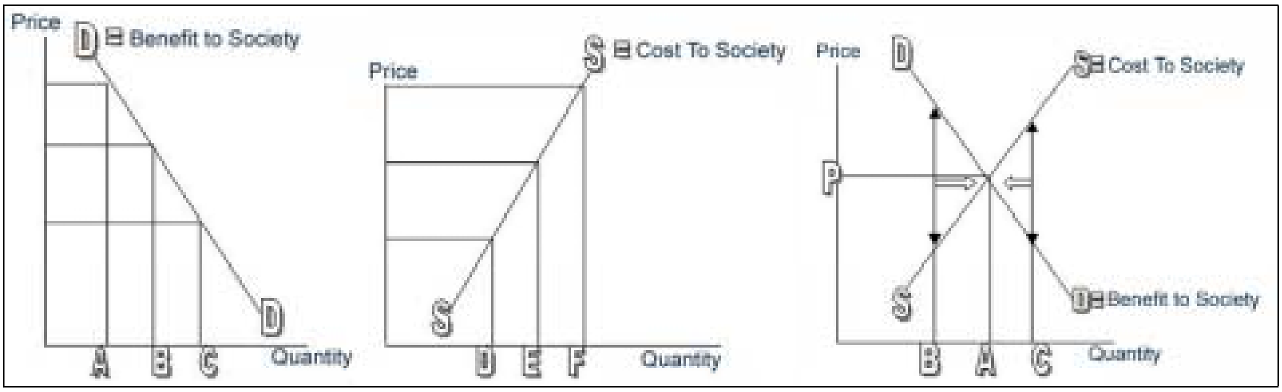

Figure 3. 1 Marginal cost and benefits in the efficiency model
(Supply and Demand: The Market Mechanism, 2001)

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* Pearson Education Limited 2000, Longman Dictionary of Contemporary English 3rd Edition

In the figure 3.1, the demand curve, which is shown in the first graphic, represents the importance of the goods and services to society. The cost of these goods and services in production process is represented by the supply curve in the second graphic.

Three quantity levels of demand and supply are shown in a normal market. These levels are shown in the figure 3.1. Efficiency in the market is provided when supply and demand balance each other. "*Price provides the incentive to both the consumer and producer. High prices encouraged more production by the producers, but less consumption by the consumers. Low prices discourage production by the producer, and encouraged consumption by the consumers. Both incentives push the price to balance the forces of consumption (demand) and production (supply). Economists call this balance: equilibrium."*(Renner, 2001). In the last chart, "P" is the equilibrium price and "A" is the equilibrium quantity in which an efficient equilibrium outcome for society is provided.

Quantity "B" is inefficient, because demand cannot be supplied in the system. When quantity increases, inefficiency decreases and the gap disappears. At "A" there is no gap and the benefit to society is equal to the cost to society. There is also inefficiency in Quantity "C", because supply is larger than demand. When quantity decreases, inefficiency decreases and the gap disappears.

Environmentalists differs from the economists with their concept "*Eco-Efficiency*" which was first was declared by the World Business Council for Sustainable Development (WBCSD) in 1992. Eco-efficiency starts from issues of economic efficiency, which have positive environmental benefits (www.uneptie.org, 2002). Eco-Efficiency is defined as "*the delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life cycle, to a level at least in line with the earth's estimated carrying capacity."* (www.uneptie.org, 2002)

Environmentalists demand improvements at the quality of life and wealth creation for all. The reduction of the damage to the planet should be the most important benefit for the society.

1. Efficiency in Urban Transit

Efficiency has a major importance in urban transit, because transit is a service industry and if the supplied service is not consumed in right time and place, it cannot be stored for the next time. Transport planning should estimate the exact amount of demand and should supply the service with the least required amount of 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 Urban Transport is relevant with such factors: (European Commission Transport RTD Programme, 2001)

- Capital, operating and maintenance (including energy) **cost**s.
- **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.
- **Utilisation 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.

The users, operators and city (environment) are the important parts of holistic efficiency view: (European Commission Transport RTD Programme, 2001)

- The operator aims to increase performance with the minimum use of resources. They are concerned with the cost minimization and increased productivity.
- The users require quality in services in terms of accessibility, comfort, reliability, safety and security, affordability and convenience.
- The city (environment) requires minimum damage for sustainability.

In this section efficiency will be discussed related to the operators' viewpoint. However, the mass transit that takes account into the operators' benefits would have positive or negative impacts on both the users, and the environment.

The definition of efficiency for an urban transit action for operators can be specified as follows: (Black, 1995)

- Appropriate account of travel demand, and true choice of mode through this demand
- Choice of the convenient route between the zones
- Using the transportation modes in their maximum capacities
- Assignment of the types, size and the frequency of the vehicles depending on the calculations
- Considering the operation cost of the system
- Land Use integrated and future projected planning

In general, densities of housing, offices, factories, and shops influence usage of public transport or other land uses. The number of people using public transport determines the form of public transport, which is most suitable in terms of cost and effectiveness in providing a service.

There is also a relationship between lengths of journeys and the public transport modes. Generally long journeys refer the use of high capacity modes. But there are of course exceptions. For example, residential densities in most parts of Paris are much higher than in London whereas journeys to work are shorter. However, there is a relation ship between city population, land use densities and journey lengths by public transport.

The mode choice of relate to the spacing of stops and the number of routes. Closely spaced stops give slow services whereas widely spaced stops give faster services. Buses or minibuses are more suitable for closely spaced stops and dispersed routes, railways for widely spaced stops and concentrated routes.

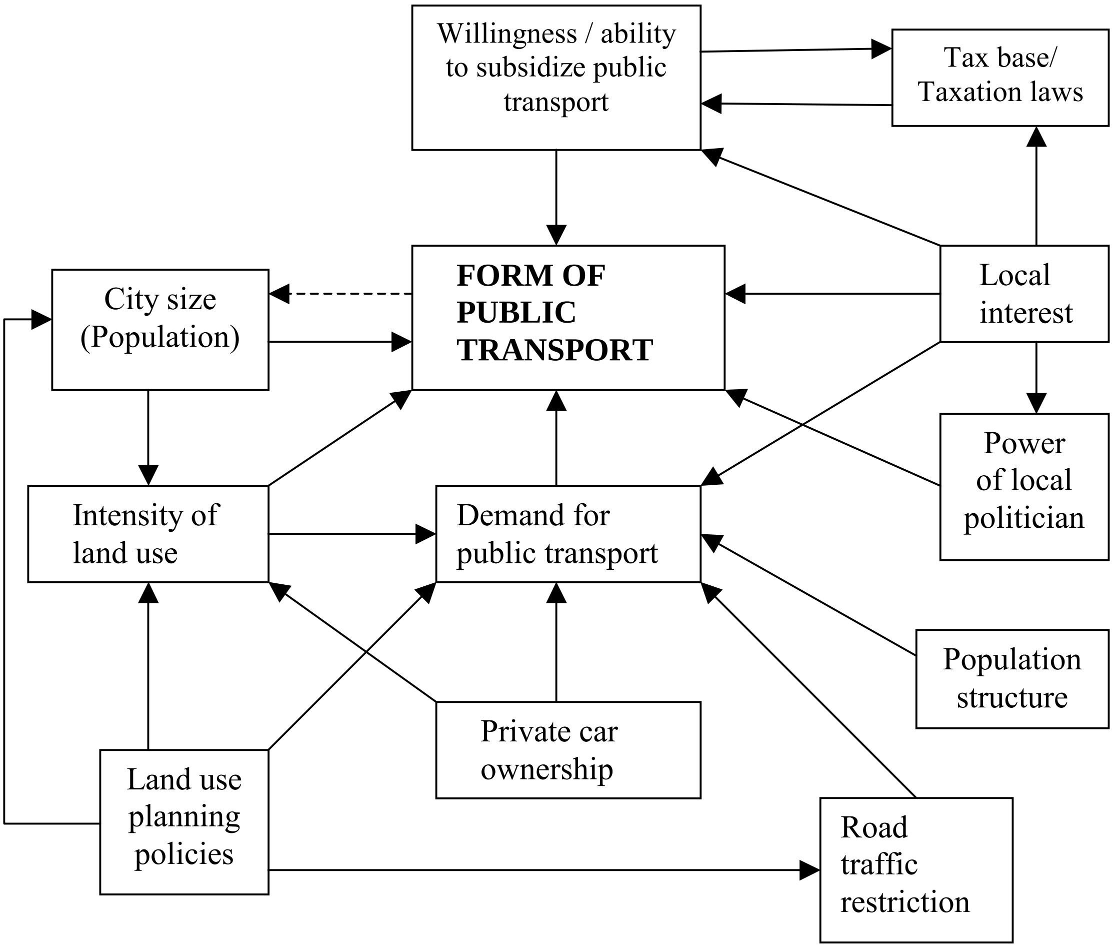

Figure 3. 2 Some factors affecting choice of public transport policies
(Simpson, B. J., Transportation for Cities, 1976)

There are several interconnected factors that are affecting the choice of public transport policies. As seen in figure 3.2, form of public transport is relevant with the local politicians, land use and population of the city and also the demand for public transport.

1.1. Estimating Travel Demand

In general transport planners implement Four Step Planning Process to estimate the appropriate travel demand. The steps can be summarized as follows:

Step 1: Trip Generation

The trip generation model predicts the total number of person trips produced by and attracted to each zone. The study area is distinguished in several zones and an O-D (Origin-Destination) matrix is formed by the data collected.

Step 2: Trip Distribution

Connects trip ends (productions and attractions) to create a flow of trips. There are different models for each trip purpose; the widespread one is the gravity model.

Step 3: Modal Split (Mode Choice)

Estimate the proportions of travelers that will use different transportation modes. Usually the number of person-trips is divided into two modal groups; personal or transit trips.

Step 4: Traffic (or Network) Assignment

Mode specific trips are assigned to networks. Vehicle trips assigned to roadways;

–Transit trips assigned to transit routes

–Generally trips are assigned “all-or-nothing”

–Assigned to minimum cost routes

–Do not consider available capacity

Selection of a transit mode between the zones should be after this four-step planning process. Estimated travel demand must be supplied by the appropriate transit mode according to efficiency concept in urban transit. High capacity mode decision for a low travel demand corridor will cause inefficient transit operation for over-utilizing and under-utilizing the system.

1.2. Designing an Efficient Rail Route

While designing an efficient rail route, the several issues to take care are about choosing routes and stations: (Black, 1995)

- The routes should be as straight as possible, because curves cause delays.
- Routes running through dense activity centers such as commercial areas should be preferred.
- Stations should be placed near dense activity areas providing transit users to be within walking distance
- In the lower density areas, feeder bus routes should be designed rather than the rail terminal, because this is more economical
- Stations should be located at points where bus routes cross, because many passengers reach rail systems by busses
- Deep tunnels should be avoided as much as possible, because they are expensive and also have the disadvantage of increasing vertical travel and train platform.

1.3. Efficient Operating Approach

The operation of mass transportation has many factors, so there is need of functional organization. Its complexity can be seen in the Figure 3.3. In general mass transportation includes three functions, which can be dispersed to its subtitles. These functions are general services, marketing operations and information services. (Dickey, 1983)

- General services are the main objectives of this system that enable to organize servicing. The servicing issues are selection, training and providing safety of personnel, selection of equipment and providing maintenance of the system with a plan.
- Sales, advertising, community relations, transportation services, control routing and scheduling are the functions of marketing and operations.
- Information services are about office services and accounting such as data collection, analysis and records. This function is important to use for management purposes and decision-making.

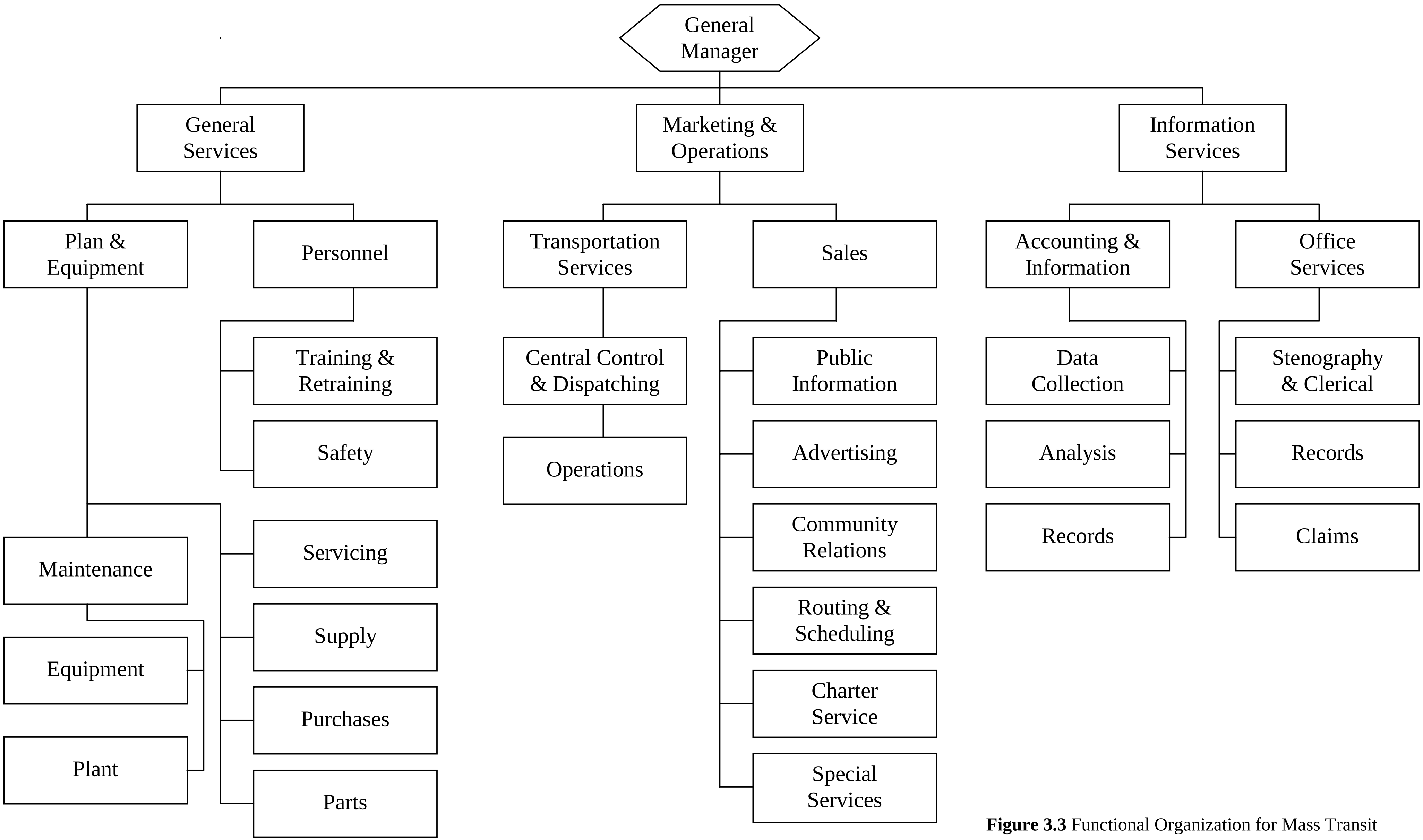

Figure 3.3 Functional Organization for Mass Transit (Dickey, 1983, pp: 555)

2. Method of Comparative Benchmarking Analysis

Comparative Benchmarking Analysis is a tool, which enables to measure efficiency with limited data. It stands on the base of comparing the similar systems and understanding processes of the best practices to improve the system that will be measured. EQUIP* explains four basic steps to define Comparative Benchmarking:

Self-assess to understand your own processes and performance in detail
Analyze others' successful processes and performance.
Compare your performance with that of others you have analyzed.
Implement the necessary changes to close the performance gap.

In this method understanding the best practices and the ability to innovate your system is very important. Every organization has its own specific needs, so you do not copy the others' practices. Comparative Benchmarking is a dynamic process by which the experience you had from the others is adapted to your system. EQUIP expresses that the method evolves with growing experience, and with application to different organizational and cultural settings.

According to EQUIP to benchmark successfully:

- A shared, common vision of the performance improvement goals and objectives
- Open and committed high level support
- The commitment of all stakeholders in the process to progress and change
- A willingness to examine critically one's own practices
- The ability and willingness to co-operate and share information and expertise with others
- To be able to learn from others' best practices
- The flexibility to implement the necessary changes
- Procedures to monitor subsequent progress

Method of benchmarking has applied to many different areas in both private and public sector. It has successful results of improving performance at individual departments or company levels.

There are also groups, which improve their performance continuously by a network between themselves. In mass transit Nova and CoMET are the most known groups of metro organizations. (See page 39)

* EQUIP (Extending the Quality in Public Transport) One of the important studies of Comparative Benchmarking Analysis, see page 42

2.1. Applications of Comparative Benchmarking In Public Transport*

Performance of a system is not only relevant with the technique of it, but also the users' behaviors are important. Thus benchmarking in transport needs qualitative data besides quantitative data. As W. Adeney** defined "*Benchmarking is not only a tool to compare, it also has the potential to be used to respond more effectively to passengers' needs by assessing and comparing their experiences of the transport services where they live*".

One of the organizations of Benchmarking is The Communication that is leaded by Directorate-General Transport of European Commission. It was first presented at a conference on Transport Benchmarking: Methodologies, Applications and Data Needs. They apply Benchmarking as a tool for improving transport. Intensity, modal split and productivity are their indicators to benchmark the transport systems of EU, USA and Japan. There are nine main benchmarking steps of The Communication:

1. Identification of relevant objectives and areas
2. Selection of relevant dimensions
3. Identification of indicators and data needed
4. Data collection, analysis and assessment
5. Identification of benchmarks
6. Analysis of reasons for performance differences
7. Strategy development
8. Implementation
9. Monitoring of results

The communication underlines the possibilities and potentials of Benchmarking to increase efficiency and sustainability in transport policy.

One of the important benchmarking studies of the recent years, EQUIP (Extending the Quality in Public Transport) Project. In this study Comparative Benchmarking is described as a cyclical process. This process includes nine stages (See figure 3.4).

Defining and agreeing on the success factors of the system is the first stage of this cycle. Development and measurement of indicators to measure performance are following this stage. These three stages are the scope of EQUIP.

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* The information in this section is compiled from the site http://www.equipproject.ie
** William Adeney, EQUIP Deliverable, 2000)

The operators compare their performance with the others at the fourth stage. This enables them to discover the weaknesses of their systems as the fifth stage. After identifying the areas to be improved relevant processes are reviewed to learn best practice from benchmark partners.

Operators decide and plan their improvements to implement. Monitoring the performance and reviewing the indicators periodically are necessary stages to start cycle again in this dynamic process.

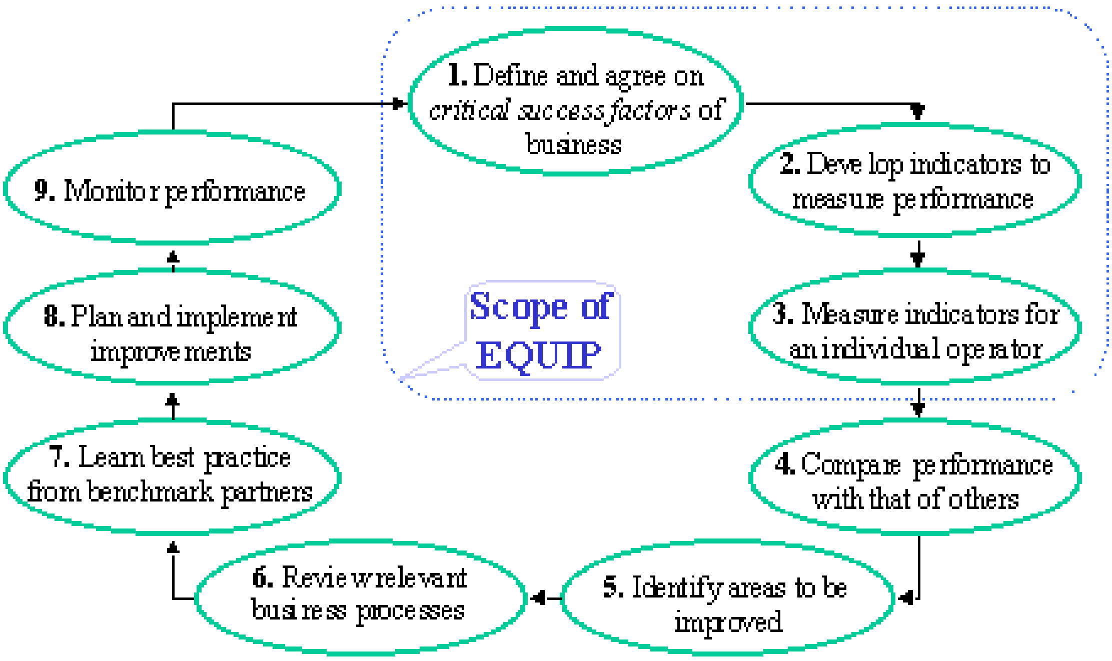

Figure 3. 4 The Cyclical Process of Benchmarking
(EQUIP, State-of-the-Art in Benchmarking of Quality in Public Transport, 2000)

Benchmarking methodology is used in several transport projects especially in Europe. According to the EQUIP Project's literature survey, there are 79 references from which 69 are national reports, journals or publications and 8 from European Union and 2 from United states. Some of these projects are briefly described below.

2.1.1. KiPa-Project

KiPa (Project for Developing and Realizing Competitive Transportation Services) is started in 1997 with 14 inter-urban bus companies. 10 more companies have joined the project in January 2000. Finnish Bus and Coach Association lead this project. Its Benchmarking tools and Methodology are developed by Trans Control Ltd. This private Finnish Company determined a process in which an external expert evaluates the public transport company. The indicators of this project to measure the operators' performance are below:

- Measurement of the current competitiveness on the different areas of business:
    - Customer satisfaction
    - Employee satisfaction
    - Operational efficiency
    - Acquisition of resources
    - Financial performance
    - Strategic Status and Know-how.
- Comparison of each sector of the company's performance against the values of the best practice companies in the business using the confidential Trans Control Database which contains values of the performance indicators of tens of bus companies in Finland.
- Report on the areas of business that need improvement.

They give company a "certificate of competitiveness", which represents company's performance on different factors.

2.1.2. SAMPO Project

The main objective of the SAMPO - (System for Advanced Management of Public transport Operations) project was declared as to improve the possibilities of mobility of citizens in rural and urban areas through the provision of integrated Demand Responsive Transport Services.

They evaluated indicators in four main areas:

- Technical Performance
- Service Provision
- Economic Viability
- Market Projection.

2.1.3. SESAME Project

This project was carried out from January 1996 to April 1998, to construct the database about land use and transport of Europe. 36 European cities from 5 EU countries (Germany, United Kingdom, France, Spain, Netherlands) and Switzerland took part in the project. The main objectives of the SESAME project were:

- To define the relevant indicators of transport, traffic, land use and relevant externalities for transport/land-use planning;
- To analyze the relationships between these indicators in view of deriving a better policies' impacts understanding; and

- Based on the indicators and their relationships, provide an operational framework for evaluating and effectively planning local policies (a database structure, guidelines for surveys, reference scenarios and analytical methods for exploitation).

