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16. Abstract

As the cities of Texas are pursuing transportation plans, the information presented in this reference manual will assist decision-makers involved in the planning, designing and implementation of public transit service. Included in the manual is information on the following subject areas:

- Roles of urban transit;
- Historical development of transit;
- Trends in transit utilization;
- Rail transit (light rail, rail rapid, regional rail and automated guideway transit);
- Electric trolley bus transit;
- Motor bus transit;
- Paratransit (demand-responsive transportation, taxi, and jitney);
- Public transit planning;
- Managing and operating transit systems; and
- Marketing transit services.

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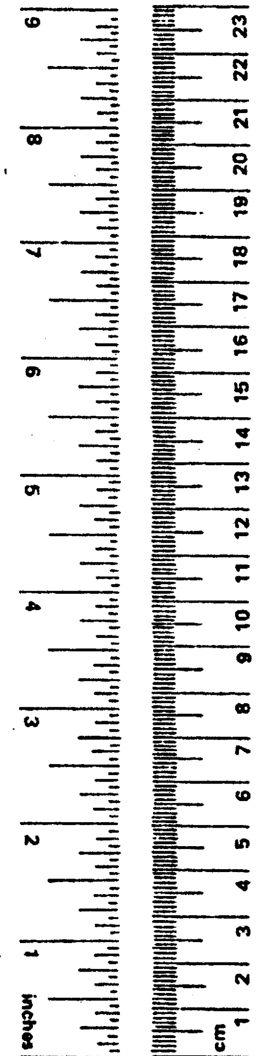
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

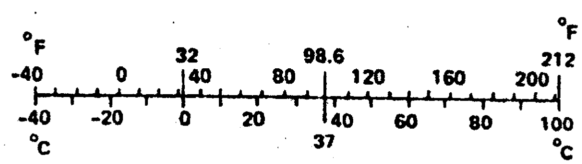
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



TEXAS PUBLIC TRANSIT REFERENCE MANUAL

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Technical Report 1082-1F
Study 2-10-85-1082

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Urban Mass Transportation Administration

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ABSTRACT

As the cities of Texas are pursuing transportation plans, the information presented in this reference manual will assist decision-makers involved in the planning, designing and implementation of public transit service. Included in the manual is information on the following subject areas:

- Roles of urban transit;
- Historical development of transit;
- Trends in transit utilization;
- Rail transit (light rail, rail rapid, regional rail and automated guideway transit);
- Electric trolley bus transit;
- Motor bus transit;
- Paratransit (demand-responsive transportation, taxi, and jitney);
- Public transit planning;
- Managing and operating transit systems; and
- Marketing transit services.

Key Words: transit, public transportation, mass transportation, light rail transit, rail rapid transit, regional rail, automated guideway transit, people movers, intermediate capacity transit systems, electric trolley bus transit, bus transit, busway, bus rapid transit, park-and-ride, paratransit, demand-responsive transportation, taxi, jitney, transit demand estimation, fare elasticities, service elasticities, transportation system management, transit marketing.

SUMMARY

Several larger cities in Texas are currently pursuing major mass transportation plans. Some are also considering the implementation of internal circulation systems which may tie into the mass transportation systems. Still other cities are seriously considering either the implementation of new or the upgrading of existing public transportation systems. Depending upon the role to be served, a number of different transit technologies and operating strategies can be employed.

The principal objective of this reference manual is to present information on the state-of-the-art in transit technology. As such, this manual is intended to assist in the decision-making process by providing an overall view of transit technology, its relative costs, and examples of how it has been implemented.

Roles of Urban Transit

Public transit can effectively serve a variety of functions within an urbanized area. The 3 principal roles of transit as defined in this reference manual are:

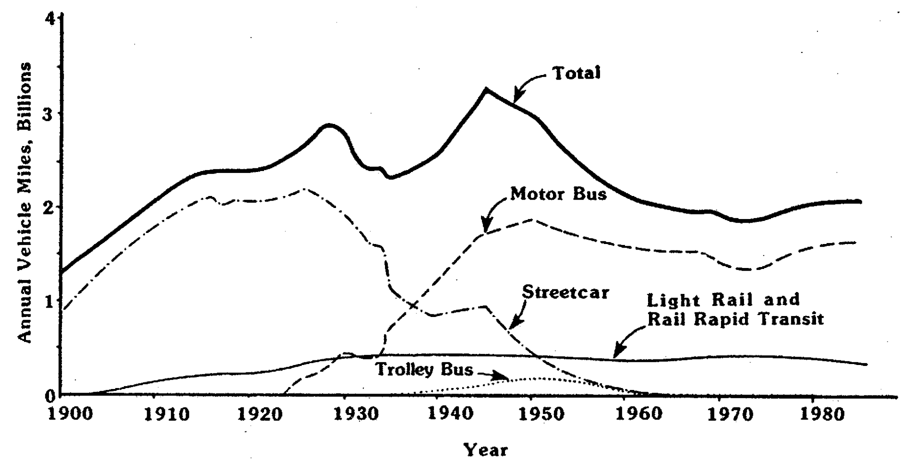
- **Public Transportation** - This form of transit primarily provides some level of mobility to persons who have no other means of transportation. Public transportation helps these persons reach important community destinations, such as employment, shopping and medical facilities. As such, public transportation fulfills a social-welfare need.
- **Mass Transportation** - The primary objective of mass transportation is to provide for the rapid movement of large volumes of persons to major activity centers (such as CBDs) in order to help serve peak travel requirements within major travel corridors. Mass transportation serves an economic need rather than the social need served by public transportation.
- **Internal Circulation** - Within major activity centers where parking is often scarce or restricted, travel distances can become too lengthy to be served only by walking. Some form of transit service is necessary to serve an internal circulation function within these areas.

Historical Development of Transit

Three distinct periods of technological innovation in American public transit emerge. The first, prior to 1870, involved movement by animal or locomotion by foot. Thus, the "walking city" characterized American urban form. The second period, 1870 to 1920 -- and especially the two decades at the turn of the century -- witnessed dramatic technological innovation. These include the streetcar, cablecar and electric rail rapid transit. The second period also witnessed the growth of the suburbs along the development of these radial transportation lines. Historians consider this the "streetcar era." The third period, from 1920 to the present, saw the establishment of the age of the automobile and, to a lesser extent, the motor bus. This age can be considered the "automobile era."

Trends in Transit Utilization

The development of public transit can be divided into 5 categories: rapid growth (1900-1919), stabilization (1920-1939), war-induced growth (1940-1945), lengthy decline (1946-1970) and slow re-emergence (1971-present). Figure S-1 shows trends in public transit ridership and vehicle-miles traveled from 1900 to 1983.



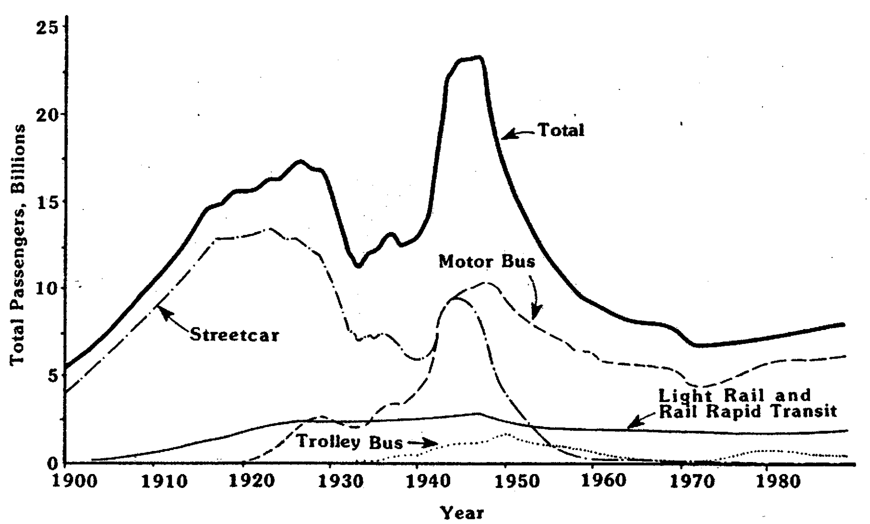


Figure S-1
Trends in Public Transit Vehicle-Miles and
Ridership in the United States

Rail and Automated Guideway Transit

Definitions

Light rail transit (LRT) is defined as an urban railway mode that utilizes predominantly reserved, but not necessarily grade-separated, rights-of-way. Its electrically propelled dual-rail vehicles operate singly or in trains. Power supply is from an overhead wire system and fare collection is on board. Access to the vehicles may be from ground level or from high-level platforms.

Rail rapid transit (RRT) is defined by dual-rail vehicles propelled by electricity transmitted through a side-running third rail. Because of its power supply, rail rapid must operate on fully-protected, exclusive, grade-separated rights-of-way. The use of paired vehicles coupled into trains, high-level platform passenger loading, and fare collection at stations are typical for rail rapid systems. Automated train operation is also common on some modern systems.

Regional rail (RGR) is characterized by the use of diesel-electric locomotives pulling passenger coaches, self-propelled passenger coaches that are diesel-mechanical powered, and occasionally electrified multiple-unit equipment. Regional rail trains share mainlane railway trackage and rights-of-way with intercity passenger and freight service. Low-level passenger loading is common and fare collection is on board.

Automated guideway transit (AGT) is characterized by unmanned, automatically controlled vehicles operated on fixed guideways along exclusive, fully protected rights-of-way. Automated guideway transit vehicles are self-powered by electric motors located on the vehicles or powered by linear induction, active track motors. Vehicles may be operated singly or in trains. Fares are collected at stations.

Functions

Light rail may function in a variety of roles, but is typically used to provide primary transit service in medium- to large-sized metropolitan areas. Network configurations may consist of either a single route in a heavily traveled urban corridor, with feeder routes to other primary transit services, or routes that branch out to outlying areas which provide their own feeder service.

Rail rapid transit is typically implemented as a primary transit service to accommodate high levels of demand in heavily traveled corridors. Rail rapid transit generally exists only in the largest metropolitan areas. Networks are typically radial in nature.

Automated guideway transit functions as a tertiary transportation service and may be found in 2 basic forms. The first, people movers, typically functions as internal circulation, short-haul or shuttle services within small, high density areas such as airports, amusement parks, universities and (in the near future) central business districts. Route configurations may be a single- or dual-lane loop or single lines. The newest form of automated guideway transit, intermediate capacity transit systems, typically provide line-haul service in medium-sized metropolitan areas with route configurations linear in nature.

At the present time, 1 light rail line is in operation in Texas: the Tandy subway in downtown Fort Worth. Two people mover systems have also been implemented, one serves the Dallas-Fort Worth Airport and the other serves the Houston Intercontinental Airport.

Electric Trolley Bus Transit

Electric trolley bus transit is characterized by rubber-tired buses which operate on existing surface arterial streets and highways, usually in mixed traffic. Trolley buses are propelled by electric motors which receive power through power collection poles attached to the vehicle roof that slide along a pair of overhead contact or "trolley" wires. Fares are collected on board.

Developed in the early 1900s, the electric trolley bus mode was intended to offer an intermediate capacity and level-of-service between that of the streetcar/light rail mode and the motor bus mode.

Electric trolley bus systems have operated in a total of 49 cities in the U.S. (including Dallas) and 14 cities in Canada. Five systems in the U.S. and 4 in Canada remain in operation today. Dallas' system ceased operation in 1966.

Motor Bus Transit

A motor bus is a rubber-tired, self-propelled, manually steered transit vehicle with the fuel supply (usually diesel) carried on board the vehicle. With the ability to operate on most streets, arterials and expressways, motor buses provide a range of services (short-haul, long-haul, express, shuttle, etc.) with varying levels-of-service and performance. The vast majority of buses operate in mixed traffic. A small (but growing) number of cities have reserved and/or separated lanes for exclusive use by buses and other high occupancy vehicles (vanpools, carpools).

Buses typically operate on fixed routes, on fixed schedules, making periodic stops for passenger boarding and deboarding. Operators can place buses on any street, as demand requires. Buses may stop at many points, which can change. These factors make rapid introduction, changes and bus route and stop extensions easy.

More than 1,000 motor bus systems operate in the United States and Canada today. Eighteen cities in Texas provide municipal bus service. Seven of these cities also provide special park-and-ride bus service.

Paratransit

Paratransit is an urban transportation mode characterized by small-capacity highway vehicles operating on public streets and highways in mixed traffic. Paratransit service is provided by public or private operators and it is available to certain groups of users or to the general public, but adaptable in its routing and scheduling to individual user's desires in varying degrees.

Paratransit systems can effectively function in a variety of transportation roles including:

- Citywide transit in which the transit demand of an entire city is served;
- Transit feeders for line-haul transit service;
- Low-density urban or rural transit where demand is too low or too unpredictable to be adequately served by conventional fixed-route transit modes; and
- Specialized transportation service for elderly and handicapped persons who are unable to use conventional fixed-route modes.

Three different modes typically used to provide public paratransit service (i.e., service adjustable to the individual user's desires which is open to the general public) are demand-responsive (dial-a-ride) service, taxicabs, and jitneys.

At least 231 demand-responsive systems are known to exist in the U.S. today. Thirteen of these operate in Texas cities. More than 4,000 U.S. taxi companies, including 378 in Texas, also provide service. Only 2 jitney operations of any significance operate today. These are located in Atlantic City and San Francisco.

Public Transit Planning

Urban transportation planning plays an important role in the overall effort of meeting the transportation needs of urban areas. As the planning process has come to include a wide range of issues, impacts, and alternatives, and has come to involve a larger number and greater diversity of participants, it has become increasingly more complex. While planning for transit services is but one component of the overall transportation planning effort, it has become an increasingly important one -- particularly in those urban areas of Texas and the U.S. which are actively pursuing methods of restoring (or maintaining) acceptable levels of mobility to provide for continued economic growth and a better quality of life for its residents. Key to public transit planning is transit demand estimation, transit policy making and goal setting, fares and service levels and marketing transit services.

The cost of providing service is one final important consideration. Operating costs per passenger for selected transit modes are presented in Table S-1. Nationally, passenger and other transit revenues cover only about 32% of the total operating costs of providing service. Federal, state and local assistance are required to offset the deficits.

Table S-1
Estimated Operating Cost Per Passenger for Selected Transit Technologies

Technology	Range	Non-Weighted Average
Light Rail Transit (n=10)	$0.34 - $3.13	$1.04
Rail Rapid Transit (n=12)	$0.45 - $2.17	$1.14
Regional Rail (n=9)	$1.84 - $9.50	$5.09
Automated Guideway Transit (n=13)	$0.04 - $1.03	$0.36
Electric Trolley Bus Transit (n=5)	$0.41 - $1.37	$0.77
Motor Bus Transit (n=1,022)	-----	$0.85
Demand-Responsive Transit (n=33)	$1.44 - $14.16	$6.77

IMPLEMENTATION STATEMENT

Several larger cities in Texas are currently pursuing major mass transportation plans. Some are also considering the implementation of internal circulation systems which may tie into the mass transportation systems. Still other cities are seriously considering either the implementation of new or the upgrading of existing public transportation systems. Depending upon the role to be served, a number of different transit technologies and operating strategies can be employed. The intent of this document is to present technical information that will be of value to decision-makers in assessing the advantages and disadvantages of alternative transit technologies.

DISCLAIMER

This report was prepared by the Texas Transportation Institute for the Texas State Department of Highways and Public Transportation in cooperation with the U.S. Department of Transportation, Urban Mass Transportation Administration.

The contents of this report reflect the views of the authors who are responsible for the opinions, findings and conclusions presented herein. The contents do not necessarily reflect the official views or policies of the sponsors. This report does not constitute a standard, specification or regulation.

ACKNOWLEDGEMENTS

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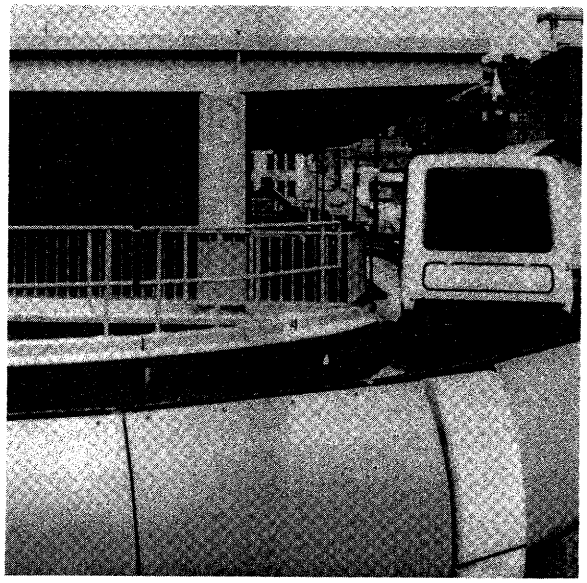
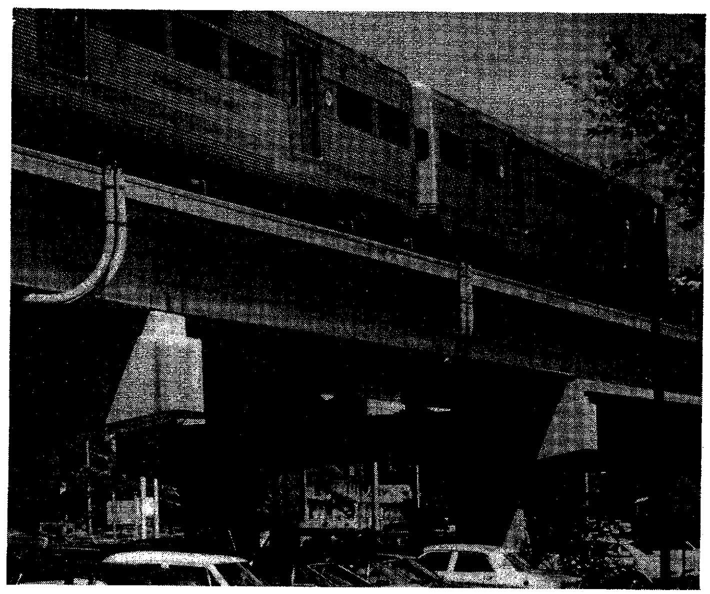
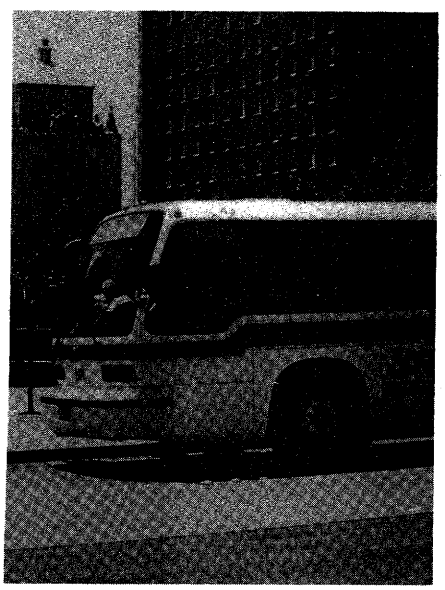




Chapter 1



Introduction

• 1 •

Introduction

The beginning of 20th Century America was characterized by densely populated urban centers and public transportation carrying its highest number of travelers. Then, in the early 1920s came the automobile and the subsequent decline of transit ridership. (Transit is used in this manual as a broad term encompassing both public and mass transportation which are defined later.) Americans developed an entire way of life based on the personal mobility afforded by the automobile. Texas was no exception. An excellent system of urban highways was constructed, usually in advance of development. This network of highways allowed urban residents to move farther from the city centers and places of employment to low density residential suburbs composed of single-family homes on individual lots. During this time, transit played a rather insignificant role as Texans took full advantage of the personal freedom provided by the automobile. The resulting low density, auto-oriented urban form functioned very well in Texas for many years. Then in the 1970s came the following:

- Mass migration to the Sun Belt which led to drastic, unexpected increases in traffic congestion;
- Interest in revitalizing our urban centers;
- Substantial inflation;
- The first serious petroleum shortages;
- Increasing support and federal funds for public transit; and
- A reduction in the rate of highway construction.

These events, along with a growing concern for providing increased mobility to persons who did not own or have access to private automobiles, have led to a renewed interest in public transportation in Texas.

Roles of Urban Transit

Public transit can effectively serve a variety of functions within an urbanized area. The 3 principal roles of transit as defined in this reference manual are: 1) public transportation; 2) mass transportation; and 3) internal circulation. While many transit systems are designed to fulfill one primary role, it is possible for a system to serve multiple roles.

Public Transportation

Within every urban area exists a segment of the population which does not have regular access to private means of transportation due to age, income or physical limitations. A transit system implemented to primarily serve this group of transportation disadvantaged individuals is typically referred to as a public transportation system. In this instance, transportation is provided as a public service to the nondriving segment of the community and, as such, functions to fulfill a social need. Although public transportation systems can never match the flexibility, convenience, availability or speed of private transportation, they can nevertheless provide transit dependent persons with at least some service to most areas within the community at an affordable cost to the patron.

Public transportation service may be implemented in a number of ways depending upon the needs of the area being served. Examples include regularly scheduled bus service, demand-responsive or "dial-a-ride" transportation service, and subsidized taxi operations.

Mass Transportation

Another way in which transit may function is in the role of mass transportation. The primary objective of mass transportation is to provide for the rapid movement of large volumes of persons to major activity centers (such as the CBD) in order to serve peak travel requirements within major travel corridors. Mass transportation serves an economic need rather than the social need served by public transportation. Because mass transportation is designed to serve "choice" riders rather than "captive" riders, a level-of-service must be provided which is consistent with user needs and at a fare competitive with the cost of available transportation alternatives.

Mass transportation systems typically take the form of rail rapid, light rail, or express motor bus (park-and-ride) service; these systems are most effective when used to serve high-volume movements between fixed points of concentrated activity along high-density corridors. Thus, mass transportation has been used effectively in cities such as New York, Chicago and Philadelphia where high-density residential areas exist.

Internal Circulation

Within major activity centers where parking is often scarce or restricted (such as large downtown areas, universities, airports, and amusement parks), travel distances can become too lengthy to be served only by walking. Some form of transit service is necessary to serve an internal circulation function within these areas. In this role, a number of different types of transit systems have been used effectively, including shuttle-type bus service, trolleys, and streetcars. More recently, automated guideway transit (people movers and intermediate capacity transit systems) have also been successfully implemented to fulfill internal circulation or short-haul type of service. The internal circulation role of transit is relatively new to Texas. It has , however, been applied at locations such as the Dallas-Fort Worth and Houston airports.

Purpose of This Reference Manual

Several larger cities in Texas are currently pursuing major mass transportation plans. Some are also considering the implementation of internal circulation systems which may tie into the mass transportation systems. Still other cities are seriously considering either the implementation of new or the upgrading of existing public transportation systems. Depending upon the role to be served, a number of different transit technologies and operating strategies can be employed.

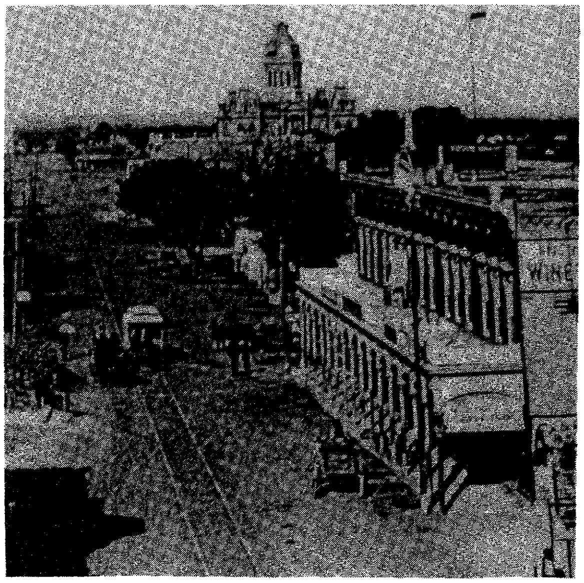
The principal objective of this reference manual is to present information on the state-of-the-art in transit technology. It is not intended to be a complete library on transit, as such an effort would require several volumes. Instead, this manual is intended to serve as a concise resource in the areas of public transportation, mass transportation and internal circulation with listings of references for more detailed information. As such, this manual is intended to assist in the decision-making process by providing an overall view of transit technology, its relative costs, and examples of how it has been implemented.

Reference Manual Content

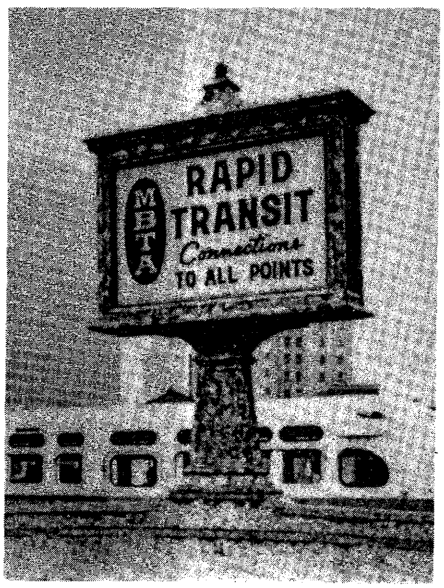
In recent years, several major studies have been performed which have addressed various aspects of transit technology. The pertinent data described in these sources are summarized in this reference manual. In addition to this introductory chapter, the manual is comprised of the following 8 chapters:

Chapter 2 - Overview of Transit
Chapter 3 - Rail Transit
Chapter 4 - Electric Trolley Bus Transit
Chapter 5 - Motor Bus Transit
Chapter 6 - Paratransit
Chapter 7 - Public Transit Planning
Chapter 8 - Managing and Operating Transit Systems
Chapter 9 - Marketing Transit Services

This reference manual is designed to allow the user to refer to the Table of Contents to identify those sections of the manual that present information relative to the transit alternative or issue being evaluated.



Chapter 2



Overview of Transit

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Overview of Transit

Historical Development of Transit

It has been said that "the modern American city had arrived by the last third of the nineteenth century" (1).* Until that time compactness characterized all American cities. Historians labeled this early urban configuration the "walking city" because of its size, density and major mode of conveyance. Human feet were the heaviest users of streets. During this time, the two basic forms of intraurban power were "the strength and stamina of humans and horses" (2).

Early Forms of Public Transit

In 1829, New York City experienced what was to be the first modern predecessor of today's public transit systems. The horse-drawn omnibus was a large, horse-drawn coach designed to transport urban public over fixed routes for fixed fares. It offered speeds of 3 miles per hour, comparable to walking. By mid-century, the success of the omnibus multiplied and Boston, Philadelphia, Baltimore, Washington, St. Louis, Pittsburg and Cincinnati all boasted service. In spite of its widespread popularity, public transit remained a luxury which only the wealthy could afford. The vast majority of the population remained on foot.

Combining the technology of the omnibus and the railroad in 1832, the New York and Harlem Railroad pioneered "the next major development in urban mass transportation" with the horse railway or horse tramway (1). Running horse-drawn coaches over rails instead of cobblestones, the horse railway enabled horses to pull larger, heavier cars for a longer smoother ride at speeds of about 4 miles per hour. George Francis Train, an American, developed the first horsecar but constructed the "Marble Arch Street Railway" in England (3). By the 1860s almost all American cities and towns of any size boasted of horse- or mule-powered railway companies (3).

Horse tramways in Texas developed around the 1870s. In 1868 the Houston City Railroad Company opened as Texas' first system in a city with public transportation operating today (4). The Dallas City Railroad Company

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*Numbers in parentheses refer to references listed at the end of the chapter.

followed in 1871 (5). By 1886, ten tramways provided service in Texas cities. Table 2-1 shows the city, system name and date of opening for the horse tramways in Texas. All of these systems used mules to pull the cars.

Table 2-1
Horse Tramways Operating in Texas

City	System Name	Opening Date
Austin	Austin City Railroad Company	1874
Corpus Christi	Gusset Street Railway	1890
Dallas	Dallas City Railroad Company	1871
	Dallas Street Railroad Company	1875
	Commerce & Envay Street Railway Company	1876
	Dallas Belt Street Railway Company	1884
El Paso	El Paso Street Railway	1882
Fort Worth	Fort Worth Street Railway Company	1876
	North Side Railway	1887
Galveston	Galveston City Railroad Company	1867
Houston	Houston City Railroad	1868
	Houston City Street Railway	1874
Lockhard	unknown	1882
Paris	Paris Railway Company	1878
San Antonio	Alamo Plaza-San Pedro Springs Rapid Transit	1878
Taylor	Taylor Street Railway	1891
Waco	Waco Electric Railway & Light Co.	1892
Waxahachie	Waxahachie Street Railway Company	1889

Source: References 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 and 14.

Because they laid track on public streets, railway companies needed city-granted franchises to operate. Thus, it was early that the local government became involved in public transit. Often these franchises stipulated fare structures, street maintenance duties including snow removal and summer watering down the unpaved part of the street and some required the railway company to pave the entire street from curb to curb.

Despite its advantages over the omnibus, the horse-drawn railway suffered from lack of alternate power. Horses were the most expensive part of the investment. They cost up to "$200 each, and a transit company had to own from five to eight times as many horses as cars" (2). Costly to buy and expensive to maintain, horses grow old and are susceptible to diseases and epidemics. For example, in 1872 an equine respiratory disease killed over 2,250 horses in three weeks in Philadelphia (2). Such disasters seriously disrupted an already slow and expensive form of urban transportation.

The cablecar successfully replaced the horse with mechanical power. In 1869 Andrew Hallidie invented the cablecar grip which allowed a continuously running cable in a slot between the tracks and beneath the street to be grasped and released so cars could start and stop (3). First operated in San

Francisco in 1873, the cablecar system soon became largest in Chicago with the North Chicago City Railway's 82 miles of track. Cablecars carried passengers at speeds of up to 9 miles per hour. In spite of low operating costs, the cablecar's extensive capital costs (estimated at $100,000 per route mile) required large numbers of people to move to be economically feasible (3). Still, the cablecar like the omnibus and horse-drawn railway, helped draw urban development out along its routes (3).

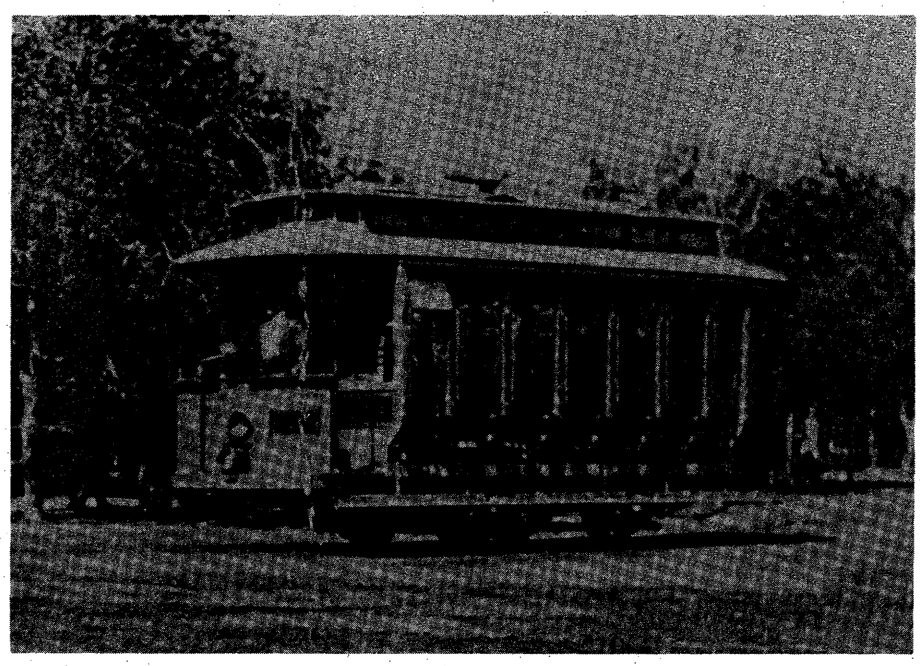
At least 13 cities in Texas operated mule-drawn tramways using vehicles such as this 1870s car (left).

First operated in San Francisco in 1873, the cable car (right) replaced horse and mule power with mechanical power.

Dallas appears to be the only Texas city which considered the establishment of a cablecar system. In May of 1890, A. W. Childress proposed a cable railway line on Elm St. from Houston to Haskell (5). In June of 1891 around 3,000 feet of conduit had been laid (6). Childress sold these rights to Queen City Railway Company and after three successive sales, the project was never completed as a cablecar line, but rather as an electric streetcar line (5, 6).

Lasting for less than two decades, the era of the cablecar ended (except in San Francisco) with the rise of the electric trolley at the beginning of the twentieth century. In 1884 Cleveland offered the first regular electric streetcar service in America. Proving unreliable, officials abandoned the line in the following year. It was not until the Sprague Electric Railway and Motor Company built the Richmond Union Passenger Railway in 1888, did the electric streetcar boom. In 1886, Montgomery, Alabama became the first U.S. city to have a citywide street railway run by electricity (14). In 1890, 70% of street railway mileage used animal power; by 1902, 97% of mileage ran off electricity (2).

With few exceptions, every Texas city presently with transit service had electric streetcar companies as their predecessors. Lubbock appears to be the only bus system that did not begin with streetcar service (15). The Laredo Electric Railway Company claimed honors as the first electric railway system west of the Mississippi River with electric streetcars on December 5, 1889 (16). The Austin Rapid Transit Railway Company electrified their operations on February 27, 1891 and Houston City Street Railway Company followed on June 12, 1891 (4, 7).



In December 1889, Laredo became the first city west of the Mississippi River to be served by electric streetcars.

Table 2-2 shows the system names, dates of operation and city served for the systems serving identifiable electric streetcar companies in Texas' cities. Before the 1920s, thirteen of the systems consolidated or went under financially. During the 1930s, ten additional systems consolidated or went bankrupt. Another three companies went by the wayside in the 1940s. By the 1950s only Dallas and El Paso offered electric streetcar operations (5, 17). Dallas phased out its streetcar service in 1956. Keeping with service initiated in 1902 El Paso offered the sole electric streetcar service from El Paso across the international bridge into Juarez until May 4, 1974 (17, 18).

Table 2-2
Electric Streetcar Companies Operating in Texas' Cities

City	System Name	Dates of Operation
Abilene	Abilene Traction Company	1921-1931
Amarillo	Amarillo Street Railway System	1908-1923
	Amarillo Traction Company	1910-1926
Austin	Austin City Railway Company	1891-1902
	Austin Rapid Transit Railway Company	1889-1891
	Austin Electric Railway Company	1902-1940
Beaumont	Beaumont Traction Company	1900-1937
Bryan	Bryan-College Station Interurban Railway	1910-1923
Corpus Christi	Corpus Christi Railway & Light Company	1914-1930
Corsicana	unknown	unknown-1931
Dallas	North Dallas Circuit Railway	1889-1901
	Dallas Consolidated Traction Company	1890-1956
El Paso	El Paso Electric Railway Company	1902-1974
	El Paso & Juarez Street Railway Company	1892-unknown
Fort Worth	Northern Texas Traction Company	1911-1939
	Baptist Seminary Street Railway Company	1910-1913
Galveston	Galveston Electric Company	1890-1905
	Galveston-Houston Electric Company	1890-1938
Houston	Houston City Railway Company	1891-1940
	Bayou City Street Railway	1891-1940
Laredo	Laredo Electric Railway Company	1889-1935
Marshall	Marshall Traction Company	unknown-1927
Paris	Paris Transit Company	1901-1927
Port Arthur	Port Arthur Traction Company	1904-1937
San Angelo	San Angelo Power & Traction Company	1908-1915
San Antonio	San Antonio Public Service	1917-1933
	San Antonio Traction Company	1900-1917
	San Antonio Rapid Transit Street Railway	1890-1895
Wichita Falls	Wichita Falls Traction Company	1909-1932

Source: References 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 15, 16, 17, 18, 19, 20, 21 and 23.

At least 29 railway companies provided electric streetcar service in 19 Texas cities between 1889 and 1974. Photo above shows a streetcar operated in Dallas in 1946.

Public Transportation in the Twentieth Century

With the lower capital and operating costs, faster service and lower fares, the electric streetcar opened American cities for land development. Throughout much of America, the expansion of the "streetcar suburbs" involved cooperation between the developer-speculator and the transit lines. With an average speed of at least 10 miles per hour, the electric trolley permitted workers to reside in the suburbs and to work in the central business district. Thus, within a few years the electric streetcar played an important role in shaping the city as the population it served located along the expanding rail system (3). This fingering growth along transportation lines replaced the compactness of urban form which had characterized American cities when walking and horsepower were the dominant forms of transportation.

Early twentieth-century use of streetcar systems in most large and medium-sized cities was but the beginning of a sequence of public transit improvements: streetcar vehicle improvements, infrastructure projects, and new modes like the motor bus and electric trolley bus. Streetcar technology improved and by the 1920s four-axle cars replaced the 1900s two-axle car.

In spite of record patronage levels, streetcar systems faced rapidly rising costs and a regulated nickle fare. By the 1920s, the systems were hard pressed to meet the challenge of the coming automobile age (25). Competition from the automobile began to divert ridership and the cars created congestion impeding streetcar operations. To improve operations and reduce track maintenance costs, streetcar system operators began to convert streetcar lines to motor bus operations (3).

Motor Bus Tranist

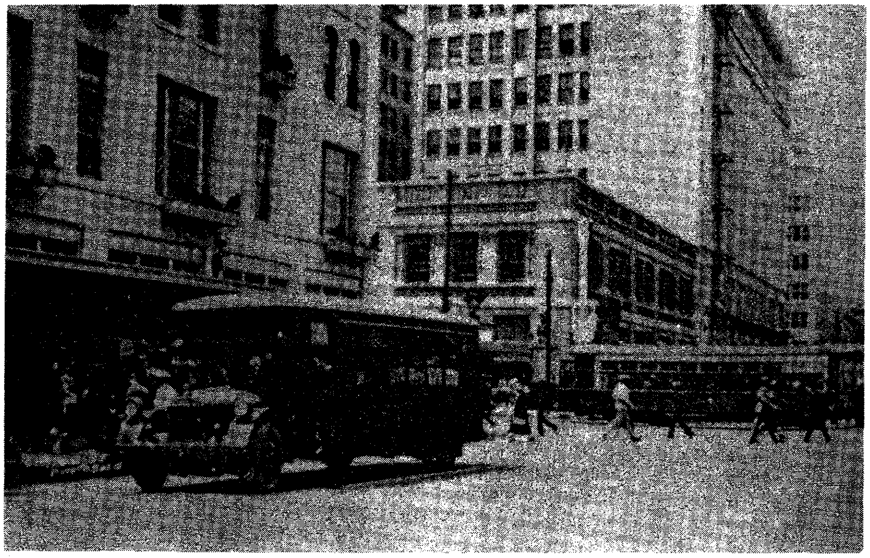
As early as 1905, the Fifth Avenue Coach Company in New York replaced its omnibuses with imported double-decker motor buses. In 1912, Cleveland Railways began to use buses as feeders to its streetcar lines (3). It was, however, the Fageol brothers who in the 1920s provided a front-engine bus designed to be a passenger bus. The twenties and thirties saw additional vehicle body and power improvements and by 1939 the rear-mounted diesel engine and automatic transmission powered the typical intraurban motor bus.

Using locally-modified truck chasis and bus body San Antonio operated the first Texas buses in 1922 (23). Houston streets first carried buses in 1924 with El Paso, Fort Worth and Dallas following suit over the next two years. Table 2-3 shows the year and city in which buses first operated. Several cities which no longer have transit service saw motor bus systems operate briefly after World War II.

Table 2-3
Introduction of Bus Technology in Texas

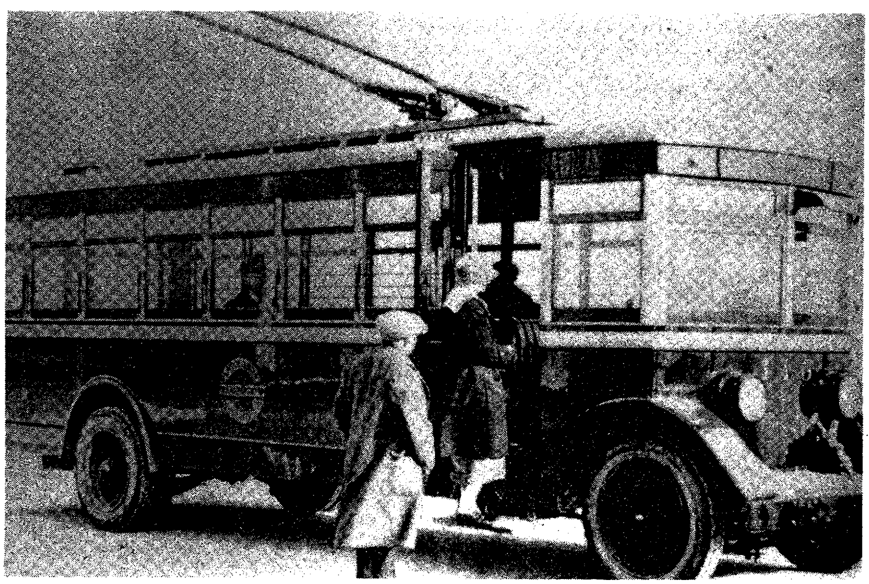
City	Year of Bus Introduction
Amarillo	1927
Austin	1928
Baytown	1948
Beaumont	1930
Brownsville	1950
Corpus Christi	1931
Dallas	1926
Del Rio	1952
Denton	1937
El Paso	1925
Fort Worth	1926
Galveston	1928
Garland	1947
Greenville	1940
Houston	1924
Laredo	1936
Longview	1947
Lubbock	1932
Lufkin	1948
Paris	1927
Plainview	1950
Port Arthur	1937
San Angelo	1932
San Antonio	1922
Victoria	1950

Source: References 4, 5, 6, 7, 8, 9, 10, 11, 12, 14, 15, 16, 17, 18, 19, 20, 21, 22, and 23.



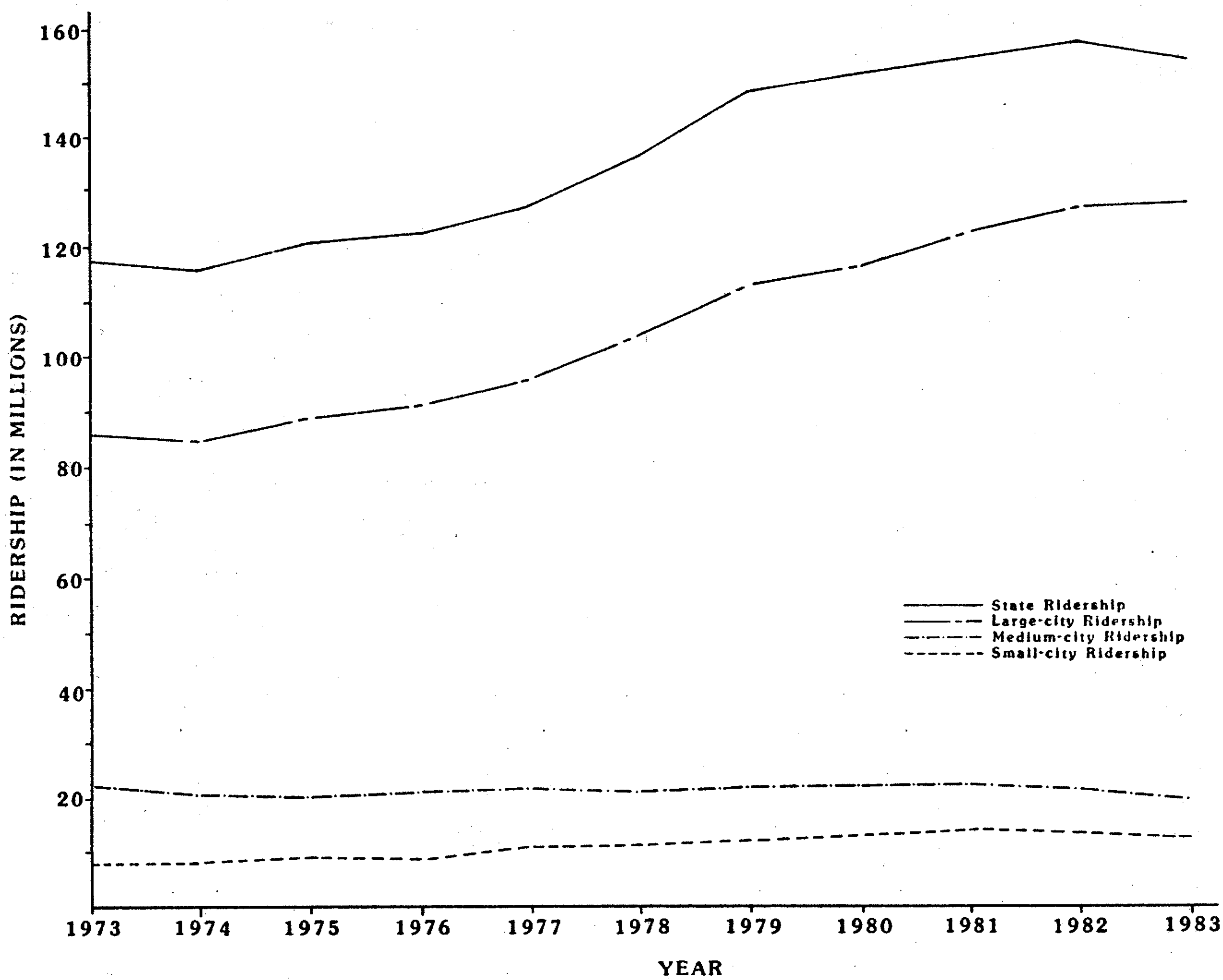
Both streetcars and buses provided transit service in downtown Houston in 1926 (left).

A 1930s Houston bus is pictured next to a 1920s bus (right).



Many transit systems used the electric trolley bus as an interium vehicle in the replacement of electric streetcars with motor buses (left).

Today, 18 cities in Texas operate municipal bus transit systems. Figure 2-1 shows the passenger ridership for the Texas transit systems from 1973 to 1983. The ridership data are presented for the state and are categorized by size of city served by the system. Large cities (over 500,000 population) include Houston, Dallas and San Antonio. Medium cities (between 200,000 and 500,000 population) include Fort Worth, El Paso, Austin, and Corpus Christi. Small cities (under 200,000 population) include Abilene, Amarillo, Beaumont, Brownsville, Galveston, Laredo, Lubbock, Midland, Port Arthur, San Angelo, Waco and Wichita Falls.



Source: References 26 and 32.

Figure 2-1
Texas Transit Ridership 1973-1983

Electric Trolley Bus Transit

The twentieth century also witnessed the invention of the electric trolley bus. With twin trolley poles for electrical power from overhead wires, electric trolley vehicles used rubber tires and operated on streets like motor buses. Able to utilize existing electrical generation infrastructures, the electric streetcar systems often used electric trolley buses as interim vehicles in the long term replacement of electric streetcars with motor buses (3). In Texas, electric trolley buses operated in Dallas from 1945 until 1966 when they were replaced with new diesel motor buses.

Suitable for relatively short-haul, low-speed travel, the electric streetcar, motor bus and trolley bus failed to provide high-speed suburban and commuter linkages. Parallel with local transit service, large cities began to utilize rail technology for higher speed services on lines with separated rights-of-way.

Rail Transit Modes

Three types of services emerged: suburban railways, interurbans and rail rapid transit. Suburban railways originated as local service on main, intercity rail lines with intercity trains making stops in the suburbs as they entered a large city. These operated as "commuter railroads;" the first American service in 1838 was the Boston and West Worcester Railroad designed for wealthy "exurban" communities. By 1900, the suburban railways began to electrify so after World War II, most suburban and regional rail systems operated on electrical traction.

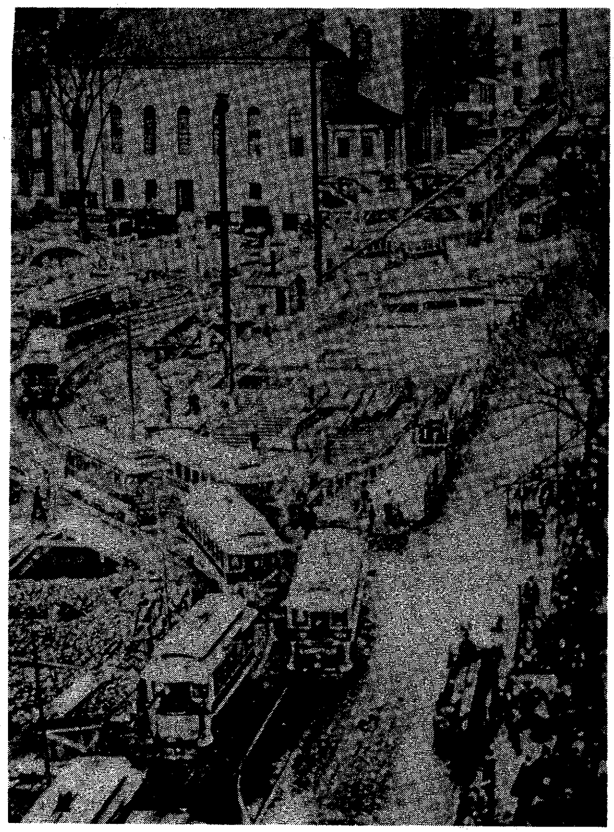
Developed after the invention of electrical traction, interurbans are large streetcar-like vehicles operating on private rights-of-way between adjacent communities. Unlike suburban railways, these interurbans ran strictly between cities specifically for passenger service. Connecting cities at distances of 10 to 50 miles, the interurbans focused on passenger travel between these towns. With average speeds of 10 to 50 miles per hour, the interurbans enjoyed their national zenith in 1913. Their success was, however, short-lived and the automobile eclipsed the interurban.

The first interurban railroad in Texas opened in 1901. The last electric interurban constructed in the United States was from Houston to Goose Creek (Baytown) in 1927. In Texas, about nineteen systems were built with over 600 miles of track (28). Dallas possessed one of the largest systems in the country. With 250 miles of track, the Texas Electric Railway operated until December 31, 1948, the last interurban in Texas (29).

Another important urban rail mode, rail rapid transit is intraurban transit on fully separated rights-of-way (25). At the turn of the century, companies in several of the largest, most congested cities raised parts of their tracks on stilts to give their vehicles unrestricted impedance from pedestrians and animal-powered vehicles (1). Called the electric elevated railways, the "els" operated in New York, Chicago, Boston, Philadelphia, Brooklyn and Kansas City. As early as 1874, New York boasted a steam-powered elevated system but the vibration, noise, dirt and danger of falling ashes discouraged other cities from following suit with steam-powered vehicles.

Henry M. Whitney constructed the first underground tunnel, or subway, for his streetcar vehicles in 1897 in Boston. The tunnel's success prompted New York City to construct its first subway which opened in 1904. With the exception of Philadelphia's combined subway-el in 1908, no additional underground projects followed until Chicago in the 1930s.

Elevated railways ("els") operated in New York City (above) as early as 1874. The first underground subway for streetcar vehicles was constructed in 1897 in Boston (right).

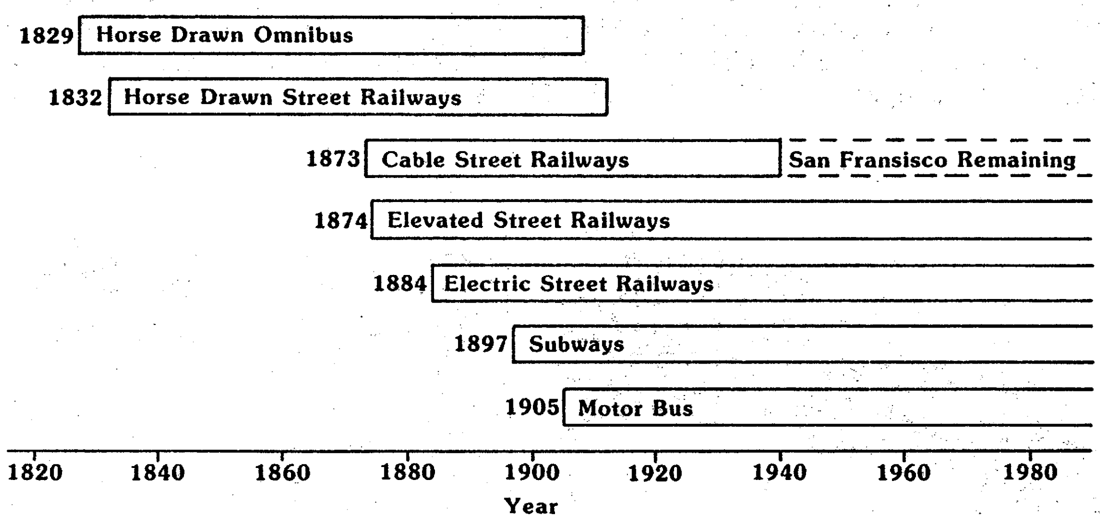


Construction of additional subways halted until the 1950s when Cleveland and Toronto opened their systems. Montreal and the San Francisco Bay area built their systems in the 1960s and 1970s. By 1976, 10 rail rapid systems operated in the United States: Chicago, Cleveland, Boston, New York, Camden (New Jersey), Oakland/San Francisco, Philadelphia, Washington, D.C., Montreal and Toronto (30).

Since 1976, the city of Atlanta has constructed a rail rapid system. Parts of the systems in Miami and Baltimore have opened and additional lines are under construction.

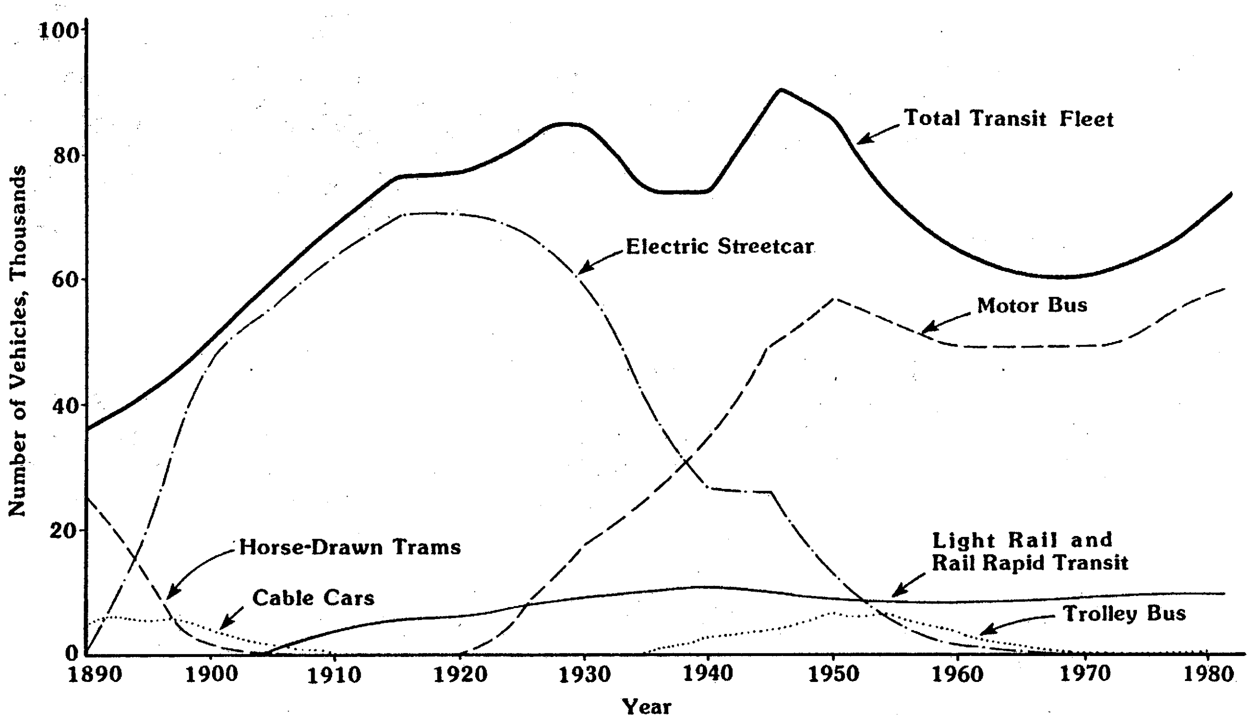
Summary

Figure 2-2 summarizes the technological developments in public transit in the United States and Figure 2-3 shows the changing public transit vehicle mix over time.



Source: Adapted from Reference 14.

Figure 2-2
Chronology of U.S. Urban Transit

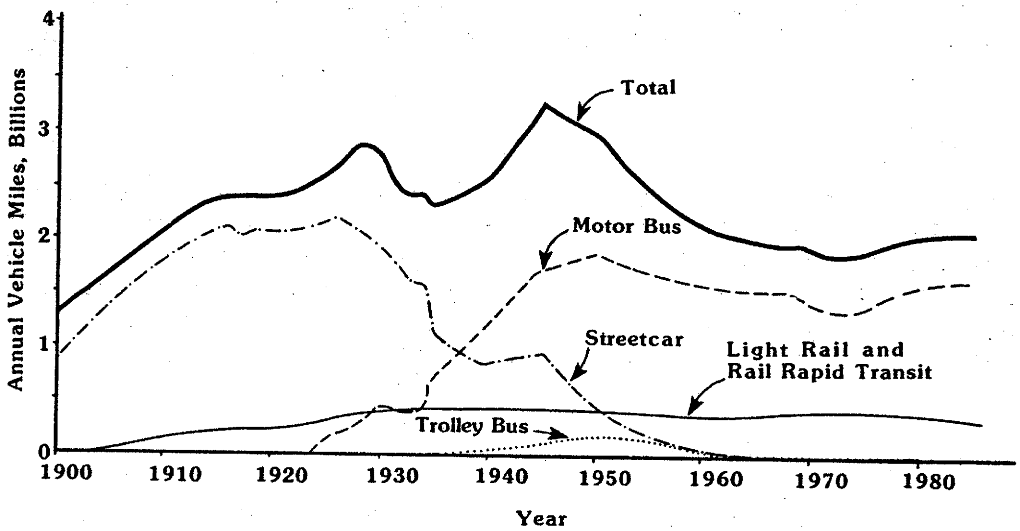


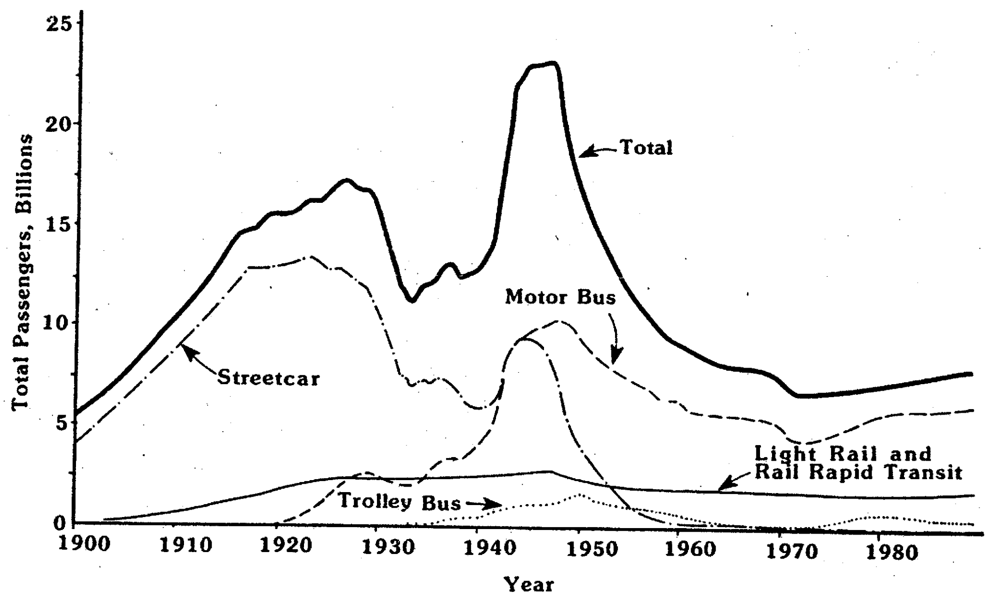
Source: References 26 and 32.

Figure 2-3
Trends in U.S. Transit Vehicle Mix from 1890 to 1980

Trends in Transit Utilization

The development of public transit can be divided into four categories: rapid growth, stabilization, war-induced growth and lengthy decline (3). A fifth period of slow re-emergence is occurring. Figure 2-4 shows trends in public transit ridership and vehicle-miles traveled.





Source: References 26 and 32.