They analyzed the relationship between land use partners, transport supply and travel demand. Their aim was to support political and investment decisions in the field of integrated urban land use and transport planning. To improve knowledge they provided:

- A selected choice of transport and land use indicators
- A detailed description of data sources and definitions
- A Pan European database built with these indicators
- A qualitative and quantitative analysis of the indicators

Comparative Benchmarking was also used in several Urban Transport Projects. Some of them are:

- Mongolian Urban Passenger Transport Project (1995-1997)
- Institutional Reform in the Public Transport System of Medium Sized Cities (Russia, 1996-1998)
- Public Road Passenger Transport Master Plan (Latvia, 1996-1997)
- Urban Passenger Transport project (Uzbekistan, 1998)

2.2. Comparative Benchmarking In Metro Systems CoMET and Nova*

Since 1995, the method of Comparative Benchmarking has been applied to metros within the groups that enable data share and the investigation of best practices between each other.

One of the benchmarking groups is COMeT that started with 5 Members in 1995 and had 9 members in 1999.The other group is NOVA Club that started with 7 large and medium sized Metros in 1998.

2.2.1. **CoMET -** (the Community of Metros)

CoMET that established in 1995 includes nine of the world's largest urban railways; Berlin, Hong Kong (MTRC), London, Mexico City, Moscow, Paris, New York, Sao Paulo, and Tokyo (TRTA). The project functions "*to identify and implement*

* Information of this section is from; Adeney, W., Indicators - lessons learned from the CoMET and Nova metro railway benchmarking studies, Imperial College, London, 2001

best practice through benchmarking comparisons and analytical case studies"(Adeney, 2001). A key performance indicator system is developed in the process.

The original objectives of CoMET were defined as below:

- To build a system of indicators to identify best practice, which can then be accepted and used by the participants,
- To use this system of indicators for internal management,
- To help priorities areas for improvement internally, and in addition,
- To provide comparative information for the Board, Government or Regulator.

2.2.2. Nova

Nova was established in 1998 as the second group of metros that apply the method of Comparative Benchmarking. Its members are 7 medium sized metro systems; Glasgow, Hong Kong (KCRC), Lisbon, Madrid, Newcastle, Oslo, and Singapore.

2.2.3. Experience of CoMET and Nova

Three types of performance indicator have been improved by CoMET and Nova; Operations based, customer focused and city context. (Adeney, 2001)

> "Operations based - a system of 32 operational performance indicators, 17 top level and 15 secondary indicators representing six functional areas of the railway business:
>
> | | |
> |---|---|
> | Asset Utilization, | Service Quality, |
> | Efficiency, | Financial, |
> | Reliability, | Safety |
>
> The data set behind this set of indicators is collected to standard definitions by all 16 metros of CoMET and Nova, on an annual basis, and there is now time series data for up to 7 years.
>
> Customer focused - a standardized customer survey is being used to develop a set of "soft" indicators and data is now collected every two years through a standardized customer satisfaction survey. This allows us to benchmark customer satisfaction over a range of issues between the 16 participants.
>
> City Context – structured indicators are currently being developed for the relationship between metros and cities in which they are situated. For example:
>
> - City effects - such as demographics, land use and city governance,
> - Demand – modal share, relative prices, and
> - The relationship between cities and metro performance."

NOVA and CoMET underline the necessity of performance indicators and their usage in benchmarking process. "…*they do not provide complete answers in themselves. Performance indicators should be used to identify differences between* *benchmarking partners, and changes in organizations over time. They act as pointers to identify areas or subjects for further analysis."*(Adeney, 2001)

3. The Use of Comparative Benchmarking Analysis

Comparative Benchmarking typically involves the use of partial productivity measures. So it can be carried out with limited data, and the results are easy to understand.

A common criticism of comparative benchmarking exercises is that they do not take account of the potential substitutability of different factors of production. However, in the case of Mass Rapid Transit, there are multiple outputs rather than inputs.

NERA[*] in its draft final report listed the following indicators as an example to measure the performance of the rail systems:

- Average cost per veh-hr or veh-km
- Comparison of operating cost, capital investment with budget
- Vehicle-hrs or km
- Veh-hrs / vehicle or veh-km / vehicle
- Revenue veh-hr / total veh-hr
- Crew-hrs paid / revenue veh-hr
- Vehicles in service in peak / vehicles between peaks
- Lost veh-km (categorised by missing staff, vehicles, congestion)
- Categorisation of fleet by type, capacity, age
- Number of breakdowns in service per 1000 veh-km
- Maintenance workers per vehicle
- Accidents per 1000 veh-km
- Revenue / cost ratio

[*] NERA, **Review of Overseas Railway Efficiency**, A Draft Final Report For The Office of the Rail Regulator, London, 2000

3.1. The EQUIP Project

One of the important studies of Comparative Benchmarking Analysis in public transport is the Project EQUIP (Extending the Quality in Public Transport) that aims to develop a Handbook in this field. The main source of this study is the literature, the results of other projects dealing with quality and benchmarking in public transport. Its Handbook will enable urban transport operators to self-asses their internal performance.

The EQUIP project is important with its countless indicators and the systematic classification of these indicators. It has developed 12 main clusters from the indicators. (See Table 3.1)

Table 3. 1 The list of the main clusters of EQUIP Project (EQUIP, 2000)

Cluster	Level
Asset/Capacity utilization	Service delivered (operator) *Strong and direct influence of the operator*
Reliability	
Production costs	
Financial performance	
Technical performance	
Payment method	
Environmental impacts	
Employee satisfaction	
Strategic status	
Customer satisfaction	Service perceived (Customer, end-user) *Indirect influence of the operator*
Safety and security	
Legal and operational framework	Operational Framework *Normally low influence of the operator*

The units that used in the EQUIP Project are below;

- a = year
- km = kilometer
- h = hour
- min = minute
- veh. km = vehicle kilometer
- pass. km = passenger kilometer

For example; the indicators that classified into Asset/Capacity utilization cluster (See table 3.2) measure "*how efficiently the operators utilize their fleet and how efficient is their service in terms of patronage levels.*" (EQUIP, 2000)

Table 3. 2 The list of Asset/Capacity utilization indicators (EQUIP, 2000)

Name of the Indicator	**Definition**
Average to off-peak vehicles in service ratio [-]	Ratio of average number of vehicles in service (normal non-peak time) to minimum level in scheduled service during the day
Boarding time [min]	Average boarding time over all stops/station (representative sample)
Driver utilizations [h/driver]	Vehicle hours a year divided by total number of drivers
Driver utilization [veh.km/driver]	Vehicle km a year over total number of drivers (representative sample)
Load factor [-]	Ratio of passenger kilometers per seat kilometers
Operating speed [km/h]	Average trip length (km) divided by actual journey time (h) – measurement of real journey time
Passenger km [pass.km/veh.]	Passenger km per vehicle in operation
Peak to off-peak ratio [-]	Ratio of maximum vehicles in service (normally morning peak) to minimum level in scheduled service during the day
Stopping-time [min]	Average stopping-time (min) related to average traveling-time measurement of a sample
Total staff per vehicle owned [persons/veh.]	Total staff divided by total number of vehicles owned
Total to off-peak ratio [-]	Ratio of total number of vehicles (in service + spare fleet) to minimum level in scheduled service during the day
Total vehicle-km per staff [km/person]	Total vehicle-kilometers divided by total number of productive staff
Vehicle life (by vehicle type) [km/veh.]	Total number of kilometers achieved per vehicle during its economic life
Vehicle utilization [h/veh.]	Vehicle operation hours a year over total number of vehicles

EQUIP defined 6 indicators to measure the reliability of the transport system. They are suitable for international benchmarking because they are comparable and not dependent on monetary units.

Table 3. 3 The list of Reliability Indicators (EQUIP, 2001)

Name of the Indicator	**Definition**
Actual public transport runs operated [%]	Percentage of planned trips which are actually operated
Cancelled runs [-]	Percent of cancelled runs in relation to total runs
End point punctuality [%]	Percentage of late arrivals (equal to or more than 5 min. late) at a selected timing end-point over total number of public transport runs (representative sample)
Fleet reliability [Number/10^6 veh.km]	Number of breakdowns over 10^6 vehicle km
Starting punctuality [%]	Percentage of late departures (equal to or more than 5 min. late) over total number of public transport runs (representative sample)
Timing point punctuality [%]	Percentage of late trips (equal to or more than 5 min. late) in a selected timing point (stops/station) over total number of public transport runs (representative sample)

Production cost indicators (See table 3.4) measure how efficiently the operator is able to provide the service with the available resources.

Table 3. 4 The list of Production cost indicators (EQUIP, 2000)

Name of the Indicator	Definition
Costs per number of employees [Euro/a]	Each cost component (1 to 7) divided by total number of employees
Costs per operating hours [Euro/a and h]	Each cost component (1 to 7) divided by total number of operating hours
Costs per passenger journeys [Euro/a]	Each cost component (1 to 7) divided by total number of passenger journeys
Costs per passenger km [Euro/a and km]	Each cost component (1 to 7) divided by total number of passenger km
Costs per turnover [Euro/a]	Each cost component (1 to 7) divided by turnover
Costs per vehicle km [Euro/a and km]	Each cost component (1 to 7) divided by total number of vehicle km
Costs per vehicles [Euro/a and veh.]	Each cost component (1 to 7) divided by total number of vehicles
Costs per working hours [Euro/a and h]	Each cost component (1 to 7) divided by total number of working hours
Cost-structure [%]	Percentage of total cost: 1. Wage bill, 2. Maintenance costs (excluding salaries), 3. Annual cost of fleet ownership, 4. Insurance cost, 5. Energy cost, 6. Marketing & Promotion cost, 7. Other costs

The financial performance indicators (See Table 3.5) measure the overall financial performance of the operator. These indicators can mainly be derived from the production cost indicators.

Table 3. 5 The list of Financial performance indicators (EQUIP, 2000)

Name of the Indicator	Definition
Costs per number of employees [Euro/a]	Total cost/number of employees
Costs per operating hours [Euro/a and h]	Total cost/operating hours
Costs per passenger journeys [Euro/a]	Total cost/passenger journeys
Costs per passenger km [Euro/a and km]	Total cost/passenger km
Costs per turnover [Euro/a]	Total cost/turnover
Costs per vehicle km [Euro/a and km]	Total cost/number of vehicles
Costs per working hours [Euro/a and h]	Total cost /total number of working hours
Cost recovery ratio [%]	Percentage of total costs recovered from operating revenue (i.e excluding subsidy)
Operating profit/loss [%]	Total revenues (including subsidy) divided by total cost

Technical performance of the operator can be measured by 6 indicators according to the EQUIP project. They measure how efficiently the operator uses technical devices e.g. for fleet management, communication between vehicles and fleet management center and transactions.

Table 3. 6 The list of Technical performance indicators (EQUIP, 2000)

Name of the Indicator	Definition
Average age of the vehicle-fleet [years]	Average age of the vehicles in regular service, divided by different modes as busses, trams, metros, regional-trains)
Automatic vehicle location (AVL) [%]	The percentage of network covered by AVL system
Communication system [-]	Use of communication system between vehicle (driver) and control-centre. Rate 0=none, 1=voice, 2=data)
Frequency [min]	Mean time-table headway of all lines in minutes (peak-time, off-peak-time on week-day, off-peek-time on Sunday).
Speed [km/h]	Travel speed km/h (City-centre, low density area, and rural area)

Chapter 4

APPLICATION OF COMPARATIVE BENCHMARKING ANALYSIS TO THE İZMİR'S CASE

1. Current Transport Supply Systems of İzmir

Geographical location of İzmir is available to all main types of transportation systems, which are aviation, waterways, railways and highways.

1.1. Regional, National and International Connections

The international airport Adnan Menderes is located 18 km south of İzmir near Cumaovası. Domestic and international flights are provided by Turkish Airlines and also by other international Airlines. Buses and the railway are connecting the airport with the center of İzmir.

There is also an international harbor in the bay of İzmir and the Turkish Maritime Lines operate ferry services linking İzmir to İstanbul and Venice (Boesefeldt, 1990).

The railway system of İzmir was part of the national railway network and it was operated by Turkish State Railways (TCDD). It is currently modernized by TCDD. The line between Aliağa and Cumaovası that is 80 km long will be the suburban railroad of İzmir. It will be powered by electricity from overhead wire.

The main roads that connect İzmir to the surrounding regions are seen in the figure 4.1. Metropolitan buses and minibuses are operating between İzmir and the towns around the city. The main bus terminal is located 6 km east of İzmir near Işıkkent.

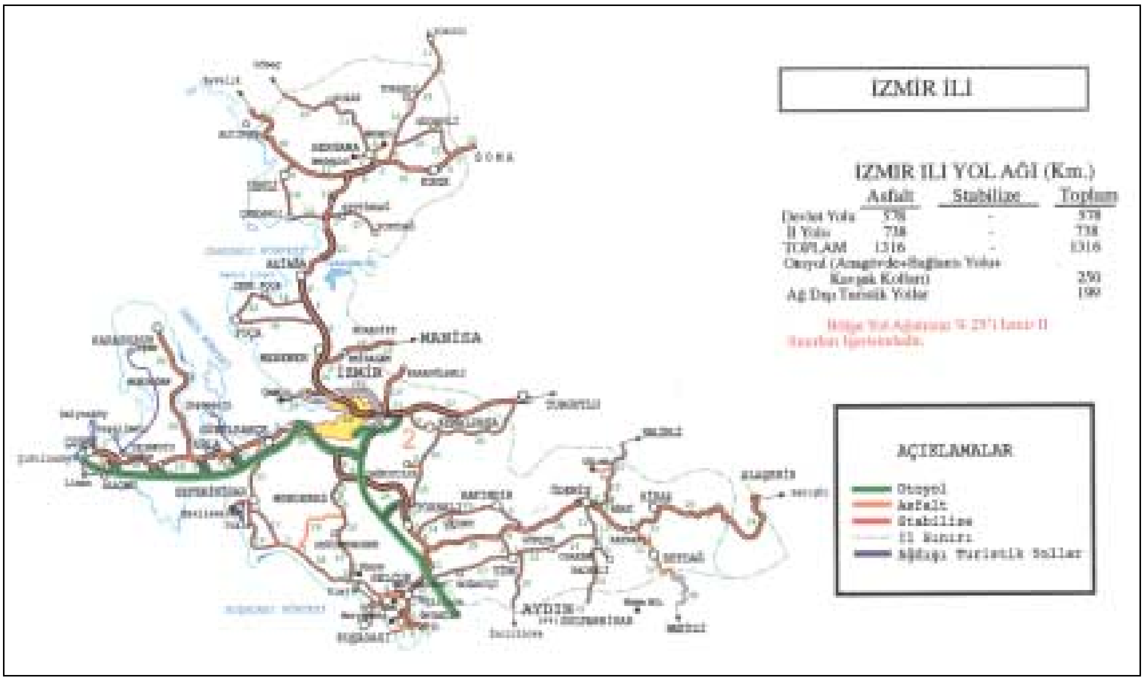

Figure 4. 1 Main Higways of İzmir (TCK, İzmir Bölge Müdürlüğü, 2000)

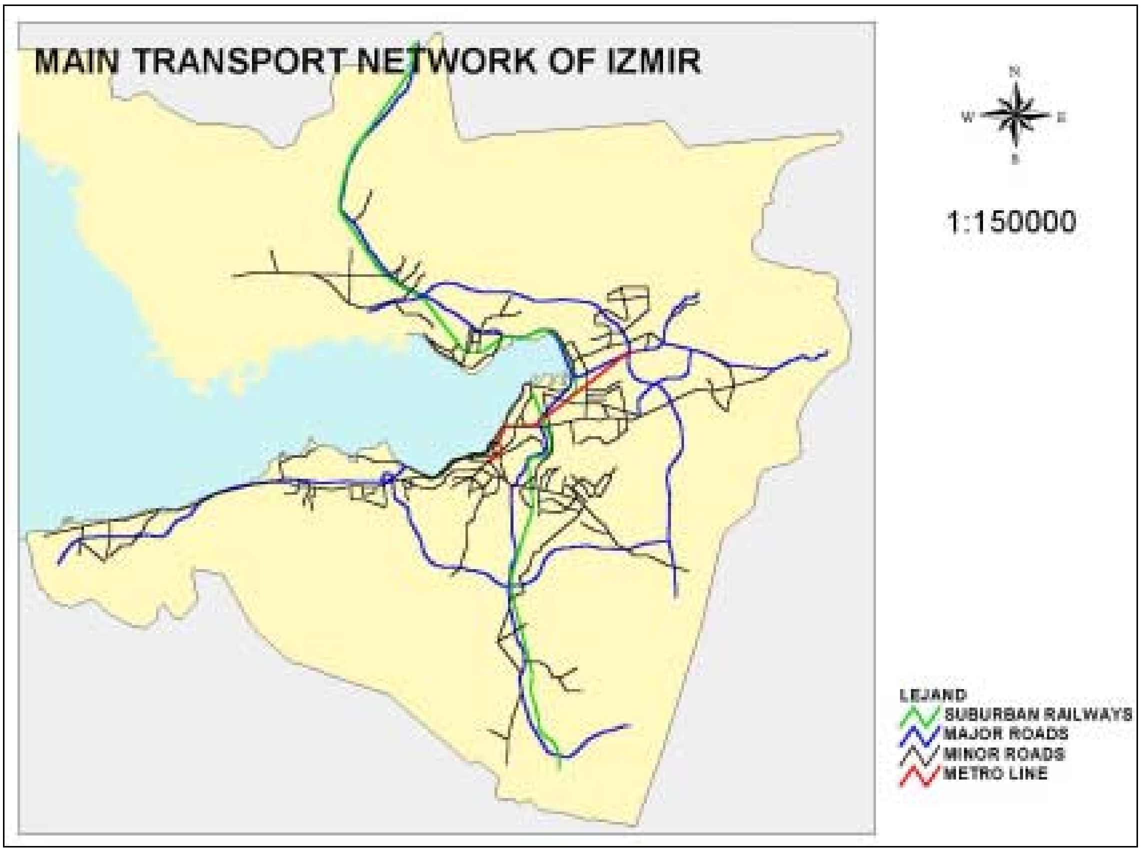

Figure 4. 2 Main Transport Network of İzmir Metropolitan Area
(Derived from the city map of İzmir Metropolitan Area, 1998)

1.2 Urban Transport Systems

The previous transport studies done for İzmir were as follows:

- 1969 Eylül, Tekser İzmir İstikşafi Ulaşım Etüdü
- 1974 Haziran, İzmir Ulaşım Etüdü (Jameson, Mackay and Partners)
- 1980 Ağustos, İzmir Toplu Taşim Optimizasyon Etüdü (OECD Raporu)
- 1989 Ocak, Mevcut Ulaşım Sistemleri Raporu (İzmir Belediyesi)
- 1989 Şubat, İtalyan Transystem Firmasiyla Ulaşım Etüdü Anlaşmasi
- 1992 Nisan, Heusch Boesefeldt Ulaşım Etüdü Raporu (İzmir Hafif Raylı Sistemi Teklif Dosyası)
- 1998, İzmir Ulaşım Master Planı Güncelleştirme Raporu, Boğaziçi Üniversitesi, Yapı Teknolojisi Uygar Merkezi

Transport network of İzmir was constituted of bus, ferry, railway, and other private modes (taxi, dolmuş and service buses) until the operation of metro (See table 4.1). Transit major stations of this system were Montrö, Konak, Karşıyaka, Bornova, Buca and Fahrettin Altay. (See figure 4.3)

Table 4. 1 Average Number of Passengers Per Day*

Years/ Modes	1969	1984	1989	1990	1996	1997
RAIL	28,321	23,660	28,900	30,000	40,000	6,600
FERRY	31,593	25,381	30,480	30,000	40,000	27,600
BUS	277,947	753,043	800,000	700,000	1,000,000	931,500
TOTAL MASS TRANSIT	337,861	802,084	859,380	760,000	1,080,000	965,700
TAXI & DOLMUŞ	216,764	73,680	105,876	225,000	310,000	225,000
PRIVATE CAR	31,181	113,000	281,000	585,000	940,000	780,000
MINIBUS	10,000	373,050	459,159	460,000	540,000	520,000
TOTAL	585,806	1,361,814	1,705,415	2,030,000	2,870,000	2,490,700

* Adapted from the previous transport studies of İzmir and the data given by the municipality.

Figure 4. 3 Bus Routes of İzmir in 1998 (İBŞB, Eshot Genel Müdürlüğü)

In 2000, Municipality of İzmir tended to the integration of the different modes of mass transit with the contribution of metro mode. The metro is considered to be the backbone of mass transit in this integration project. Figure 4.4 shows the draft of the new transit system of İzmir. According to the municipality, integration consists of:

- Network Integration: Completion of different modes' routes.
- Tariff Integration: Adaptation of timetables of different modes.
- Toll Collection: Use of smart card "Kentkart" in all modes
- Feeder Lines: New short lines to support metro and ferry
- Graduated Pricing: Pricing via length of routes

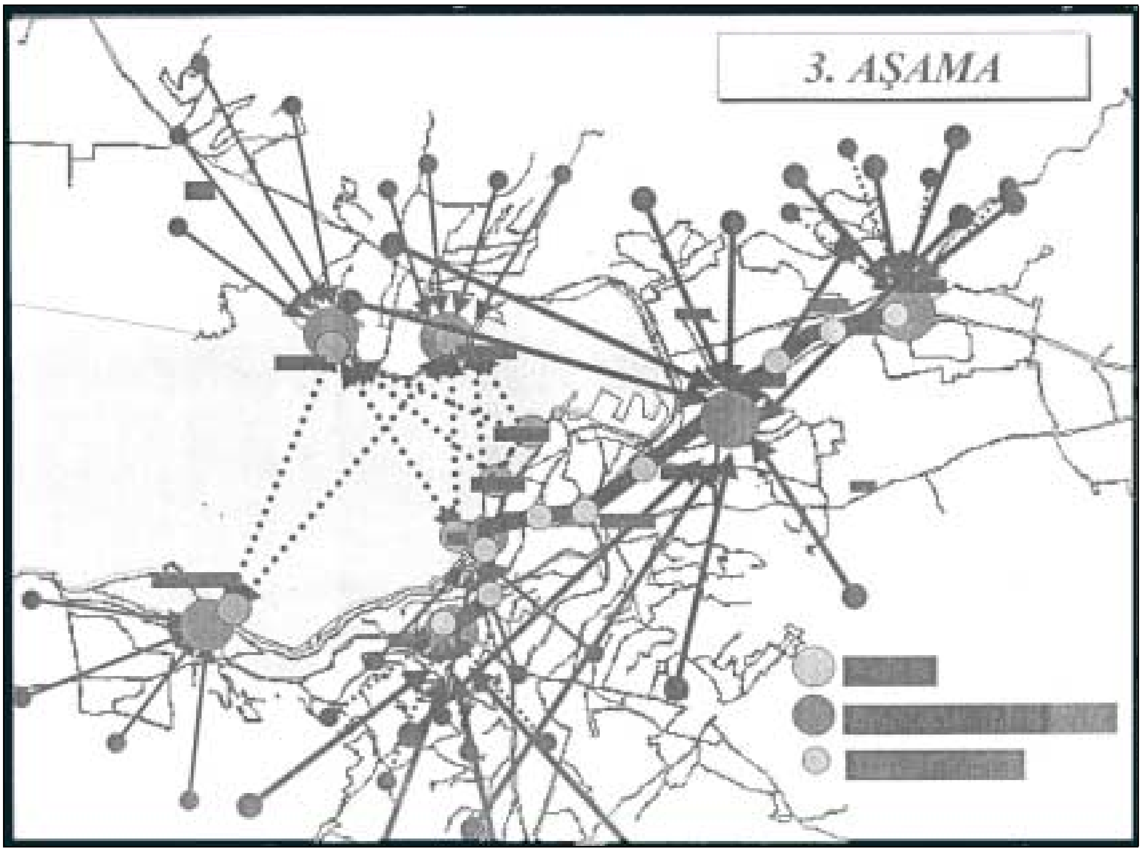

Figure 4. 4 Draft Diagrammatic Network of İzmir Mass Transit System, 2001
(İBŞB, Eshot Genel Müdürlüğü)

After the metro service and adaptation of integration as transport policy, the total mass trips and the distribution rates of these trips to the modes have changed. (See table 4.4) The population of İzmir at the same year was 2,250,149 (DİE, İzmir).