Figure 2-4
Trends in U.S. Public Transit Vehicle-Miles and Ridership

Initial Rapid Growth (1900-1919)

From 1900 to 1919 per capita public transit ridership rose faster than did the urban population. Historians cite the electrification of the horse railways as the driving force behind this rapid growth. Offering high operating speeds and vehicle capacity, the electrified public transit modes permitted suburbanization to occur. This dispersion of the "walking city," in turn, created the need for greater transit travel. During 1910-1915, however, several factors were beginning to affect growing ridership. Increasing automobile use, competition with jitneys and increasing transit operating costs were beginning to outstrip transit productivity (25).

Stabilization (1920-1939)

The stabilization period lasted from 1920 to 1939. While ridership levels consistently held the 12 to 13 billion passenger mark, transit's actual market share began to decline since urbanization was increasing. Most trolley and streetcar companies were suffering from over-capitalization. With assets in trackage and rolling stock, transit operators were paying off bonds instead of investing profits in transit improvements (4).

War-Related Growth (1940-1945)

During World War II, transit ridership exploded, so by 1945 ridership levels doubled pre-war ridership. War-induced activities such as gasoline rationing, tire and parts shortages and automobile production ceasing caused this ridership gain.

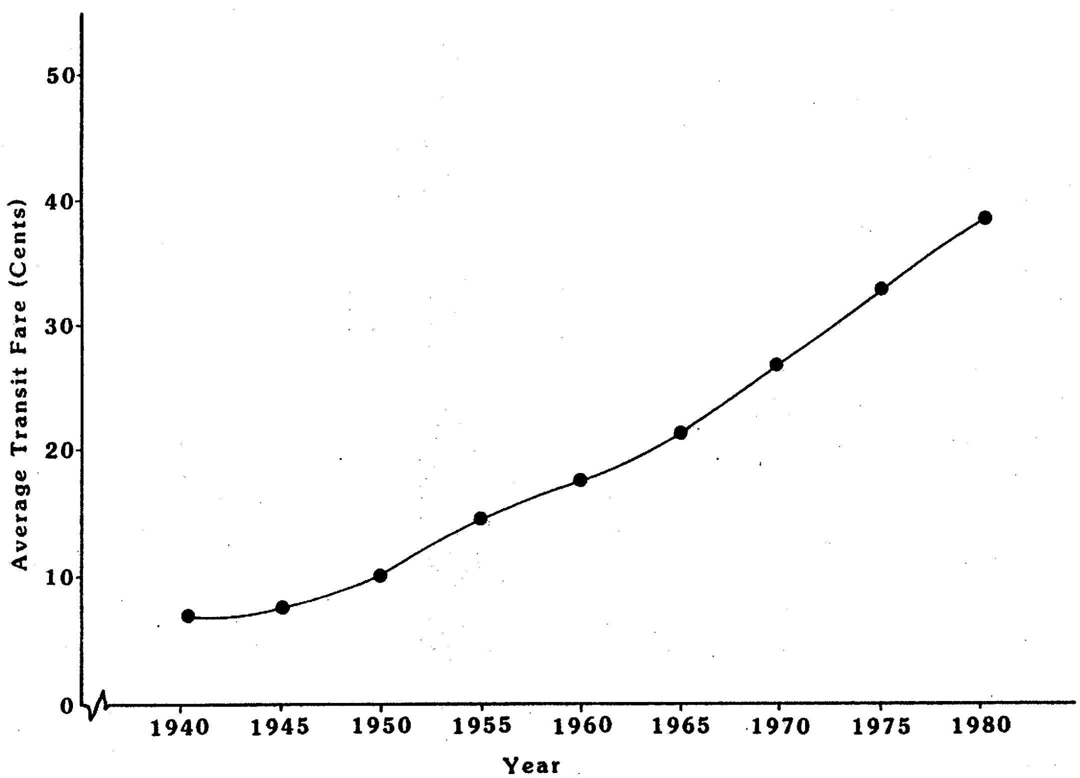
Lengthy Decline (1946-1970)

Transit ridership faced a lengthy decline after World War II. The five-day work week replaced the six-day one, and overall employment fell after the war. As automobile production began to satisfy demand, transit ridership began to decline at increasing rates. This decline, however, did not hit all cities equally. Smaller cities, under 50,000 population, faced the sharpest declines in ridership from 1945 to the present. With attractive rail service and expensive parking costs, large cities have faced less serious ridership declines.

Nevertheless, the decline in transit patronage was real. A combination of economic developments, government policies and transit management factors contributed to this decline. Rising personal income permitted people to purchase the mass-produced automobile. These affluent travels demanded and received new roads. Supported by virtually every social sector, the National System of Interstate and Defense Highways was to become the largest public works project in the history of the world (3).

Beginning with funding in 1952, the interstate system increased with the Federal Aid Highway Act of 1956. With the Highway Revenue Act of 1956, the former legislation created the Highway Trust Fund to pay for the interstate and other highway facilities (25). Government housing policies further contributed inadvertently to transit's demise. With federally insured home mortgages, the Veterans' Administration and Federal Housing Administration permitted single family-detached home ownership at unprecedented levels. These typically low density developments were ill-suited to traditional motor bus or streetcar service.

In addition to rising automobile use and low density development, transit properties suffered from management and operating deficiencies. The Public Utility Holding Company Act of 1935 had forced many electric power and petroleum trusts to divest themselves of their financial interests in transit properties. In the long run, the effect on transit was to remove its sources of both capital and management (25). Transit systems operating as monopolies, however, undertook little renovation between the end of the war and the early 1960s. Dominated by one manufacturer, bus vehicle design stagnated in the United States until the 1970s (26). By 1960 the transit industry had begun a downward spiral of decreasing ridership, leading to reduced revenue, reduced service and even greater ridership declines. In 1968 the transit industry reported its first net operating loss although average fares had risen from 6.9 cents in 1945 to 23 cents (25). Figure 2-5 shows the average transit fares from 1940 to 1980. Rising fares and labor strikes exacerbated the downward spiral in transit ridership.

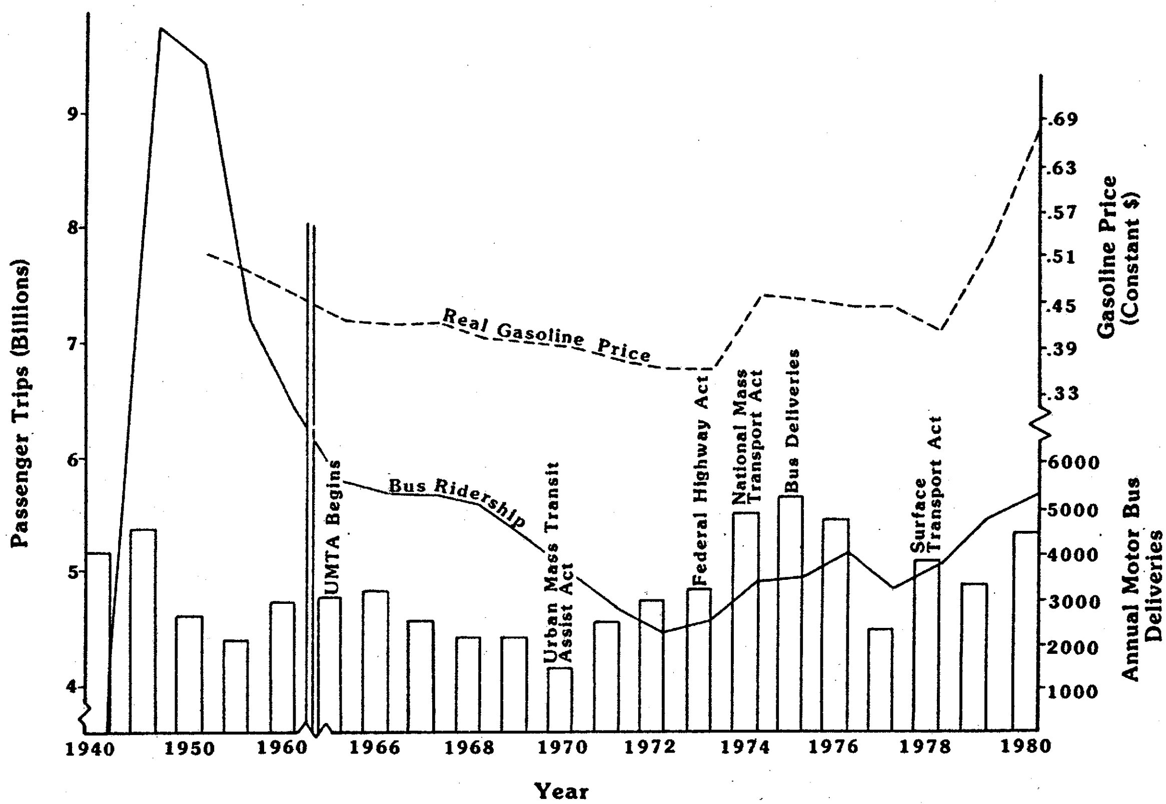


Source: References 26 and 32.

Figure 2-5
Average U.S. Transit Fares from 1940 to 1980

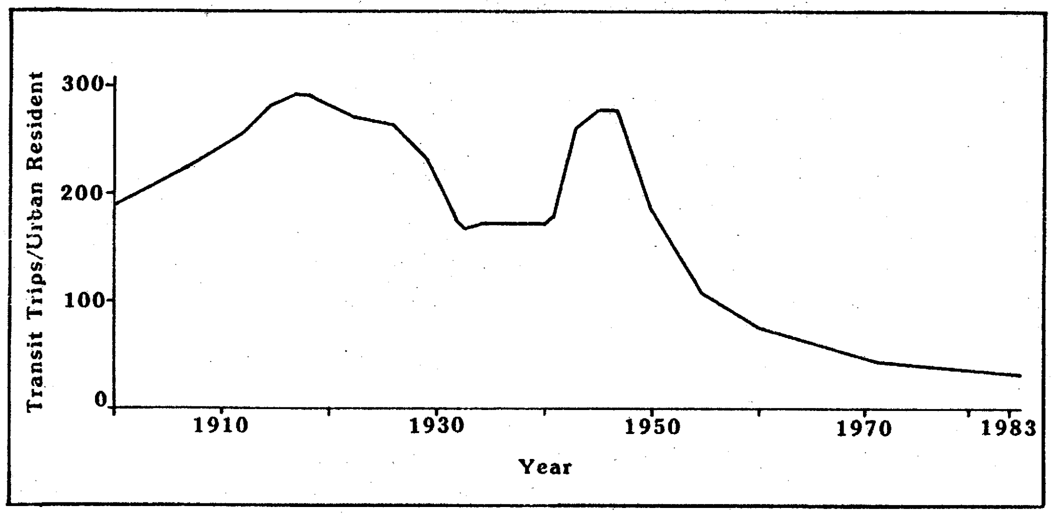
Slow Re-Emergence

The two greatest ridership growth periods for transit since World War II have been during the gasoline shortages of 1974 and 1979 (26). Since 1974 overall transit ridership has been increasing slowly. The number of new transit vehicles delivered to properties across the country has been increasing annually from 1,700 new vehicles delivered in 1970 to 4,800 new vehicles delivered in 1980 (26). Figure 2-6 shows the trend in bus ridership, bus deliveries and real gasoline prices from 1940 to 1980 (27). Figure 2-7 presents the trend in transit trips per urban resident from 1900 to 1983. The federal government began providing assistance for capital purchases in 1964 and for operating assistance in 1974 (26), which has made the ridership and vehicle increases possible. Table 2-4 shows federal capital and operating assistance since 1964. An analysis of the table shows the recent slow gains in transit ridership reflect over $15 billion in federal capital assistance and nearly $4 billion in operating assistance.



Source: Reference 27.

Figure 2-6
Trends in U.S. Ridership, Bus Deliveries and Real Gasoline Prices from 1940 to 1980



Source: Adapted from Reference 26.

Figure 2-7
Trends in U.S. Transit Trips Per Urban Resident

Table 2-4
Federal Capital and Operating Assistance
for Mass Transportation: 1964-1983

Year	Capital Assistance (millions)	Operating Assistance[1] (millions)
1965-1969	$ 547.8	---
1970	133.4	---
1971	284.8	---
1972	510.9	---
1973	863.7	---
1974	955.9	---
1975	1,287.1	$ 142.5
1976	1,954.8	411.8
1977	1,723.7	571.8
1978	2,036.9	685.3
1979	2,101.6	868.5
1980	2,787.1	1,120.7
1981	2,945.7	1,129.5
1982	2,544.1	1,055.5
1983	3,161.6	887.9
Total	23,839.1	6,873.5

[1]Operating assistance became available in 1975.
Source: Reference 26.

Trends in Transit Ownership and Management

Private to Public Ownership Shifts

Over the last 100 years, the transit industry has experienced a gradual, but definite, shift from private ownership to various structures of public ownership. Table 2-5 shows the publicly owned transit systems as a portion of the transit industry. The use of rail technology with the horse omnibus and later streetcar on public rights of way forced private transit operators into franchise agreements with the cities on whose streets the rails lay. Often fixed fares became part of the franchise agreement. Later, it was revealed that "mountainous capitalization created in the more severe days of strong monopoly have resulted in inflexibility and have made the traction companies loath to adjust fares to changed conditions of demand" (3). Whereas early in the twentieth century transit operators felt fixed fares guaranteed profit, the operators faced rising labor and operating costs by World War I.

Table 2-5
Publicly Owned Transit as a Portion of the Transit Industry

Statistic	Calendar Year				
	1940	1950	1960	1970	1980
Number of Transit Systems	20	36	58	159	576
Percent of Industry Total	2%	3%	5%	15%	55%
Total Transit Vehicles Owned and Leased	4,934	24,570	23,738	40,778	64,128
Percent of Industry Total	7%	28%	36%	66%	90%
Vehicle Miles Operated (Millions)	NA	NA	NA	1,280	1,939
Percent of Industry Total	NA	NA	NA	68%	93%
Linked Passenger Trips (Millions)	NA	NA	NA	4,567	5,945
Percent of Industry Total	NA	NA	NA	77%	94%

Note: NA Indicates data not available.

Source: Reference 26.

With electrification, the industry restructured during the 1920s. Large utility holding companies controlled transit operations as well as holding other utilities. The streetcar companies used holding company credit for capitalization and consequently offered high levels of service. Federal antitrust legislation, however, put an end to this practice by the late 1930s.

Facing decreasing demand, decreased service, increased fares, aging fleet and increasing debts, by mid-century private companies petitioned local officials to provide subsidies or purchase the systems. Thus, by the 1970s virtually all of the large transit operators passed from private to public ownership. Only the smaller properties carrying few patrons remained in private ownership. Even in most of these systems, the operators relied on public funds to subsidize their operating costs.

This trend of public ownership also affected Texas transit properties. In 1954, all but one (San Angelo) of the 37 Texas cities with transit companies had privately owned systems (22). By 1964, at least fourteen Texas cities ceased having transit operations. By 1972, five other cities lost transit service (32). By 1974, 14 out of 18 Texas systems received local public tax support or were municipally owned. In 1984, Texas possessed 18 publicly owned municipal transit systems. Four small municipal systems and two intercity bus companies offering limited intracity service are the only remaining private operations left in the state (31). Table 2-6 shows the dates Texas public transit systems went from private to public ownership.

Table 2-6
Private to Public Ownership of Texas Transit Systems

City	Year of Public Acquisition
Amarillo	1966
Austin	1973
Beaumont	1972
Corpus Christi	1966
Dallas	1964
El Paso	1976
Fort Worth	1972
Galveston	1972
Houston	1974
Laredo	1976
Lubbock	1971
Port Arthur	1979[1]
San Angelo	1932
San Antonio	1956

[1]Ceased private operations in 1970, public reopened service in 1979.
Source: References 4, 5, 7, 8, 9, 10, 11, 12, 13, 15, 16, 17, 18, 19, 20, 21, 22 and 23.

Creation of Regional Transit Authorities

Six of the publicly-owned transit systems in Texas are Metropolitan Transit Authorities (MTAs). These systems receive a 1/4% to 1% dedicated sales tax to fund their operations (31). Table 2-7 shows the names of the MTAs and the date the voters approved their creation. It also shows the outcome of the unsuccessful attempts to create MTAs in several cities.

Table 2-7
Regional Transit Authorities in Texas

Transit Authority	City	Date of Referendum	Election Results(%)	
			Yes	No
Houston Area Rapid Transit Authority (HARTA)	Houston	October 1973	25	75
VIA Metropolitan Transit	San Antonio	March 1978	66	34
Metropolitan Transit Authority (METRO)	Houston	August 1978	60	40
Lone Star Transit Authority	Dallas-Ft. Worth	November 1981	40	60
El Paso Transportation Authority	El Paso	November 1981	44	56
Dallas Area Rapid Transit (DART)	Dallas	August 1983	60	40
Fort Worth Transportation Authority (FWTA)	Fort Worth	November 1983	56	44
Capital Metro	Austin	January 1985	59	41
Corpus Christi Regional Transportation Authority	Corpus Christi	August 1985	65	35
Arlington Transportation Authority	Arlington	August 1985	44	56

Source: Reference 31.

Energy Effectiveness of Urban Public Transit Modes

Public transit's energy efficiency serves as one of its most attractive characteristics to both its passengers and policy makers. Local intracity bus service accounted for .36% of national petroleum consumption for transport in 1983. This amounted to 11.9 million barrels of petroleum compared to automobile and taxis consumption of 2,747.3 million barrels (33).

Average vehicle occupancies are the most important factor in determining energy effectiveness for transporting passengers. Because of their high average occupancies, transit modes generally have a lower energy consumption per unit than do other modes. Three general categories of factors influence the energy consumption of a transit mode. These include vehicle characteristics, right-of-way characteristics and operational aspects of the service.

Table 2-8 shows the energy efficiencies of different urban transportation modes. Although the ranges for the modes overlap, transit modes generally have much greater energy efficiencies than the private automobile. The values represent averages, so the marginal addition of another passenger to an existing transit service is low and may be negligible. Thus, increasing the occupancy of transit vehicles is very energy efficient.

Table 2-8
Energy Efficiency of Different Urban Passenger Transportation Modes

Mode	Vehicle Capacity (seated persons/ vehicle)	Vehicle Occupancy (persons/ vehicle)	Measure of Energy Efficiency			
			(vehicle miles/ gallon)	(passenger miles/gallon)	(vehicle miles/ kilowatt hour)	(person miles/ kilowatt hour)
Standard Auto	6	1.2 - 2.8	9.0 - 14.2	54.0-85.2	0.6 - 1.0	0.7 - 2.9
Compact Auto	4 - 5	1.2 - 2.8	17.0 - 19.2	68.0-96.0	1.2 - 1.4	1.5 - 3.9
Carpool	6	2.0 - 6.0	9.0 - 14.2	54.0-85.2	0.6 - 1.0	1.3 - 6.1
Standard Bus	45 - 70	10 - 70	3.1 - 5.0	139.5-350.0	0.2 - 0.4	2.2 - 26.1
Trolley Bus	45 - 70	10 - 70	3.5 - 6.6	157.5-462.0	0.1 - 0.3	2.9 - 19.9
Streetcar/Tram, Light Rail Transit	80 - 200	15 - 200	2.6 - 8.2	208.0-1640.0	0.1 - 0.4	1.8 - 77.7
Rail Rapid Transit: Old Systems	130 - 180	20 - 180	3.5 - 6.0	455.0-1080.0	0.2 - 0.3	3.4 - 51.0
Rail Rapid Transit: New Systems	150 - 200	25 - 200	5.6 - 8.2	840.0-1640.0	0.1 - 0.2	3.0 - 35.4

Source: Adapted from Reference 25.

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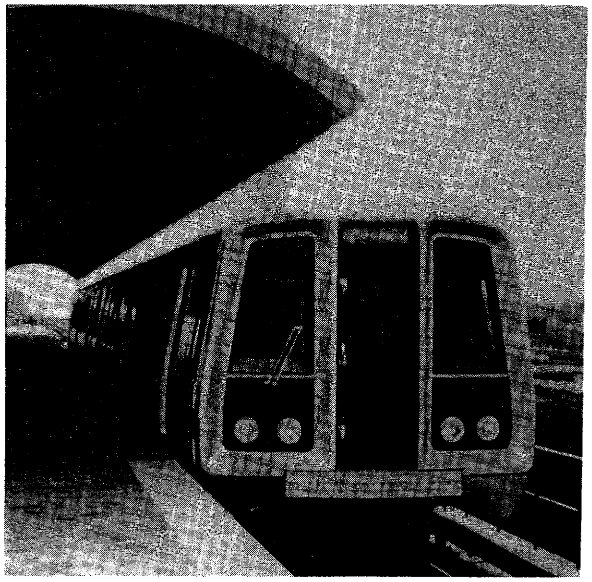
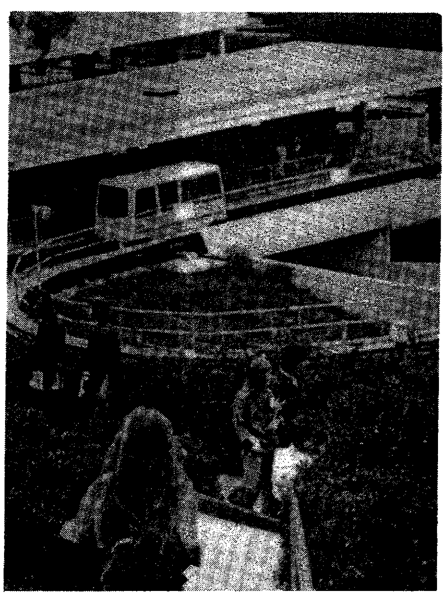
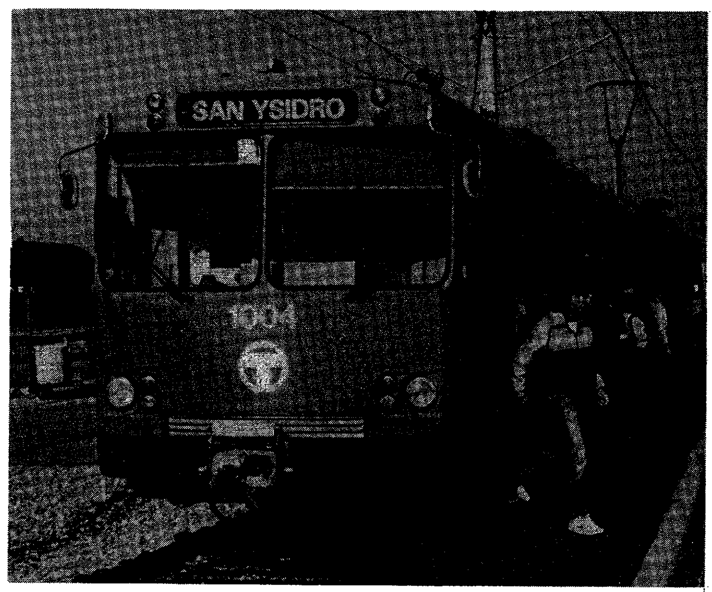


Chapter 3



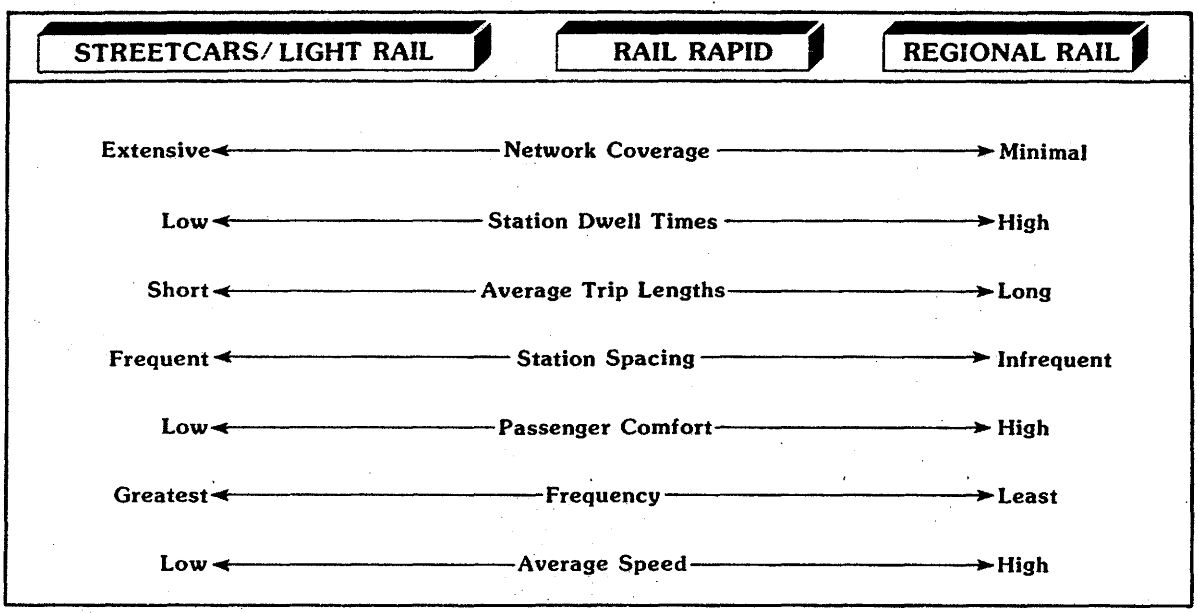


Rail Transit

•3•

Rail Transit

Rail transit technology is composed of a series of distinct fixed guideway modes which range from single-vehicle streetcars operating at relatively low speeds in mixed-flow traffic to multi-car trains operating on high-speed, highly automated, regional or commuter rail systems. Generally speaking, rail transit may be classified into 3 basic categories: (1) Streetcars/Light rail transit; (2) Rail rapid transit; and (3) Regional rail. Each rail mode is designed to fulfill a specific level of travel demand within a specific urban/suburban setting. A generalized relationship between the various rail modes is illustrated in Figure 3-1.



Source: Adapted from Reference 1.

Figure 3-1
Relationship of Rail Transit Modes to Each Other

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*Numbers in parentheses refer to references listed at the end of the chapter.

General Characteristics

Rail transit modes can be distinguished from motor bus and other transit modes by the following general characteristics (2):

- **External Guidance** - Rail vehicles are physically guided by the track on which they run.

- **Rail Technology** - Flanged steel wheels which run on a pair of steel rails both support and guide rail vehicles. (Note: Some systems, such as Montreal's, utilize rubber-tired vehicles which operate along concrete guideways.)

- **Electric Propulsion** - Except for a few regional rail systems which utilize diesel traction, rail transit systems are electrically powered.

- **Right-of-Way Separation** - A variety of right-of-way (ROW) alignments are utilized by rail transit depending upon the particular mode. These ROW alignments can be categorized into the following 3 basic types according to the degree of separation from other traffic forms.

  - **Shared ROW** - Transit ROW is on the surface streets along with mixed traffic. Preferential treatment in the form of reserved lanes or signal preemption may be given to the transit vehicles, or they may travel mixed with other traffic.

  - **Separate ROW** - Transit ROW is separated from other traffic by curbs, barriers, grade separation, etc., but has grade crossings for vehicles and pedestrians.

  - **Exclusive ROW** - Transit ROW without grade crossings or any legal access by other vehicles or persons. Also referred to as "grade-separated," "private," or "fully controlled" ROW, it can be a tunnel, aerial or at grade level.

Light Rail Transit

Light rail transit (LRT) is an evolutionary development of streetcar transit toward modern rail rapid transit. Within the United States, the transition from streetcar to light rail transit was in most cases gradual and the distinction between the 2 modes is often difficult to make. This has led the transit industry to combine streetcar operations with light rail for analytical purposes and the terms streetcars, light rail transit and trolley are now used synonymously.

Originally, the term "light rail transit" was applied to rail systems in European cities where subways were constructed to house electric streetcar lines through the city centers. Light rail transit made its first appearance in the United States in 1897 with the opening of a subway in Boston.

Description (1, 2, 4)

Light rail transit (also referred to as streetcars and trolleys in some locales) is an urban railway mode which is generally defined by the following.

- LRT utilizes predominatly reserved, but not necessarily grade-separated, right-of-way.
- Power distribution for LRT vehicles is through overhead electrical wires.
- Service is provided in single- or dual-directional rolling stock.
- Passenger loading typically occurs at low- or dual-level loading platforms at stations or stops.
- Fare collection is either on-board, by way of a self-service system, or the honor system.
- Vehicles are generally operated singly during off-peak service and in trains during peak periods.
- Speeds, capacity and overall performance characteristics are typically lower than for most rail rapid transit systems.
- LRT is specifically applied to systems which employ a lighter rail weight -- 100 pounds per yard or less, as compared to 115-135 pounds per yard for rail rapid.
- Light rail rapid transit, the highest form of LRT, is characterized by a fully separated ROW or only a few grade crossings which permits vehicles to travel at a higher speed.

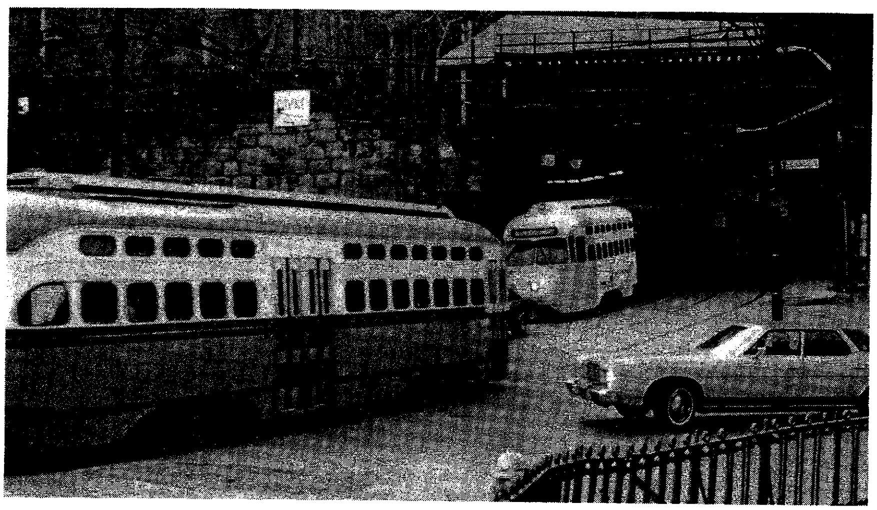
Design and Operating Characteristics

Vehicle Technology (1, 4, 5, 6, 7, 8, 9, 10). The first light rail vehicle to be placed into service in North America was the Electric Railway President's Conference Committee Car (PCC). The design of the PCC Car was conceived as a result of a $750,000 research effort sponsored by 25 operating LRT companies in the late 1920s. The first PCC cars were delivered to Brooklyn and Queens in 1936. Ten years later, 2,864 PCCs were in operation on 19 rail systems in North America. Use of PCC cars peaked in 1950 with a total of 4,919 vehicles in operation. PCC car production was discontinued in the middle 1950s, yet up until the late 1970s, all LRT systems, as well as almost all streetcar systems in North America, had rolling stock which consisted almost entirely of PCCs. Even though the PCC cars are gradually being replaced by modern light rail transit vehicles, many systems (including Boston, Chicago, Fort Worth, Newark, Philadelphia, Pittsburgh and Toronto) continue to maintain and recondition old PCC cars for use today.

Specific physical and performance characteristics for the PCC car and 5 other light rail vehicles currently in use in the United States and Canada are presented in Table 3-1.

Another light rail vehicle manufactured by the Tokyu Car Company has just recently been put into service in Buffalo, N.Y. Buffalo's LRVs are single-unit, double-ended vehicles which seat 49 passengers and feature both high- and low-level boarding. (Note: Double-ended vehicles feature a control cab at each end of the vehicle which enables it to be operated in both directions without having to physically turn the vehicle around.)

Other LRVs soon to be in service include 26 articulated light rail cars on order from Bombardier Ltd. of Canada and Barre, Vermont for the Portland, Oregon light rail system. Portland's LRVs will seat 76 passengers and offer dual level boarding (6, 9). In Sacramento, California, 26 double-ended articulated vehicles of German design have been ordered from Siemens-Allis. The Sacramento LRVs, based on an advanced design of the U2, will include 64 seats and air conditioning, and will be able to operate singly or in trains of up to 4 cars (10).



Examples of LRVs include: President's Conference Committee Car in Pittsburgh (left), Tokyu Car Company LRV in Buffalo (below left) and Duwag U2 LRV in San Diego (below right).

Table 3-1
Specific Physical and Performance Characteristics for Selected Light Rail Vehicles

Characteristics	President's Conference Committee Car[1]	U.S. Standard Light Rail Vehicle[1]	Canadian Light Rail Vehicle	SEPTA Light Rail Transit Car	DUWAG U2 Vehicle	Shaker Heights Rapid Transit Vehicle
Length (feet)	43.5 to 50.5	71.0	50.7	53.0	75.4	79.9
Width (feet)	8.3 to 9.0	8.8	8.3	8.8	8.7	9.4
Height (feet)	10.1	11.5	10.7	10.8	7.5	12.4
Articulation	None	Single	None	None	Single	Single
Net Weight (pounds)	23,000 to 42,000	67,000	52,000	54,000	66,000	84,000
Truck Centers (feet)	Varies	23.0	21.0	25.4	25.3	27.0
Minimum Horizontal Radius (feet)	Varies	42.0	36.0	60.0	82.0	100.0
Minimum Vertical Radius (feet)	Varies	310[2], 460[3]	800[4], 122[5]	NA	1,640	3,900, 3,788
Manufacturer	St. Louis Car, Pullman	Boeing-Vertol Company	Hawker-Siddeley Canadian, Ltd.	Kawasaki Heavy Industries, Ltd.	Waggoner Fabrik Uerdiggen A.B.	Breda Costruziani Ferroviarie
Approximate Design Year	1933	1973	1975	1979	1965	1979
Floor Height/Headroom (feet)	2.8/varies	2.8/7.1	3.0/6.8	NA	3.2/7.2	3.3/7.0
Door Type/No. per Side	Folding/2 or 3	plug/3	folding/2	folding/2	folding/4	folding/3
Design Capacity: Seats/Standees	49 to 69/varies	68/151	42 to 47/90	50/50	64/98	84/138
Maximum Speed (mph)	50	50	50	50	50	55
Service Acceleration (mph/sec)	3.1	2.8	3.3	NA	2.2	2.8
Service Deceleration (mph/sec)	3.1	3.5	3.5	NA	2.7	3.5
Emergency Deceleration (mph/sec)	6.5	4.0-6.0	6.5	NA	6.7	4.0-6.0
Maximum Design Grade (%)	6.5	9.0	8.0	NA	4.4	5.0
Capital Cost Per Unit[6]	$15,000-$32,000[7]	$494,000	$502,000	$410,000	$845,000	$759,000
Systems Using Vehicle	Boston Chicago Fort Worth Newark Philadelphia Pittsburgh Toronto	Boston San Francisco	Toronto	Philadelphia	San Diego Edmonton Calgary	Cleveland

Note: NA indicates data not available.
[1]No longer in production, but is still widely used.
[2]Single Vehicle.
[3]Coupled.
[4]Concave.
[5]Convex.
[6]1979 dollars except where noted.
[7]Original cost.
Sources: References 1, 4, 5,6, 7, and 8.

Travel Ways (1, 2, 4). Because of its operating characteristics and power collection, light rail has more travel alignment options available than any other form of rail transit. Possible travel ways include:

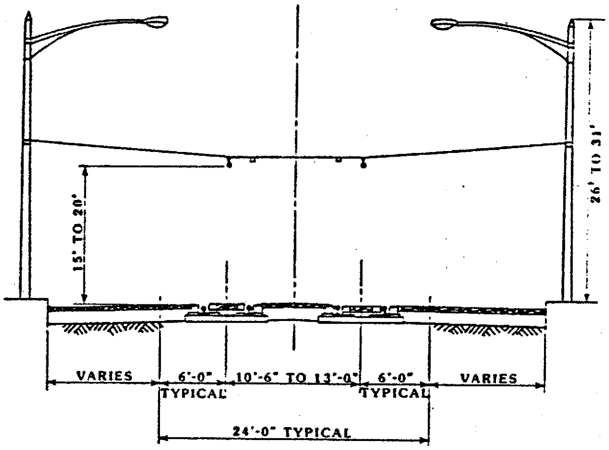
- Subways or tunnels (exclusive ROW below ground in high density areas);
- Viaducts or aerial ways (exclusive ROW above ground in high density areas);
- Freeway ROW (alignments located either on the side of the freeway between the shoulder and the edge of the ROW or within the median area);
- Railroad ROW (either exclusive or joint use);
- Reserved transit lanes (separated from other traffic by striping, pylons or mountable barriers);
- Dedicated street ROW (reserved ROW located in the center of a street by the use of full curbs with a raised or lowered median area or by separation of the track by fencing greenery or concrete barriers);
- Mixed traffic operation along city streets; and
- Shared with other land uses (pedestrian malls, parks, etc.).

Typical cross-sections for light rail transit operations are presented in Figures 3-2 and 3-3.

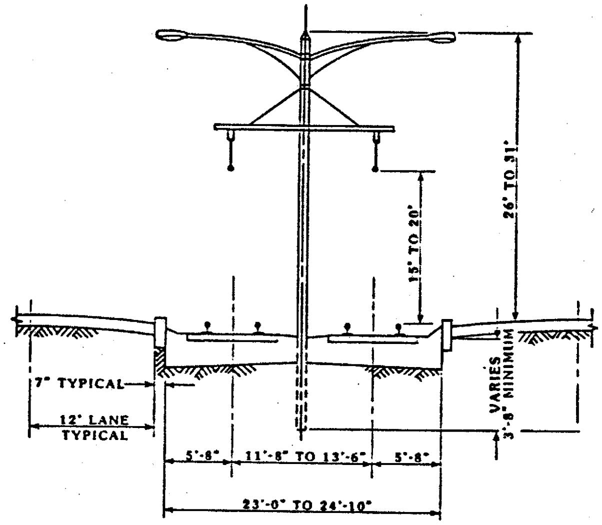
Typically, a substantial portion of LRT operations are on exclusive rights-of-way which may or may not be grade-separated. Separation may amount to as little as 0% or as much as 90% of the total network length. Practical considerations may dictate separating sections in the central city or on congested arterials first in order to eliminate or minimize sources of service disturbances. Thus, LRT systems in many cities utilize tunnels or subway sections in the most congested areas of the city in an effort to offer the highest quality of service possible.

Alignment standards and station features for LRT can be identical to those for rapid rail systems, yet the same LRT vehicles can also operate on existing streetcar lines with curb-height stop platforms. This flexibility enables a gradual upgrading of streetcar systems to LRT standards in a new ROW or the gradual upgrading of LRT to rail rapid standards without service interruptions and with immediate utilization of newly completed sections. Such staging of LRT improvements allows the investment to be tailored to local conditions, desired service quality, and the availability of capital funds (2).

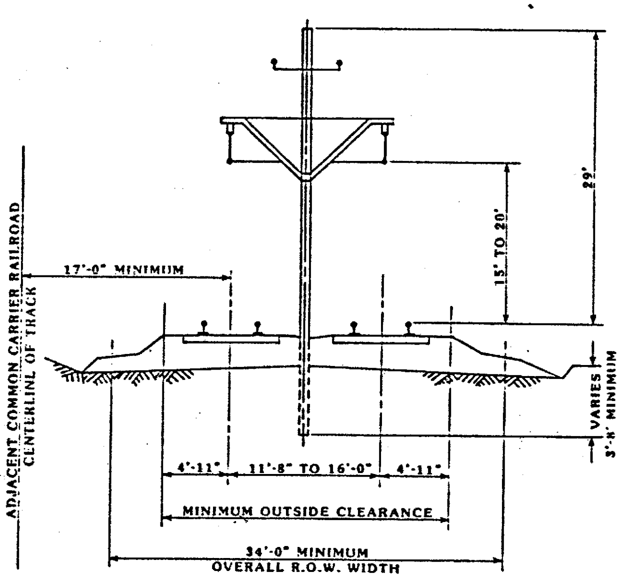
TYPICAL CROSS-SECTION FOR LIGHT RAIL TRANSIT OPERATION IN PAVED AREAS



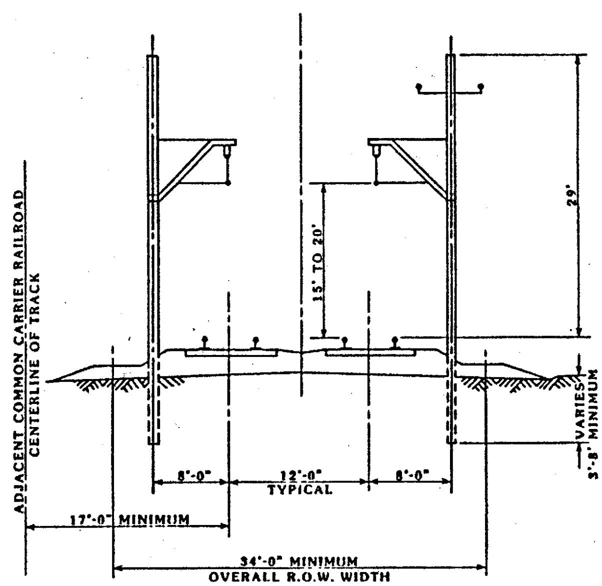
TYPICAL CROSS-SECTION FOR LIGHT RAIL TRANSIT OPERATION IN STREET MEDIAN



TYPICAL CROSS-SECTION FOR LIGHT RAIL TRANSIT OPERATION AT-GRADE WITH CENTER POLE



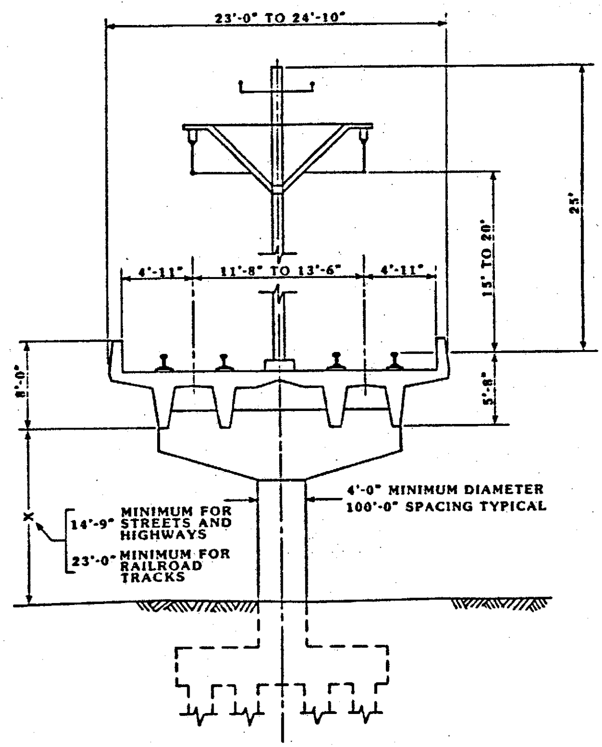
TYPICAL CROSS-SECTION FOR LIGHT RAIL TRANSIT OPERATION AT-GRADE WITH SIDE POLES



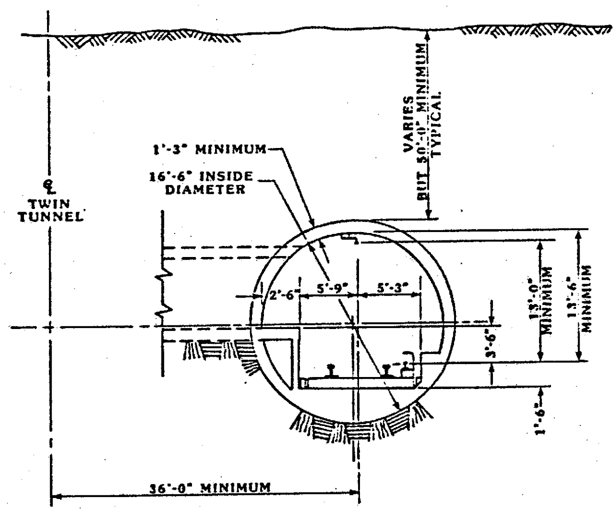
Source: Reference 1.

Figure 3-2
Typical Cross-Sections for Light Rail Transit Operations

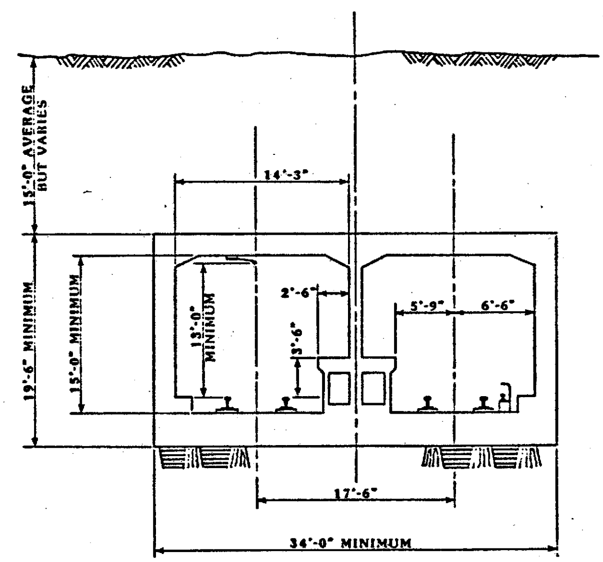
TYPICAL CROSS-SECTION FOR LIGHT RAIL TRANSIT OPERATION ON ELEVATED STRUCTURE



TYPICAL CROSS-SECTION FOR LIGHT RAIL OR RAIL RAPID TRANSIT OPERATION IN BORED DEEP TUNNEL SUBWAY



TYPICAL CROSS-SECTION FOR LIGHT RAIL OR RAIL RAPID TRANSIT OPERATION IN CUT-AND-COVER SUBWAY



Source: Reference 1.

Figure 3-3
Typical Cross-Sections for Light Rail Transit Operations

Guideway Design (1, 2, 4). Right-of-way and guideway requirements for LRT operations dictate the following.

- A 24- to 35-foot minimum ROW for dual track.
- A 40-foot minimum ROW at stations.
- Use of American rail widths (4 feet 8 1/2 inches) and higher rail weight at approximately 100 pounds per yard.
- Overhead electrical pickup.
- Minimum curve radii of 42 feet.
- Maximum gradient of 4-9% (specific values depend on ROW type, vehicle performance, climate and other considerations).
- Minimum clearances of 15 feet.

Stops and Stations (1, 2). Stops and station configurations for LRT systems can be designed to conform to the desired capital investment. LRT stations are generally spaced at 0.2 to 1.05 mile intervals and may be either at-grade or grade-separated. Platform lengths should be able to accommodate the longest light rail trains. Typical platform lengths for at-grade stations range from 100 to 300 feet while platforms for underground stations may be 300 feet or more in length.

Operating and Performance Characteristics (1, 11). Operating and performance characteristics for light rail may be defined in terms of speed, headway and capacity.

Speed. Light rail transit speeds can be expressed in terms of absolute vehicle speeds, typical operating speeds, or average scheduled speeds over the length of the transit route.

- Light rail vehicles generally have a maximum attainable speed of about 50 miles per hour (Table 3-1).
- Typical operating speeds are a function of the type and configuration of the guideway; LRT systems are exposed to the greatest constraints on operating speeds of any of the rail modes. Maximum vehicle speeds can be obtained on fully grade-separated ROW or where crossings are fully protected. On reserved ROW that is shared with public streets, operating speeds are limited to those of surrounding traffic. In mixed traffic operation, it is usually necessary for both the motor vehicle and transit vehicle traffic to operate at the same speeds. Pedestrian malls require a further reduction in maximum speeds for safety reasons, usually 15 to 20 mph. Additional speed restrictions may also be required to negotiate sharp curves and turnouts.
- Average speeds for LRT systems are influenced by the acceleration and deceleration characteristics of the vehicles, station spacing, the extent of grade-separated and at-grade operation, and the extent of priority over conflicting traffic. Average operating speeds for

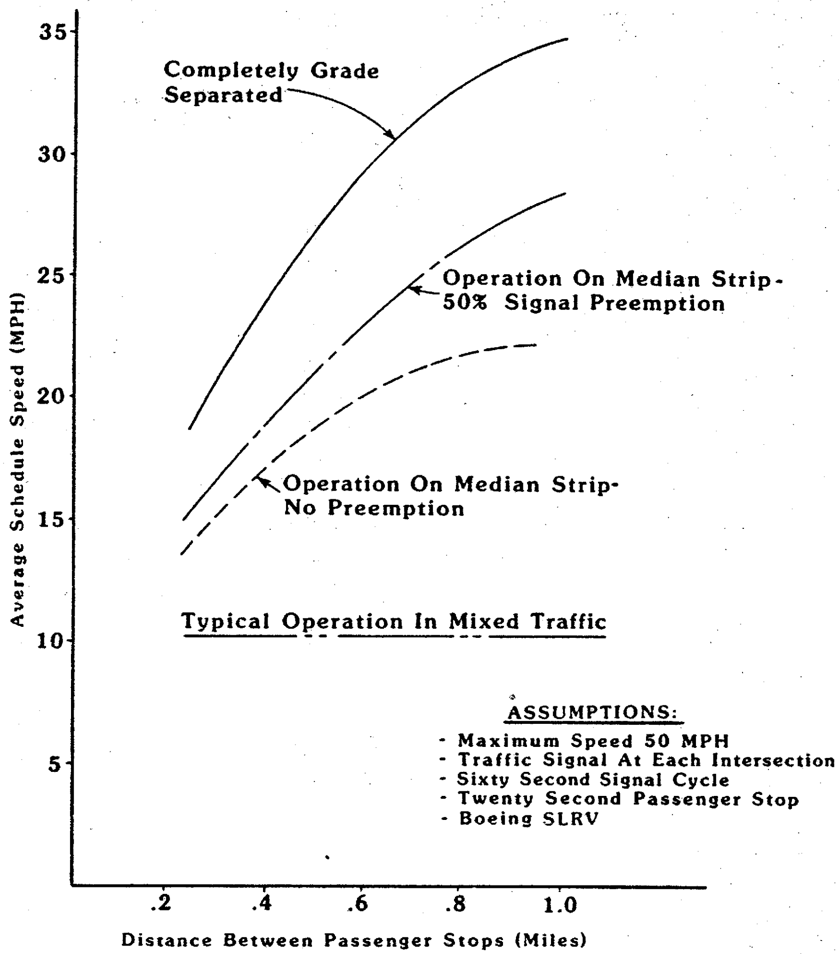
selected light rail systems in the U.S. and Canada are presented in Table 3-2. Those systems with an average operating speed of 10 mph are essentially streetcar operations. An overview of speed relationships for light rail systems is illustrated in Figure 3-4.

Table 3-2
Estimated Average System Travel Speed and Trip Length for Selected Light Rail Transit Systems

System, Year	Avg. Stop Spacing (miles)	% Grade Separated	Avg. Trip Length (miles)	Average Speed (mph)	
				Including Layover	Excluding Layover
Canada					
Calgary, 1983	---	---	5.5	----	20.0
Edmonton, 1976	0.9	22%	3.5	18.0	22.0
Toronto, 1976	---	---	6.2	9.0	9.7
United States					
Boston, 1976					
Green Line	0.58	55	4.5	10.1	12.4
Mattapan-Ashmont	0.6	99	---	----	12.0
Buffalo	0.45	81	---	----	23.0
Cleveland, Shaker Hts., 1983	0.45	53	7.9	16.8	23.0
New Orleans, St. Charles, 1976	----	0	2.2	----	9.3
Newark, Subway, 1976	0.40	99	2.8	15.0	21.5
Philadelphia, 1976					
Streetcars	----	0	---	----	9.0
Subway-Surface	----	---	3.1	9.0	11.2
Media-Sharon Hill	0.42	---	---	----	16.0
Norristown	1.05	100	---	22.0	30.0
Pittsburgh, South Hill, 1976	0.37	3	7.0	11.8	13.6
Portland	0.60	---	---	----	20.0
San Diego, 1983	0.88	0	8.5	----	29.0
San Francisco, MUNI, 1976	0.23	17	2.9	9.4	----
Range	0.23-1.05	0%-100%	2.2-8.5	9.0-22.0	9.0-30.0
Avg., Non-Weighted	0.58	44%	4.9	13.5	17.6

Source: Reference 11.

Headway. While LRT vehicles may operate as frequently as every 60 seconds, light rail headways typically vary from 5 to 10 minutes during weekday peak periods, 10 to 15 during weekday midday periods and 15 to 30 minutes during weekday evenings. Saturday light rail service is usually similar to weekday service except that peak-period headways are not as frequent. Late night/early morning service (when provided) is usually 60-minute headways.



Source: Reference 11.

Figure 3-4
Relationship Between Speed and Station Spacing for
Selected Light Rail Transit Systems

Capacity. The maximum attainable passenger capacity of a LRT system is directly related to the vehicle capacity, train length and headway. The type of ROW and constraints imposed by at-grade operation may also affect the potential capacity of LRT operations.

Modern light rail systems (in an effort to attain the highest possible speeds) generally do not operate on headways of less than 2 minutes. Train consists typically average 2 to 4 cars per train. Table 3-3 presents data on the range of passenger-per-hour capacities attainable under various vehicle and operational configurations, based upon recent vehicle designs.

Table 3-3
Theoretical System Capacities Per Hour for Light Rail Transit

Headway in Minutes	System Capacity per Number of Vehicles in Train[1]			
	1	2	3	4
1	8,820	17,640	26,460	35,280
2	4,410	8,820	13,230	17,640
5	1,764	3,528	5,292	7,056
10	882	1,764	2,646	3,528
15	588	1,176	1,764	2,352
20	441	882	1,323	1,764
30	294	588	882	1,176
60	147	294	441	588

[1]Assumes use of a single-articulated light rail vehicle having a total design capacity of 147 passengers, including 68 seated passengers and 79 standees.
Source: Reference 1.

The extreme values in the Table 3-3 matrix would only be reached under special circumstances and are, therefore, unrealistic when applied to normal operating conditions. Maximum capacities for light rail are affected, at least partially, on the type of alignment. Frequent grade crossings and integration of light rail signal systems with those governing motor vehicle traffic at street intersections may cause additional delays and necessitate speed restrictions. Table 3-4 indicates the relative maximum capacity that could be expected under various alignment alternatives.

Table 3-4
Comparison of Capacities for Various Light Rail Transit Alignments

Type of Alignment	Approximate Design Capacity (passengers per hour)
Exclusive Grade-Separated Subway, Aerial, or Surface Guideway	20,000-30,000
Reserved Surface Guideway, Median, or Side of Road, Reserved Lane, or Transit Mall	10,000-20,000
Mixed Traffic Operation	5,000-10,000

Source: Reference 1.

Actual existing peak-hour passenger volumes observed on selected LRT lines (significantly lower than maximum design capacities) are presented in Table 3-5.

Table 3-5
Peak-Hour Patronage on Selected Light Rail Transit Lines (8:00 - 9:00 a.m., Inbound to CBD)

System, Year Line	Peak-Hour Inbound			8:00-9:00 a.m. as a % of All Day Inbound	
	Trains	Cars	Passengers	Cars	Passengers
Canada					
Edmonton, 1978	12	24	2,100	9.2%	23.2%
United States					
Boston, 1976					
W. Green Line	36	88	6,900	8.0	19.1
Newark, 1976					
Newark Subway	30	30	1,500	12.8	25.7
Philadelphia, 1976					
Market St. Tunnel	73	73	3,700	10.8	24.8
Pittsburgh, 1976					
South Hills[1]	51	51	3,800	16.1	30.7
San Francisco, 1977					
MUNI[1]	68	68	4,900	9.3	12.3
Range				8.0% - 16.1%	12.3% - 30.7%
Avg., Non-Weighted				10.6%	22.9%

[1]Street operation prior to tunnel completion.
Source: Reference 11.

Attributes (1, 12, 13, 14)

Light rail transit exists in many forms and occupies a rather broad middle ground between motor bus and rail rapid transit. The principal attributes of the LRT mode include the following.

- Depending on the percentage of at-grade operations, a light rail system can be implemented for less cost than a conventional rail rapid system.

- Light rail can offer a quality of service very similar to that of rapid rail, depending on its level of sophistication.

- Light rail vehicles can operate singly or in trains. The trainability of LRT vehicles is an advantage in accommodating fluctuating ridership demands and route headways while keeping the size of the operating crew to a smaller, stable level.

- Due to the wide variety of guideway alignment alternatives available, the construction of LRT systems need not necessarily involve the high costs of tunneling, elevated structures and grade separation required for rail rapid facilities. In addition, design criteria for gradients, curvature and horizontal and vertical alignment of LRT facilities are much less restrictive than for rail rapid systems.

- The lower capital costs of the guideway, stations and support facilities enable the implementation of an LRT network denser than that of an equivalent rail rapid network while still providing a level-of-service close to that offered by rail rapid transit.

- Since light rail vehicles can be operated in mixed traffic on surface streets as well as over exclusive rights-of-way, service to certain high-density urban activity centers can be provided at a lower cost with light rail than with rail rapid. Furthermore, construction of LRT systems can usually be accomplished more quickly than can construction of rail rapid transit systems.

- LRT systems can more readily be developed in stages based on the needs of the urban area and the availability of resources. This has led to the upgrading of streetcar systems to LRT systems in many cities.

- Another idea which is gaining popularity in certain Western European countries is to develop rail rapid transit systems by first utilizing light rail transit in an incremental, evolutionary manner in order to minimize the immediate acquisition of expensive ROW and construction subway or elevated segments and staging future upgrading as the need arises. In this instance, referred to as pre metro, light rail facilities may be installed in reserved lanes on city streets until the ridership justifies a more exclusive alignment. Many route segment staging opportunities are available because of the easy implementation of surface alignments and the readily available ROW.

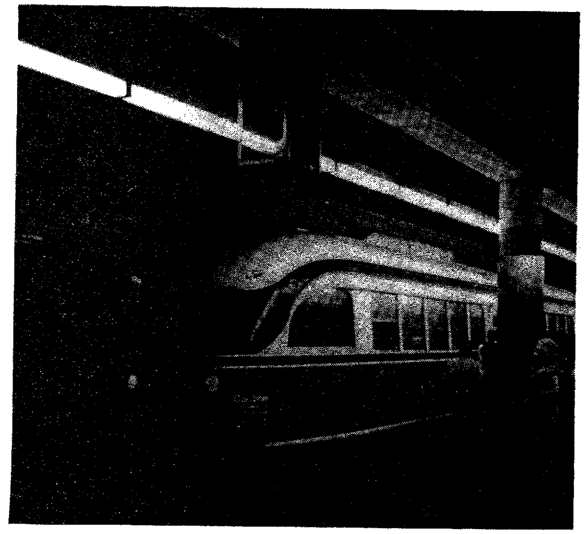
- All components and materials necessary for the construction and implementation of light rail transit are proven. This off-the-shelf availability reduces the implementation time required before the system can become operational.

Examples of Light Rail Transit Systems in the United States and Canada

The following 15 cities in the U.S. and Canada have streetcar/light rail systems currently in operation.

- Boston
- Buffalo
- Calgary
- Cleveland
- Chicago
- Edmonton
- Fort Worth
- Newark
- New Orleans
- Philadelphia
- Pittsburgh
- San Diego
- San Francisco
- Seattle
- Toronto

Characteristics of these light rail systems are presented in Table 3-6. Characteristics of future LRT systems (either under construction or proposed) are highlighted in Table 3-7.



Light rail operations can be found in (counterclockwise): Philadelphia, Pittsburgh, Fort Worth, Boston and San Diego.