Table 4. 2 Distribution Rates of Mass Transit Modes, 2000

Year 2000	Distribution Rate of Mass Transit Modes %			Total Number of Trips
	Bus	Ferry	Metro	
January	98	2	0	21,200,000
March	-	-	-	23,100,000
April	97	3	0	-
May	-	-	3	23,950,000
June	93	4	3	21,950,000
August	92	5	3	20,000,000
September	91	5	4	24,000,000
October	88	4	8	24,550,000
November	87	4	8	25,550,000
December	85	4	11	22,800,000

(İBŞB, UKOME, Center for Coordination of Transportation)

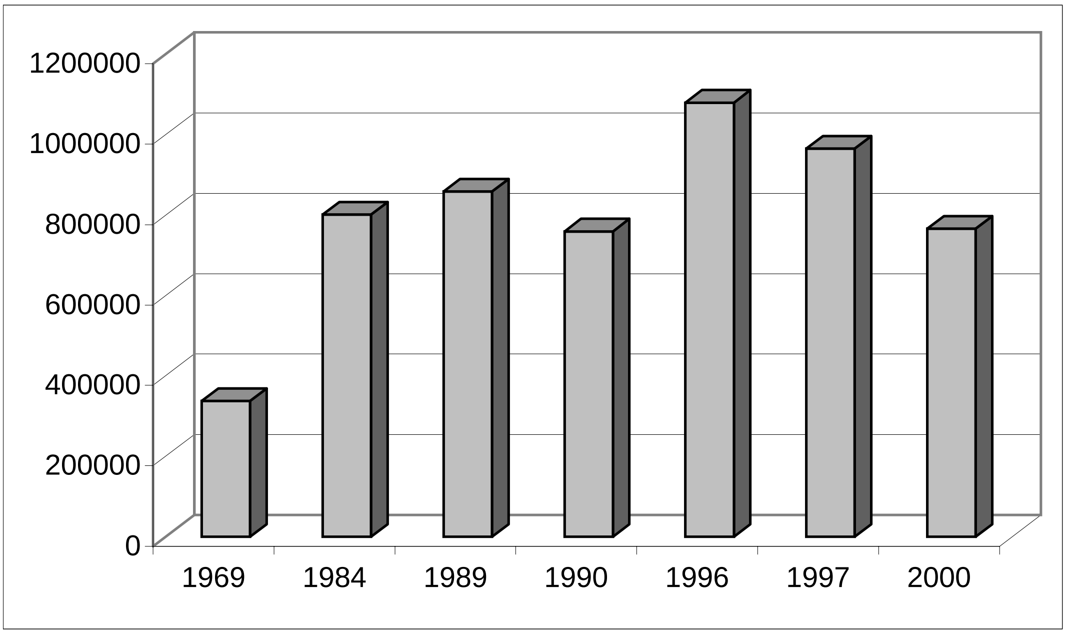

Figure 4. 5 Number of mass transit trips per day for years

(Adapted from the previous transport studies of İzmir and the data given by the municipality)

The data of the years 1996-1997 was taken from the study of Boğaziçi University (1998, İzmir Ulaşım Master Planı Güncelleştirme Raporu) and the year 2000's data was given by the UKOME. If the data of the reports are reliable, it can be said that:

- The increase of a city population does not always mean that there will be increase in the number of mass transit trips in the city.

Table 4. 3 Increase of Population within the municipality boundaries of İzmir (İBŞB)

YEARS	POPULATION OF PROVINCE	POPULATION OF İBŞB	POPULATION INCREASE OF iBŞB	INCREASE RATE OF İBŞB POPULATION
1965	1,024,667	601,000	-	-
1970	1,427,173	796,000	195,000	5,8%
1975	1,673,966	985,000	189,000	4,4%
1980	1,976,763	1,191,000	206,000	3,8%
1985	2,317,829	1,490,000	299,000	4,5%
1990	2,694,770	1,757,000	267,000	3,3%
1995	3,133,012	2,431,000	674,000*	6,5%
2000**	3,642,523	2,740,000	309,000	2,4%
2005**	4,234,895	3,074,000	334,000	2,3%
2010**	4,923,602	3,431,000	357,000	2,2%

(Adapted from the previous transport studies of İzmir and the data given by the municipality)

* In 1993 Elections, İBŞB population increased remarkably with the participation of Çiğli, Balçova, Narlıdere, Güzelbahçe ve Gaziemir settlements.

**Population Projection of İzmir Ulaşım Master Planı, Güncelleştirme Raporu, 1997

According to the Heusch Boesefeldt report (1992 Nisan, Heusch Boesefeldt Ulaşım Etüdü Raporu) the increase in city population would bring the following trips in 2010:

- İnönü Street daily 180,000 ppd (passengers per direction)
- Eşrefpaşa Street daily 210,000 ppd
- Varyant Street daily 300,000 ppd

From this point of view, Boesfeldt compared the capacities of three mass transit modes (See table 4.4). Metro, Light Rail, and Bus (not the bus travel ways, bus only lanes or BRT systems). As mentioned in chapter 3, the capacity of the bus travel ways, bus only lanes and bus rapid transit systems are higher than the ordinary bus systems. However, Heusch Boesfeldt did not consider such systems. In the report, Boesfeldt proposes at least a rail system to provide its estimated trips for the year 2010.

In this case, Vuchic's ROW categorization becomes important for the planners who should propose a mass transit system to response the travel supply. They should first decide the ROW category for the estimated trips rather than the mass transit mode at the moment.

Table 4. 4 Boesefeldt's capacity comparison of the rail and bus systems

MODES	Capacity		Headway	Average speed (km/h)
	Pass/veh	Pass/phpd		
Metro	750	15,000-40,000	1.50-5.00	30-40
LRT	300	5,000-30,000	2.50-5.00	25-35
Bus	100	500- 8,000	0.75-10.00	10-25

(Heusch Boesefeldt Ulaşım Etüdü Raporu, 1992)

2. Application of the Method

In this section, the method of comparative benchmarking analysis will be used to measure the efficiency of İzmir Metro System. The last stage of the method, which is to improve the performance of the system, will not be considered here, but left to the operator's initiative. Because this method -especially the last stage- requires a real benchmarking group and this group should share their data with each other.

The following flow chart will be applied in the method:

- **Self Assessment:**
  Obtaining geographical and quantitative data of İzmir Metro
  A general evaluation of İzmir Metro through this data
- **Selection of Similar Systems:**
  Determining similarity criteria for metro systems
  Finding several rail systems similar to İzmir Metro
- **Indicators:**
  Determining the performance indicators of metro systems through efficiency concept
- **Comparison & Benchmarking:**
  Comparing the performance of the systems through the indicators
  Identification of benchmarks
  Evaluation of İzmir Metro's performance through these benchmarks

2.1. Self Assessment

Current mass rapid transit system of İzmir is the metro line between Üçyol and Bornova as seen in the figure 4.6.

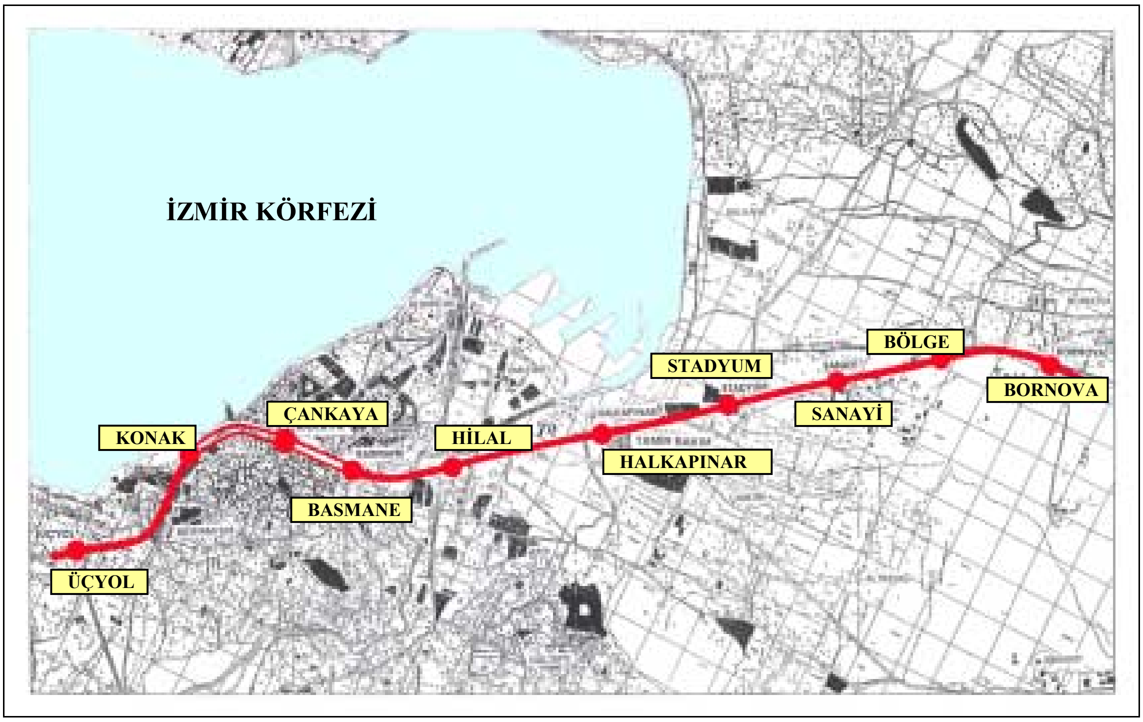

Figure 4. 6 First Stage Route of İzmir Metro (İzmir Büyük Şehir Belediyesi)

In 1989, Heusch und Boesefeldt Company started its studies and prepared a Transport Master Plan for İzmir in 1992. According to this plan they proposed 50 km long metro system for İzmir, for the target year 2010. The construction was started in 1994 and the first stage was finished in 2000.

Current line of İzmir Metro has 10 stations and it is 11.6 km long. Different types of stations were used, because of the topography of the route (see figure 4.7). The stations Üçyol, Konak, Çankaya and Basmane are underground, Hilal and Stadyum are elevated, Halkapınar, Sanayi and Bölge are at level, and Bornova is U type tunnel (See figure 4.7). Total length of the tunnels is (from Üçyol to Basmane) 4.5 km. The length of the elevated section is 2.8 km; 3.6 km length at level and 0.7 km is U type tunnel. Total capital cost of the system is 604,000,000 $.

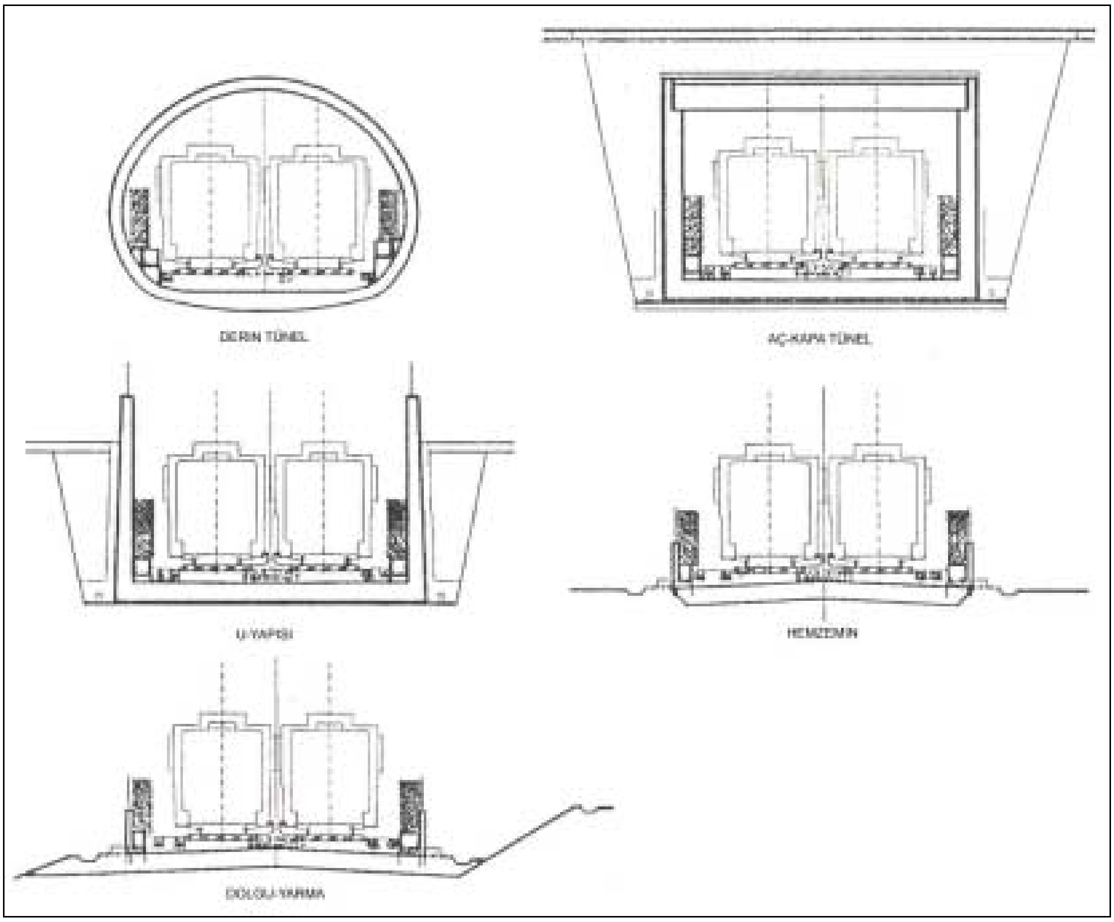

Figure 4. 7 Types of Stations (Türkyılmaz M., Metro İstasyonlarının Arazi Kullanım Kararlarına Etkisi, Bornova Örneği, DEÜ-City Planning, 1996,page; 79)

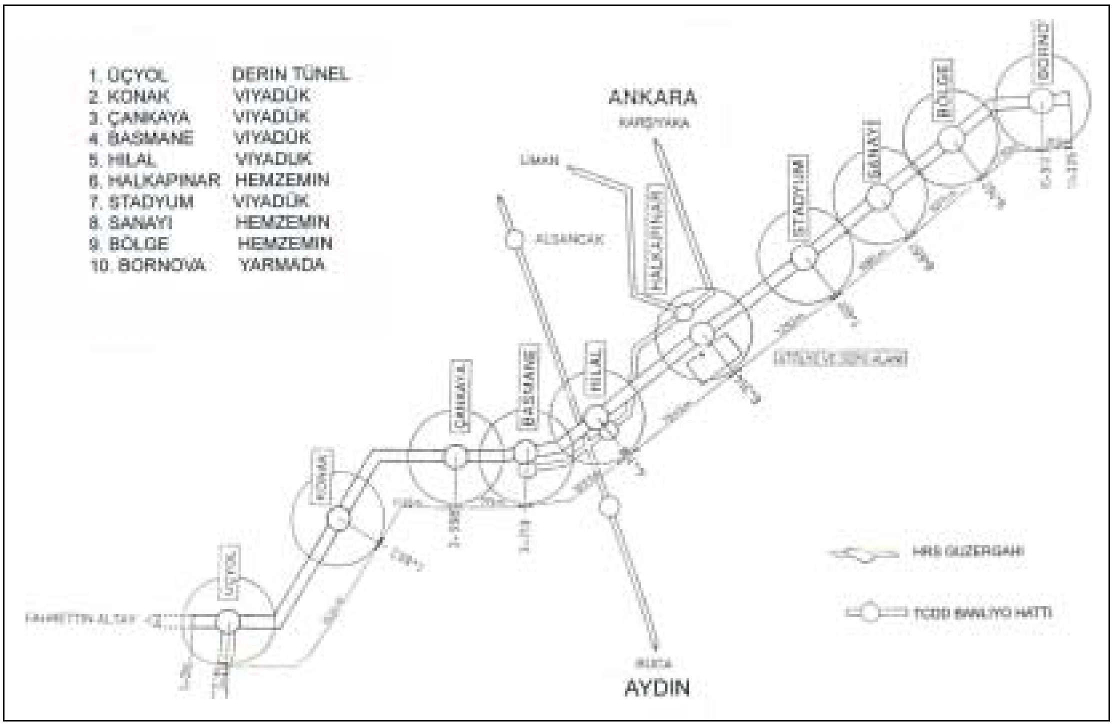

Figure 4. 8 Locations and Types of İzmir Metro Stations (Türkyılmaz M., Metro İstasyonlarının Arazi Kullanım Kararlarına Etkisi, Bornova Örneği, DEÜ-City Planning, 1996,page; 80)

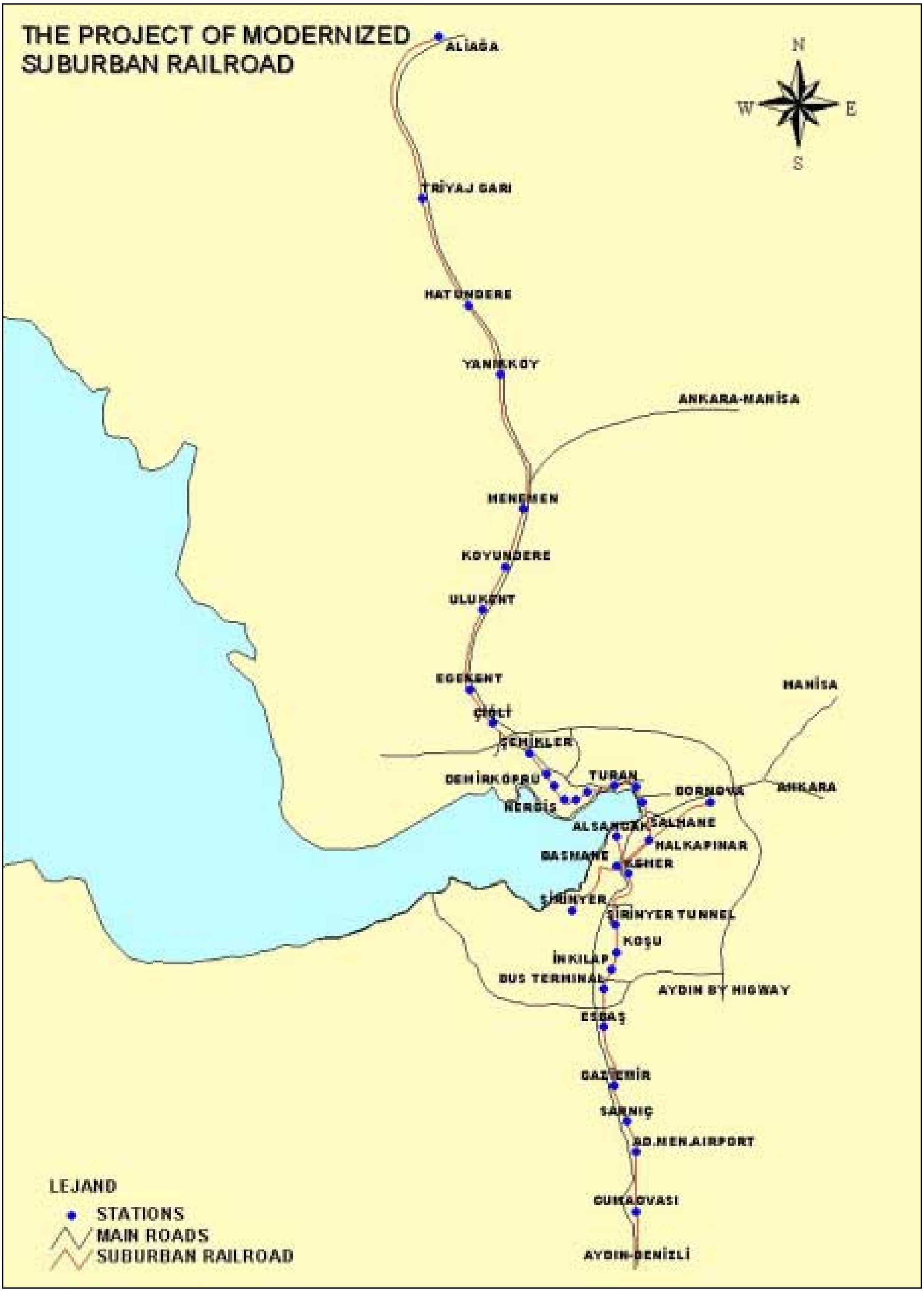

Figure 4. 9 İzmir Metro and TCDD Suburban Railroad Routes (İBŞB Rail System Department)

The second stage of İzmir Metro is going to be Üçyol-Fahrettin Altay Route. The length of this route will be 5.2 km and it will have 5 stations. The whole route will be underground. When the second stage will be completed, it is going to constitute a 17 km effective transport route with 15 stations on the way where dense traffic flow occurs.

Moreover; totally 97 km effective transport opportunity is going to be created when Aliağa-Adnan Menderes route has completed as metro standards. Final system is going to reach 50 km with Buca, Çiğli and Narlıdere extensions and Üçyol-Halkapınar route will be the "backbone route" for these extensions in the 2000's (İzmir Metro A.Ş.). The whole network of İzmir Urban Rail System is seen in figure 4.9.

Technical characteristics of the current system given by the staff of İzmir Metro is on the table below:

Table 4. 5 Technical Characteristics of İzmir Metro

Total Length	11.6 km
Travel Time (Üçyol-Bornova)	16 min 23 sec
Maximum Capacity	1,700,000 passengers / day
Peak Hour Capacity	45,000 pphpd (pass. per hour per direction)
Feasible Capacity	400,000 passengers / day
Average Trip Length	6 km / passenger

Frequency	2.5 min
Number of Vehicles in Series	3-4-5 vehicles
Total Number of Vehicles	45 vehicles

Maximum Speed	80 km / hour
Commercial Speed	40 km / hour
Distance Between Two Stations	0.6 – 1.6 km

Number of Passenger Seats	45 person
Number of Passenger on Foot	8 p/m^2 280-264 person
Maximum Passenger Capacity	300 p / vehicle

As seen in the table, the feasible capacity is already defined as 400,000 passengers/day whereas average daily number of trips is 68,371 passenger/day. This shows that the system is not efficient from the economists' point of view.

Smart card system "Kentkart", and token is being used for ticket collection, so the trips can be counted perfectly. The figure below gives the number of passenger per day for each month of the year 2001.