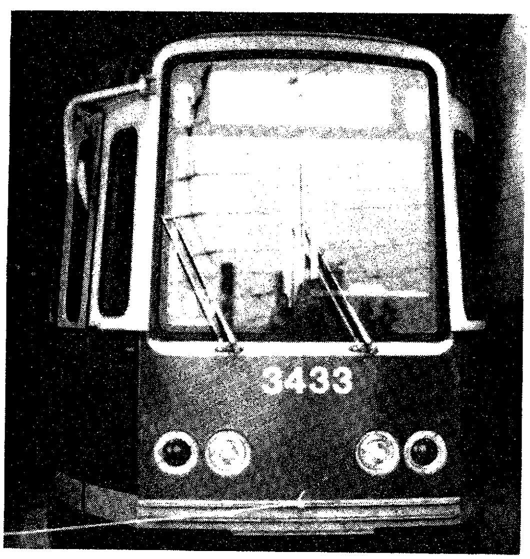


Table 3-6
Characteristics of Light Rail Transit Systems in the United States and Canada (1983)

System	Operating Authority	Total Revenue Vehicles	Number of Routes	Directional Miles Track	Killowatt Hours of Power (000)	Operational Characteristics
Canada						
Calgary	City of Calgary	53	1	15.5	7,363.9	• CBD mall, mostly at-grade with separations at major intersections • 15 stations (8 downtown)
Edmonton	Edmonton Transit System	37	1	12.8	NA	• Subway in CBD, otherwise at-grade in RR ROW; numerous grade crossings • 8 stations (4 in subway)
Toronto	Toronto Transit Commission	372	9	145.0	NA	• Mixed traffic street operation
United States						
Boston	Massachusettes Bay Transportation Authority	229	Greenline-4 Matt.-Ash-1	83.4	17,221.0	• Green line - subway, grade-separated surface operation, at-grade in street/highway median, street operation in mixed traffic and former commuter rail ROW; 48 grade crossings & 26 grade separations. • Mattapan-Ashmont - grade-separated surface operation; 1 crossing and 8 grade separations.
Buffalo	Niagara Frontier Transportation Auth.	27	1	12.8	NA	• 1.2-mile CBD mall, remainder in subway • 14 stations (6 in CBD)
Chicago	Chicago Transit Authority	1	NA	NA	NA	• Former RR ROW, grade-over-grade crossings • Operates as rail rapid transit feeder between Skokie & Howard Street RRT terminal with no intermediate stops
Cleveland	Greater Cleveland Rapid Transit Auth.	48	2	29.0	13,302.0	• Grade-separated ROW in CBD, abandoned RR ROW and medians of suburban boulevards, shares 5 miles of track with rail rapid trains • 29 stations
Fort Worth	Tandy Corporation	6	1	2.0	NA	• CBD subway & grade-separated surface operation • Privately owned & operated without public subsidy • Park-and-Ride operation

Newark	Transport of New Jersey	26	1	9.0	4,098.3	• CBD subway for 1.5 miles, 3 miles of grade-separated parkside track & abandoned ROW canal. • 1 grade crossing & 8 grade separations
New Orleans	New Orleans Regional Transit Authority	35	NA	13.1	2,570.4	• Reserved median space with grass between rails, reserved paved lane in street & mixed traffic street operation downtown • 98 grade crossing & 1 grade separation
Philadelphia	Southeastern Pennsylvania Transportation Authority	313	NA	175.9	57,172.0	• Streetcars - reserved paved lane in street & mixed traffic street operation; 24 grade crossings • Subway-Surface - subway, at-grade in street/highway median & mixed traffic street operation; 4 grade crossings • Media-Sharon Hill - Private ROW at-grade, reserved paved lane in street & mixed traffic street operation; 45 grade crossings & 2 grade separations • Norristown LRRT - Totally grade-separated surface operation; 36 grade separations • Over 300 stations on all lines
Pittsburgh	Port Authority of Allegheny County	87	4	51.7	11,664.0	• South Hills - Transit tunnel, at-grade private ROW, at-grade in street/highway median & mixed traffic street operation; 43 crossings & 14 grade separations
San Diego	San Diego Metropolitan Transit Development Board	24	1	16.5	6,297.0	• Shared ROW with lightly used RR bed, at-grade in street median & mixed traffic street operation • 18 stations
San Francisco	San Francisco Municipal Railway	140	5	41.1	49,778.0	• CBD subway, old trolley tunnels, at-grade private ROW, at-grade in street/highway median & mixed traffic street operation • 2 LRT lines duplicate BART lines (but on different alignment) • 39 grade crossings & 2 grade separations • Over 60 station

Source: References 11, 13, 15, 16, 17 and 18.

Table 3-7
Characteristics of Selected Future LRT Systems

Location	Length	Characteristics
Dallas	160.0	• Conceptual plan • Primarily in railroad ROW; 98 stations
Detroit	15.0	• Preliminary engineering • 4.2 miles in CBD subway, 3.5 miles elevated, 7.3 miles at-grade, 17 stations (6 in CBD)
Houston	0 to 75 (varies)	• CBD subway, mostly in RR or freeway ROW
Los Angeles		
Long Beach	22.5	• CBD subway, planned for 1988 opening • 25 stations
Century Fwy.	17.5	• Engineering stage • Located in freeway median, 10 stations
Milwaukee	14.3	• Planning stages
Oklahoma City	17.4	• Preliminary planning stage, 9.6-mile Phase I proposed to open in 1989
Pittsburgh	10.5	• Stage I upgrade of existing LRT, including 1.2-mile subway and maintenance facilities
Portland, OR	15.0	• Under construction - open in 1986 • Reserved area on CBD streets, uses RR, freeway & street ROW at-grade, 25 stations
Sacramento	18.3	• Under construction - open in 1987 • CBD mall, single track, virtually no new ROW; 26 stations
St. Louis	18.0	• Preliminary planning stage • Existing CBD RR tunnel, mostly at-grade with new ROW east of CBD and RR ROW west of CBD
San Jose/Santa Clara County	20.0	• Under construction - open in 1987 • Mostly at-grade along available ROW, in road/highway median and in abandoned RR alignment; 18 stations

Source: References 11, 21, 22 and 23.

Ridership. Average weekday patronage for selected LRT systems in the United States and Canada are presented in Table 3-8.

Table 3-8
Typical Weekday Passenger Volumes for Selected Light Rail Transit Systems

System	Length (miles)	Typical Weekday Patronage
Canada		
Calgary (1981)	7.5	38,000
Edmonton (1981)	4.5	20,000
Toronto (1976)	46.3	350,000
United States (1976)		
Boston		
Green Line	27.2	151,000
Mattapan-Ashmont	2.6	14,000
Cleveland, Shaker Heights	13.1	19,000
New Orleans, St. Charles St.	6.5	25,000
Newark, Subway	4.2	12,000
Philadelphia		
Streetcars	51.2	130,000
Subway-Surface	22.3	65,000
Media-Sharon Hill	11.9	14,000
Norristown LRRT	13.6	10,000
Pittsburgh, South Hills	24.8	24,000
San Diego (1984)	16.0	16,000
San Francisco, MUNI	22.0	85,000

Source: Reference 11.

Employees Per Passenger (11). When rail transit vehicles are operated in trains, one train operator can transport many more passengers than one bus operator. Rail transit is, therefore, frequently thought of as being less labor intensive than motor bus transit. This in turn, has lead to the argument that rail transit operating costs are lower.

This theory fails to consider 2 important factors, however. First, many light rail transit vehicles are operated singly, except during peak periods. Second, the provision of rail transit service requires additional personnel for security, maintenance of track and railways, and station attendants. Therefore, the average number of employees per passenger for light rail transit is not significantly different than that for bus transit (Tables 3-9 and 3-10). However, the relatively wide variation in employees per passenger between LRT systems suggests that the average value may not be truly representative. In fact, the most recently implemented systems (San Diego, Calgary, Edmonton) do have fewer employees per passenger.

Table 3-9
Employees Per Passenger for Selected Light Rail Transit System

System	Annual Rail Patronage (millions)	Rail Employees	Employees Per Million Passengers
Canada			
Calgary, 1983[1]	12.2	106	8.7
Edmonton, 1976[2]	6.3	113	17.9
Toronto, 1976[2]	112.6	1,048	9.3
United States			
Boston			
1983[1]	22.6	380	16.8
1976[2]	46.0	1,391	30.2
Cleveland			
1983[1]	4.7	263	56.0
1976[2]	4.7	147	31.3
New Orleans, 1983[1]	6.1	115	18.9
Newark, 1976[2]	2.2	44	20.0
Philadelphia			
1983[1]	44.6	1,371	30.7
1976[2]	14.8	407	27.5
Pittsburgh			
1983[1]	4.9	387	79.0
1976[2]	6.5	403	62.0
San Diego, 1983[1]	4.2	71	16.9
San Francisco			
1983[1]	48.2	899	18.7
1976[2]	19.3	329	17.0
Range			8.7 - 79.0
Avg., Non-Weighted			22.9[3]

[1]Data presented in "APTA 1984 Operating Statistics."
[2]Data presented in "Urban Rail in America: An Exploration of Criteria for Fixed-Guideway Transit."
[3]Pittsburgh data not included in the average. Including Pittsburgh data results in an average of 28.8, greater than the bus data.
Source: Reference 11.

Table 3-10
Employees Per Passenger for Regular Route Bus Service

Bus System	Annual Bus Patronage (millions)	Bus Employees	Employees Per Million Passengers
Atlanta	84.9	2,034	23.9
Boston	102.7	2,646	25.8
Chicago	474.0	7,423	15.7
Cleveland	73.9	1,642	22.2
Dallas	35.8	1,108	30.9
Fort Worth	5.3	242	45.8
Houston	52.1	2,194	42.1
Los Angeles	415.9	8,361	20.1
Milwaukee	76.6	1,462	19.1
Miami	64.1	1,918	29.9
New York City	1,062.1	15,328	14.4
Ottawa	111.6	1,882	16.9
Philadelphia	186.5	3,470	18.6
Pittsburgh	83.5	2,381	28.5
Portland, Oregon	47.4	1,716	36.2
San Antonio	33.4	911	27.2
Seattle	60.6	2,374	39.2
Vancouver, B.C.	102.9	2,941	28.6
Washington, D.C.	178.0	4,410	24.8
Range			14.4-45.8
Avg., Non-Weighted			26.9

Source: Adapted from Reference 11.

Cost of Light Rail Transit

Capital Cost (11). The cost of implementing a light rail transit system depends largely on the extent of grade separation required. When extensive portions of the system are elevated or depressed, such as in the case of Buffalo, light rail can cost as much to construct as rail rapid. Conversely, systems built entirely at-grade on readily available right-of-way can be implemented for as little as $8 to $10 million per mile. Table 3-11 summarizes the capital costs associated with recently constructed or proposed light rail systems in the U.S. and Canada.

Operating Costs (15, 18, 24). Estimated operating costs per passenger and per passenger-mile for 8 light rail systems in the U.S. and 2 systems in Canada are presented in Table 3-12. As this table indicates, operating costs can vary widely from system to system. Operating cost per passenger ranges from $0.34 to $3.13, and operating cost per passenger-mile ranges from $0.06 to $0.83.

Table 3-11
Estimated Capital Cost for Selected Light Rail Systems

System/Location	Length (miles)	Capital Cost ($ millions) Total	Cost/Mile
Canada			
Edmonton	6.4	$ 92.2[1]	$ 14.4[1]
Calgary (existing)	7.7	176.0[1]	22.6[1]
(extension)	4.5	234.0	37.3
United States			
Buffalo	6.4	500.0	78.1
Dallas	160.0	3,200.0	20.0
Detroit	15.0	720.0	48.0
Houston			
Consultant Report[2]	106.5	3,185.0	29.9
METRO Plan[3]	62.9	1,158.0	18.4
Los Angeles			
Long Beach	22.5	690.0	30.7
Century Freeway	17.5	255.0	17.5
Milwaukee	14.3	166.0	11.6
Oklahoma City	17.4	154.0	8.9
Pittsburgh	10.5	559.0	53.2
Portland	15.0	210.0[4]	14.0
St. Louis	18.0	229.0	12.7
Sacramento	18.3	156.0	8.5
San Diego (existing)	15.9	224.0	14.1
(planned extension)	4.5	33.0	7.3
San Jose/Santa Clara	20.0	382.0	19.1
Range			$7.3-$78.1
Avg., Non-Weighted			$24.5

[1]Canadian dollars
[2]Outside consultants assessment of a previous Houston LRT plan
[3]Data for Westpark, FW&D, and MKT corridors. Does not include yards and shops, SC&C and rolling stock.
[4]An additional $100 million is being spent for freeway improvements.
Source: Adapted from reference 11.

Light rail transit was implemented in San Diego at a cost of $14.1 million per mile.

Table 3-12
Estimated Operating Cost Per Passenger and Per Passenger-Mile
for Selected Light Rail Systems for 1983

System	Annual Passengers (millions)	Annual Passenger-Miles (millions)	Annual Operating Cost ($ millions)	Operating Cost ($) Per Passenger	Operating Cost ($) Per Passenger-Mile
Canada					
Calgary[2]	11.4	63.0	$ 3.84[1]	$ 0.34[1]	$ 0.06[1]
Toronto	92.3	572.0	44.65[1]	0.48[1]	0.08[1]
United States					
Boston	21.7	30.4	17.56	0.81	0.58
Cleveland	4.9	37.2	7.10	1.45	0.19
San Diego	4.2	35.5	4.20	1.01	0.12
San Francisco	47.4	138.1	29.81	0.63	0.22
Newark	3.2	6.3	3.07	0.96	0.49
Philadelphia	44.6	108.1	37.96	0.85	0.35
Pittsburgh	4.9	18.5	15.36	3.13	0.83
New Orleans	5.9	16.8	4.32	0.73	0.26
Range				$0.34-$3.13	$0.06-$0.83
Avg., Non-Weighted				$1.04	$0.32

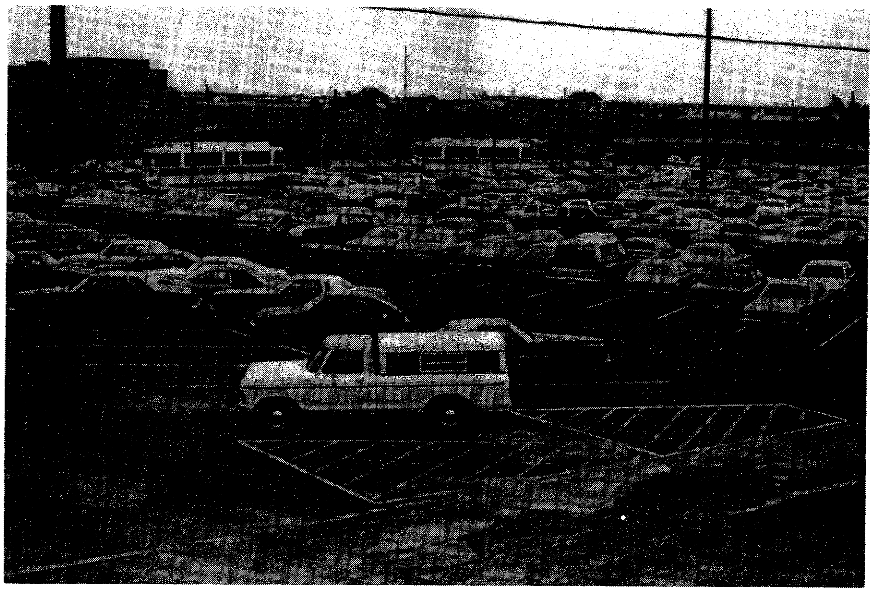
[1]Canadian dollars
[2]1982 statistics
Note: In some cases, statistics in this table differ slightly from those in Table 3-9 because of differences in reporting time periods.
Source: References 15, 18 and 24.

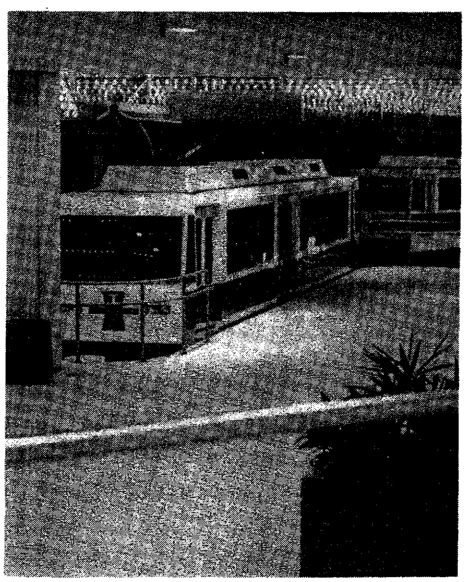
Application of Light Rail in Texas (25)

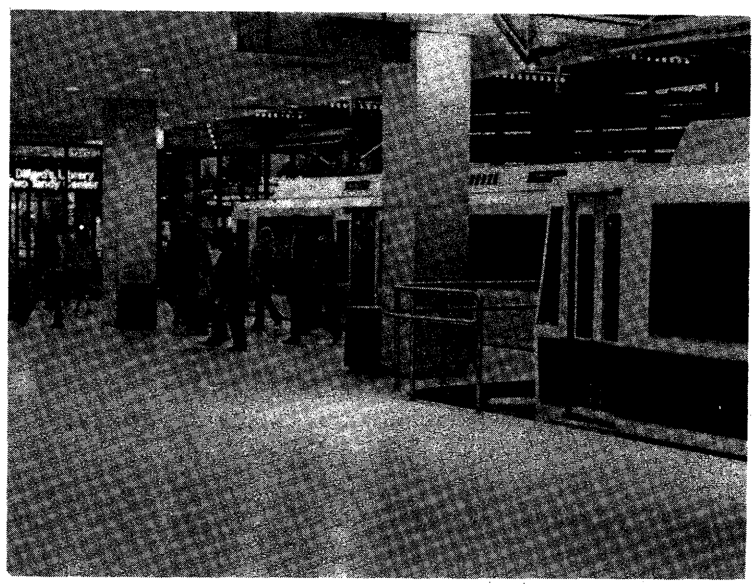
For the past 22 years, a 1-mile long subway system has been in operation in Fort Worth, Texas. Fort Worth's subway is unique in that: (1) It is the only U.S. LRT line that serves as a shuttle between a CBD and peripheral parking lots and (2) It is the only LRT line which is privately owned and operated without financial assistance from any level of government - local, state or federal. Construction of the $1-million subway was financed by Marvin and Obie Leonard, pioneer merchants of Fort Worth, to provide free subway service to their downtown department store from a large parking lot on the banks of the nearby Trinity River. The idea was to keep customers coming downtown to shop at their store rather than at the newer suburban shopping malls that were being built. A fleet of 5 modernized and customized PCC cars was placed into service in February 1963 when the M and O Subway (named for Marvin and Obie Leonard) officially opened.

The subway was used not only by Leonard's Department Store customers, but also by its employees, other workers in the CBD, and tourists. In fact, the subway began operating on peak-period frequencies at 7:30 a.m. in order to carry commuters from their free parking spaces to their downtown jobs, even though Leonards did not open for business until 10:00 a.m. Both the store and the LRT line have changed ownership twice since 1963. The present owner, Tandy Corporation, has completely refurbished the system. Included in the overall improvements was the redesign and overhaul of the fleet of PCC cars. All have been air-conditioned, modified for high-level platform boarding and fitted with new contemporary-styled car bodies. The vehicle propulsion equipment was also overhauled.

The Tandy subway in Fort Worth is the only light rail operation in Texas. However, the characteristics of light rail, the wide variety of locational and alignment options available, and the passenger-carrying potential of light rail have made this mode attractive to a number of cities in the state. Among those cities which are planning, proposing, or considering light rail systems are Houston, Dallas, San Antonio, Austin and Galveston.







Tandy Corporation's 1-mile long light rail operation in Fort Worth provides service from a park-and-ride lot to downtown Fort Worth.

Rail Rapid Transit

Although often considered a "modern" transit technology, the rail rapid transit (RRT) mode is actually the oldest form of mass transportation still in significant use today. In fact, the Boston and Chicago rail rapid systems were in operation as early as 1871 and, by 1908, New York City and Philadelphia also had major RRT systems in service.

Designed to be implemented in heavily traveled urban corridors, rail rapid transit has been most effective at serving large volumes of travel to downtown areas. For those systems listed in Table 3-13, between 61% and 86% of the total trips had at least one trip end downtown.

Table 3-13
Estimated Percent of Trips With at Least One Trip End Downtown for Selected Rail Rapid Transit Systems

System, Year	% Origins in CBD	% Destinations in CBD	% With One Trip End in CBD
Canada			
Toronto, 1976	36	36	72
United States			
Atlanta, 1980	NA	NA	75
Boston, 1973	42	42	84
Chicago, 1972	36	36	72
Cleveland, 1976	35	35	70
Miami, 1985	NA	NA	61
New York City, 1974	41	41	82
Philadelphia			
Lindenwold, 1976	43	43	87
SEPTA, 1975	35	35	70
San Francisco, 1977	40	40	79
Washington, D.C., 1984	NA	NA	68
Range	32-43	32-43	61-86
Avg., Non-Weighted	38	38	75

Note: NA indicates data not available.
Source: Reference 11.

Description (1, 2, 4)

Rail rapid transit (also referred to as heavy rail, conventional rail, subway, metro, elevated, "El" or "L" railway), is typically characterized by the following.

- RRT systems utilize dual guideways located on exclusive, fully grade-separated rights-of-way with no external interferences.

- Power distribution for RRT vehicles is through a third-rail electric power pick-up.
- Comparatively heavy weight dual-directional rolling stock, often operated in semi-permanently coupled (or "married") pairs, is used.
- Vehicles linked together in trains of up to 10 cars (or 5 pairs of cars) are operated during peak periods.
- Passenger boarding/alighting is by way of high-level loading platforms located at on-line stations (no by-pass tracks).
- Fare collection is accomplished at station turnstyles.
- Cab signals with some degree of automated train operation are used.

Rail rapid transit vehicles do not necessarily operate with steel wheels on steel rails. The Montreal system uses rubber-tired vehicles operating on concrete guideways. The Montreal operating characteristics are similar to conventional rail rapid.

Rail rapid transit utilizes dual guideways on exclusive, fully protected, grade-separated rights-of-way. RRT vehicles are propelled by electricity transmitted through a side-running third rail.

Design and Operating Characteristics

Vehicle Technology (1, 2, 26). Numerous rail rapid transit cars have been manufactured during the last century. Specific physical and performance characteristics for vehicles built for the newer, "modern" RRT lines are presented in Table 3-14. Characteristics for vehicles built since 1970 for service on the older "conventional" rail rapid lines are summarized in Table 3-15.

Table 3-14
Physical and Performance Characteristics for Selected Rail Rapid Transit Vehicles

Characteristics	Port Authority Transit Corporation Lindenwold 251 Series Car	San Francisco Bay Area Rapid Transit District Vehicle	Washington Metropolitan Area Transit Authority 2000 Series Vehicle	Metropolitan Atlanta Rapid Transit Authority Vehicle	Baltimore Regional Rapid Transit Authority Vehicle[1]
Type of Car	Married Pair	Single Car	Married Pair	Married Pair & Single Unit	Married Pair
Length (feet)	67.8	75.4[2]	75.0	75.0[2,3]	75.0
Width (feet)	10.1	70.0[3]	10.1	75.3[4]	10.2
Height (feet)	12.3	10.5	10.8	10.5	12.0
Net Weight (pounds)	74,000	59,000[2] 58,400[3]	72,000	76,000	77,000
Truck Centers (feet)	47.5	50.0	52.0	52.5	52.0
Minimum Horizontal Radius (feet)	125.0	400.0	225.0	350.0	250.0
Minimum Vertical Radius (feet)	2,000	1.5%/100 ft	2,000	1.5%/ 100 ft	2,000
Builder	Vickers Canada, Inc.	Rohr Industries	Breda Construzioni Ferroviarie	Societi' Franco-Belge de Material de Chamins de Fer	Budd Company
Year Built	1979	1970-1974	1980	1977-1978	1980
Floor Height/Headroom (feet)	3.8/7.1	3.2/7.2	3.3/6.8	3.7/6.8	3.6/7.2
Number of Doors per Side	2	2	3	3	3
Design Capacity Seats/Standees	80/20-120	72/48-144	68/119-164	68/72-182[2,3]	74/90-199
Maximum Speed (mph)	75	80	75	75	70
Service Acceleration (mph/sec)	3.0	3.0	3.0	3.0	3.0
Service Deceleration (mph/sec)	3.0	3.0	3.0	3.0	3.0
Emergency Deceleration (mph/sec)	Above 3.0	3.0	3.2	3.5	3.2
Maximum Design Grade (percent)	NA	4.0	4.0	3.0	NA
Capital Cost Per Unit (1979 $)	$942,000	$642,000	$740,000[5] $792,000[6]	$719,000	$616,000

Note: NA indicates data not available.
[1]Vehicle also used by Metropolitan Dade County Transportation Administration.
[2]A Car only.
[3]B Car only.
[4]C Car only.
[5]Cam Control.
[6]Chopper Control.
Source: Reference 1.

Table 3-15
Physical and Performance Characteristics for Selected Rail Rapid Transit Vehicles in the U.S. and Canada

Characteristic	Chicago Transit Authority 2420 Series Car	Greater Cleveland Regional Transit Authority 171 Series Car	New York City Transit Authority R-46 Car	Port Authority Trans. Hardsom Corporation P-3 Car	Toronto Transit Commission Class H-5 Car	Massachusettes Transportation Authority 1200 Series Car
Type of Car	Married Pair	Single Car Unit	4-Car Units	A Car;2, 3 or 4 car units	Married Pair	Married Pair
Length (feet)	48.3	70.3	75.0	51.3	74.8	65.3
Width (feet)	9.3	10.5	10.0	9.2	10.3	9.2
Height (feet)	12.0	12.0	12.1	11.6	11.9	12.0
Net Weight (pounds)	50,500	64,000	88,955[1], 85,270[2]	60,000	67,110[1], 64,240[2]	67,000
Truck Centers (feet)	33.7	49.6	54.0	33.0	52	46.5
Minimum Horizontal Radius (feet)	85.0	120.0	145.0	80.0	230.0	120.0
Minimum Vertical Radius (feet)	Angularity of drawbar ±4%	2,000	2,500	900.0	2,000	2,000
Manufacturer	Boeing-Vertol	Pullman-Standard	Pullman-Standard	Hawker-Siddeley	Hawker-Siddeley	Hawker-Siddeley
Year Built	1976-78	1970	1975-77	1972	1977-80	1978-79
Floor Height/Headroom (ft)	3.8/7.4	3.5/8.1	3.9/6.9	3.8/6.9	3.7/7.1	3.7/7.1
Number of Doors per Side	4	4	8	4	8	3
Design Capacity Seats/Standees	43/57[1]; 49/101[2]	80/40	70/280[1], 76/274[2]	35/180	76/159	58/162
Maximum Speed (mph)	70	55	80	70	55	
Service Acceleration (mph/sec)	3.2	2.75	2.5	2.5	2.5	2.5
Service Deceleration (mph/sec)	3.2	3.0	2.3 from 80 mph	3.0	2.8	2.75
Emergency Deceleration (mph/sec)	6.5	3.5	3.0	3.0	3.0	3.25
Maximum Design Grade (%)	NA	NA	NA	NA	NA	NA
Capital Cost Per Unit	$300,000 avg.	$251,950	$275,381	$182,000	$389,200	$586,000

Note: NA indicates data not available.
[1]A car only.
[2]B car only.
Source: References 1 and 26.

Generally speaking, vehicles designed for the conventional rail rapid systems resemble standard railway passenger equipment and feature control and signal systems that are compatable with older equipment already in service on a particular line. Modern rail rapid transit cars, on the other hand, have a streamlined appearance and have incorporated features designed to reduce noise and improve suspension for a higher quality ride.

The typical rail rapid vehicle configuration is a single non-articulated design supported by 2, 2-axle trucks at both ends. A control cab is located at one end, and the vehicle can travel in one direction only. Most rail rapid systems semi-permanently couple 2 cars into "married pairs." Each pair then becomes bi-directional. A few systems, however, such as Philadelphia's Lindenwold line and Atlanta's MARTA system, operate some single vehicles with control cabs at each end.

Travel Ways (1). Rail rapid transit vehicles are electrically propelled by voltages which typically range from 600 to 1,000 volts dc. The current is transmitted to electric traction motors through an energized third rail, mounted on the railroad track cross ties on the outside of and adjacent to one of the running rails. Third rail shoes attached to the vehicle trucks slide along the third rail for current collection. The third rail type of operation is preferred for high-capacity trains of 4+ cars because of the rail's superior conduction properties as compared with overhead electrical wire. A few RRT systems (such as Cleveland's) utilize overhead trolley wire for power distribution.

For safety reasons, the use of a third rail requires complete grade separation of RRT lines from other traffic. This, in turn, limits the travel alignment options available (as compared to LRT). Typical RRT travel ways include:

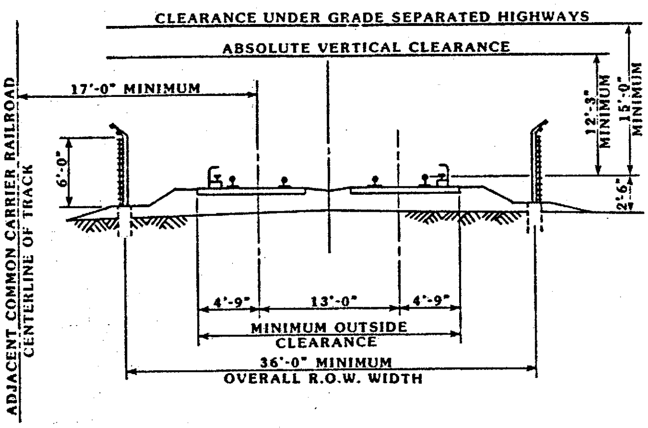
- Subways, tunnels, or depressed ROW alignments,
- Elevated or aerial guideways; and
- Surface operation utilizing freeway medians or railroad rights-of-way (surface portions are usually fenced off, with no grade crossings with streets or railways).

Typical cross-sections for rail rapid transit operation are presented in Figure 3-5.

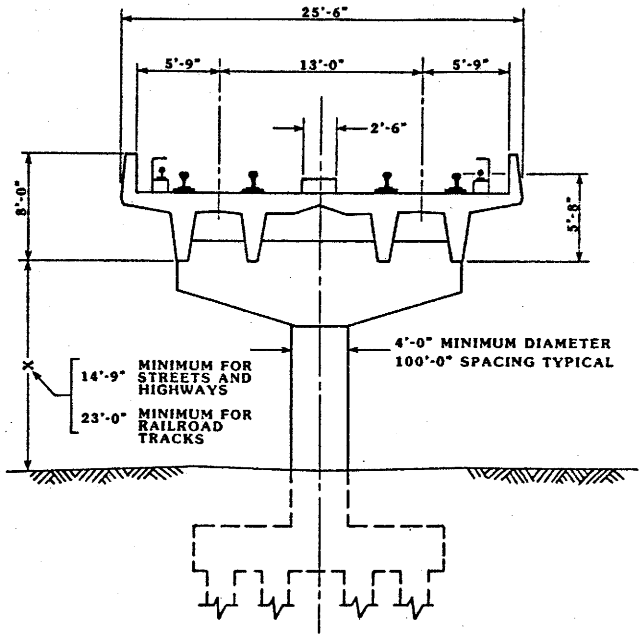
Guideway Design (1). Minimum curvatures and maximum gradient for RRT guideway design are summarized below.

- Absolute minimum horizontal curvature is a function of the specifications of the vehicles to be selected for operation. Minimum track centerline radii for modern rail rapid vehicles vary between 200 and 400 feet, although such curvature is restricted to vehicle storage yards and emergency crossovers between double tracks.
- Typical mainline minimum horizontal curvature for rail rapid is similar to that for regional rail and common carrier freight track-

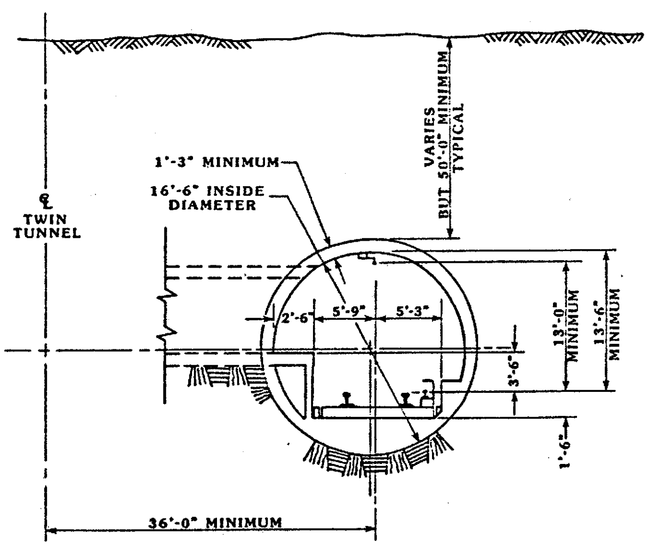
TYPICAL CROSS-SECTION FOR RAIL RAPID TRANSIT OPERATION AT-GRADE



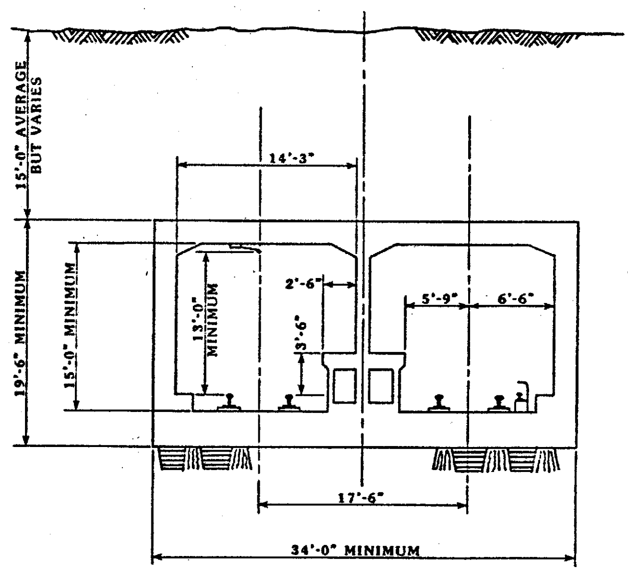
TYPICAL CROSS-SECTION FOR RAIL RAPID TRANSIT OPERATION ON ELEVATED STRUCTURE



TYPICAL CROSS-SECTION FOR LIGHT RAIL OR RAIL RAPID TRANSIT OPERATION IN BORED DEEP TUNNEL SUBWAY



TYPICAL CROSS-SECTION FOR LIGHT RAIL OR RAIL RAPID TRANSIT OPERATION IN CUT-AND-COVER SUBWAY



Source: Reference 1.

Figure 3-5
Typical Cross-Sections for Rail Rapid Transit Operation

age, with values ranging between 1 and 7 degrees (radii of 5,729 and 818 feet, respectively).

- Maximum grades negotiable depend on vehicle specifications, with modern RRT vehicles generally being able to climb 3% to 4% gradients.

Stations (1, 4, 11). All rail rapid systems utilize stations that are grade-separated from other facilities and have full control of passenger access. RRT stations are typically spaced from 0.4 to 2.3 miles apart. Station spacing in the range of one-half mile is generally applied where it is desirable to keep walking distances within acceptable limits, while station spacing of 1 to 2 miles is typical for park-and-ride operations in residential neighborhoods.

Rail rapid stations consist of 1 or 2 levels and vary from 300 to 700 feet in length, depending upon the longest train length which must be accommodated at the platforms. Overall widths are generally a minimum of 45 feet, with concourse levels sometimes being wider in subway segments. Actual platform width should be no less than 12 feet. A common feature of some underground stations is direct pedestrian access via passageways to adjacent activity centers such as shopping areas, and other business establishments.

Operating and Performance Characteristics (1, 11). The characteristics of speed, headway and capacity for rail rapid transit systems are defined in the following sections.

Speed. Rail rapid transit speeds can be expressed as maximum vehicle speeds, typical operating speeds or average speeds over the length of the rail line.

- Most rail rapid transit vehicles have maximum attainable speeds in the range of 70 to 80 miles per hour (Table 3-15). A few, however, have somewhat lower maximum speeds. Those with the lower speeds (typically 55 to 65 mph) are generally found on the older, conventional RRT lines.

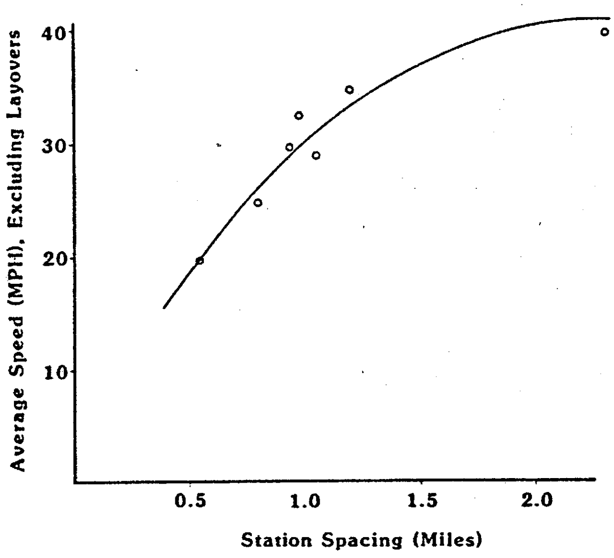
- Unlike light rail, typical operating speeds for RRT are constrained only by the configuration of the guideway and station spacing. Because rail rapid systems operate on totally grade-separated, exclusive right-of-way, maximum vehicle speeds on the main line can be achieved except when negotiating some curves and when passing through stations.

- As in the case of LRT, average speeds for RRT are a direct function of station spacing (Figure 3-6). Unlike LRT, however, frequent stops and conflicts with other traffic do not present problems for RRT operation. This results in higher average operating speeds for RRT. In fact, the average operating speed (excluding layovers) for all RRT systems listed in Table 3-16 of 32 mph is twice as high as the 16 mph average operating speed for the LRT systems listed in Table 3-2. Nevertheless, referring to speeds of 32 mph as "rapid" is somewhat misleading by today's standards. The term rapid was a more apt description when first applied in relation to alternative modes in the late 1800's and early 1900's.

Table 3-16
Estimated Average System Operating Speed for Selected Rail Rapid Transit Systems

System, Year	Average Including Layover	Speed (mph) Excluding Layover	Number Of Stations	Distance Between Stops (miles)
Canada				
Toronto, 1976	20.4	NA	59	0.58
United States				
Atlanta, 1980	24.5	33.7	25	1.00
Baltimore, 1984	----	----	9	0.90
Boston, 1976	15.6	----	43	0.78
Chicago, 1976	19.9	24.6	143	0.70
Cleveland, 1976	22.8	29.0	18	1.13
Miami, 1985	----	----	20	1.00
New York CTA, 1976	18.3	----	458	----
Philadelphia				
Lindenwold, 1976	28.0	34.8	13	1.18
SEPTA, 1976	17.5	----	62	0.39
San Francisco, 1977	33.6	40.0	34	2.30
Washington, D.C., 1980	20.7	30.0	60	1.00
Range	15.6-33.6	24.6-40.0	----	0.39-2.30
Avg., Non-Weighted	22.1	32.0	----	0.96

Source: Reference 11.



Source: Reference 11.

Figure 3-6
Relationship Between Average Speed and Station Spacings for Selected Rail Rapid Transit Systems

Headway (1). Vehicle speed and the degree of automatic train protection dictate how short a headway can be safely achieved for RRT systems. For safety reasons, higher speeds require longer headways than do lower speeds. Automatic train protection systems also regulate train spacings and include built-in safety margins which prohibit shorter headways that might otherwise be possible under visual/manual control. Actual headways for rail rapid transit vary between operations, but may be typified by two modern systems in the United States: Philadelphia's Lindenwold line and Washington, D.C.'s Metro system. The Lindenwold line has operated 24 hours per day, 7 days per week continuously since service commenced. Headways range from 2 to 5 minutes during peak periods, 7.5 minutes during the midday, 10 minutes during evenings, and 60 minutes between midnight and 6 a.m. On Sundays, there is a 15-minute headway. Washington's Metro system provides headways of 5 minutes during peak periods and 10 minutes during off-peak periods.

Capacity (1, 11). The maximum passenger-carrying capacity of a rail rapid transit system is determined by the vehicle capacity, train length and headway. Other design, policy and institutional considerations which reflect local conditions also influence capacity. For example, the capacity of a new rail rapid system is controlled principally by initial guideway design constraints. Table 3-17 provides data on the range of theoretical passenger-per-hour capacities possible under various vehicle and operational configurations, based on contemporary vehicle designs. The extreme values in the matrix would only be reached under unusual circumstances, and are therefore, unrealistic when applied to normal operating conditions. In general, rail rapid transit is cited as being able to accommodate peak-hour travel demands in the range of 10,000 to 40,000 passengers per hour. This is assuming double track guideways, one track for each direction of travel. Actual peak-hour patronage for selected RRT lines in the United States and Canada is presented in Table 3-18. On one Manhattan line, more than 53,000 passengers are moved by 28 trains during the peak-hour. Depending on vehicle design, as many as two-thirds of the passengers may be standees on heavily traveled lines.

Table 3-17
Theoretical System Capacities Per Peak Hour for Rail Rapid Transit

Headway in Minutes	System Capacity per Number of Vehicles in Train[1]					
	1	2	4	6	8	10
2	6,660	13,320	26,640	39,960	53,280	66,600
5	2,664	5,328	10,656	15,984	21,312	26,640
10	1,332	2,664	5,328	7,992	10,656	13,320
15	888	1,776	3,552	5,328	7,104	8,880
20	666	1,332	2,664	3,996	5,328	6,660
30	444	888	1,776	2,664	3,552	4,440
60	222	444	888	1,332	1,776	2,220

[1]Assumes use of rail rapid transit vehicle having a total design capacity of 222 passengers, including 74 seated passengers and 148 standees.

Source: Reference 1.

Table 3-18
Peak-Hour Patronage on Selected Rail Rapid Transit Lines

System, Year, Line	Peak-Hour Inbound		8:00-9:00 a.m. as a % of all Day Inbound	
	Trains	Passengers	Cars	Passengers
Canada				
Montreal, 1976				
N Line 2, Rue Berri	23	28,230	9.2%	28.8%
E Line 1, Blde Mais.	17	19,110	7.3	27.3
TOTAL/Avg., Montreal	70	65,586	8.2	27.2
Toronto, 1976				
N Yonge-University	30	22,900	9.0	22.6
E Danforth	22	22,700	7.4	25.2
W Bloor	22	21,500	7.5	22.4
N Spadina (1980)	25	10,427	NA	NA
United States				
Atlanta, 1980				
East Line	6	4,250	7.7	21.2
West Line	6	3,725	7.7	21.9
Boston, 1976				
S Red Line	22	8,651	10.2	22.9
TOTAL/avg., Boston	137	43,061	9.0	26.4
Chicago, 1976				
SW Dan Ryan	17	12,498	11.8	24.5
NW W-NW	22	10,213	12.2	25.5
TOTAL/Avg., Chicago	121	52,816	10.6	20.5
Cleveland, 1976				
E Joint Tract	9	4,100	11.0	24.0
W Airport	14	5,413	12.9	24.0
Manhattan, 1976				
N IRT, Lexington Ave., Express	23	35,700	9.9	28.5
E IND, Queens	28	53,330	10.5	33.9
N IRT, Broadway, Express	19	27,290	8.5	24.6
TOTAL/Avg., NYCTA	352	433,040	10.0	29.5
Philadelphia, 1976				
N SEPTA Broad	23	10,600	12.6	17.3
TOTAL/Avg., Philadelphia	169	43,900	12.6	20.5
San Francisco, BART, 1977				
E Transitway Tube	11	8,016	11.7	27.8
W Mission Street	10	6,510	10.1	34.5
Washington, DC, 1980				
W Blue Line	20	13,000	8.4	25.0
N Red Line	12	12,000	8.8	25.2
E Blue Line	20	8,000	8.4	27.0

Note: NA indicates data not available
Source: Reference 11.

Attributes (1, 2)

The principal attributes of rail rapid transit include the following.

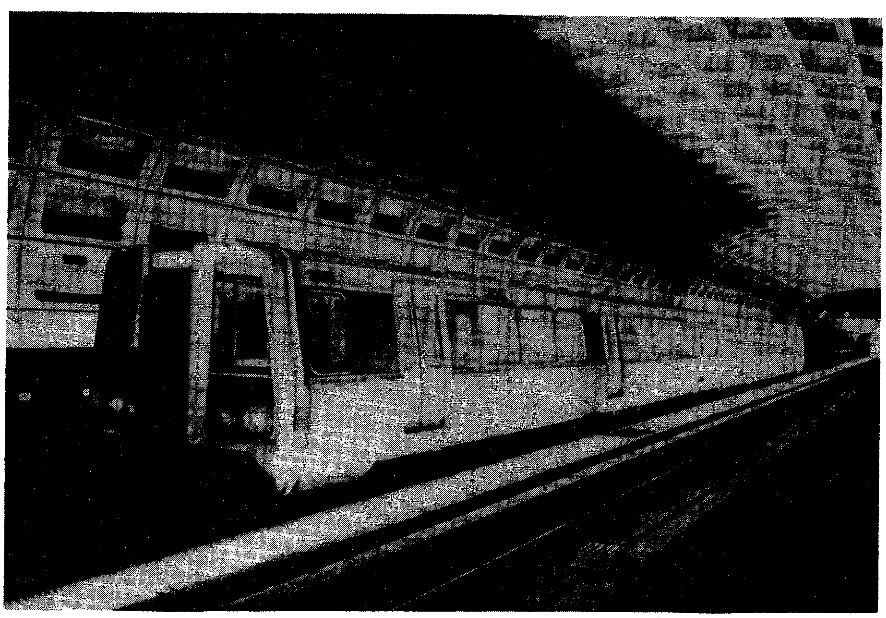
- Rail rapid transit vehicles can be operated in trains with total passenger-carrying capacities of up to 2,700 per train resulting in a potential passenger-to-operator ratio of up to 2.7 times that of light rail transit. The trainability of RRT vehicles is also advantageous in accommodating fluctuating demands and headways while maintaining a relatively stable operating staff. RRT is generally able to handle capacities greater than those which can be served by other primary transit modes.

- Simple guidance, electric traction and operation on exclusive, fully grade-separated rights-of-way allow rail rapid transit vehicles to travel at the maximum speed possible with given station spacings while maintaining passenger comfort, high power utilization efficiency, high reliability and virtually absolute safety.

- Automated operation can be utilized to the greatest extent possible.

- Rail rapid is generally the most capital intensive primary transit mode, requiring a major capital investment to implement a usable segment.

- The development of a rail rapid transit system requires a lengthy implementation period, particularly when substantial portions of the system are built in subways. The construction of a rail rapid system is also disruptive to the urban area and is characterized by long periods of negative impacts.



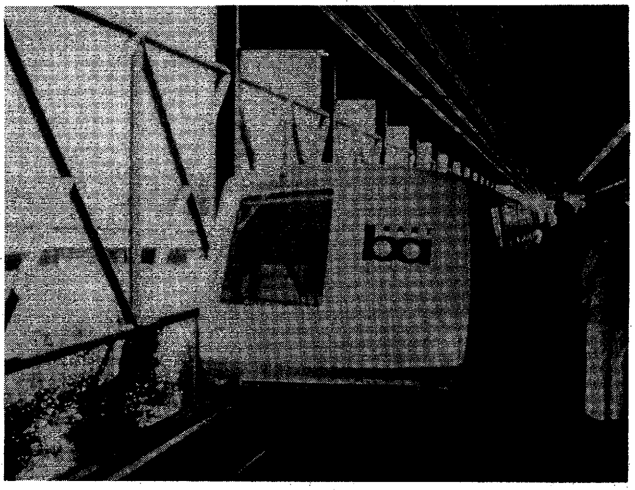
Rail rapid is generally a capital intensive mode requiring a lengthy implementation time, particularly when substantial portions of the system are built in subways.

Examples of Rail Rapid Transit Systems in the United States and Canada

Rail rapid transit systems are currently operating in the following cities in the U.S. and Canada.

- Atlanta
- Baltimore
- Boston
- Chicago
- Cleveland
- Miami
- Montreal
- New York
- Philadelphia/Newark
- San Francisco
- Toronto
- Washington, D.C.

Rail rapid systems can be found in Philadelphia/Newark (left), Atlanta (below left) and San Francisco (below right).



Characteristics of these RRT systems are presented in Table 3-19.

Ridership and Employees Per Passenger. Annual patronage and the employees per passenger for selected RRT systems in the United States and Canada are presented in Table 3-20. As the figures indicate, the average number of rail employees per passenger for rail rapid transit is comparable to (not lower than) that for motor bus transit (Table 3-10), which again questions the theory that rail modes are less labor intensive than motor bus transit.

Table 3-19
Characteristics of Rail Rapid Transit Systems in the United States and Canada

System	Operating Authority	Total Revenue Vehicles	Number of Routes	Directional Miles of Track	Killowatt Hours of Power/ Year (000)	Metropolitan Area 1980 Population	Annual Ridership (millions)
Canada							
Montreal	Montreal Urban Community Transit Commission	759	3	58.0	174,632.0	2.8	164.2
Toronto	Toronto Transit Commission	632	2	95.0	---	3.0	243.1
United States							
Atlanta	Metropolitan Atlanta Rapid Transit Authority	120	4	46.8	28,000.0	1.6	39.9
Baltimore	Baltimore Regional Rapid Transit Authority	72	---	15.5	---	1.8	11.4
Boston	Massachusettes Bay Transportation Auth.	503	3	106.0	130,818.0	2.7	129.4
Chicago	Chicago Transit Authority	1,197	6	205.6	287,390.0	6.8	149.8
Cleveland	Greater Cleveland Transportation Authority	92	1	41.4	19,740.0	1.8	6.8
Miami	Metropolitan Dade Co. Transportation Admin.	136	1	42.0	---	2.6	5.1[1]
New York	N.Y. City Transit Auth.	6,217	32	685.5	1,687,148.0	15.6	1,517.5
	Staten Island Rapid Tran.	52	---	20.6	15,252.6	15.6	5.8
	Port Authority Trans Hudson Corporation	289	---	---	73,334.4	15.6	59.6
Philadelphia	Lindenwold-Port Auth. Transit Corp. of PA and NJ	121	4	30.5	2,473.0	4.1	10.7
	Southeastern PA Transportation Auth.	267	3	70.4	109,242.0	4.1	98.3
San Francisco	Bay Area Rapid Transit	463	3	184.2	168,546.0	3.2	57.7
Washington, DC	Washington Metropolitan Area Transit Authority	293	5	105.0	179,036.0	2.8	95.5

[1]Estimate
Source: Reference 1, 11, 15, 27, and 28.

Table 3-20
Employees Per Passenger For Selected Rail Rapid Transit Systems

System	Annual Ridership (millions)	Employees	Employees Per Million Passengers
Canada			
Montreal	164.2	1,837	11.2
United States			
Atlanta	39.9	715	17.9
Boston	129.4	3,131	24.2
Chicago	149.8	4,286	28.6
Cleveland	6.8	302	44.4
New York CTA	1,517.5	33,046	21.8
New York PATH	59.6	1,123	18.8
Philadelphia-Lindenwold	10.7	319	29.8
Philadelphia-SEPTA	98.3	1,837	18.7
San Francisco	57.7	2,010	34.8
Washington, DC	95.5	2,653	27.8
Range			11.2-44.4
Avg., Non-Weighted			25.3

Source: References 11 and 18.

Cost of Rail Rapid Transit

Capital Costs (13). The capital costs associated with implementing rail rapid transit systems are difficult to estimate since it is not always possible to determine exactly what is included in the cost values reported. Because this mode must utilize totally grade-separated and protected rights-of-way, rail rapid transit is the most capital intensive of all transit technologies. Table 3-21 highlights available capital cost data for several RRT systems recently implemented (or proposed) in the U.S.

Operating Costs (15, 18). Table 3-22 presents estimated operating costs per passenger and per passenger-mile for selected rail rapid systems in the U.S. and Canada. These costs range from $0.45 to $2.17 per passenger and from $0.13 to $0.33 per passenger-mile.

Application of Rail Rapid Transit in Texas

At the present time, there are no rail rapid transit systems in operation, under construction or proposed in Texas. A rail rapid system was proposed for Houston in 1983, but was turned down by popular vote.

Table 3-21
Estimated Capital Cost for Selected Rail Rapid Transit Systems

System	Service Data and Status	Length (miles)	Capital Cost ($ millions)	
			Total	Cost/Mile
Atlanta ($ 1979)	1979	25.0	$ 1,722	$ 68.9
	Ultimate	53.0	3,400	64.1
Baltimore	1984	8.0	797	99.6
	Extension	6.0	198	33.0
Houston	1983 bond proposal	18.0	1,700	94.4
Los Angeles	Initial Plan	4.4	1,180	268.2
	Ultimate	18.6	3,400	182.8
Miami	1984-85	20.5	1,050[1]	51.2
San Francisco ($ 1972)	1972	71.5	1,600[2]	22.4
Washington, DC	1976	39.0[3]	2,700	69.2
	Planned	89.5	7,100	79.3
	Ultimate	101.0	12,000+	120.0
Range				$22.4-$268.2
Avg., Non-Weighted				$ 96.1

[1] Connects to a 1.9 mile people-mover for downtown distribution. People-mover cost is $146 million, or $76.8 million per mile. See "Automated Guideway Transit" section.
[2] This is 1972 dollars. Currently valued at over $5 billion, or about $79 million per mile.
[3] This is the initial 39-mile section. Currently, 60.5 miles are in operation.
[4] Current Dollars.

Note: In general, costs shown are in construction year dollars. No attempt has been made to express all costs in current dollars.

Source: Reference 11.

Rail rapid transit was implemented in Miami at a cost of $51.2 million per mile.

Table 3-22
Estimated Operating Cost Per Passenger and Per Passenger - Mile for Selected Rail Rapid Systems for 1983

System	Annual Passengers (millions)	Annual Passengers-Miles (millions)	Annual Operating Cost (millions)	Operating Cost ($)	
				Per Passenger	Per Passenger-Mile
Canda[1]					
Montreal	163.2	574.7	$ 109.9	$0.67	$0.19
Toronto	243.1	851.0	110.0	0.45	0.13
United States					
Atlanta	39.8	131.4	20.5	0.52	0.16
Baltimore	11.4	--	18.0	1.58	--
Boston	129.4	393.5	131.0	1.01	0.33
Chicago	149.8	1,093.2	190.8	1.27	0.17
Cleveland	6.8	69.9	12.2	1.79	0.17
New York City	1,157.5	6,330.8	1,514.4	1.31	0.24
Philadelphia					
Lindenwold	10.7	92.8	16.2	1.51	0.17
SEPTA	98.3	540.3	92.3	0.94	0.17
San Francisco	57.7	725.1	125.3	2.17	0.17
Washington, DC	95.5	413.1	122.4	1.28	0.30
Range				$0.45-$2.17	$0.13-$0.33
Avg., Non-Weighted				$1.14	$0.20

[1]Canadian dollars

Source: References 13, 17 and 20.

Regional Rail

Regional rail (RGR) transit systems are operated by transit authorities or by railroad agencies under contract along rights-of-way which are also used to provide intercity passenger and freight service. RGR vehicles, operated individually or in trains, typically rely on diesel-electric propulsion. Most RGR networks consist of a number of lines radiating from the CBD with stations located at suburban town centers. Central city stations are often combined with intercity rail stations, but are limited in number and provide little downtown coverage. Regional rail primarily serves the suburb-to-CBD commuter travel and therefore, usually has heavily peaked and highly directional travel.

Description (1, 2)

Regional rail systems (frequently designated commuter rail or suburban rail) can be defined by the following conditions.

- RGR systems utilize heavy weight rolling stock of mainline railroad dimensions and design with high seating capacities.

- Diesel-electric locomotive propelled trains or self-propelled diesel-electric vehicles are used.

- Track and right-of-way are shared with intercity passenger and freight train operation. Rights-of-way are usually grade-separated, but many have signalized grade crossings.

- Tickets and fares are generally collected on board.

- Station spacings are comparatively long.

- Service is concentrated in peak home-to-work commuting periods.

- Passenger boarding/alighting is predominately at low level loading platforms.

Design and Operating Characteristics

Vehicle Technology (1, 31). Existing regional rail rolling stock can be divided into two overall physical configurations based on the form of propulsion:

- Electrified multiple-unit equipment; and

- Diesel-powered equipment consisting of either unpowered passenger coaches pulled by diesel-electric locomotives or self-propelled diesel-mechanical coaches.

Electrically-Powered Equipment. In the New York City and Philadelphia metropolitan areas, most of the regional rail service is provided by electrically powered multiple-unit cars. These cars are typically 85 feet long, 10 feet wide, and 14 feet high, and seat from 90 to 130 passengers. Some use 600 to 650 volts dc third rail; others use catenary overhead at 11,000 volts ac, 25 Hz; and one in New Haven uses both. In Chicago, 2 regional rail services are electrified and use a 1500 volts ac catenary system. Because electrified regional rail requires a very large capital investment for the electrical power distribution facilities, the use of electrified RGR is very rarely justified. Those facilities in New York City, Philadelphia and Chicago were largely constructed between 1907 and 1933, with only a limited number of refurbishments and extensions during the early 1970s. Electrification of these services were the result of the desire for efficiency in providing high density passenger service and because of smoke abatement situations resulting from steam locomotive operation in tunnels and central city areas.

Diesel-Powered Equipment. The most common form of RGR equipment is diesel-powered. Modern diesel-powered regional rail train operation is characterized by the utilization of either bi-directional trains hauled by locomotives or self-propelled passenger coaches. Bi-directional trains generally consist of a locomotive and unpowered coach combination in what is referred to as a "push-pull" train operation where the locomotive pulls the train when traveling in one direction and then pushes it when traveling in the reverse direction. This type of operation eliminates the need for physically turning the train.

Except for minor modifications, the diesel-electric locomotives used in regional rail service are essentially no different than those used in intercity passenger and freight service. Fuel oil is carried on board and fed into the diesel engine, which turns a generator-alternator producing 600 volts dc, which in turn powers the traction motors. The diesel engine also drives the air compressor for the brake system and an auxiliary generator to supply on-board electrical power to the passenger coaches.

Passenger coaches used for regional rail service may be either single-level or bi-level. Bi-level coaches are extensively utilized in areas such as San Francisco, Chicago and Toronto to increase capacity. The use of bi-level coaches in other areas, particularly in the northeastern cities of the U.S., is frequently constrained by vertical clearances, however.

Passenger coaches for regional rail service may be either single-level or bi-level. Bi-level coaches (above) are utilized to increase capacity.

Where necessary train length and capacity are small, self-propelled coaches are often used. Self-propelled coaches have a control cab located at each end and offer a seating capacity comparable to that of a single-level coach. Self-propelled coaches are bi-directional and have multiple-unit capabilities, although the training of more than a few units is generally not considered to be as cost-effective as using a locomotive-hauled train.

Currently, only one self-propelled coach is manufactured in the U.S.: The Budd Company's Model SPV-2000. Specified physical performance characteristics for the SPV-2000 and a current model passenger locomotive are presented in Table 3-23. Additional characteristics of the SPV-2000 are presented with characteristics of selected passenger coaches in Table 3-24.

Table 3-23
Characteristics of Selected Regional Rail Propulsion Units

Characteristic	Electro-Motive Division Model F40PH Diesel-Electric Passenger Locomotive	Budd Company Model SPV-2000 Self-Propelled Vehicle
Length (feet)	56.2	85.3
Width (feet)	10.7	10.5
Height (feet)	15.4	14.3
Weight (pounds)	259,000[1]	127,000[4]
Truck Center/Minimum Radius	33.0/315.0[2]	59.5-NA
Year Built	1976 to date	1978 to date
Maximum Speed (mph)	65[3]	80
Service Acceleration (mph/sec)	NA	0.5[5], 0.6[6]
Service Deceleration (mph/sec)	NA	2.2
Emergency Deceleration (mph/sec)	NA	3.0
Capital Cost per Unit (1979 $)	$929,000	$960,000
Multiple-Unit Capability	Optional	Yes
Horsepower	3,000	360 or 720

Note: NA indicates data not available.
[1]Loaded weight including fuel and other supplies.
[2]Coupled to 89-foot passenger car.
[3]Greater maximum speed is available with optional gear ratios.
[4]Ready-to-run, without passenger load.
[5]One-car train.
[6]Two-car train.
Source: Reference 1.

Another prototype light weight diesel railcar, the 54-passenger model 141 Railbus, manufactured by Associated Rail Technologies, Inc. of Great Britain is being extensively tested in the U.S. Several cities, including Cleveland, Miami and Philadelphia, have expressed interest in ordering the model 142 Railbus, a newer version which seats 64 people and costs between $350,000 and $400,000 (32).

Travel Ways (1). Because only existing mainlane railway facilities are typically utilized for regional rail service, the completed guideway is already in place and the travel ways are limited to the common carrier railway network that radiates out of the CBD.

A typical cross-section for regional rail transit operation is presented in Figure 3-7.