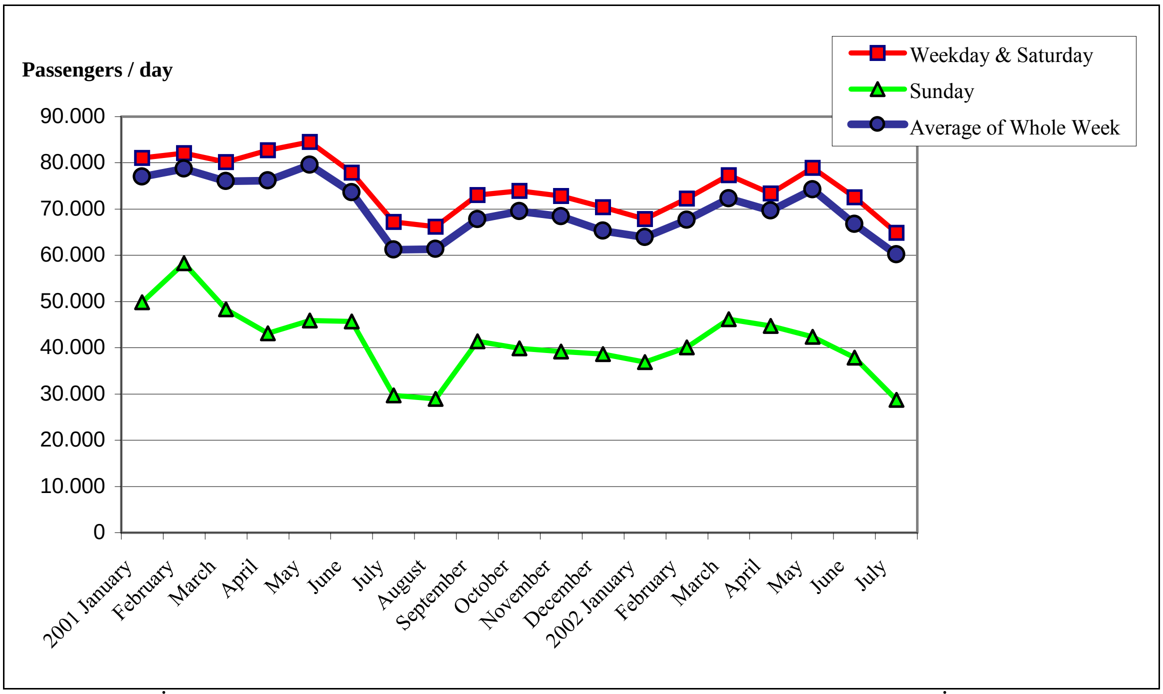

Figure 4. 10 İzmir Metro Travel Demand Trend of the Year 2001-2002 (İzmir Metro A.Ş.)

Chart shows that the utility is the lowest in July and August. If the 17% home-school trips (figure 4.15) considered, it can be interpreted as the result of school holiday. Through the year 2001 data, approximate annual revenue of the system is compiled on the table below.

Table 4. 6 Average Number of Trips & the Calculation of Revenue*

Ticket	Rate	Dispersion of Passengers		Ticket Fee**	Revenue (TL/day)
Smart Card	0.63	0.63X71,152=	44,825.76	450,000 TL	20,171,592,000
Reduced SmartCard	0.27	0.27X71,152=	19,211.04	325,000 TL	6,243,588,000
Token	0.10	0.10X71,152=	7,115.20	750,000 TL	5,336,400,000

Daily Average # of Trips:	71,152 pass./day	**Daily Total Revenue**	31,751,580,000 TL
Hourly Average # of Trips:	3,953 pass./hour		19,850$**

Annual # of Trips (2001)	25,970,398 pass./year	**Annual Rev.**	7,245,250$**

**Compiled from the data given by the Metro A.Ş*
***September 2002*

İzmir Metro A.Ş. surveyed on passengers about their travel behaviour in December 2001. Average walking time -to stations or from stations to destinations- is 9 minutes that refers to 800-metered radius catchment area for each station.

Figure 4.11 shows the land use distribution around the current line. The amount of each land use type in the catchment area of the line is compiled and shown in the figure 4.12.

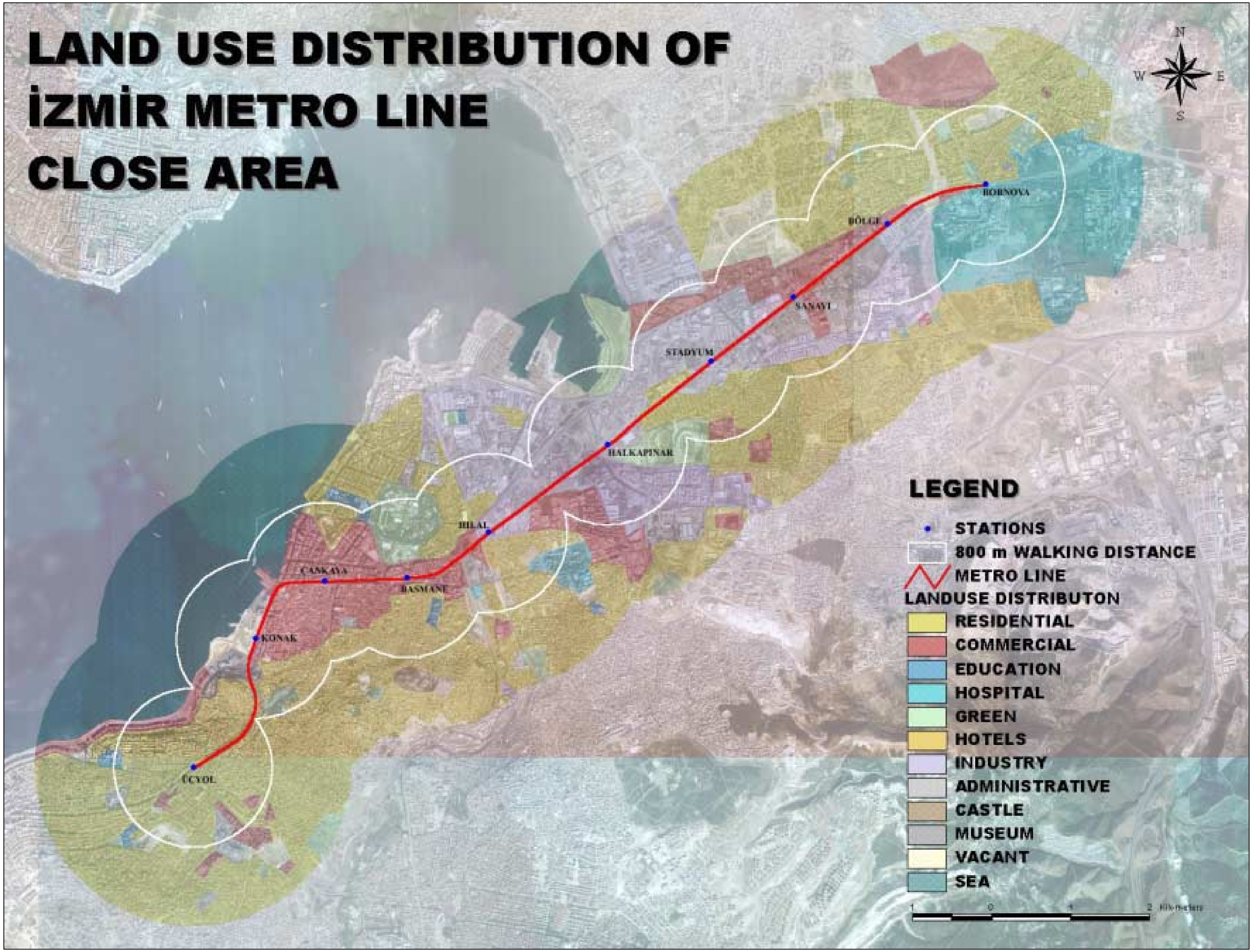

Figure 4. 11 Land use distribution of İzmir Metro close area (Satellite view of the year 2000 is obtained from the archive of Inst. Dr. Ömür Saygın)

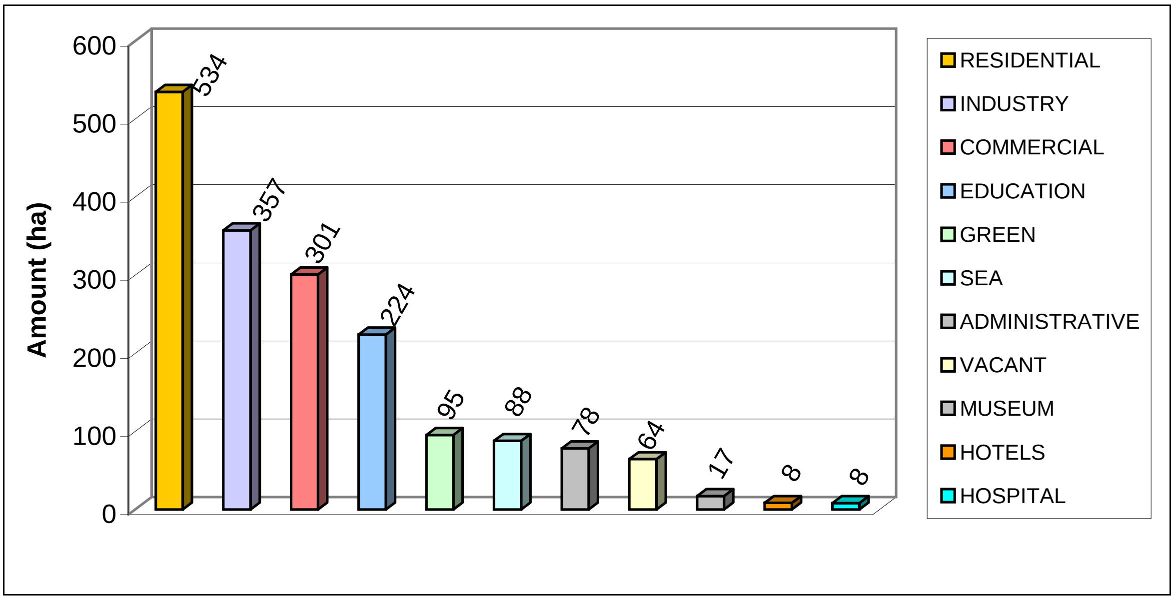

Figure 4. 12 Amount of Area Distribution of Land Use Types in the catchment area

Total amount of the catchment area is about 1775 ha. As seen the amount of the useless area (sea and vacant) is 152 ha. This chart may be useful in the improvement stage when compared to the other systems' land use distribution.

Other findings based on the survey of İzmir Metro A.Ş. is as follows:

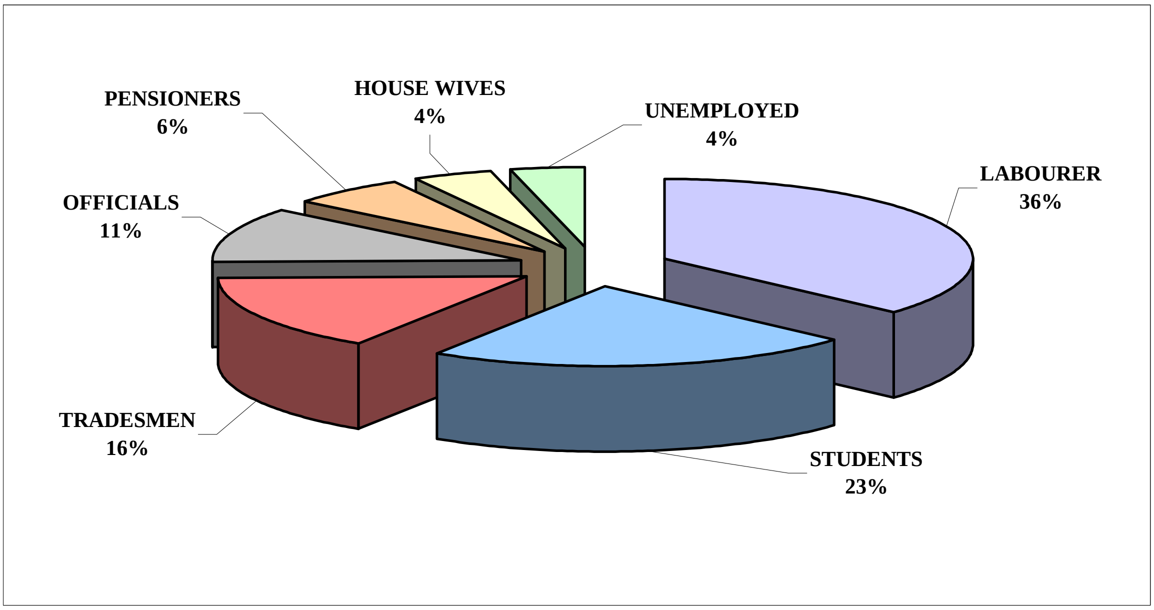

Figure 4. 13 Profession Distribution of the passengers (İzmir Metro Survey, December 2001)

It is seen in the figure 4.13 that, %63 of the passengers have jobs. Workers are the majority of these passengers. This data can be verified, if it is coincided with the land use distribution in the catchment area of metro line. Because, there is 357 ha industrial region in the catchment area, which is about %20 of the total catchment area.

Again, a land use-travel route relation can be established from the other results that are seen in the figure 4.13. For example; 23% of the passengers are students and this is related with the proximity of the University of Ege to the metro line. Probably, the officials and the tradesman are using the Çankaya and Basmane stops. The pensioners, housewives and the unemployed people have 14% rate in total.

Metro has passengers from nearly all of the central districts of İzmir. But, if the tables 4.7, 4.8 and 4.9 are examined, it is seen that the district of Bornova has influenced from the Metro more than the others. This is most probably because it is related with the route and the location of the line. There is a remarkably difference between Bornova and the other districts. This is an important finding to evaluate the other districts that are close to metro.

The table 4.7 shows that majority of the passengers resides in Bornova, Üçkuyular-Esentepe, Yeşilyurt-Limontepe regions.

Table 4. 7 Residential Area Distribution of the Passengers (İzmir Metro Survey, December 2001)

DISTRICTS	**# of Pass**	**Percent**
BORNOVA	2581	34,41%
ÜÇKUYULAR-ESENTEPE	1472	19,63%
YEŞİLYURT-LİMONTEPE	741	9,88%
ALTINDAĞ	643	8,57%
BUCA	486	6,48%
KONAK	414	5,52%
BALÇOVA-NARLIDERE	318	4,24%
KARŞIYAKA	287	3,82%
BAYRAKLI	138	1,84%
KADİFEKALE-ÇİMENTEPE	125	1,67%
GAZİEMİR	105	1,40%
ŞEHİR DIŞI	89	1,19%
BÜYÜK ÇİĞLİ	65	0,87%
PINARBAŞI	36	0,48%
TOTAL	**7500**	**100%**

When it is asked to the passengers that use metro to go to school, where their school were, the answer was Bornova with 63%. This is again can be explained with the proximity of University of Ege to the metro line. Üçkuyular-Esentepe and Konak regions come after Bornova.

Table 4. 8 School Area Distribution of the Passengers (İzmir Metro Survey, December 2001)

DISTRICTS	# of Pass	Percent
BORNOVA	969	63,37%
ÜÇKUYULAR-ESENTEPE	149	9,74%
KONAK	120	7,85%
BUCA	95	6,21%
ŞEHİR DIŞI	54	3,53%
ALTINDAĞ	52	3,40%
BALÇOVA-NARLIDERE	43	2,81%
YEŞİLYURT-LİMONTEPE	29	1,90%
KARŞIYAKA	8	0,53%
KADİFEKALE-ÇİMENTEPE	3	0,20%
GAZİEMİR	3	0,20%
PINARBAŞI	2	0,13%
BÜYÜK ÇİĞLİ	2	0,13%
TOTAL	**1529**	**100%**

The workplaces of the passengers are mostly in Bornova, Konak ve Üçkuyular-Esentepe regions.

Table 4. 9 Workplace Distribution of the Passengers (İzmir Metro Survey, December 2001)

DISTRICTS	# of Pass	Percent
BORNOVA	1502	30,35%
KONAK	1294	26,15%
ÜÇKUYULAR-ESENTEPE	858	17,34%
ALTINDAĞ	594	12,00%
PINARBAŞI	155	3,13%
ŞEHİR DIŞI	104	2,10%
BUCA	98	1,98%
YEŞİLYURT-LİMONTEPE	91	1,84%
BALÇOVA-NARLIDERE	86	1,74%
KARŞIYAKA	50	1,00%
GAZİEMİR	44	0,89%
BÜYÜK ÇİĞLİ	39	0,79%
BAYRAKLI	26	0,53%
KADİFEKALE-ÇİMENTEPE	8	0,16%
TOTAL	**4949**	**100%**

Figure 4.14 shows the distribution of the passengers' trip purposes. 59% of the whole passengers travel for work and 17% of them travel for school. This shows that 76% of the trips are regular and 24% of them are irregular.

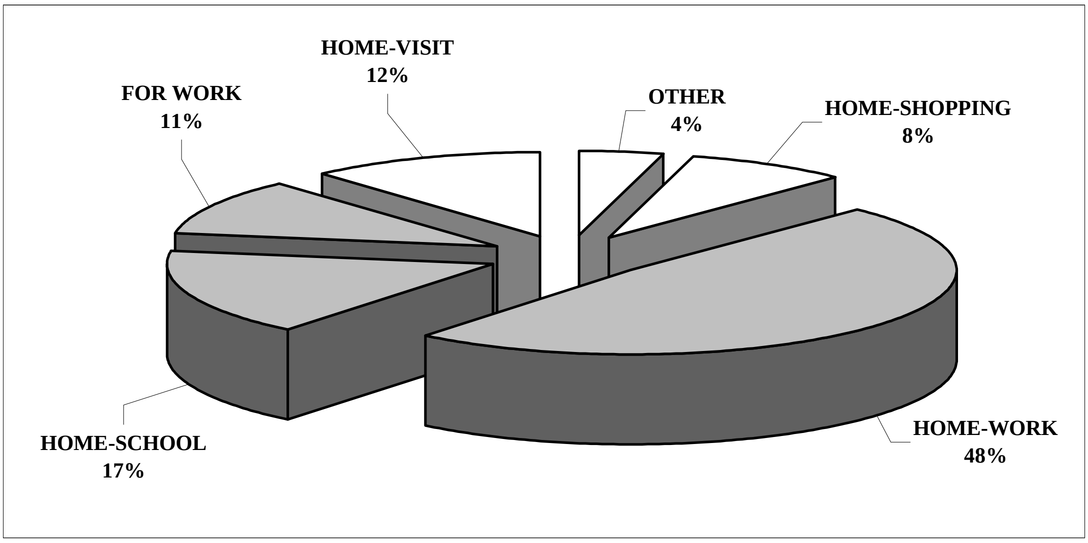

Figure 4. 14 Distribution of trip purpose (İzmir Metro A.Ş. Survey, 2001)

As seen in table 4.10 most of the passengers go to and come from the stations on foot. Remarkable of them get on feeder buses, so improvement attempts should take into account this kind of travel behaviours.

Table 4. 10 Used Transportation Mode Before or After Getting on Metro

TRANSPORT MODES	**BEFORE**		**AFTER**	
	TIME (min)	**PERCENT**	**TIME (min)**	**PERCENT**
FRIEND'S CAR	11	1,41%	20	0,31%
BICYCLE	12	0,10%	11	0,10%
DOLMUŞ / MIDIBUS	17	2,44%	16	1,53%
OWN CAR	12	2,11%	10	1,06%
BUS (FEEDER)	16	**18,86%**	16	**18,75%**
BUS (FEE 1)	17	2,60%	16	1,47%
BUS (FEE 2)	24	8,56%	24	4,98%
BUS (FEE 3)	33	1,95%	34	1,13%
SERVICE	22	0,96%	19	1,17%
TAXI	8	0,40%	9	0,48%
STEAMSHIP	19	0,62%	19	0,67%
ON FOOT	9	**59,98%**	9	**68,35%**
TOTAL		100,00%		100,00%

(İzmir Metro A.Ş. Survey, 2001)

Through this finding, the residential population density of the catchment area becomes important. Because home-based trips are related to the residential population density, so to understand the residential population densities of the districts in the catchment area the figure 4.15 was derived.

Üçyol station has the densest residential population in its catchment area. There are not so much dense areas around the other stations such as Bölge, Sanayi, Hilal and especially Halkapınar. This situation suspected of whether the route choice of metro is appropriate or not.

In the improvement stage, the catchment area of the other metro systems should be examined. Land use types and population densities of their catchment areas should be compared with İzmir Metro's, and the necessary changes should be employed to improve the performance, as the method requires.

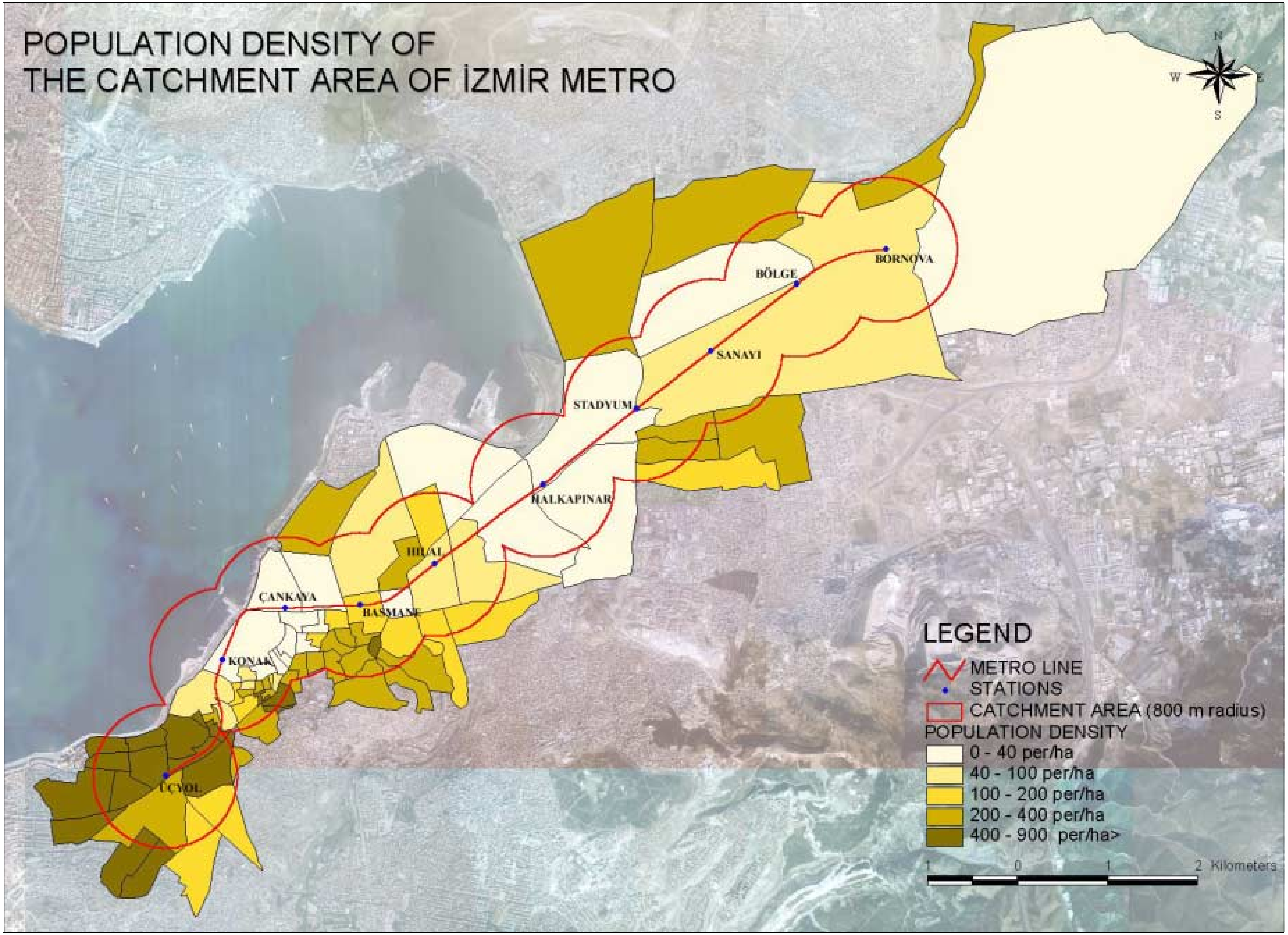

Figure 4. 15 Estimated* Residential Population Density by Districts, 2000

*See Appendix A

2.3. Selection of the Relevant Systems

Technical characteristics of 150 urban rail systems are investigated and 16 of them are chosen as similar systems to İzmir Metro. The systems, which have the approximate length to İzmir Metro, and the ones that are at most two lanes, are selected. Length of the systems is the main criteria for selection.

Data of İzmir Metro belongs to the year 2001* and data of Ankara Metro belongs to the year 1998**. Data of the other systems belong to the year 1996***.

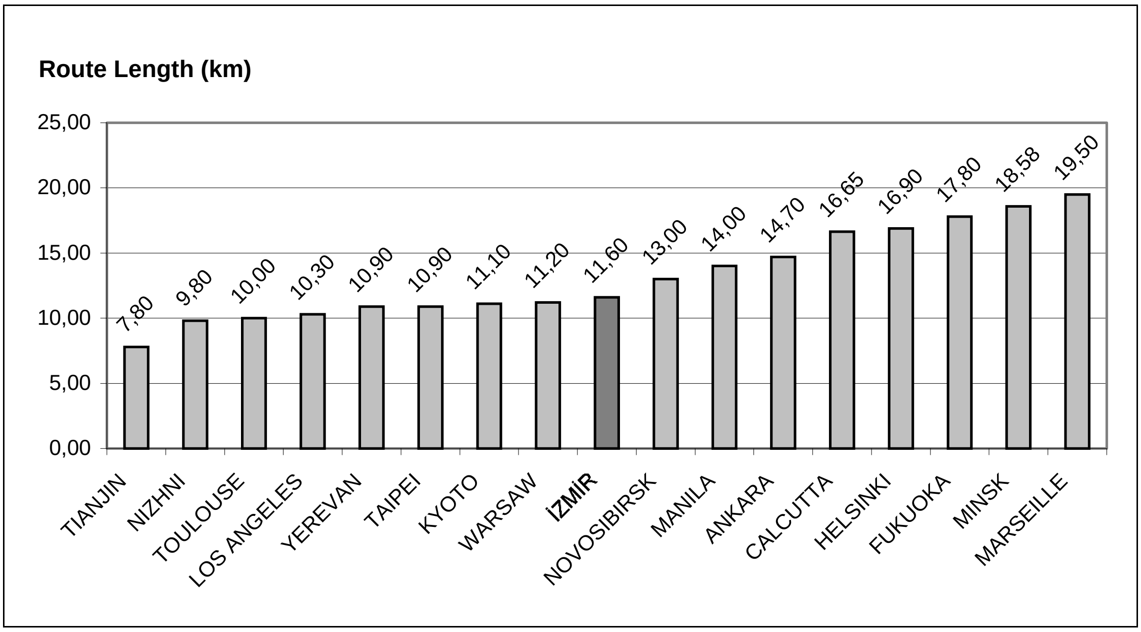

Figure 4. 16 Route Length of the Selected Systems (World Metro Systems, 1997)

In the figure 4.16 geographical distribution of the selected systems can be seen. The countries are;

Armenia; Yerevan

China; Tianjin

France; Marseille and Toulouse

Japan; Fukuoka and Kyoto

Russia; Nizhni Novgorod and Novosibirsk

Turkey; Ankara and İzmir

Belarus; Minsk

Finland; Helsinki

India; Calcutta

Philippines; Manila

Taiwan; Taipei

U.S.A.; Los Angeles

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* Obtained from İzmir Metro A.Ş.

** Obtained from Doğru N., Impact of Ankaray Light Rail Transportation System on The Mode Choice Characteristics of the Population A Long Its Catchement Area, ODTU-City Planning, 1999

*** Obtained from Garbutt, Paul, World Metro Systems. (2nd ed.), Singapore Capital Transport Press

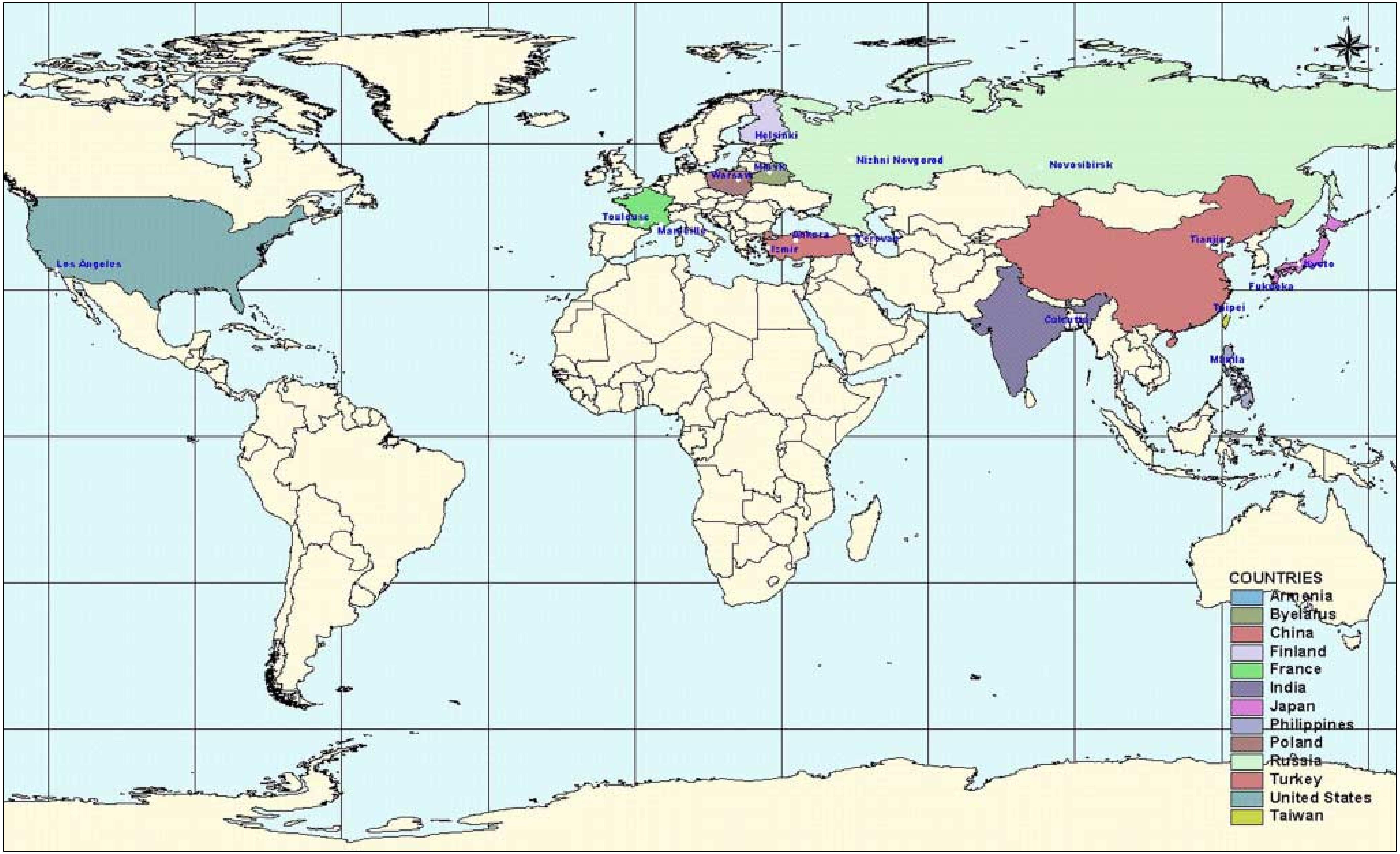

Figure 4. 17 Geographical Distribution of the Systems Worldwide (Derived from the database files of ArcView-GIS Software)

Table 4. 11 Technical Characteristics of the Selected Systems (Garbutt, P, 1997, World Metro Systems. (2nd ed.) Singapore Capital Transport Press.)

CITY	Population of the City		Year Opened	Route Length	Track Gauge	Max. Grad	Min. Radius of Curves	No. Of Stations	Power Supply	Current Colection	No. Of Cars	Max Car Length	Max Car Width	Anual Passengers
ANKARA	1997	3.258.000	1998	14,60 km	1,435 m	-	-	10	750 V	3 Rail	108	-	-	50.133.405
CALCUTTA	1996	12.118.000	1984	16,65 km	1,676 m	2,0%	300 m	17	750 V	3 Rail	144	19,50 m	2,74 m	30.000.000
FUKUOKA	1998	2.359.400	1981	17,80 km	1,067 m	-	-	20	1500 V	Overhead	132	-	-	114.800.000
HELSINKI	1999	945.700	1982	16,90 km	1,524 m	3,5%	400 m	13	750 V	3 Rail	84	22,50 m	3,20 m	37.100.000
İZMİR	2000	2.250.150	2000	11,60 km	1,435 m	4,8%	250 m	10	750 V	3 Rail	45	23,50 m	2,76 m	25.970.398
KYOTO	1998	1.995.330	1981	11,10 km	1,435 m	3,2%	260 m	13	1500 V	Overhead	102	20,00 m	2,70 m	75.800.000
LOS ANGELES	1998	15.781.300	1993	10,30 km	1,435 m	4,0%	274 m	8	750 V	3 Rail	30	22,86 m	3,20 m	5.000.000
MANILA	1995	9.454.000	1984	14,00 km	1,435 m	0,4%	250 m	18	750 V	Overhead	64	29,28 m	2,50 m	120.000.000
MARSEILLE	1999	1.398.100	1978	19,50 km	Rubber Tyred	7,0%	105 m	24	750 V	Side-beams	144	16,19 m	2,60 m	54.700.000
MINSK	1999	2.224.585	1984	18,58 km	1,524 m	4,0%	300 m	17	825 V	3 Rail	132	19,21 m	2,70 m	149.000.000
NIZHNI NOVG.	1998	2.730.173	1985	9,80 km	1,524 m	4,0%	400 m	8	825 V	3 Rail	36	19,21 m	2,70 m	66.000.000
NOVOSIBIRSK	1998	2.157.174	1985	13,00 km	1,524 m	4,0%	400 m	10	825 V	3 Rail	72	19,21 m	2,70 m	82.000.000
TAIPEI	1997	6.398.400	1996	10,90 km	Rubber Tyred	-	-	12	750 V	Side-beams	102	26,00 m	2,06 m	35.000.000
TIANJIN	1998	9.570.000	1980	7,80 km	1,435 m	3,0%	300 m	8	750 V	3 Rail	18	19,52 m	2,65 m	10.500.000
TOULOUSE	1999	729.760	1993	10,00 km	Rubber Tyred	7,0%	150 m	15	750 V	Side-beams	58	26,00 m	2,06 m	50.800.000
WARSAW	1997	2.418.400	1995	11,20 km	1,435 m	3,1%	300 m	11	750 V	3 Rail	42	19,20 m	2,70 m	35.000.000
YEREVAN	1998	1.772.927	1981	10,90 km	1,524 m	4,0%	250 m	9	825 V	3 Rail	108	19,21 m	2,70 m	52.300.000

2.4. Indicators

Total costs and benefits of a mass transit system are directly relevant with its efficiency. Capital cost of a system is depended on the total length of the line, number of stations, number of vehicles, technology and the construction methods (tunnel, at level or elevated) of the system. Operating cost of a system is depended on the number of staff, the expended energy, periodical maintenance and other expenses.

Benefits as the other base of the system's efficiency turn on the number of passengers carried in a certain time. Besides the decrease in traffic congestion or air pollution, increases in the life quality are other intangible benefits. Therefore, in this stage, the measurable and data-available costs and benefits are dealt with. The rate of the outputs (benefits) to inputs (costs) should be the main criteria to determine the indicators for benchmarking.

Possible indicators to measure efficiency according to the operator's viewpoint can be determined as follows:

- Capital cost of the system; is important to measure if the investment is close to the worldwide standards.
  For ex: **capital cost / km** represents amount of capital that spent per kilometer
- Operating cost of the system; is important to measure the operating performance of the system
  For ex: **operating cost / pass** represents amount of capital that spent per passenger.
- Number of Passengers carried in a certain time, is important to measure whether the system is employed in its capacity
  For ex: **number of passengers / day**
- Length of the system
  Example: **passengers / km**
- Number of Stations is relevant with the capital cost
  Example: **passengers / station**
- Number of Staff is relevant with the operating cost
  Example: **number of staff / km**
- Number of vehicles
  Example: **number of passengers / vehicle**

- Amount of catchment area of the system
  Example: **catchment area / km**
- Population of the city; the ratio of the passengers to the city population is important to understand the benefits ratio to the whole city.
  Example: **daily passengers / city population**

However, the data that could be reached is shown on the table 4.9. Therefore the indicators that will be employed to measure efficiency of the systems are defined as:

- **pass. / km** → Annual number of passengers per km
- **pass. / station** → Annual number of passengers per a station
- **pass. / vehicle** → Annual number of passengers per vehicle
- **veh. / km** → Operating number of vehicles per km
- **pass. / population** → Daily number of passengers per city population

2.5. Comparison & Benchmarking:

In comparing İzmir Metro with the other rail systems, a virtual benchmarking group has been set up. The participants of this group are; Ankara, Calcutta, Fukuoka, Helsinki, İzmir, Kyoto, Los Angeles, Manila, Marseille, Minsk, Nizhni, Novosibirsk, Taipei, Tianjin, Toulouse, Warsaw, Yerevan. Through the defined indicators, table 4.10 is produced. Average values of the indicators are determined as the benchmarks of an efficient system.

Table 4. 12 Comparisons of the Systems' Performance Indicators

CITY	pass /km	pass /station	pass/veh	veh/km	pass/city pop
ANKARA	3,433,795	4,177,784	464,198	7.40	4.22%
CALCUTTA	1,801,802	1,764,706	208,333	8.65	0.68%
FUKUOKA	6,449,438	5,740,000	869,697	7.42	13.33%
HELSINKI	2,195,266	2,853,846	441,667	4.97	10.75%
İZMİR	2,238,827	2,597,040	577,120	3.88	3.16%
KYOTO	6,828,829	5,830,769	743,137	9.19	10.41%
LOS ANGELES	485,437	625,000	166,667	2.91	0.09%
MANILA	8,571,429	6,666,667	1,875,000	4.57	3.48%
MARSEILLE	2,805,128	2,279,167	379,861	7.38	10.72%
MINSK	8,019,376	8,764,706	1,128,788	7.10	18.35%
NIZHNI	6,734,694	8,250,000	1,833,333	3.67	6.62%
NOVOSIBIRSK	6,307,692	8,200,000	1,138,889	5.54	10.41%
TAIPEI	3,211,009	2,916,667	343,137	9.36	1.50%
TIANJIN	1,346,154	1,312,500	583,333	2.31	0.30%
TOULOUSE	5,080,000	3,386,667	875,862	5.80	19.07%
WARSAW	3,125,000	3,181,818	833,333	3.75	3.97%
YEREVAN	4,798,165	5,811,111	484,259	9.91	8.08%
AVERAGE	**4,319,532**	**4,374,026**	**761,566**	**6.11**	**7.36%**

Average of the indicators is determined as the benchmarks of each indicator. Benchmarks are the efficiency limits of the systems. The systems that are under the level of the benchmarks will be defined as inefficient due to the related indicator.

Indicator 1: Pass. / km

This indicator marks the systems' efficiency through the number of passengers carried in a year per kilometer. It is related with both the capital cost and the operating cost. The performance efficiency of any mass transit system is directly related to the number of passengers it carries in a certain time and kilometer.

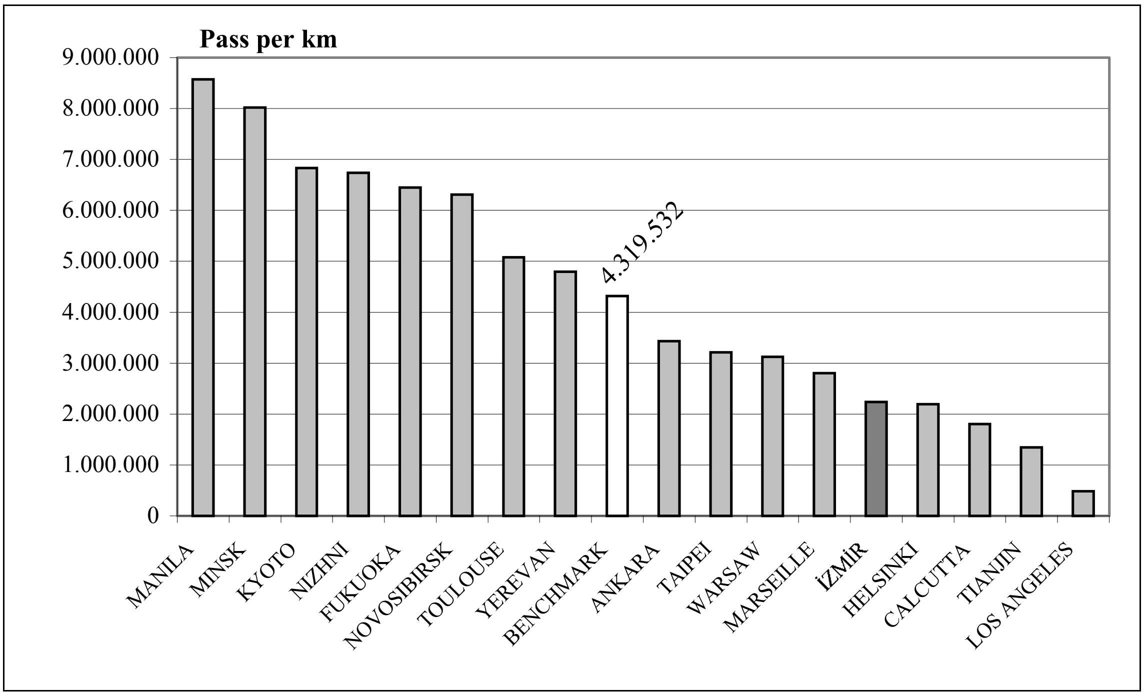

Figure 4. 18 Indicator 1, Annual number of passengers per km

Figure 4.18 shows that, İzmir and 8 other systems are under the determined benchmark (4,319,532 passengers/day), so they are inefficient according to this indicator. İzmir has 2,238,827 passengers and it is the fifth of the inefficient systems.

The operator of İzmir Metro should examine especially the systems of Yerevan and Nizhni Novogorod to improve their performance. Although these metros have shorter routes than İzmir they carry more passengers per km. Yerevan metro carries 4,798,165 passengers per km and Nizhni Novgorod metro carries 6,734,694 passengers per km. The populations of these cities are also close to İzmir's population. Nizhni Novgorod has the population of 2,730,000 and Yerevan has the population of 1,772,927 in 1998.

Indicator 2: Pass. / Station

This indicator marks the systems' efficiency through the number of passengers carried in a year per station. Annual number of passengers is the output, and number of stations is the input of the metro systems. That is more station requires more capital and operating cost. Therefore, the rate of the number of passengers to the number of stations will give us the rate of outputs to inputs.

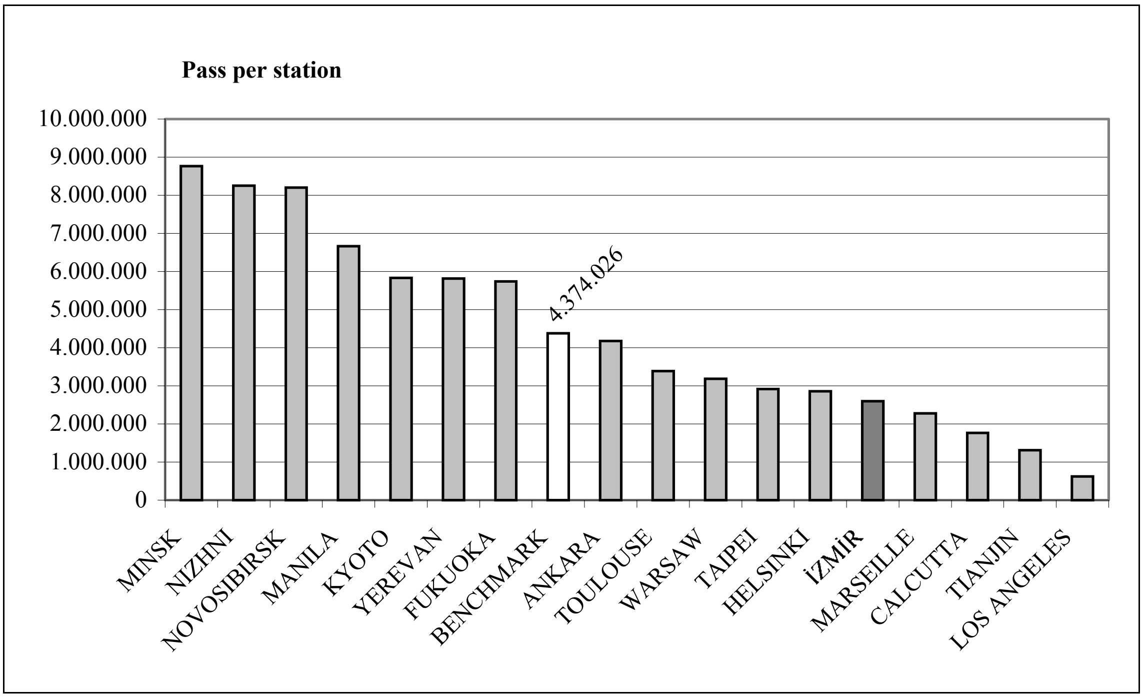

Figure 4. 19 Indicator 2, Annual number of passengers per station

10 systems including İzmir are under the benchmark (4,374,026 pass./ station). Due to this indicator, İzmir Metro is again the fifth of the inefficient systems with 2,597,040 passengers per station. Minsk seems the best and Novosibirisk has a remarkable increase in the enumeration of efficiency. Toulouse metro regresses under the benchmark level according to this indicator.

The systems to be considered by İzmir Metro operators, should be again Yerevan and Nizhni Novgorod Metro systems and in addition Novosibirisk Metro. Yerevan carries 5,811,111 pass./ station that has 9 stations. Nizhni Novgorod carries 8,250,000 pass./ station which has only 8 stations. Novosibirisk has the same number of station with İzmir that is 10 and carries 8,200,000 pass./ station.

Indicator 3: Pass. / vehicle

This indicator marks that how efficiently the vehicles are used compared to the others in the group.