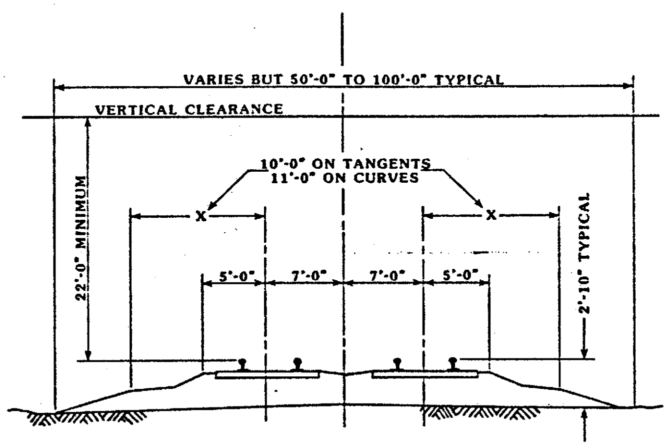
Table 3-24
Characteristics of Selected Regional Rail Passenger Vehicles

Characteristic	Model SPV-2000 Self-Propelled Vehicle	Budd Company Bi-Level Gallery Coach	Hawker-Siddeley Double-Deck Commuter Coach	Pullman-Standard Single-Level Push-Pull Coach
Length (feet)	85.3	85.0	85.0	85.0
Width (feet)	10.5	10.6	9.8	10.5
Height (feet)	14.3	15.9	15.9	12.7
Net Weight (pounds)	127,000	103,000[1] 107,000[2]	108,000	74,000[1] 78,000[2]
Truck Centers (feet)	59.5	59.5	64.0	59.5
Year Built	1978 to date	1950 to date	1977 to date	1974-1979
Number of Doors per Side	2 single	1 bi-parting	2 bi-parting	2 single
Design Capacity Seats	88	157[1], 147[2]	162	108[1], 104[2]
Floor Height/ Headroom (feet)	4.4/6.7 low	NA/NA	2.1/6.6	4.2/NA
Capital Cost per Unit (1979 $)	$960,000	$544,000[1] $627,000[2]	$685,000	$515,000[1] $605,000[2]

NOTE: NA indicates data not available.

[1]Straight coach.
[2]Coach with control cab.
Source: Reference 1.

TYPICAL CROSS-SECTION FOR REGIONAL RAIL OPERATION ON MAIN LINE OF RAILWAY



Source: Reference 11.

Figure 3-7
Typical Cross-Section for Regional Rail Operations

Stations. Stations for regional rail service are typically spaced from 0.7 to 2.8 miles apart, as compared to 0.4 to 2.3 miles for RRT and 0.2 to 1.05 for LRT. Actual facilities found at RGR stations are minimal and frequently only include platforms (generally one on each side of the double track). Sometimes regional rail operations will share a central city station structure with intercity rail passenger and/or freight service, however. Because regional rail trains are often lengthy, long platforms may be needed in order to serve the entire train. Platforms generally vary between 500 and 1,000 feet long. Low-level passenger loading may be used, requiring only low-level platforms.

Operating and Performance Characteristics (1, 33). Generally speaking, regional rail service offers the highest level of performance of any transit mode.

Speed. Regional rail speeds, defined in terms of absolute vehicle speeds, typical operating speeds and average speed over the entire line, are presented below.

- Maximum speeds of 100 mph are attainable by current production diesel-electric locomotives if supplied with one of several optional gear ratios.

- Typical operating speeds for RGR can approach the maximum speeds for which the rolling stock is designed while operating through areas that are not intensely developed. Operating speeds are constrained, however, when passing through railway switching yard districts or intensely developed areas which may have grade crossings. In these areas, operating speeds frequently must be reduced to 30 to 40 mph or less.

- Average operating speeds for regional rail are primarily the function of station spacing. Because station spacing distances are longer, average operating speeds tend to be higher for RGR than for other rail modes (Table 3-25). Local slow orders may negatively affect average operating speeds, however.

Table 3-25
Typical Average Operating Speeds for Regional Rail

Average Station Spacing (miles)	Range of Average Speeds (mph)
0-2	20-30
2-3	28-35
3-5	33-40
5-6	38-45

Source: Reference 31.

Headway. The concept of headways may or may not be applicable to the scheduling of regional rail service depending on the size of the operation. Service on large-scale operations is provided on 20 to 60 minute headways during weekday peak commuting periods. Headways of 1 to 2 hours for base service during midday and evening periods are common, and service frequencies on weekends range from 1 to 3 hours. Smaller-scale regional rail operations, on the other hand, may consist of only 1 or 2 trains inbound on weekday mornings and outbound on weekday afternoons. In these instances the concept of service frequency becomes unimportant.

Capacity. Assuming double-track guideways (one track for each direction of travel), regional rail is generally cited as being able to accommodate loads from 8,000 to 25,000 passengers per hour, depending on headway and train length. Table 3-26 presents theoretical system capacities attainable under various vehicle and operational configurations.

Table 3-26

Theoretical System Capacities Per Hour for Regional Rail

Headway	System Capacity per Number of Coaches in Train					
	1	2	4	6	8	10
5 Minutes						
Self-Propelled Vehicles	1,056	2,112	4,224	6,336	8,448	10,650
Single-Level Push-Pull Train	1,248	2,544	5,136	7.728	10,320	12,912
Train with Bi-Level Gallery Coaches	1,764	3,648	7,416	11,184	14,952	17,640
10 Minutes						
Self-Propelled Vehicles	528	1,056	2,112	3,168	4,224	5,280
Single-Level Push-Pull Train	624	1,272	2,568	3,864	5,160	6,456
Train with Bi-Level Gallery Coaches	882	1,824	3,708	5,592	7,426	8,820
20 Minutes						
Self-Propelled Vehicles	264	528	1,056	1,584	2,112	2,640
Single-Level Push-Pull Train	312	636	1,284	1,932	2,580	3,228
Train with Bi-Level Gallery Coaches	441	912	1,854	2,796	3,738	4,410
30 Minutes						
Self-Propelled Vehicles	176	352	704	1,056	1,408	1,760
Single-Level Push-Pull Train	208	424	856	1,288	1,720	2,152
Train with Bi-Level Gallery Coaches	294	608	1,236	1,864	2,492	2,940
60 Minutes						
Self-Propelled Vehicles	88	176	352	528	704	880
Single-Level Push-Pull Train	104	212	428	644	860	1,076
Train with Bi-Level Gallery Coaches	147	304	618	932	1,246	1,560

Note: Self-propelled vehicles assume a seated capacity of 88 per coach. Single-level push-pull train assumes a seated capacity of 108 in straight coaches and 104 in coach with control cab. Train with bi-level gallery coaches assume total seated capacity of 157 in straight coaches and 147 in coach with control cab.

Source: Reference 1.

Attributes (1, 2)

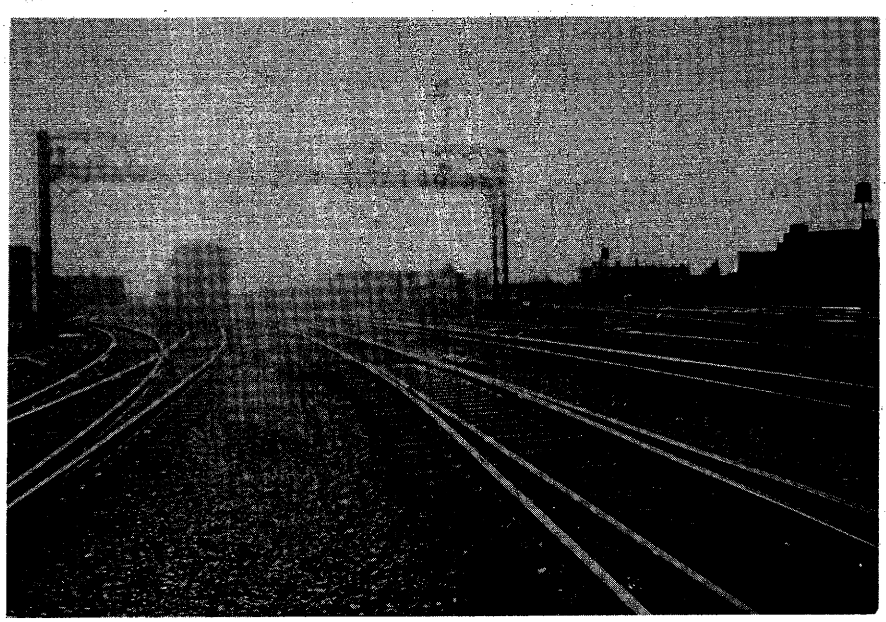
Regional rail systems possess the following attributes which demand consideration in transit system planning.

- Regional rail rolling stock is designed to conform to railroad suspension, noise insulation and seating standards. This, combined with relatively long station spacings, provides a very high level of riding comfort.

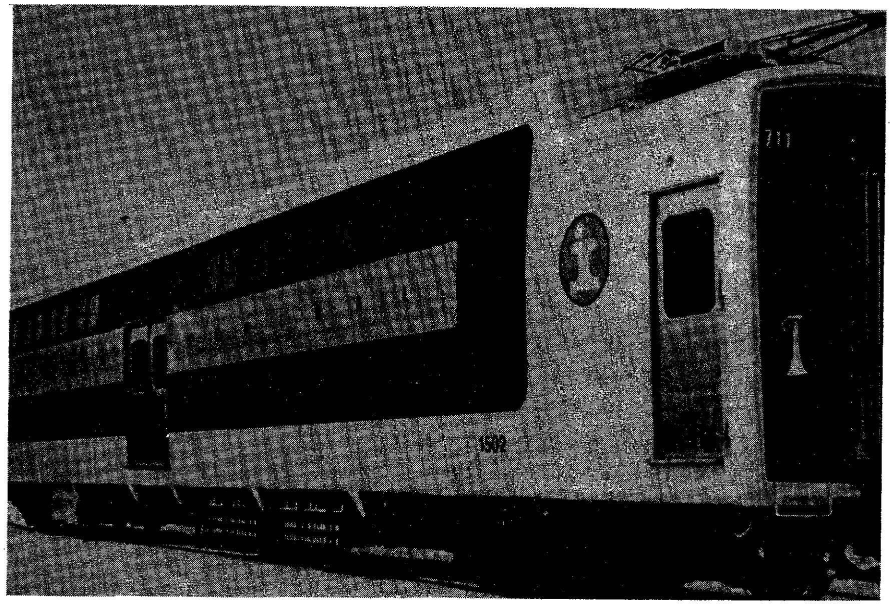
- RGR service operates on existing standard railroad right-of-way and track work. Because such alignments are shared with intercity passenger and freight train service, RGR does not require an exclusive guideway. New routes and extensions are usually implemented using existing railroad roadway, structures and rights-of-way, although substantial rehabilitation of such facilities may be required prior to initiation of service. Thus, much of the potentially expensive rights-of-way and fixed facilities already exist.

- Because most RGR service in the U.S. and Canada is provided by railroad companies, the size of the labor force for each system is determined largely by railroad policies and regulations rather than by standard transit labor practices.

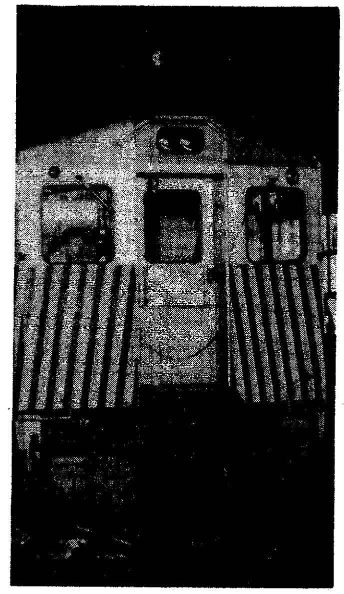
- Regional rail service is characterized by heavily peaked and highly directional service, thereby leaving equipment idle during non-peak periods. The result of this type of operation is a significant operating deficit when evaluated apart from other rail services.



Regional rail operations share standard railroad rights-of-way and track work with intercity passenger and freight train service.



Regional rail service can be found in Chicago (left), New York City (below left) and Philadelphia (below right).



Examples of Regional Rail Systems in the United States and Canada

Significant regional rail service is presently available in the following 10 metropolitan areas of the United States and Canada.

- Boston
- Chicago
- Detroit
- Montreal
- New York City
- Philadelphia
- Pittsburgh
- San Francisco
- Toronto
- Washington, D.C.

Certain routes serving Chicago, Montreal, New York City, Philadelphia and Washington, D.C. are electrified, while the remainder utilize diesel-electric locomotives. With the exception of Canada's "GO Transit" system (Government of Ontario Transit) implemented in 1967, the RGR systems listed above are generally continuations of services that date back to the early 1900s. Characteristics of these regional rail systems are presented in Table 3-27, along with average weekday patronage.

Table 3-27
Characteristics of Regional Rail Operations in the United States and Canada: 1980

Location	Number of Routes	Length of Routes (miles)	Number of Stations	Diesel-Electric Locomotives	Bi-Level Coaches	Single Level Coaches	Multiple-Unit Electric Coaches	Self-Propelled Diesel Coaches	Metropolitan Area Population (000)	Daily Passengers Carried
Canada										
Montreal	4	152	68	21[1]	9	99	16	7	2,743.0	28,800
Toronto	3	111	28	25	80	123	--	9	2,628.0	38,000
United States										
Boston	12	205	83	23	--	84	--	92	3,455.0	31,000
Chicago	15	594	269	133	649	113	185	--	7,612.0	274,000
Detroit	1	26	11	5	--	29	--	--	4,434.0	2,100
New York City	32	1,043	415	NA	--	494	2,253	11	16,468.0	573,000
Philadelphia	15[2]	483	226	3	--	6	393	18	7,077.0	114,500
Pittsburgh	2	49	15	3	--	9	--	4	2,401.0	1,950
San Francisco	1	47	26	24	46	37	--	--	4,174.0	14,000
Washington, D.C.	3	150	38	5	--	19	10	14	4,932.0	6,700

Note: NA indicates data not available.
[1]Fourteen are straight electric.
[2]Data do not include ex-Pennsylvania-Reading Seashore Lines in New Jersey.

Source: Reference 1.

Ridership and Employees Per Passenger (15). Annual patronage and the employees per passenger for selected regional rail operations is presented in Table 3-28. As these figures indicate, the average number of rail employees per passenger for regional rail operations is more than 3 times higher than that for rail rapid or motor bus transit.

Table 3-28
Employees Per Passenger for Selected Regional Rail Operations

System	Annual Ridership (millions)	Employees	Employees Per Million Passengers
Chicago - RTA			
Burlington Northern RR	11.4	384	33.7
Chicago & Northwestern RR	21.2	805	38.0
Illinois Central Gulf RR	11.2	593	52.9
Northeastern Illinois RR Corp.	13.4	929	69.3
Chicago South Shore & South Board RR	2.5	270	108.0
New York City			
Long Island Railroad	73.3	7,076	96.5
Metro-North	40.5	5,415	133.7
MTA	127.3	12,531	98.4
NJT Corporation	34.1	3,193	93.6
Philadelphia - SEPTA	12.9	1,420	110.1
Range			33.7 - 133.7
Avg., Non-Weighted			83.3

Source: Reference 18.

Cost of Regional Rail Operations

Capital Costs (1). The total capital cost associated with implementing regional rail service is extremely difficult to estimate because most of the services currently in operation date back to the early 1900s and capital cost information for these services is not readily available. Because this mode utilizes existing railroad rights-of-way and track, the major portion of capital expenditures required for initiating RGR fall into the areas of rolling stock and stations. The cost of various types of rolling stock was presented previously in Tables 3-23 and 3-24. Although RGR utilizes existing trackwork, substantial rehabilitation of the track structure or roadbed may be necessary before service can commence.

Operating Costs (15, 18). As indicated in Table 3-29, estimated operating costs per passenger and per passenger-mile vary widely from one regional rail operation to another. Operating cost per passenger ranged from $1.84 to $9.50 and operating cost per passenger-mile ranged from $0.17 to $0.66 in 1983. Although capital costs are frequently lower, operating costs for regional rail are considerably higher than those for light rail or rail rapid. The higher costs can, in part, be attributed to the rather large labor forces employed by the railroad companies providing service.

Table 3-29
Estimated Operating Cost Per Passenger and Per Passenger-Mile
for Selected Regional Rail Operations for 1983

System	Annual Passengers (millions)	Annual Passenger-Miles (millions)	Annual Operating Cost ($ millions)	Operating Cost ($) Per Passenger	Operating Cost ($) Per Pass.-Mile
Boston					
Gr. Attleboro-Tauton RTA	0.7	6.5	$ 1.29	$1.84	$0.20
MBTA	10.4	195.5	44.88	4.32	0.23
Chicago RTA	58.5	1,163.2	194.74	3.33	0.17
Detroit SEMTA	0.3	4.9	2.85	9.50	0.58
New York City					
Long Island RR & Metro-North	113.8	3,187.2	802.40	7.05	0.25
New Jersey Transit Corp	34.1	795.2	131.46	3.86	0.17
Philadelphia SEPTA	12.9	105.7	69.33	5.37	0.66
Pittsburgh PAT	0.3	5.1	1.92	6.40	0.38
San Francisco - Caltrans/S. Pac.	3.1	75.0	12.91	4.16	0.17
Range				$1.84-$9.50	$0.17-$0.66
Avg., Non-Weighted				$5.09	$0.31

Source: References 15 and 18.

Automated Guideway Transit

Automated guideway transit (AGT) is a public transit concept characterized by unmanned, automatically controlled vehicles operated along fixed guideways. AGT systems implemented to date serve a variety of transportation functions. Some systems, such as those often referred to as automated people movers, are used to provide internal circulation, short-haul or shuttle services to or within airports, amusement parks, shopping centers, universities, medical centers, and downtown areas. Other systems, such as those termed intermediate capacity transit systems (ICTS) or advanced light rail transit (ALRT), are used to provide line-haul transit service in smaller metropolitan areas.

Compared to other transit modes, automated guideway transit is a relatively new form of transit having been put into application within the last 15-20 years. Because of the experimental nature of AGT and the fact that many AGT systems in operation today are privately owned and operated, only a very limited amount of data are currently available and the reliability and comparability of that data are questionable.

Description (1, 2)

Automated guideway transit systems can generally be defined by the following characteristics.

- AGT systems utilize vehicles that travel from trip origin to trip destination without a driver; AGT vehicles are physically guided by the guideway.
- The locations of the vehicles are continuously monitored.
- All vehicle functions, such as speed, braking, length of station stop, door operation, station dispatch, headway and emergency procedures, are fully automated.
- AGT vehicles are self-powered and operate on fixed guideways along exclusive, fully protected rights-of-way.
- Service is provided in small- to medium-capacity rolling stock.
- Fare collection is at stations.
- Stations may be either on-line or off-line.
- Speeds, capacity and overall performance characteristics for automated guideway transit are typically lower than for most rail transit modes.

Design and Operating Characteristics

Vehicle Technology (1, 2). Automated guideway transit rolling stock varies in size, speed and vehicle propulsion from system to system. AGT vehicles can operate as single units, in tandem, or in small trains. Specific physical and operating characteristics of AGT vehicles manufactured for 4 people mover systems in the United States and one ICTS in France are summarized in Table 3-30.

Travel Ways. Because of its operating characteristics, automated guideway transit must be operated along exclusive, fully protected rights-of-way. Possible alignments include elevated, at-grade and underground travel ways.

Stations. Station configurations for AGT systems vary widely from site to site depending on the type of facility or area being served and the desired capital investment. Stations can be free standing or integrated into existing or new buildings. Stations may be elevated, at-grade or underground with side or center platforms. Fares may be collected automatically or manually. Station spacings generally range from 0.1 to 0.9 miles for people movers and from 0.4 to 0.9 miles for ICTS.

Table 3-30
Characteristics of Selected Automated Guideway Transit Vehicles

Characteristic	Airtrans Dallas-Fort Worth Airport	Morgantown People Mover W. Virginia Univ.	Metromover Miami	WEDway Vehicle Houston Intercontinental Airport	VAL Lille, France
Manufacturer	LTV/Vought Corp.	Alden/Boeing	Westinghouse	WED Transportation System	MATRA
Support	4 tires	4 tires	4 double tires	4 guide wheels	4 tires on 2 steer-able axles
Guidance	4 horizontal tires on side guide beams	4 horizontal on side guide beams	8 horizontal on center guide beams	front & rear guide wheels which steer the bogie thru kingpins & tierods	8 horizontal tires on side guide beams
Length (feet)	21.4	15.6	39	13.8	41.0
Width (feet)	7.4	6.0	NA	5.3	6.8
Net Weight (pounds)	11,770	8,580	NA	2,398	30,470
Capacity Per vehicle: (Seats/Total)	16/40	8/21	NA/147	6/12	22/90
Motor Power/Supply	One 56 kW, dc/48 V ac	One 45 kW, dc/ 575 V ac	NA	240 Vac, 60 Hz, 40 amp linear induction, track motors	Two 120 kW dc/ 750 V dc
Cars/Train	2	1	1 or 2	3	2
Maximum Speed	16	29	NA	15	48

Note: NA indicates data not available.
Source: References 2, 34 and 35.

Operating and Performance Characteristics (2, 34, 36). Characteristics, such as speed, headway and capacity, are presented for selected properties.

Speed. Maximum attainable speeds for selected AGT vehicles (as presented in Table 3-30) range from 16 to 29 mph for the people mover systems, while the vehicles used for the VAL ICTS have a maximum speed of 48 mph.

Average operating speeds for selected systems are presented in Table 3-31. The people mover systems, which generally have more stations per mile, have average operating speeds that range from 5 to 17 mph. The ICTS system has an average speed of 22 mph (approximately 70% of the average operating speed of rail rapid transit).

Table 3-31
Estimated Average System Travel Speed for Selected Automated Guideway Transit Systems

System	Guideway Length (miles)	Number of Stations	Average Station Spacing (miles)	Average Operating Speed (mph)
People Movers (1982)				
Airtrans	12.80	14	0.9	10
Atlanta	2.09	10	0.2	13
Busch Gardens	1.33	2	0.7	11
Disney World	0.87	1	---	5
Duke	0.34	3	0.1	14
Fairlane	0.49	2	0.2	10
Houston	1.48	9	0.2	6
King's Dominion	2.06	1	---	6
Miami Airport	0.26	2	0.1	11
Miami Zoo	1.97	4	0.5	8
Minnesota Zoo	1.25	1	---	7
Morgantown	4.30	5	0.9	17
Orlando	0.74	4	0.2	14
Pearlridge	0.23	2	0.1	7
Sea-Tac	1.71	6	0.3	12
Tampa	0.68	8	0.1	9
ICTS (1985)				
VAL	8.50	18	0.5	22
Range			0.1-0.9	6-22
Avg., Non-Weighted			0.4	11

Source: References 34 and 36.

Headway (36, 37, 38). While Morgantown people mover vehicles may operate as frequently as every 15 seconds, AGT headways typically vary from 70 seconds to 6 minutes (Table 3-32). These frequent headways (a required attribute of AGT) are considerably shorter than those for typical light rail or rail rapid systems primarily because of the short-haul, internal circulation or shuttle type of service provided in high density areas.

Table 3-32
Frequency of Service for Selected Automated Guideway Transit Systems

System	Operating Headways
People Movers	
Atlanta	100 seconds
Busch Gardens	6 minutes
Houston	3 minutes
Miami Airport	82 seconds
Miami Metromover	100 seconds
Morgantown	15 seconds (peak)
Orlando	90 seconds
Sea-Tac	100 seconds
Tampa	70 second
ICTS	
VAL	84 seconds (peak) 4 minutes (off-peak)
Range	15 seconds - 6 minutes
Avg., Non-Weighted	115 seconds[1]

[1]Peak period headway of 84 seconds for VAL was used in computation of average.
Source: References 36, 37, and 38.

Capacity (11). Automated guideway transit capacity is directly related to vehicle capacities, cars per train and headways. As would be expected, a wide variation in potential capacities exists.

Intermediate capacity transit systems were developed to serve demands in the range of 10,000 to 25,000 passengers per hour per direction. The capacity of the VAL system in Lille, France is estimated at 12,500 persons per hour per direction with a 2-car consist and twice that with a 4-car consist if operated on 1-minute headways.

For people movers, however, high capacity is not necessarily required. For example, a maximum daily ridership of 40,000 to 50,000 people might be anticipated with peak-hour demands per direction of below 7,500. In theory, the Morgantown system can accommodate about 4,100 passengers per hour per direction, while the Dallas Airtrans system can handle approximately 9,800 passengers per hour per direction.

Attributes (2, 36)

Automated guideway transit exists in many forms and plays a variety of transportation roles. Principal attributes of AGT include the following.

- AGT offers service at frequent intervals which results in a reduction in waiting time for the user.

- AGT vehicles typically have rubber tires for support and guidance. This results in superior adhesion (important for acceleration and climbing abilities) in good weather and lower noise levels in curves. On the negative side, rubber-tired vehicles require more elaborate guideways (at least 4 contact surfaces) and switches. In addition, the guideway must be heated during inclement weather which involves higher energy consumption.

- AGT vehicles utilize 2-axle support (as compared to 4-axle support for rail modes). Two-axle support allows the use of smaller vehicles where low passenger volumes are served and simpler vehicle mechanics. Riding comfort is not as high as with 4-axle supported vehicles, however.

- Small- to medium-capacity rolling stock with a large proportion of standees is common. This is generally considered advantageous for short-haul routes.

- Low to moderate speeds, adequate for short-haul service are typical. Systems, such as ICTS, can be designed with higher speeds where line operations require them.

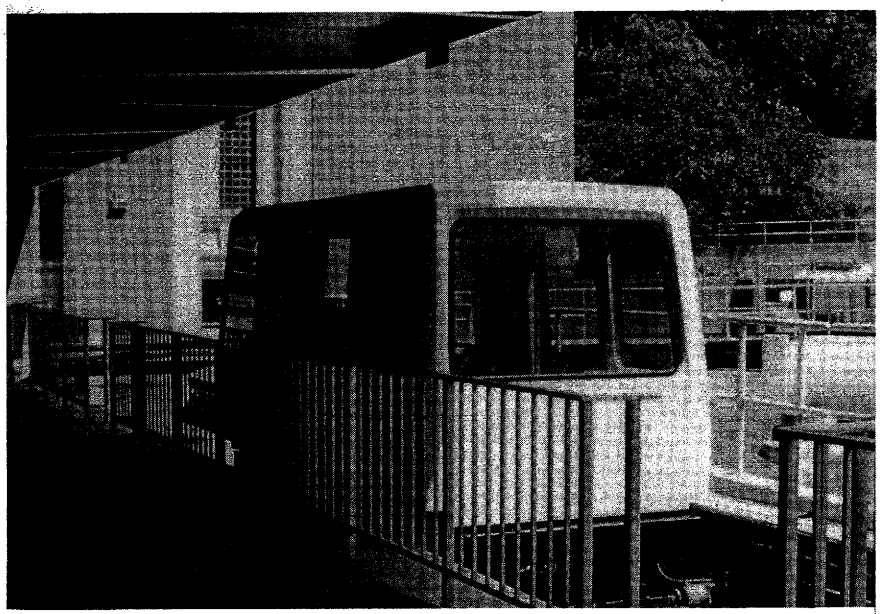
- AGT system operations are fully automated which involves considerable technical complexity of vehicles and control systems, but allows high-frequency service even for low passenger volumes, high percentages of on-time runs and high levels of safety.

- AGT vehicles are powered electrically and thus not dependent on petroleum-based fuels. Electric propulsion also eliminates the on-line emission of pollutants.

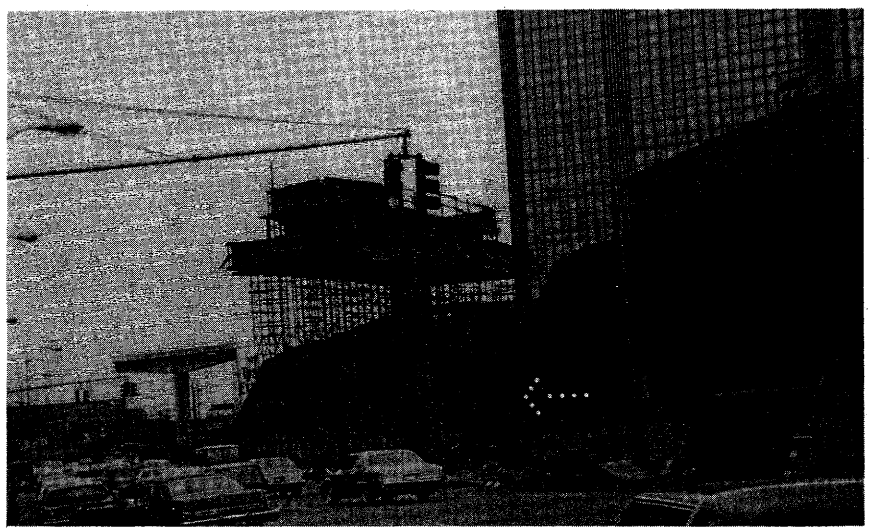
- Because AGT systems must operate on exclusive, fully-protected rights-of-way, capital cost of implementation may approach that for rail rapid systems. The experimental nature of AGT technology has also contributed to cost overruns and delays in implementation.

Examples of AGT Systems in the United States, Canada, and France

Table 3-33 presents characteristics of selected AGT systems currently in operation or under construction in 18 cities in the U.S., Canada and France. Upon completion of Metromover (the first U.S. downtown people mover) in the fall of 1985, Miami will have 3 different AGT systems in operation.



The Morgantown people mover (left) has been providing service at West Virginia University since 1979.



A downtown people mover is presently under construction in Detroit (right).

Additional automated guideway transit systems currently underway include:

- A 2.5-mile downtown people mover in Jacksonville, Florida;
- A 12.1-mile AGT to connect Disney World's EPCOT center to International Drive in Orlando, Florida;
- A 0.5-mile elevated people mover at McCarran International Airport in Las Vegas, Nevada;
- A 0.5-mile AGT between downtown Tampa, Florida and water-bound Harbor Island; and
- A 3-mile MATRA system at Chicago's O'Hare Airport.