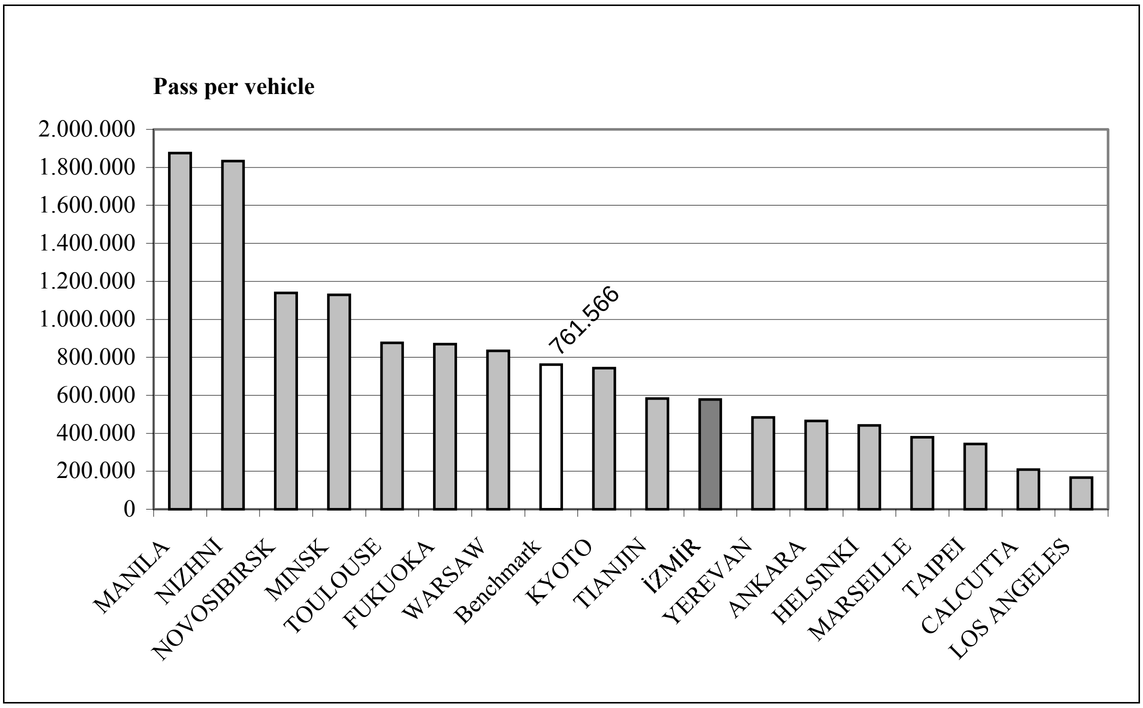

Figure 4. 20 Indicator 3, Annual number of passengers per vehicle

İzmir Metro seems better than 7 systems at this time but it is still under the benchmark. It carries 577,120 passengers per vehicle in a year with its 45 vehicles. Nizhni Novgorod Metro and Warsaw Metro seem the systems that should be examined by the operator of the İzmir Metro. Nizhni has only 36 vehicles but can carry 1,833,333 passengers per vehicle in a year. Warsaw has 42 vehicles; it can carry 833,333 passengers per vehicle in a year.

Indicator 4: Vehicle / km

This indicator marks; how many vehicles can be operated in the limited route length. Total number of vehicles per route km will measure the performance of the systems. This indicator is related to the operating efficiency.

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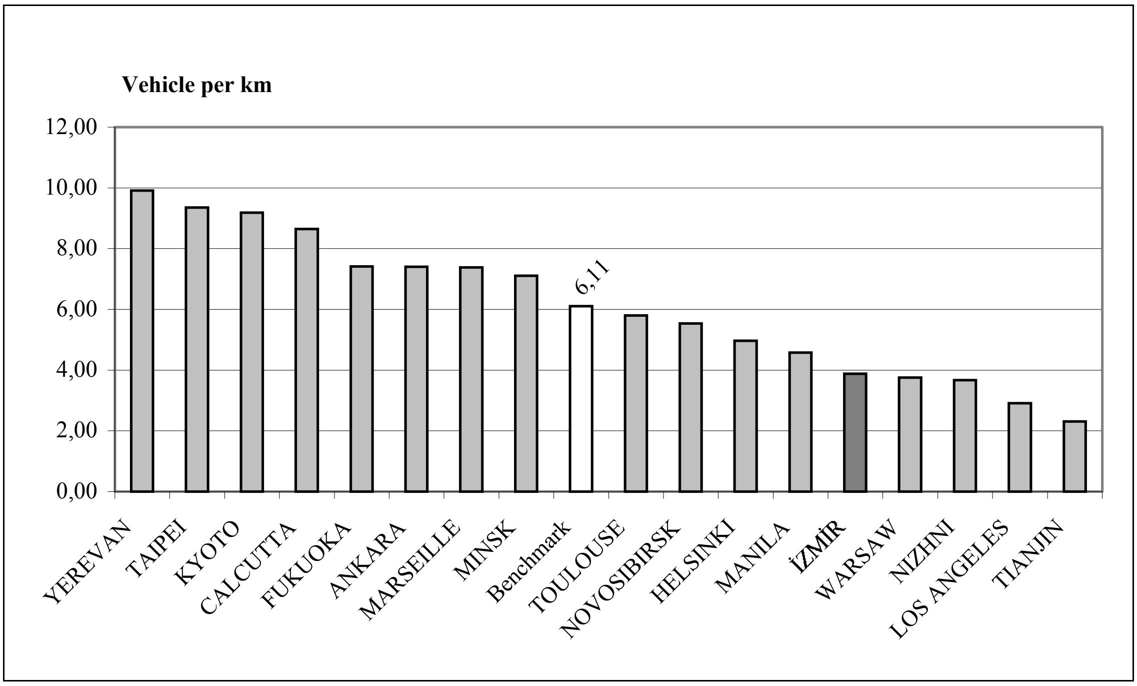

Figure 4. 21 Indicator 4, Total number of vehicles per route km

9 systems are under benchmark (6.11veh/km). Izmir Metro is again the fifth of them with 3,88 vehicles per kilometer. Ankara metro is over benchmark, so it is the sixth efficient system of the group. Again there are systems, which can be good examples for İzmir metro to improve its performance by learning them.

Indicator 5: Pass. / population → Daily number of passengers per city population

This indicator is essential to understand what percent of the citizens profit the metro system of the cities. It marks the ratio of benefits to the society.

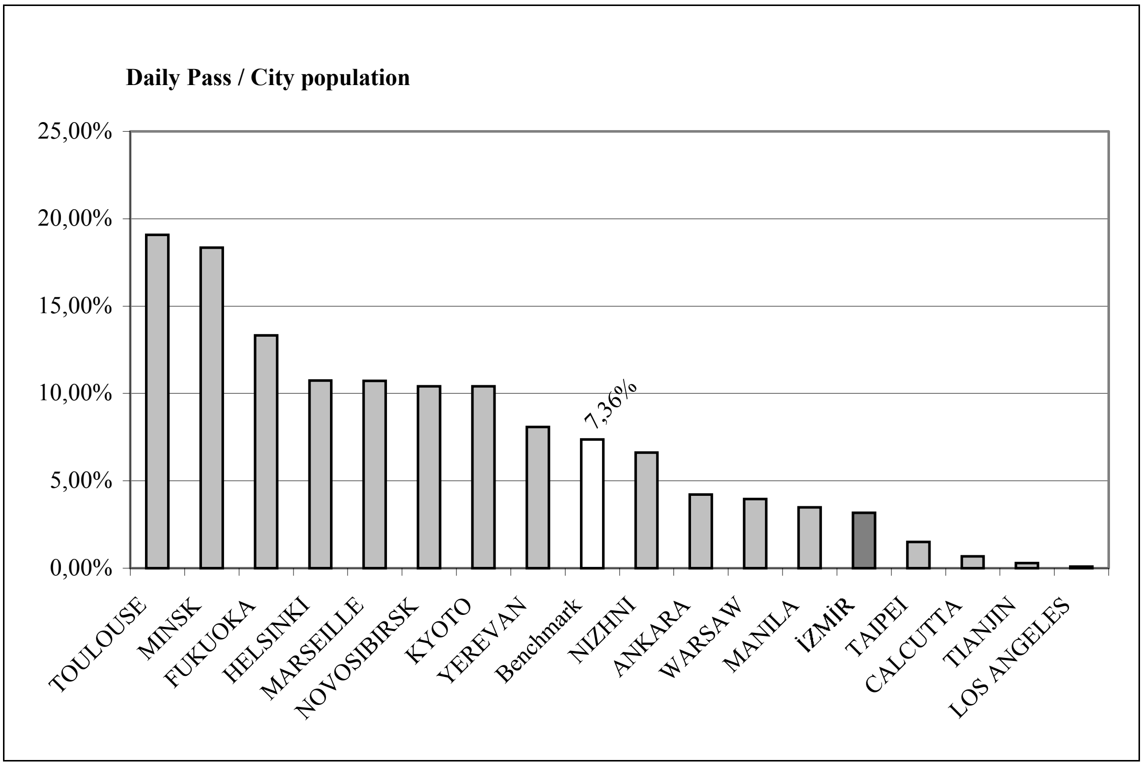

Figure 4. 22 Indicator 5, Daily number of passengers per city population

According to the benchmark, in one day at least 7,36% of the citizens should profit the system to determine that it is efficient. İzmir metro seems again inefficient due to this indicator. Only the 3,2% of İzmir citizens seem to profit the system in a day. Toulouse and Minsk metros are very successful in this indicator. They can carry nearly 20% of their citizens in a day.

As seen above systems performance changes due to the indicators. Therefore to evaluate the systems overall efficiency, the systems were scored according to their performance order for each indicator. Another graph is made to see the overall efficiency of the systems. (See the figure 4.23)

Table 4. 13 Performance scores of the systems according to each indicator

CITY	SCORES OF THE SYSTEMS					
	pass /km	pass/ station	pass/veh	veh/km	pass/pop	TOTAL
ANKARA	9	10	6	12	8	**45**
CALCUTTA	3	3	2	14	3	**25**
FUKUOKA	13	11	12	13	15	**64**
HELSINKI	4	6	5	7	14	**36**
İZMİR	5	5	8	5	5	**28**
KYOTO	15	13	10	15	11	**64**
LOS ANGELES	1	1	1	2	1	**6**
MANILA	17	14	17	6	6	**60**
MARSEILLE	6	4	4	11	13	**38**
MINSK	16	17	14	10	16	**73**
NIZHNI	14	16	16	3	9	**58**
NOVOSIBIRSK	12	15	15	8	12	**62**
TAIPEI	8	7	3	16	4	**38**
TIANJIN	2	2	9	1	2	**16**
TOULOUSE	11	9	13	9	17	**59**
WARSAW	7	8	11	4	7	**37**
YEREVAN	10	12	7	17	10	**56**

Through the total scores the graph below is occurred.

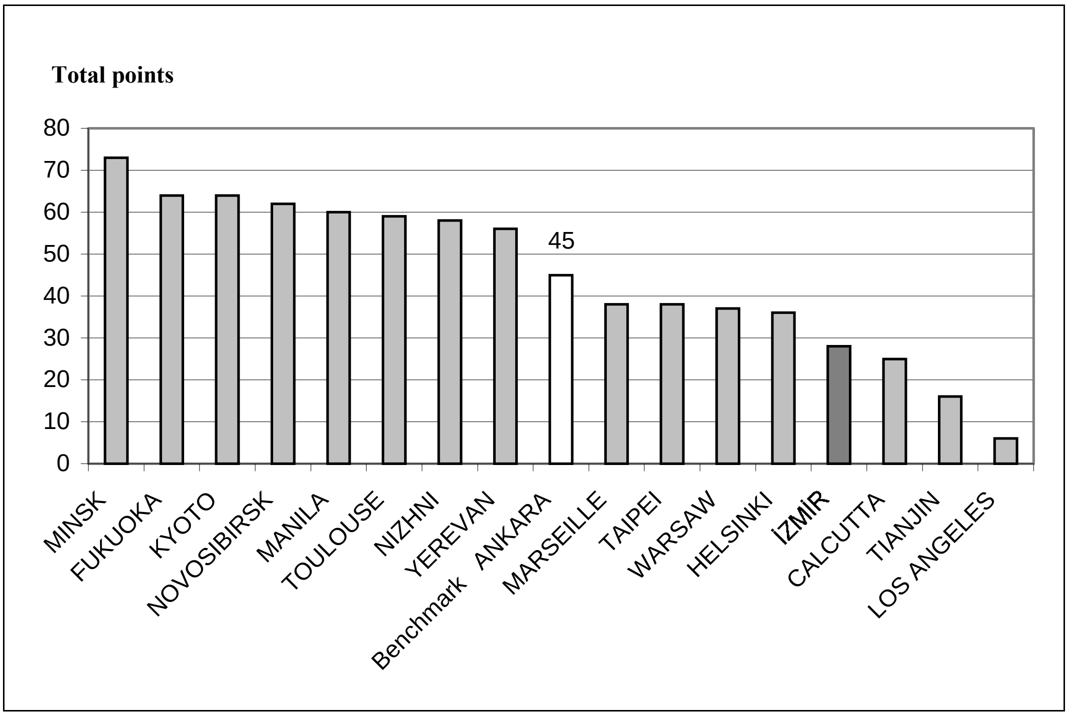

Figure 4. 23 Over all efficiency

Figure 4.23 marks the over all efficiency levels of the members. As seen in the figure the systems of Los Angeles, Tianjin, Calcutta, İzmir, Helsinki, Warsaw, Taipei, and Marseille are on the inefficiency level. These systems' operators should improve their performance by learning best practices of others that are over benchmark.

In the improvement stage; self-assessment stages of the efficient systems should be examined. For example, land use distribution and population density around the catchment area of these metros should be compared to the inefficient ones. This would give ideas to the operator (municipality) of İzmir Metro.

Findings through the self- assessment stage are:

- Amount of land use distribution in the catchment area of the line.
- Population density of the catchment area.
- Impact ratio of the line to the districts of İzmir Metropolitan Area.
- Current passenger capacity of the system (Hourly, daily, annual).
- Trend of the daily number of passengers carried by İzmir Metro (2001-2002).

A surprise finding of this research was that the cities, which have higher populations have the inefficient metro systems. They are Los Angeles with 15,781,300 populations, Tianjin with 9,570,000 populations and Calcutta with 12,118,000 populations. This shows us that the total population of the city does not always require high capacity transit modes. As mentioned in previous chapters, the population of the catchment area is effective on this issue.

Chapter 5

CONCLUSION

Transport decisions have important place to have an impact on the city macroform. For an effective public transportation; a system that is appropriate to serve all over the city should be chosen. Moreover that system should be appropriate with the development plans of that city and should also lead the realization of the planning decisions. The more passengers to carry, the more efficient public transportation system.

Efficiency in public transportation is an important issue. It is an expensive service sector and there is limited money. The maximum service should be provided with the minimum utilization of resources. Especially rail systems in public transportation have high capital and operating cost, so their efficient utilization is indisputably necessary.

İzmir Metro has been a subject of several debates since a rail system decision is taken for İzmir. It has been criticized for its decisions over, route, whether it is being right mode choice in many platforms, etc. This study is to provide a method for proving the inefficiency of İzmir Metro from the operators' viewpoint.

As the purpose of the thesis to prove, current state of İzmir Metro is inefficient with regard to the method of *Comparative Benchmarking Analysis*. Its performance is measured in a 17-membered virtual benchmarking group. İzmir Metro is under the benchmark of all indicators.

The operator of İzmir Metro should develop the improvement tools of its system as the method of benchmarking pointed out. The numeric and geographical data of the best examples of the efficient metro systems will be helpful to improve the İzmir Metro.

After determining the inefficiency of İzmir Metro, this study was to give an example for methodology. Following must be the continous projects such as:

İzmir Metro authorities should contact with the similar metro system's authorities and set up a real benchmarking group with which the data share will be possible. This would minimize the difficulty of the availability of data, which is the main constraint of this study. That open data share will enable the operators to learn best practices of each other and especially will be useful for improving the performance of the systems continuously. The best practices should be examined, the ability and willingness should be improved to share information and expertise with other participants of benchmarking group.

This study also gives ideas to the municipalities of the other cities those thinking to build MRT (Mass Rapid Transit) systems. MRT systems are not only the rail systems. The decision makers should consider the different modes of MRT systems, such as BRT (Bus Rapid Transit) systems, HOV (High Occupancy Vehicle) lanes, etc. These systems can carry the high capacity of passengers as well as the rail systems. They are preferable for the routes on which the rail is not feasible due to high investment costs. (See Chapter 2)

As mentioned before efficiency of İzmir Metro is evaluated from the view of its current state in this study. It may be more efficient than the current state when the new lines added and the necessary changes are made. However the findings can be used as a guide by the operator of İzmir Metro to improve performance in the future.

The operator of İzmir Metro is considered as the municipality of İzmir. As a matter of case, İzmir Metro A.Ş. is subsidized by the municipality of İzmir. Inefficiency of metro affects the budget of the municipality. Therefore the municipality as a decision maker of land use of the city, should deal with the performance improvement issue of İzmir Metro.

In the self- assessment stage of İzmir Metro, it is seen that; there are useless areas (vacant and sea) in the catchment area of metro. Residential population density of catchment area is too low for a transit corridor.

Also findings show that there is need of integrity of the metro with the regulation and development plans. Planning studies should start urgently. Planning decisions that are to increase density around metro stations can be considered as a solution to its current inefficient situation. Transport studies and especially the land use integrated decisions should be taken on the basis and scientific findings but not on the political ideologies should be reviewed whether the suggested additional lines for İzmir Metro are appropriate.

Transport decisions require serious accumulation of knowledge, so besides practical studies, theoretical process of improving knowledge should start.

On condition that keeping the possibility of several different factors, the impact of economic policies of the countries to the public transport systems should be mentioned. This can be followed at the results of the benchmarking method. Generally, the old Soviet cities such as Novosibirsk, Nizhni Novgorod or Yerevan have efficient metro systems. However, in Los Angeles, where the rate of private cars is so high, the metro is inefficient. As an example of Turkish cities, Ankara itself poses benchmark state, whereas İzmir is far from this. Thus Ankara Metro will be very important yardstick for the municipality of İzmir to compare its efficiency position.

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- http://www.library.ci.corpus-christi
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APPENDIX A

Formula of the population estimation:

$$P_e = \frac{P \times D_v}{C_v}$$

P_e : Estimated population of the districts (mahalle), 2000

P : Population of the county (ilçe), 2000

D_v : Number of the voters by district (mahalle), 1999

C_v : Number of the voters by county (ilçe), 1999

Table A.1 Number of 1999 voters and the estimated population by districts*

DISTNAME	Number of electors in 1999	Estimated Population of the year 2000
AKARCALI	3050	4423
AKDENİZ	138	200
AKIN SİMAVİ	3681	5337
AKINCI	571	828
ALİ REİS	1421	2060
ALTINORDU	658	954
ALTINTAŞ	4829	7002
ARAPHASAN	7791	11297
ATİLLA	7923	11488
BAHAR	3619	5248
BAHÇELİEVLER	10533	15273
BALLI KUYU	2683	3890
BARBAROS ÇAMDİBİ	6141	8904
BARBOROS	6066	8796
BOZKURT	301	436
ÇAKABEY	511	741
ÇINAR	3721	5991
ÇINARLI	208	302
DAYIEMİR	604	876
DOĞANAY	5942	8616
DUATEPE	1662	2410
EGE	1471	2133
ERGENE	7870	12671
ERZENE	16585	26702
ETİLER	1470	2132

* Accounted From The Results Of The General Elections Of Deputy (DIE, 1999) And Population Of Izmir- Konak, Bornova (DIE, 2000)

DISTNAME	Number of electors in 1999	Estimated Population of the year 2000
FAİK PAŞA	1043	1512
FATİH	247	358
FEVZİ PAŞA	180	261
GÜNEŞ	20	29
GÜNEŞLİ	3633	5268
GÜNEY	3591	5207
GÜNGÍR	987	1431
GÜZELYURT	39	57
HALKAPINAR	561	813
HİLAL	1775	2574
HURŞİDİYE	59	86
İSMETKAPTAN	157	228
KADİFEKALE	4642	6731
KAHRAMAN MESCİT	99	144
KAHRAMANLAR	3747	5433
KAZIMDİRİK	23622	38031
KEMAL REİS	2765	4009
KESTELLİ	20	29
KILIÇ REİS	6020	8729
KOCAKAPI	2347	3403
KOCATEPE	1164	1688
KONAK	176	255
KUBİLAY	2184	3167
KURTULUŞ	277	402
KÜLTÜR	7061	10238
MANAVKUYU	19053	30675
MANSUROĞLU	14764	23770
MECİDİYE	474	687
MEHMET ALİ AKMAN	5918	8581
MERSİNLİ	2006	2909
MİMAR SİNAN	4811	6976
MİRALİ	712	1032
MURAT REİS	10076	14610
NAMAZGAH	50	73
NAMIK KEMAL	521	755
ODUNKAPI	216	313
OĞUZLAR	215	312
PAZARYERİ	1089	1579
PİRİ REİS	4078	5913
RAFET PAŞA	10456	16834
REİS	7441	10789
S.NEDİM TUĞALTAY	204	296
SAKARYA	661	958
SALHANE	27083	39270
SELÇUK	2497	3621

DISTNAME	Number of electors in 1999	Estimated Population of the year 2000
SÜMER	155	225
TAN	116	168
TURGUT REİS	2736	3967
TUZCU	1674	2427
TÜRKYILMAZ	239	347
UĞUR	29	42
UMURBEY	700	1015
ÜLKÜ	1021	1480
YENİ NAMAZGAH	828	1201
YENİDOĞAN	2238	3245
YENİGÜN	41	59
YENİŞEHİR	2613	3789
YEŞİLTEPE	987	1431
YILDIRIM BEYAZIT	4938	7950
YILDIZ	87	126

APPENDIX B

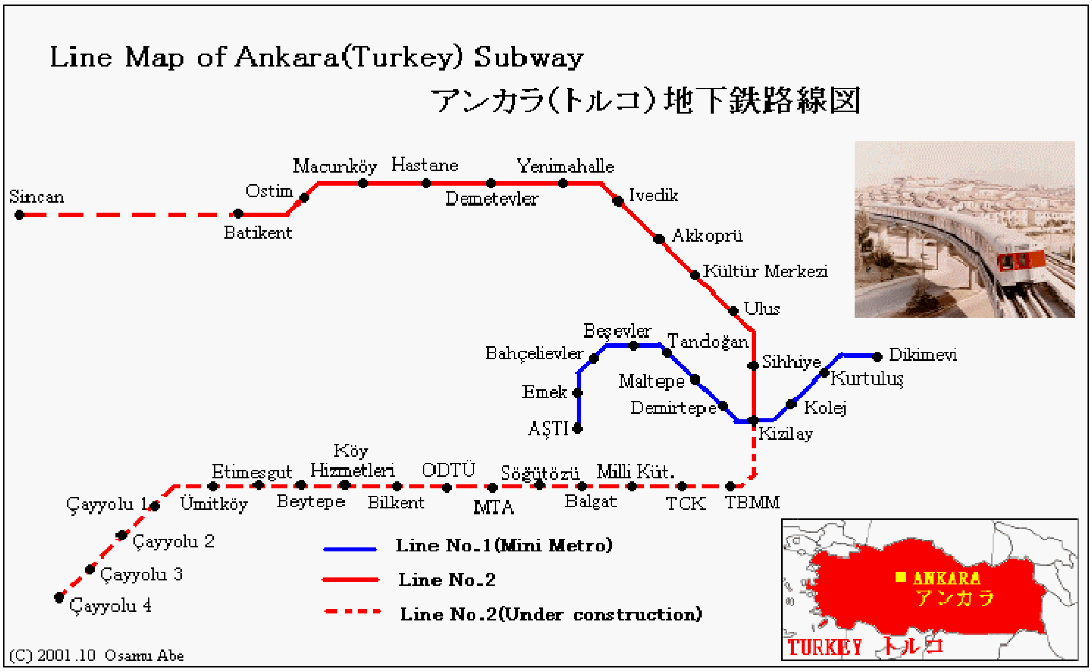

Figure B. 1 Schematic Map of Ankara Subway

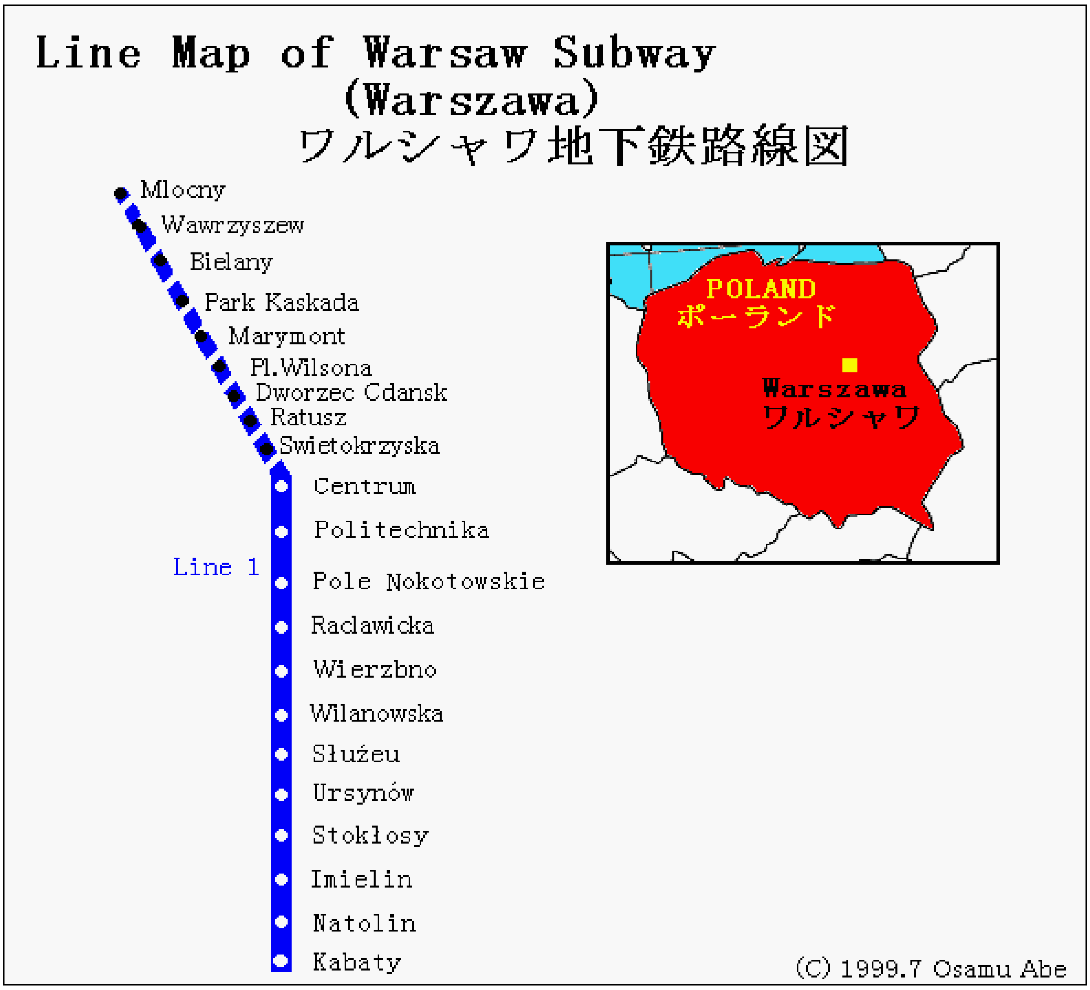

Figure B. 2 Schematic Map of Warsaw Subway

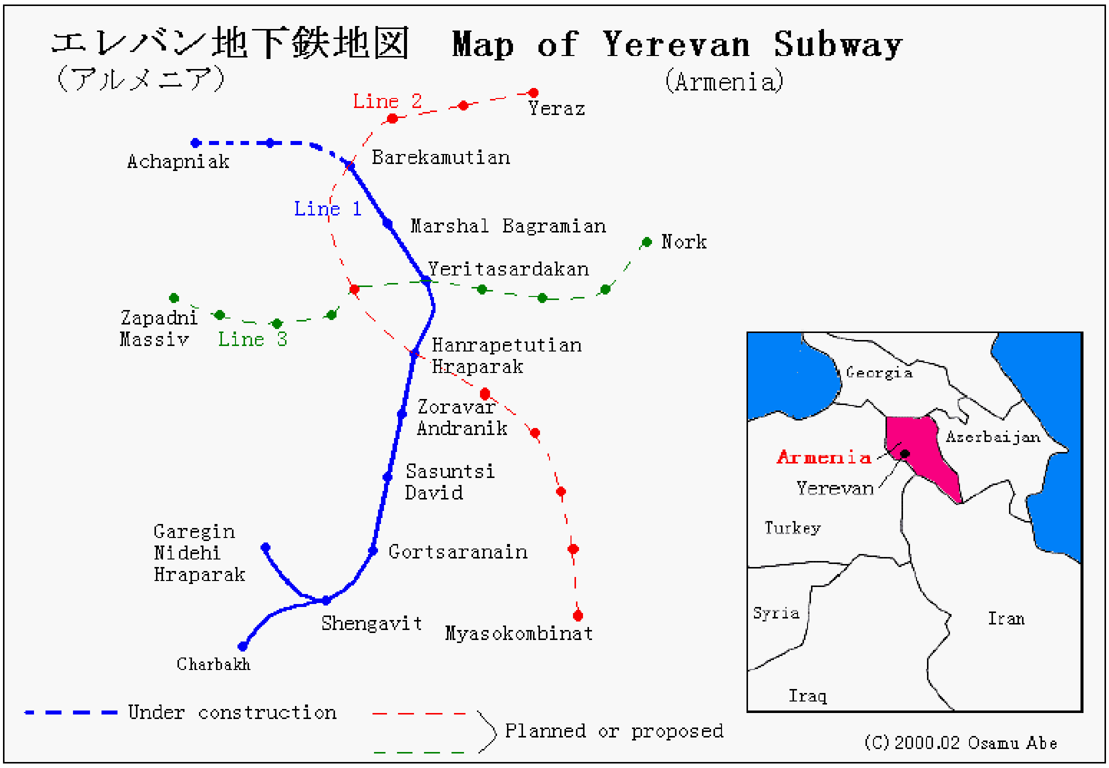

Figure B. 3 Schematic Map of Yerevan Subway

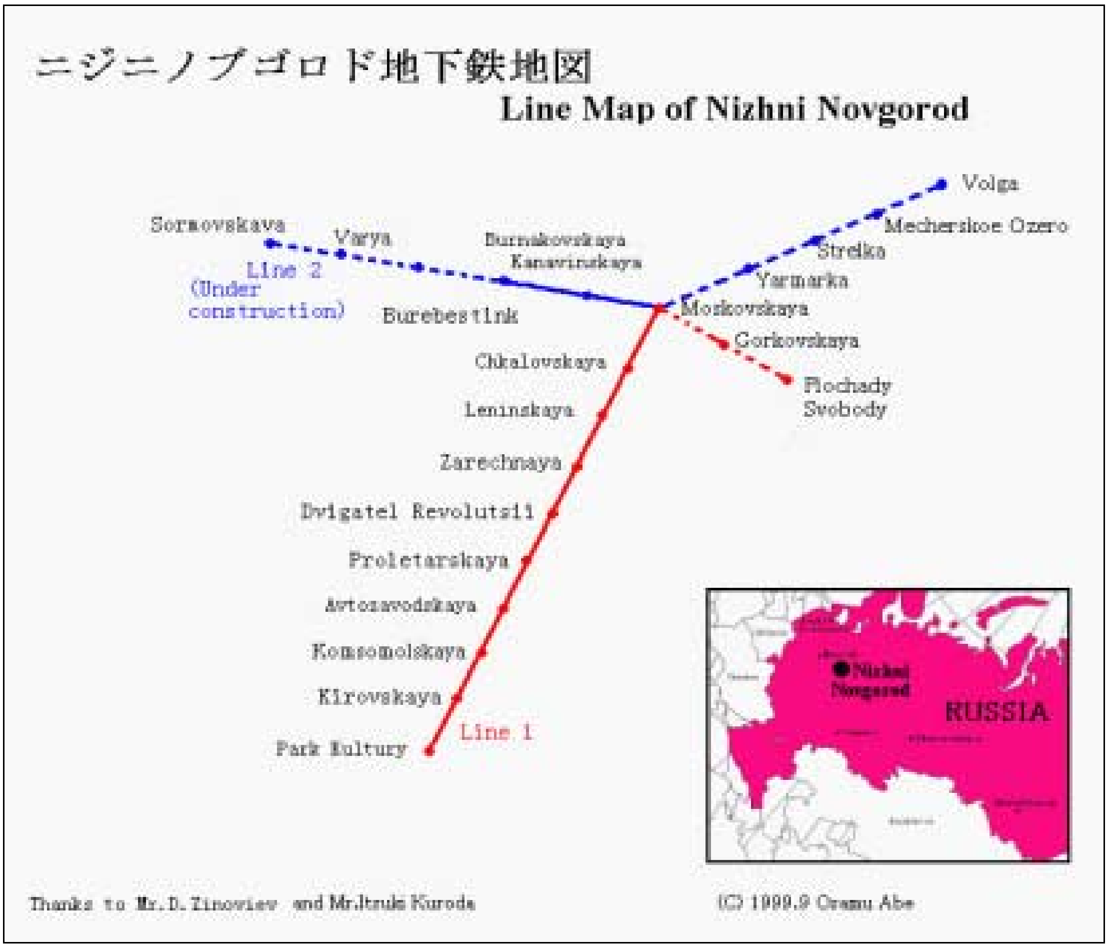

Figure B. 4 Schematic Map of Nizhni Novgorod Subway

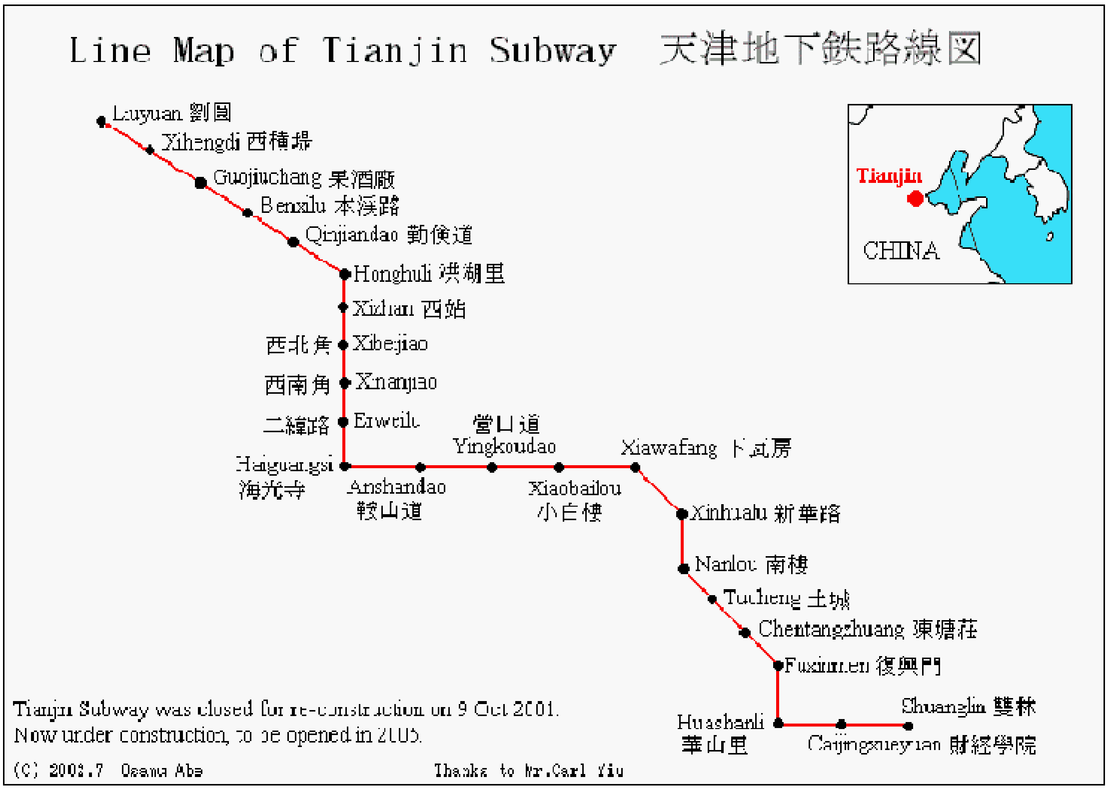

Figure B. 5 Schematic map of Tianjin Subway

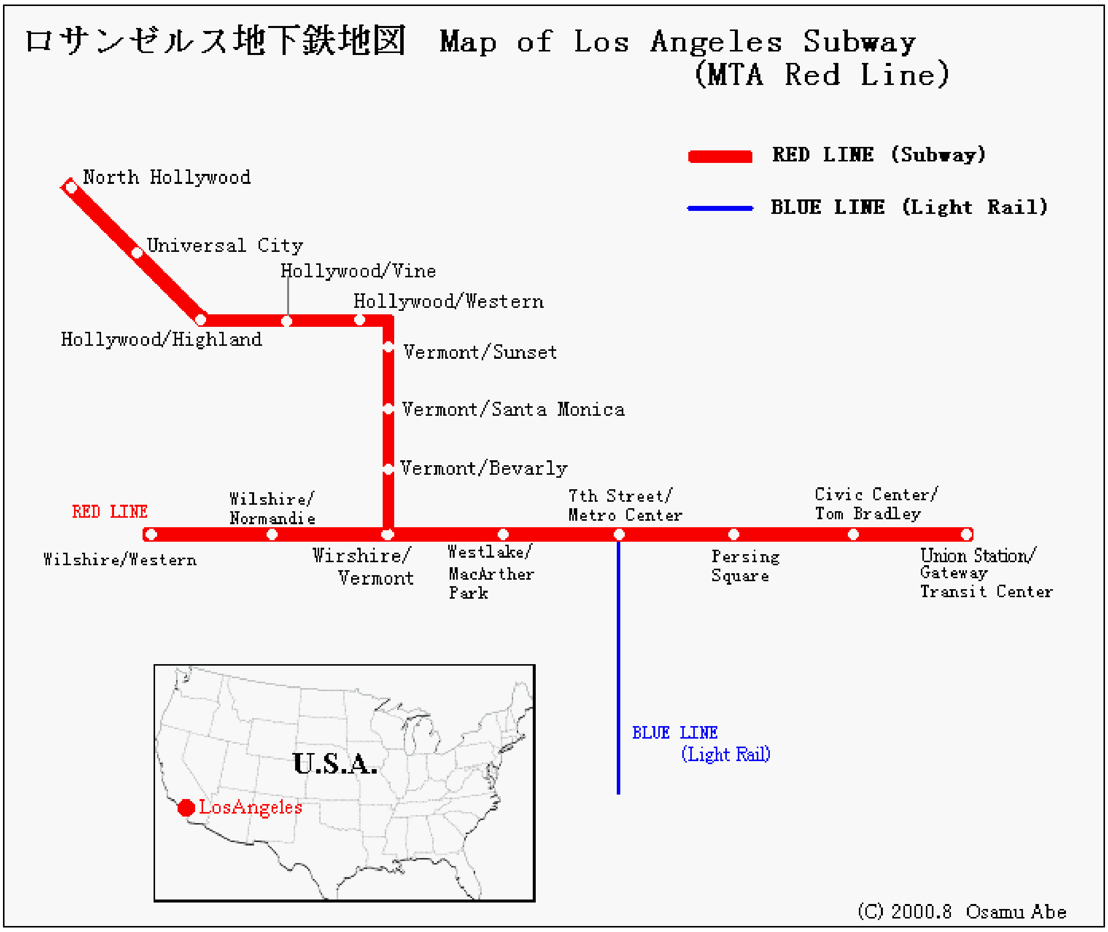

Figure B. 6 Schematic Map of Los Angeles Subway

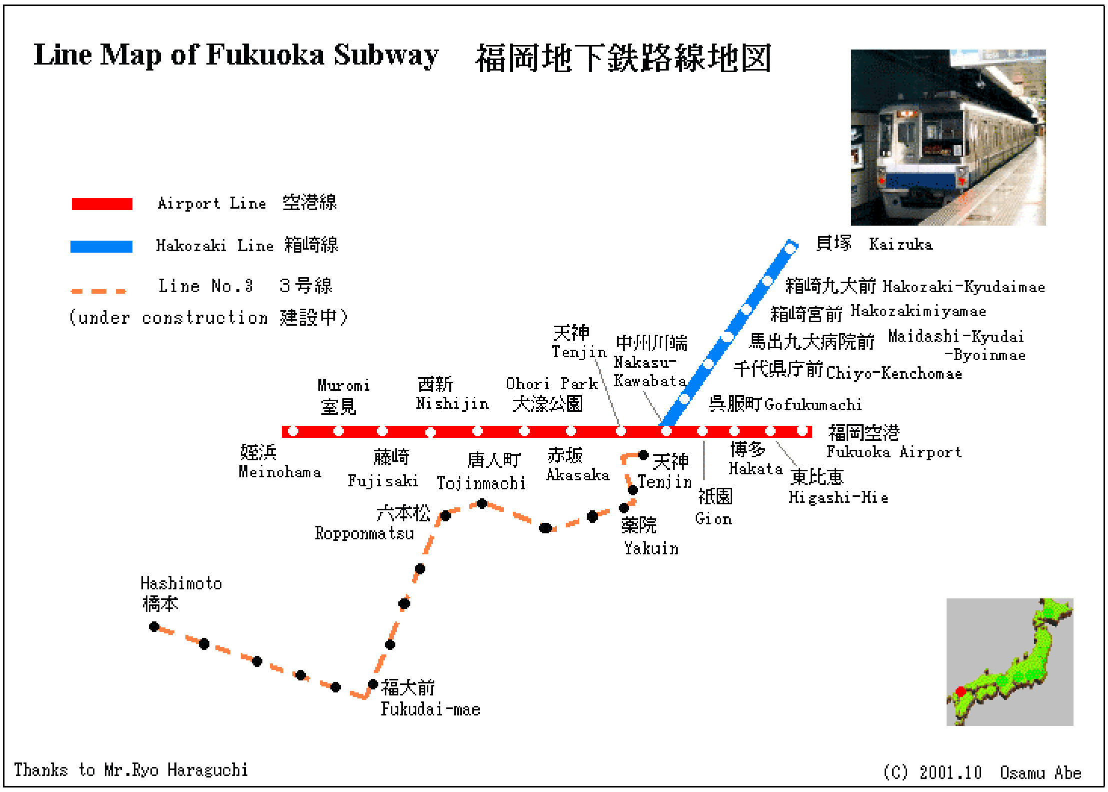

Figure B. 7 Schematic Map of Fukuoka Subway

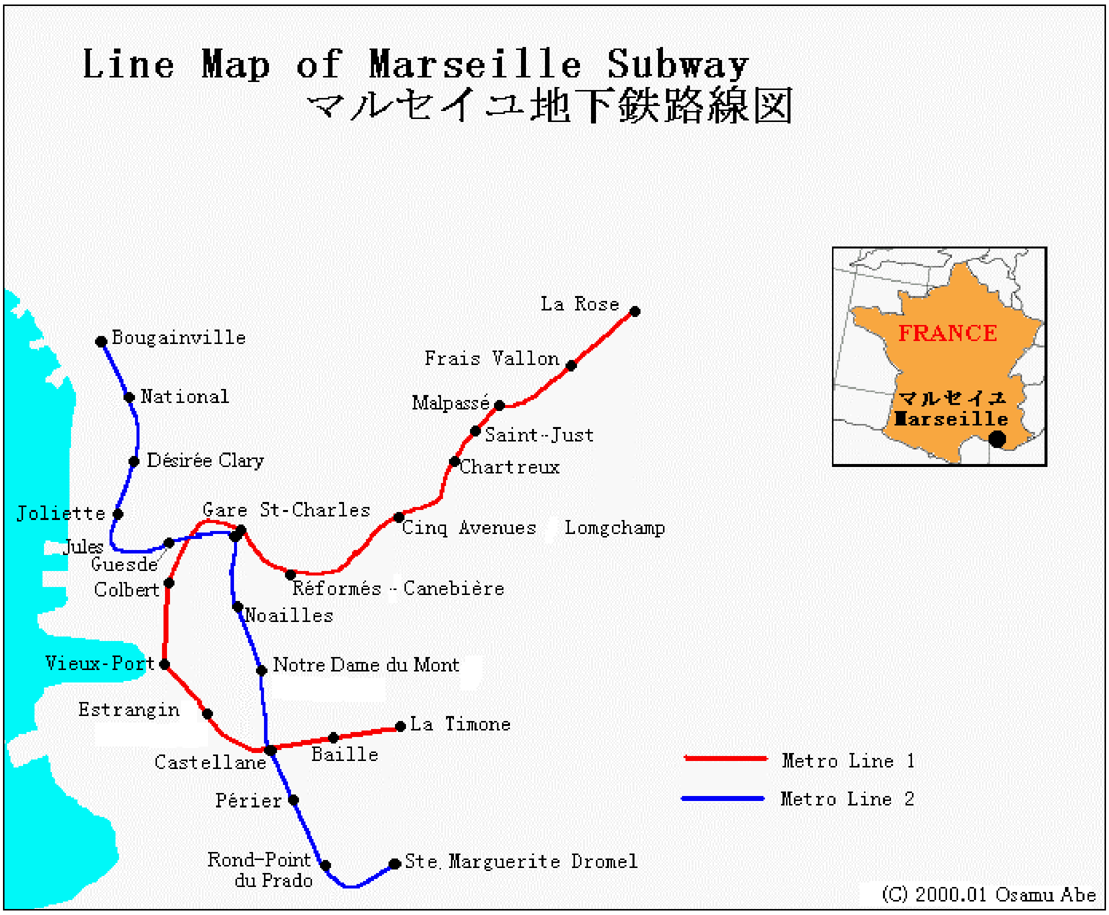

Figure B. 8 Schematic Map of Marseille Subway

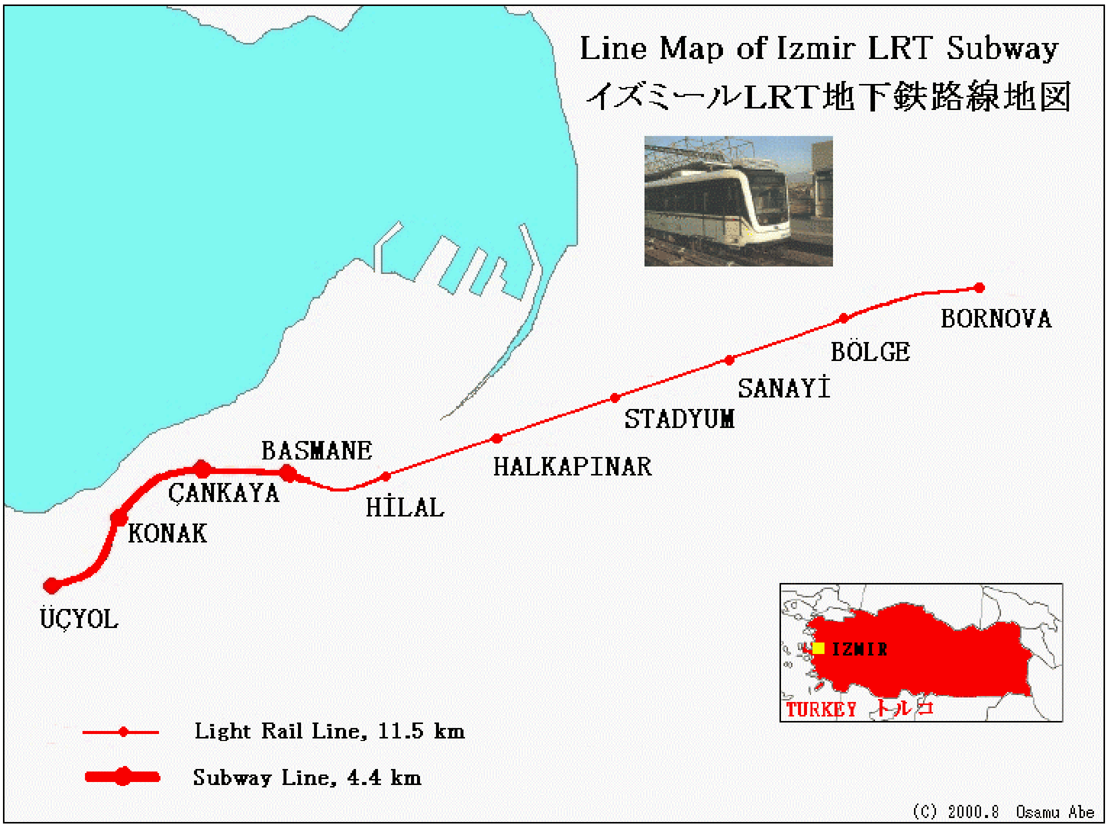

Figure B. 9 Schematic Map of İzmir Subway

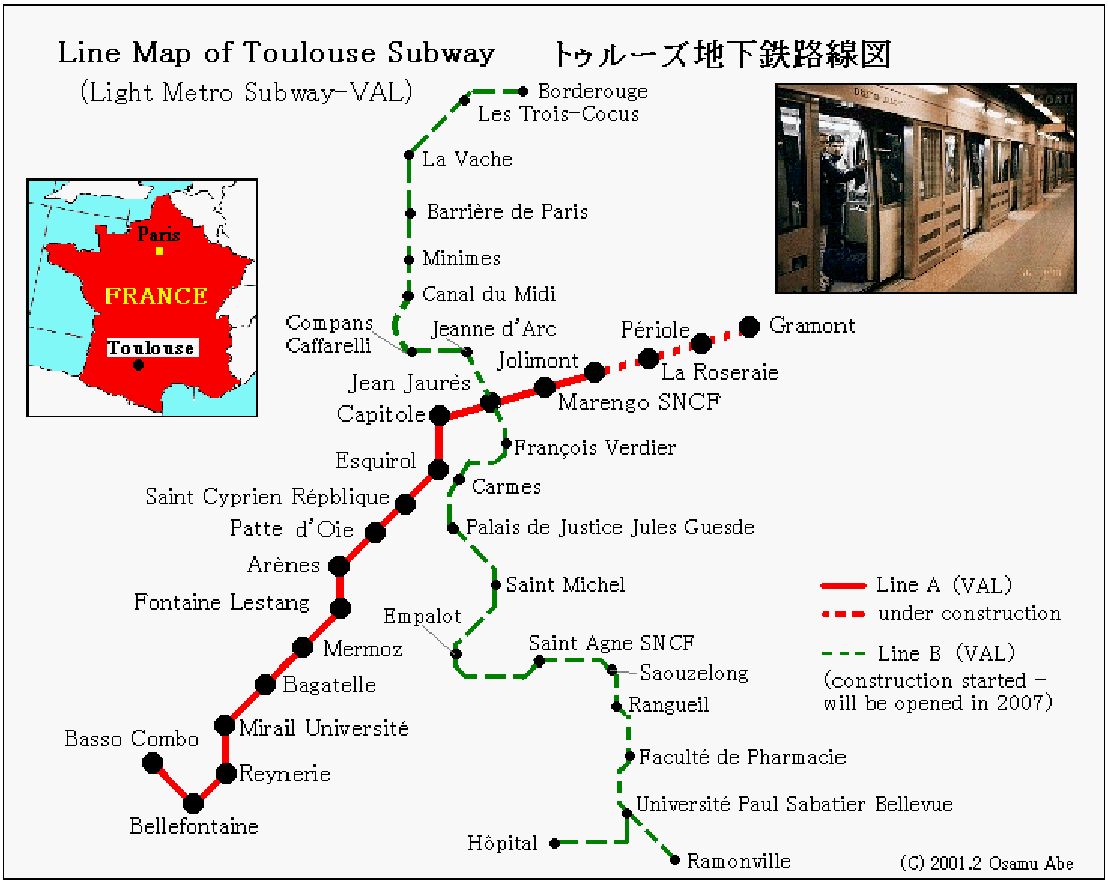

Figure B. 10 Schematic Map of Toulouse Subway

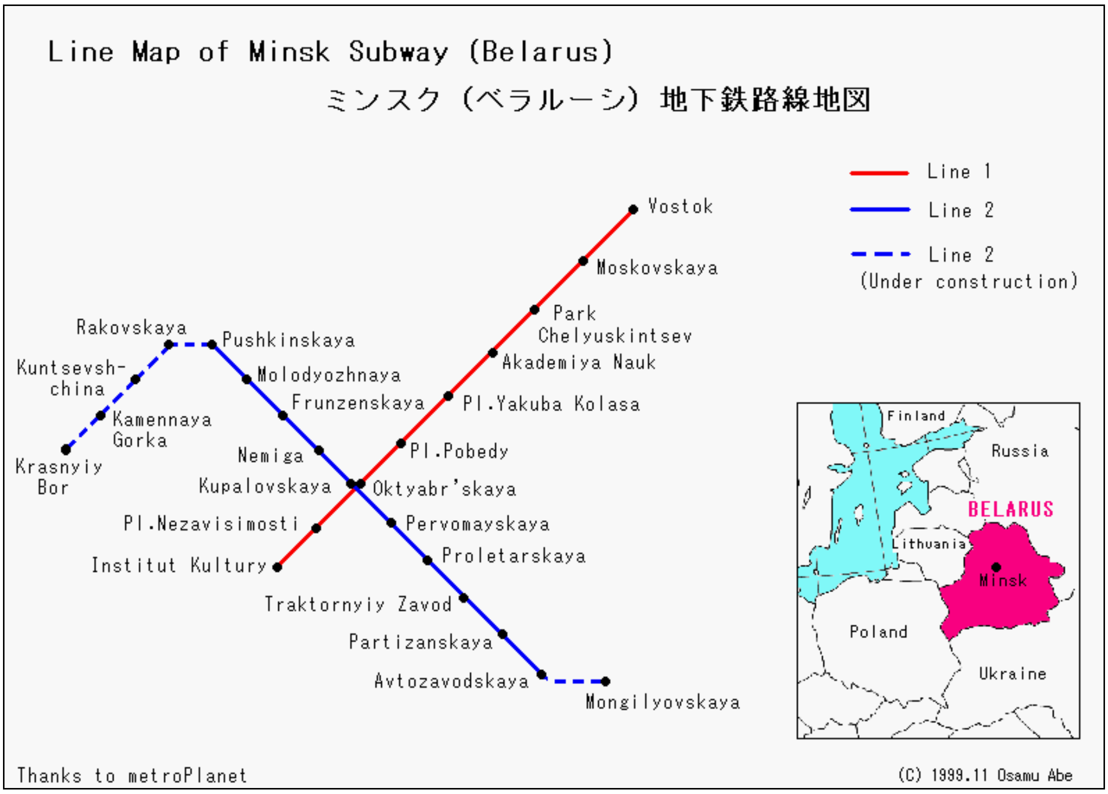

Figure B. 11 Schematic Map of Minsk Subway

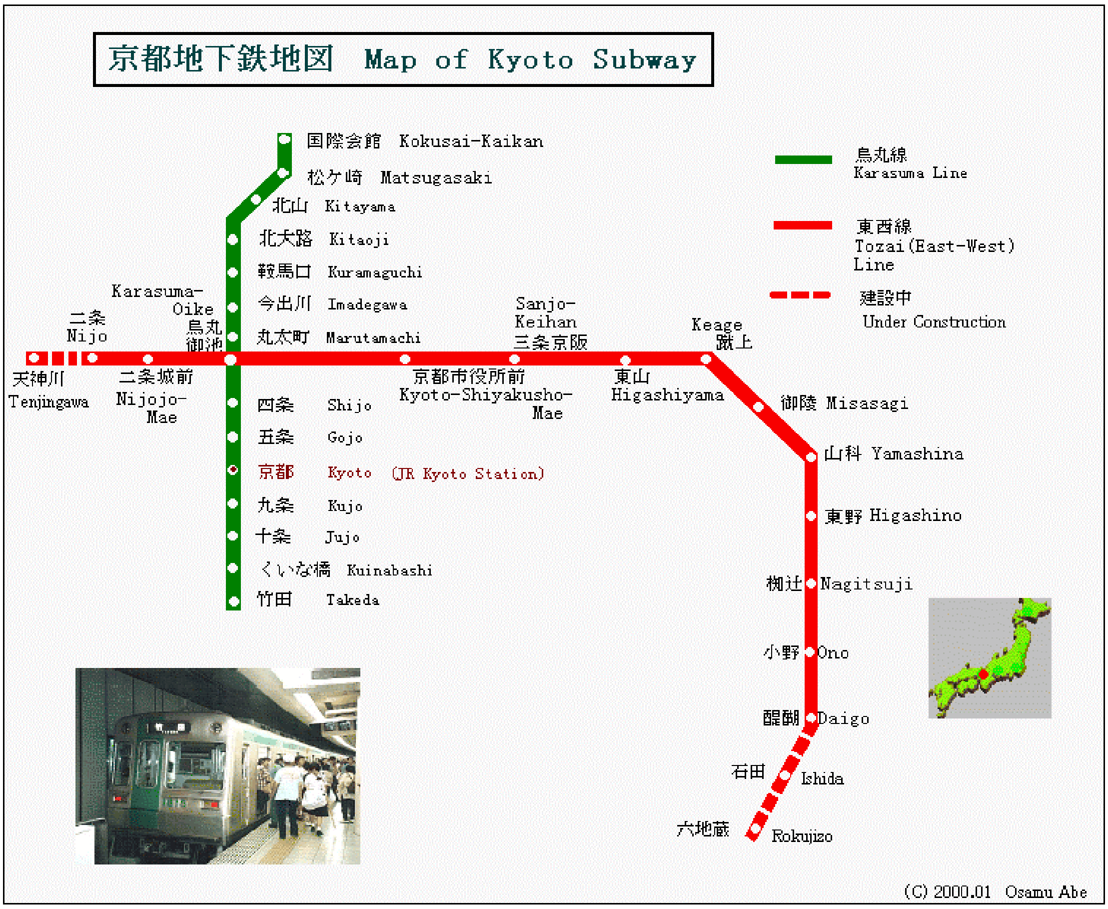

Figure B. 12 Schematic Map of Kyoto Subway

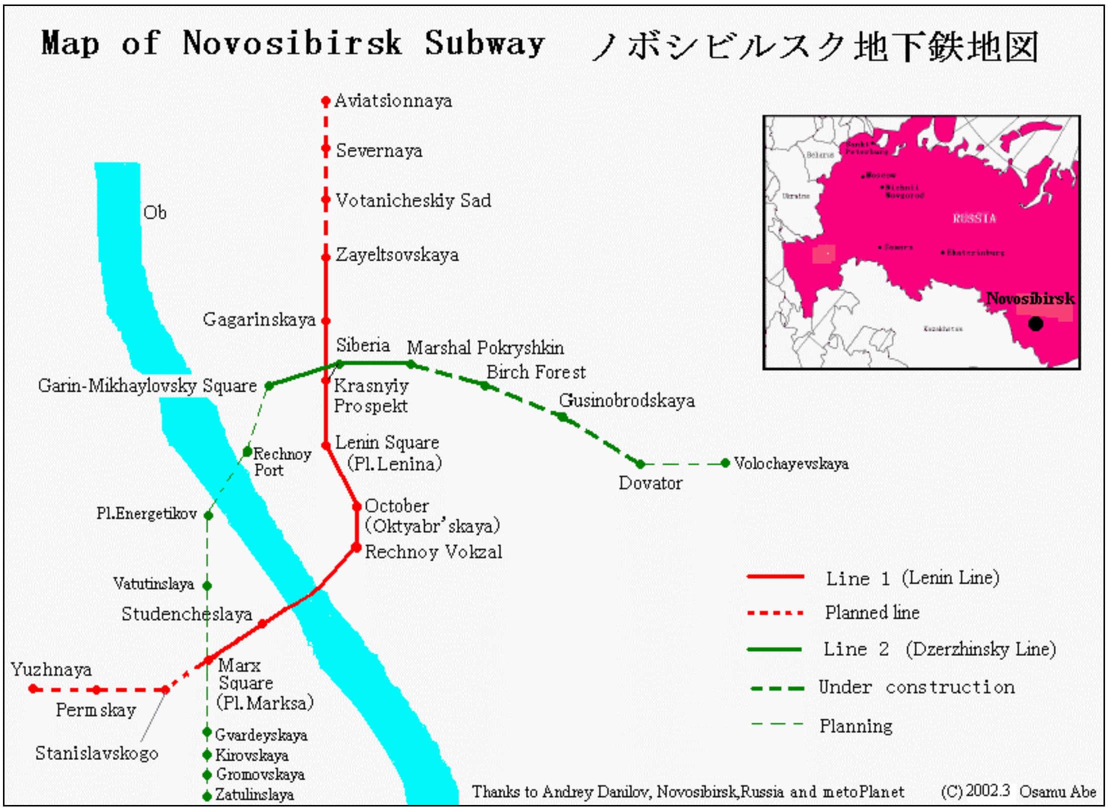

Figure B. 13 Schematic Map of Novosibirsk Subway

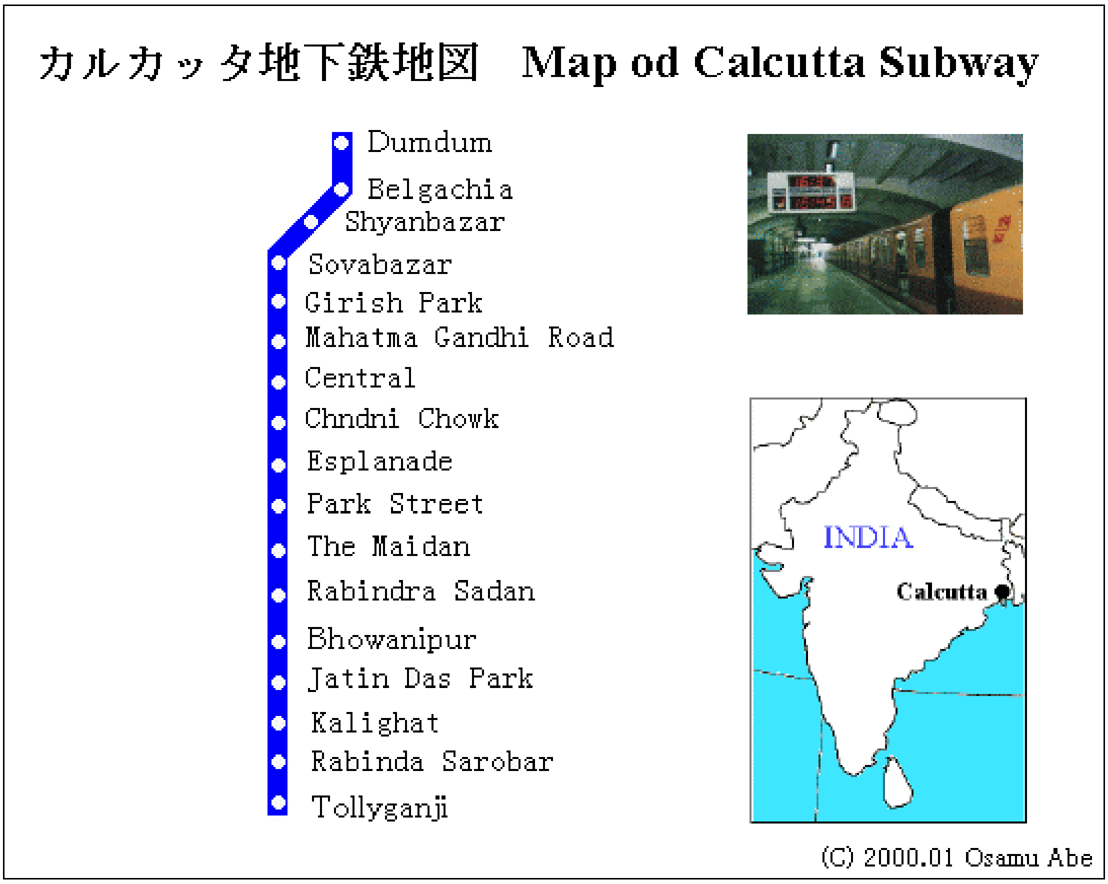

Figure B. 14 Schematic Map of Calcutta Subway

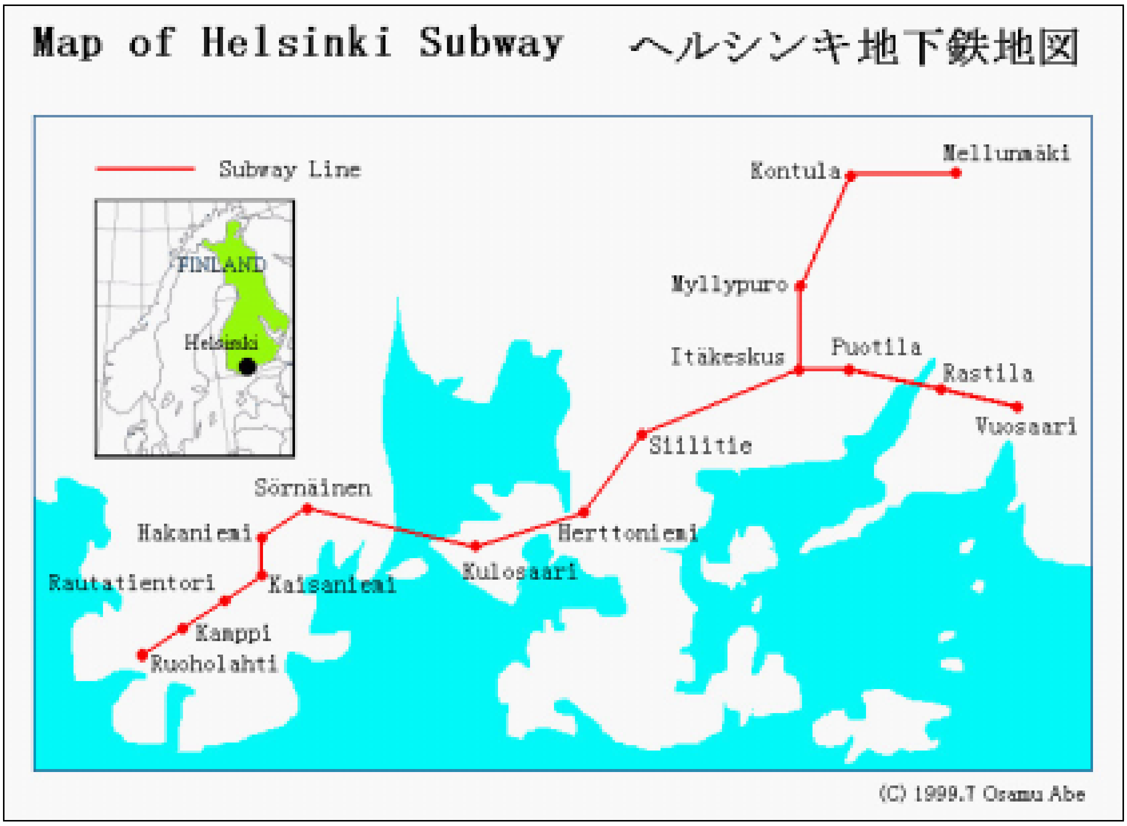

Figure B. 15 Schematic Map of Helsinki Subway

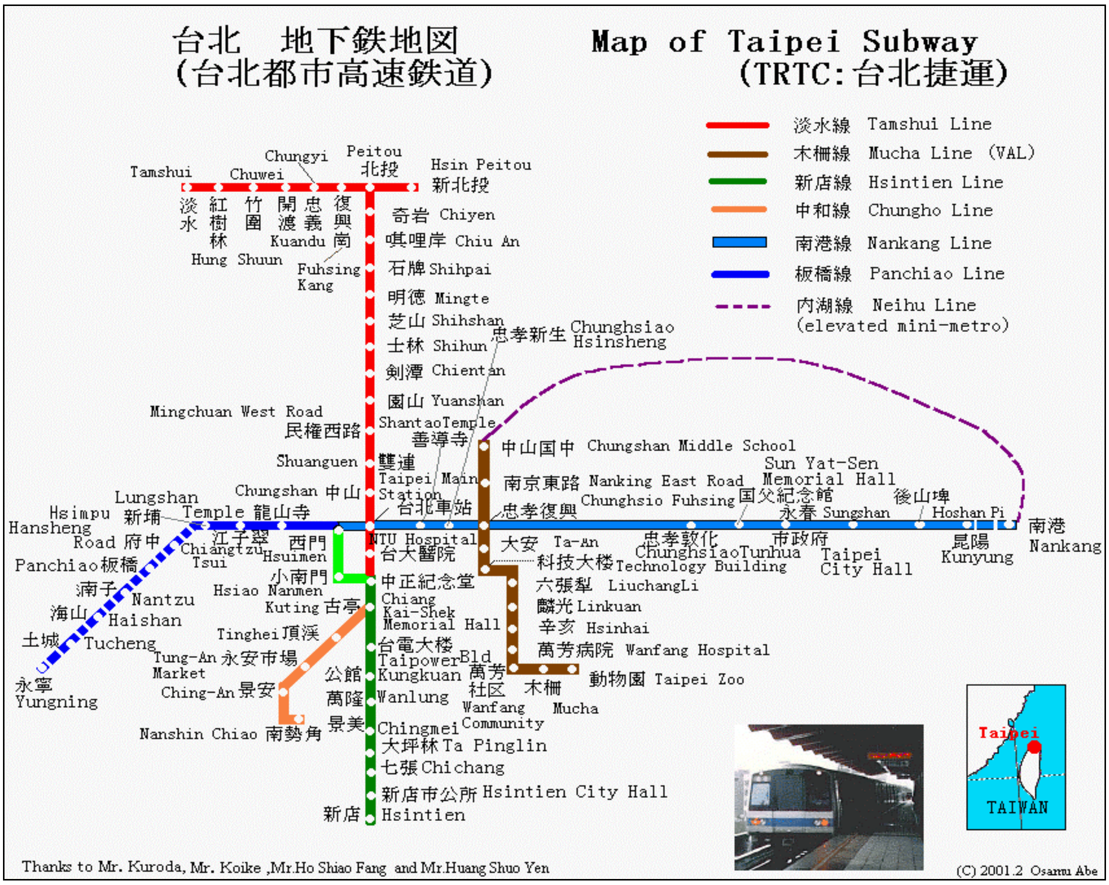

Figure B. 16 Schematic Map of Taipei Subway