Table 3-33
Characteristics of Selected Automated Guideway Transit Systems

System/Location	System Configuration	Guideway Location	Guideway Length (miles)	Number of Stations	Number of Vehicles	Vehicle Capacity	Year Opened
<u>People Movers</u>							
Airtrans - Dallas-Fort Worth Airport Dallas, Texas	single-lane multi-loops	elevated/ at grade	12.80	14	52	40	1974
Atlanta Hartsfield Int'l Airport Atlanta, GA	dual-lane shuttle with by-pass	underground	2.09	10	17	40	1980
Busch Gardens (Recreation Center) Williamsburg, Va	single-lane loop	elevated/ at grade	1.33	2	1 (2-car train)	192	1975
Detroit Downtown Peoplemover Detroit, MI	single-lane CBD collection and distribution	elevated	2.92	13	13	NA	1986
Disney World (Amusement Park) Orlando, FL	single-lane loop	elevated	0.87	1	30 (5-car train)	20	1975
Duke University Medical Center Durham, NC	double-lane & single-lane shuttle	elevated/ at-grade underground	0.34	3	4	22	1980
Fairlane Town (Shopping) Center Dearborn, MI	single-lane shuttle with by-pass	elevated	0.49	2	2	24	1976
Houston Intercontinental Airport Houston, Texas	single-lane loop	underground	1.48	9	6 (3-car train)	36	1981
King's Dominion Amusement Park Doswell, VA	single-lane loop	elevated at-grade	2.06	1	6 (9-car train)	96	1975
Miami International Airport Miami, FL	dual-lane shuttle	elevated	0.26	2	2 (3-car train)	297	1980

Miami (Downtown) Metromover Miami, FL	dual-lane loop	elevated	1.90	10	12	147	1985
Miami Zoo Miami, FL	single-lane loop	elevated/ at grade	1.97	4	3 (10-car train)	149	1982
Minnesota Zoological Garden Apple Valley, MN	single-lane loop	elevated/ at grade	1.25	1	3 (6-car train)	94	1979
Morgantown People Mover System WV Univ., Morgantown, WV	dual-lane shuttle with off line stations	elevated/ at grade	4.30	5	73	20	1975
Orlando International Airport Orlando, FL	2 dual-lane shuttles	elevated	0.74	4	4 (2-car train)	200	1981
Pearlridge Shopping Center Aiea, HI	single-lane shuttle	elevated	0.23	2	1 (4-car train)	64	1977
Seattle-Tacoma Int'l Airport Seattle, WA	2 single-lane loops with shuttle con-nection	underground	1.71	6	24	102	1973
Tampa International Airport Tampa, FL	4 dual-lane shuttles	elevated	0.68	8	8	100	1971
<u>ICTS</u>							
Scarborough, RT Toronto, Ontario, Canada	dual-lane line haul extension of existing line	elevated/at-grade/under ground	4.37	5	24 (2-car train)	NA	1985
VAL-Metro Lille, France	dual-lane line haul & CBD collection	elevated/ underground	8.50	18	38 (train sets)	90	1983
Vancouver ALRT Vancouver, British Columbia, Canada	dual-lane line-haul & downtown collection	elevated/ at-grade/ underground	13.40	15	114	84	1986

Note: NA indicates data not available
Includes a nonpassenger load car

Source: References 2, 34, 36 and 39.

Other cities with proposed or soon to be complete AGT systems are Denver and Pittsburgh. People mover projects are also again gaining momentum at Dulles, Skyharbor (Phoenix), and Kennedy Airports. Other potential people mover sites include the Newark, San Francisco, Los Angeles, Kansas City, Boston, Louisville, Pittsburgh and Toronto Airports (41, 42).

Ridership and Employees per Passenger (34, 36). Annual patronage and employees per passenger are presented in Table 3-34. Excluding data for the Miami Zoo, the number of employees per million passengers ranges from 1 to 40, which might suggest that each system has unique operating characteristics and requirements and no general conclusions can be reached on the basis of the aggregated available data.

Table 3-34
Employees Per Passenger for Selected Automated Guideway Transit System
(1982 data)

System	Annual Rail Patronage (millions)	Rail Employees	Employees Per Million Passengers
People Movers			
Airtrans (D-FW Airport)	5.6	146	26
Atlanta Airport	23.5	61	3
Busch Gardens	1.3	22	17
Disney World	5.3	15	3
Duke Medical Center	1.4	15	11
Fairlane Shopping Center	2.3	NA	--
Houston International Airport	2.2[1]	12	5
King's Dominion	0.6	12	5
Miami Airport	4.2	19	5
Miami Zoo[2]	0.06	19	316
Minnesota Zoo	0.3	12	40
Morgantown	2.9	56	19
Orlando Airport	6.7	15	3
Pearlridge Center	1.1	13	12
Sea-Tac Airport	11.0	13	1
Tampa Airport	19.4	8	1
ICTS			
VAL (Lille, France)[1]	22.3	170	8
Range[4]			1-40
Avg., Non-Weighted[4]			11

Note: NA indicates data not available.

[1] 1983 data
[2] Figures reflect one month of service
[3] 1984 data
[4] Excludes data for Miami Zoo

Source: References 18, 34, and 36.

Cost of Automated Guideway Transit

Capital Costs (34, 36). Generally speaking, the average cost of implementing automated guideway transit is higher than that for light rail transit, but lower than that for rail rapid transit. Table 3-35 presents estimates of the capital costs for 21 people mover systems and 3 intermediate capacity transit systems in operation, under construction, or planned.

Table 3-35
Estimated Capital Costs for Selected Automated Guideway Transit Systems
(1982 Dollars Except Where Noted)

System	Length (miles)	Capital Cost Total	($ Millions) Cost/Mile
People Movers			
Airtrans D-FW Airport	12.80	99.0	7.7
Atlanta Airport	2.09	73.2	35.0
Busch Gardens	1.33	7.5	5.6
Disney World	0.87	19.9	22.9
Detroit People Mover	2.90	210.0[1]	72.4[1]
Duke Medical Center	0.34	11.7	34.4
Fairlane Shopping Center	0.49	9.9	20.2
Houston (Downtown-planned)	4.50	112.0[1]	24.9[1]
Houston Intercontinental Airport	1.48	25.5	17.2
Jacksonville (Downtown-planned)	0.70	29.0[1]	41.4[1]
King's Dominion	2.06	9.0	4.4
Miami Airport	0.26	17.6	67.7
Miami Metromover			
Initial System	1.90	145.0[1]	76.3[1]
Planned Extension	2.10	210.0[1]	100.0[1]
Miami Zoo	1.97	11.4	5.8
Minnesota Zoo	1.25	10.2	8.2
Morgantown	4.30	167.6	39.0
Orlando Airport	0.74	30.4	41.1
Pearlridge Shopping Center	0.23	2.0[2]	8.7[2]
Sea-Tac Airport	1.71	67.2	39.3
Tampa Airport	0.68	23.2	34.1
Range			4.4-100.0
Avg., Non-Weighted			33.6
ICTS			
Scarborough RT, Toronto	4.3	149.0[1]	34.7
VAL, Lille, France	8.5	328.0[3]	38.6
Vancouver ALRT, Vancouver, B.C.	13.5	615.0[1]	45.6
Range			34.7-45.6
Avg., Non-Weighted			39.6

[1] 1985 dollars
[2] Estimate
[3] 1983 dollars
Source: References 11, 34 and 36.

For ICTS, implementation costs range from $34.7 to $45.6 million and average about $40 million. A much wider variation exists for the people mover systems. Capital cost estimates for people movers range from $4.4 to $100.0 million, which suggests that the average costs are not particularly representative.

Operating Costs. As was the case with capital cost data, AGT systems (Table 3-36) vary widely from system to system, again making average cost per passenger or cost per passenger-mile values questionable.

Table 3-36
Estimated Operating Cost Per Passenger and Per Passenger-Mile for Selected Automated Guideway Transit Systems for 1982

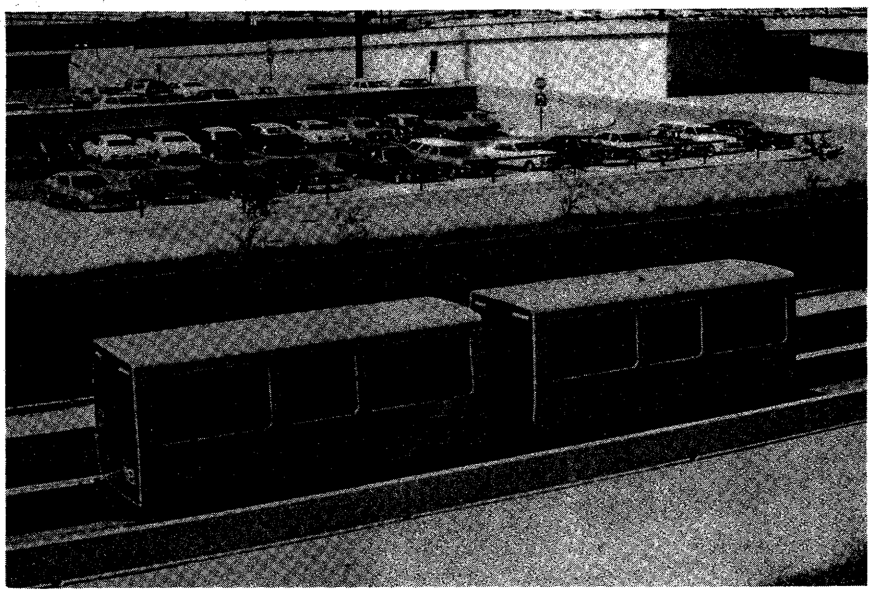
System	Annual Passengers (millions)	Annual Passenger-Miles (millions)	Annual Operating Cost ($ millions)	Operating Cost ($)	
				Per Passenger	Per Passenger-Mile
People Movers					
Airtrans	$ 5.6	$15.9	$5.31	$0.95	$0.33
Atlanta Airport	23.5	51.8	3.26	0.14	0.06
Busch Gardens	1.3	1.7	0.19	0.15	0.11
Disney World	5.3	4.6	0.45	0.08	0.10
Duke Medical Center	1.4	0.6	0.50	0.35	0.83
Fairlane	2.3	.001	NA	----	----
Houston	NCR	NCR	0.81	----	----
King's Dominion	0.6	1.2	NA	----	----
Miami Airport	4.2	1.1	0.64	0.15	0.58
Miami Zoo[1]	0.06	0.1	0.03	0.50	0.30
Minnesota Zoo	0.3	0.4	0.31	1.03	0.78
Morgantown	2.9	5.3	2.28	0.78	0.43
Orlando Airport	6.7	2.4	0.90	0.13	0.38
Pearlridge	1.1	0.2	0.34	0.31	1.70
Sea-Tac Airport	11.0	10.2	0.86	0.08	0.08
Tampa Airport	19.4	3.7	0.83	0.04	0.22
ICTS					
VAL[2]	22.3	130.0	7.39	0.33	0.06
Range				$0.04-1.03	$0.05-$1.70
Avg., Non-Weighted				0.36	0.43

Note: NCR indicates system not capable of recording
[1] Figures reflect one month of service
[2] 1984 data
Source: References 34 and 36.

Application in Texas

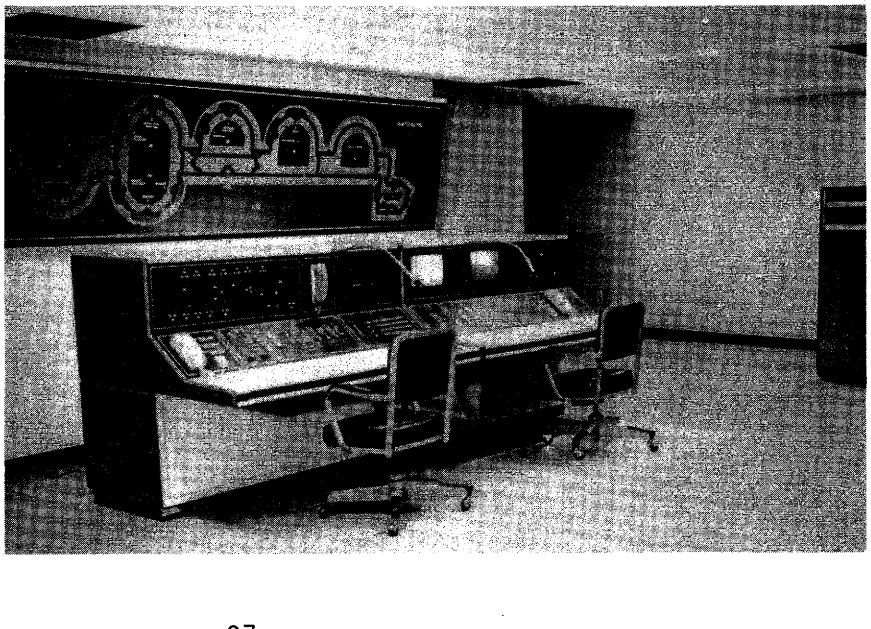
As previously indicated, 2 people mover systems are currently in operation in Texas: Airtrans which serves the Dallas-Fort Worth Airport and the WEDway People Mover which serves the Houston Intercontinental Airport.

Airtrans (4, 34). The Airtrans system, consisting of approximately 13 miles of single-lane guideway, is the most extensive AGT system in the United States. Opened in 1974, Airtrans was the first fully automated transit system to be established at an airport. The system was designed to provide intra-airport transportation service between 4 main passenger terminals, 2 remote parking lots, a hotel, an airmail facility, and maintenance, supply and control facilities. With a total of 10 interconnecting routes, fifty-two vehicles (averaging 10 mph) transport 5.6-million passengers annually. In the event of emergency or scheduled shutdowns, backup bus service is provided.



Airtrans, the first fully automated transit system to be established at an airport, is also the most extensive AGT system in the U.S.

View of the Airtrans control center (right).



WEDway People Mover - Houston Intercontinental Airport (18, 34, 43). The original people mover system developed for the Houston Intercontinental Airport (a battery-powered tug system supplied by Barrett) encountered design problems resulting from underdeveloped AGT technology. It was subsequently replaced in 1972 by a tunnel train system purchased by Westinghouse Air Brake Company and later sold to Rohr Industries.

The current system opened for service in 1981 and is the first application of the WEDway People Mover developed at Disney World. Houston's people mover, however, employs technology improvements not found in the WEDway system at Disney World and is rather unique in its integration of service-proven linear induction motor technology with a totally passive vehicle and state-of-the-art microprocessor-based control.

The system consists of 1.48 miles of underground single-lane track arranged in a continuous collapsed loop between 3 terminals, a hotel, and a parking facility. A pedestrian walkway runs parallel to the WEDway automated transit system. However, the WEDway system is considered a "must ride" system for passengers with luggage who would otherwise have to walk a minimum of 660 feet between 2 adjacent terminals. A total of 6, 3-car trains operating on 3-minute headways and averaging 6 mph transport an estimated 2.2 million passengers annually.

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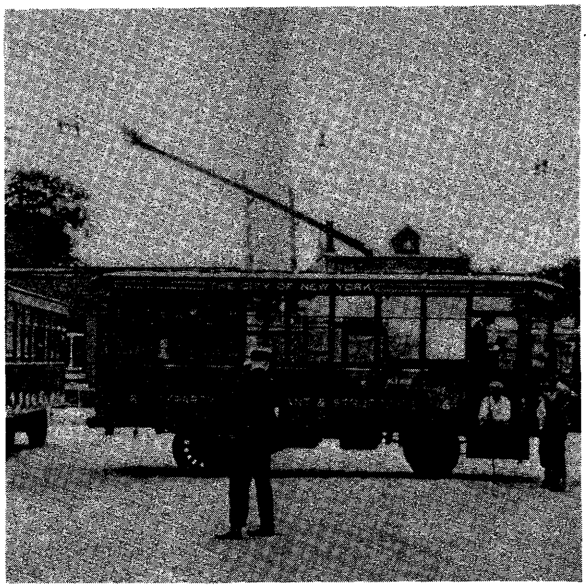
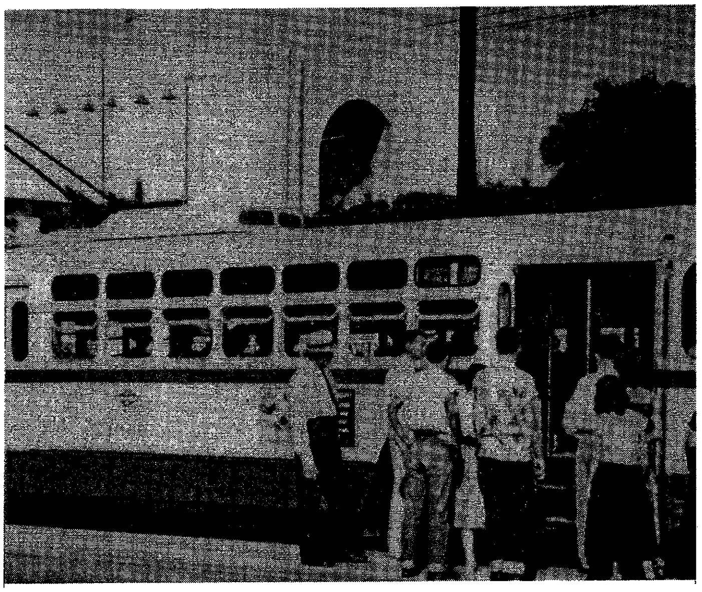
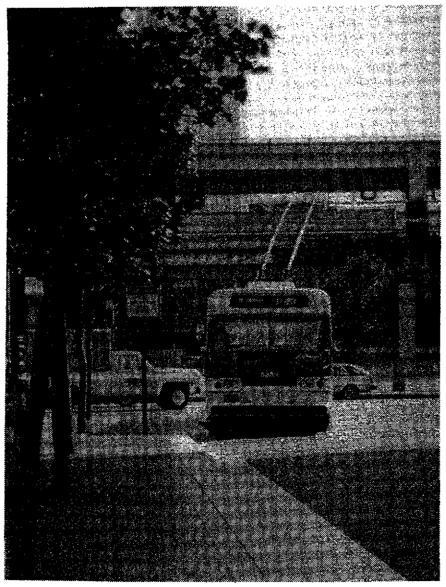


Chapter 4





Electric Trolley Bus Transit

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Electric Trolley Bus Transit

Electric trolley bus transit is characterized by rubber-tired buses which operate on existing surface arterial streets and highways, usually in mixed traffic. Trolley buses are propelled by electric motors which receive power through power collection poles attached to the vehicle roof that slide along a pair of overhead contact or "trolley" wires.

Like the motor bus mode (Chapter 5), electric trolley buses do not require the construction of a special guideway; they are designed to be operated on existing roadways and are capable of maneuvering around many obstacles such as stopped motor vehicles and barricades. Like the light rail mode (Chapter 3), electric trolley buses require an overhead power distribution system, which prevents the vehicles from being able to deviate from fixed routes. (Note: Some hybrid trolley buses, which are equipped with internal combustion engines in addition to the electric motors, are able to operate away from the overhead power supply system for short periods of time.)

Developed in the early 1900s, the electric trolley bus mode was intended to offer an intermediate capacity and level-of-service between that of the streetcar mode and the motor bus mode. Today, the American Public Transit Association estimates that electric trolley buses carry approximately 1% of transit passengers in the United States. A description of this mode along with design, operating and performance characteristics as researched by the Southeastern Wisconsin Regional Planning Commission (1)* is highlighted in the following sections.

Description

Electric trolley bus transit (also referred to as trolley coach and trackless trolley transit) is an urban public transportation mode which is generally defined by the following.

- Electric trolley buses typically operate in mixed traffic on public streets and highways.

*Numbers in parentheses refer to references listed at the end of the chapter.

- Power distribution for trolley bus operation is through an overhead network of trolley contact wires.
- Service is typically provided in electrically propelled rubber-tired transit buses of standard, single-level design.
- Fares are collected on board.

Design and Operating Characteristics

Vehicle Technology

Although some two-unit articulated vehicles have been placed into service in European cities, the single-unit nonarticulated body configuration has been the choice of systems in the United States and Canada. At present, nonarticulated vehicles for U.S. and Canadian systems are being manufactured by only 2 companies: Flyer Industries, Ltd. and Diesel Division-General Motors of Canada, Ltd. In addition, one other manufacturer, AM General Corporation of Wayne, Michigan, produced modern electric trolley buses during the late 1970s. Unlike older vehicle designs, the models available today use a body design similar to that of the urban diesel motor bus, the only major differences being the propulsion and control systems.

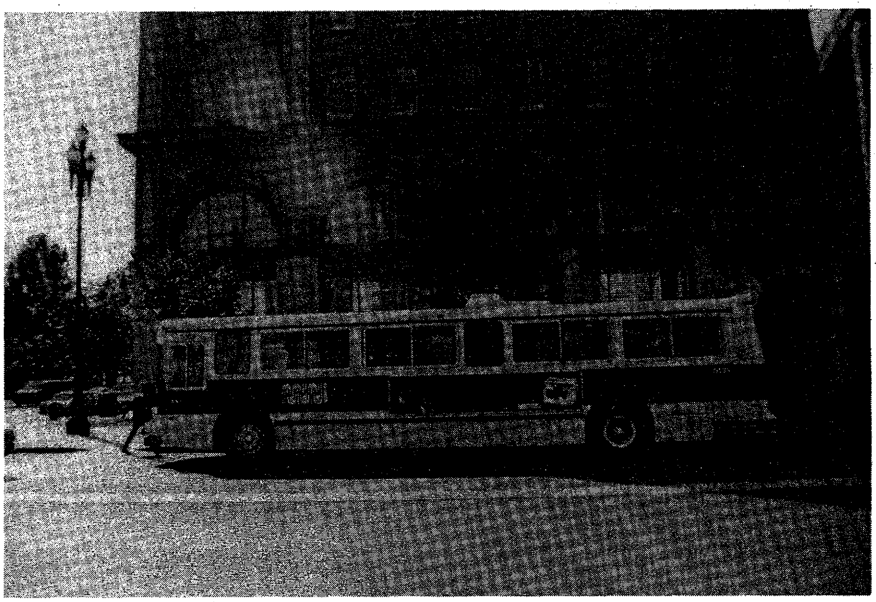
Table 4-1 presents specific physical and performance characteristics associated with the 3 modern North American electric trolley bus vehicles.

Table 4-1
Characteristics of Selected Electric Trolley Buses
(Standard Configuration)

Characteristic	AM General 10240-E	Flyer E900	GM of Canada, Ltd./ Brown, Boveri Canada, Ltd.
Length (feet)	40.0	40.0	40.0
Width (feet)	102.0	102.0	101.8
Height (inches)	123.6	122.4	135.9
Net Weight (pounds)	23,500	23,000	NA
Wheelbase (inches)	284.4	284.4	284.8
Minimum Turning Radius (feet)	37.2	37.2	42.0
Number of Doors	2	2	2
Front Door Width (inches)	30.2	30.2	30.0
Design Capacity Seats/Standees	50/25	51/26	53/27
Maximum Speed (mph)	37	40	37
Motor Type	GE 1213	GE 1213	NA
Horsepower	155	155	NA
Service Acceleration (mph/sec)	3.5	3.5	2.5
Capital Cost Per Vehicle[1]	$148,000	$146,000	$178,000

Note: NA indicates data not available.
[1]1979 dollars.
Source: Reference 1.

All 9 systems currently in operation in the U.S. and Canada have replaced substantial portions of their fleets with relatively new vehicles; more than 80% of the revenue service trolleys in use in the U.S. today were manufactured since 1974.



Flyer E900 vehicles are used in the operation of San Francisco's electric trolley bus system.

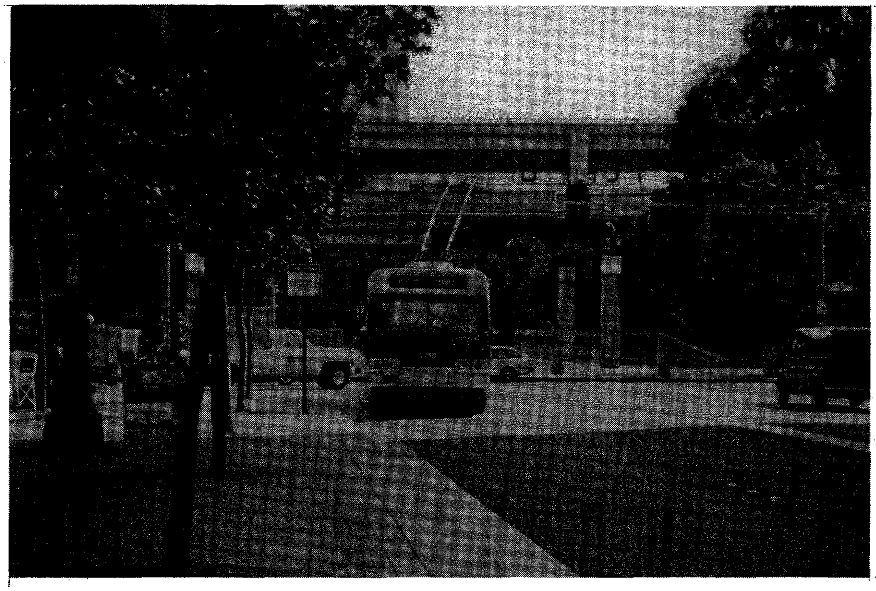
Travel Ways

Travel ways for electric trolley buses are usually restricted to surface arterial streets and highways in mixed traffic. A potential exists, however, for the operation of express service over reserved lanes on surface streets. Because maximum electric trolley bus speeds are generally 40 mph or less (Table 4-1), this mode is presently not suitable for high speed transit service in mixed traffic on freeways.

Stops and Stations

Stops and station requirements for electric trolley buses are almost identical to those for motor buses (Chapter 5). Stops are usually located at street corners where the vehicles can pull up to a curb for passenger loading and unloading. Stops at safety islands may also be used on occasion, particularly where the trolley route dictates making a left-hand turn at an intersection.

With the possible exceptions of route turnaround points or major transfer points, stations for electric trolley bus service operated on arterial street rights-of-way will generally consist of nothing more than normal bus stops with or without passenger shelters and other amenities.



Stops for electric trolley bus vehicles are usually located at street corners where the vehicles can pull up to a curb for passenger loading and unloading.

Operating and Performance Characteristics

The characteristics of speed, headway and capacity for electric trolley bus transit can be defined as follows.

Speeds

Electric trolley bus transit speeds can be expressed in terms of absolute vehicle speeds, typical operating speeds, or average operating speeds over the length of the route.

- Electric trolley buses usually have maximum attainable speeds of about 40 miles per hour (as compared to 50-55 miles per hour for typical diesel-powered transit buses).

- Typical operating speeds for electric trolley buses are a function of posted speed limits, traffic volumes and roadway geometrics -- the same factors which influence each mode traveling in mixed traffic operation. In general, operating speeds of 30 to 35 miles per hour may be attained in low- to medium-density areas, speeds of 25 to 30 miles per hour are found in higher density areas (such as CBD fringe areas) and speeds of 20 to 25 miles per hour are common along bus streets or transit/pedestrian malls in downtown areas.

- Average speeds for electric trolley buses over an entire route are influenced by surrounding traffic volumes, the number of traffic signals, traffic signal cycle lengths, turning movements, the incidence of double parking, roadway geometrics, the number of stops made, and dwell times at stops. Average speeds are, therefore, lower than typical operating speeds.

- One final factor which is unique to the electric trolley bus mode that affects system speed is the overhead contact wire system. Special work at intersections limits both the speed and acceleration of the trolleys. Higher speeds increase the possibility of dewirements.

Headway

Unlike some rail modes, vehicle spacing for the electric trolley bus mode is not controlled by a centralized, or automated traffic control system; rather, it is under the direct control of the operator of each vehicle, making headways dependent on visual and manual control. In addition, the electrical capacity of each section of overhead contact wires is another factor which influences headways. As the number of electric trolley buses in a section of overhead contact wire increases, the demand for electrical current will also increase. Each additional vehicle in the same section of overhead wire may have an effect on the headway as well as overall performance since a large number of vehicles could overload the system, resulting in insufficient power being available for each vehicle to accelerate. Furthermore, the overhead contact wires could be damaged through overheating. Therefore, sufficient electrical capacity must be available to deliver adequate power for the greatest number of vehicles operating on the shortest headway anticipated.

Specific headways for scheduled peak-period electric trolley bus service typically range from 3 to 10 minutes, depending on local demand. Due to the significant investment in the electric trolley power distribution system, service is generally implemented only on trunkline routes where daytime non-peak headways can be expected to be no longer than 10 to 15 minutes. Evening, weekend and holiday service frequency is usually similar to that for daily non-peak hours.

Capacity

The maximum attainable capacity of an electric trolley bus system is directly related to the vehicle capacity and headway.

Because vehicle body designs of currently available electric trolley buses are identical to those of currently available diesel motor buses, and because the headway characteristics for these two types of buses are quite similar, the capacity of each of the modes can be expected also to be similar. The electric trolley bus mode, which predominantly utilizes arterial street rights-of-way, can generally be expected to meet peak demands ranging from 450 to 1,500 passengers per hour. Table 4-2 illustrates the range of passengers per hour capacities attainable under the standard single-unit body configurations used by U.S. and Canadian trolley systems.

Table 4-2
Theoretical Passenger Capacities Per Hour for Electric Trolley Bus Transit

Headway	System Capacity For Standard Single-Unit Vehicle Configuration[1]
30 seconds	6,120
1 minute	3,060
2 minutes	1,530
3 minutes	1,020
4 minutes	765
5 minutes	612
10 minutes	306
12 minutes	255
15 minutes	204
20 minutes	153
30 minutes	102
60 minutes	51

Note: All calculations are based upon full-seated capacities. Passenger loads that include standees may be calculated by multiplying the theoretical capacity by the desired load factor.

[1]Assumes use of conventional single-unit vehicle with a seated capacity of 51 passengers.

Source: Reference 1.

Attributes (1, 2)

The principal attributes of the electric trolley bus mode to be considered in system planning include the following.

- Electric trolley bus systems typically operate on existing paved roadways and therefore do not require the construction of a new fixed guideway.

- The electric propulsion and power pickup from overhead wires along the lines give trolley buses performance characteristics similar to those of rail modes: powerful traction and fixed routes.

- The combination of rubber tires with electric propulsion provides electric trolleys with high but smooth acceleration and grade-climbing abilities not possible with motor buses.

- From the passengers' point of view, electric trolley buses provide a smoother, quieter ride than do motor buses. The quietness of its operation is also a positive environmental impact.

- Vehicle configurations and performance characteristics for electric trolley buses are quite similar to those for conventional diesel motor buses.

- The overhead power distribution system required for operation does not allow immediate route changes or detours, although the individual vehicles have a limited ability to move laterally under the overhead wires.

- The overhead wire system and other electrical support facilities represent a major construction element requiring some period for implementation as well as possibly resulting in some community disruption, including the undesirable visual impact of the overhead wires.

- The quality of service provided by electric trolley bus transit will be affected by surrounding traffic conditions since the mode typically operates in mixed traffic.

- Electric trolley bus vehicles cannot overtake each other without removal of the power collection poles from the contact wires or without additional overhead wires and switches.

- Electric trolley bus systems require a higher investment than diesel motor bus systems. This higher cost is due in part to the installation and maintenance of overhead wires and incidental dewiring of trolley poles. Trolley bus vehicles are also substantially (40 to 80%) more expensive than diesel buses.

Examples of Electric Trolley Bus Systems in the United States and Canada

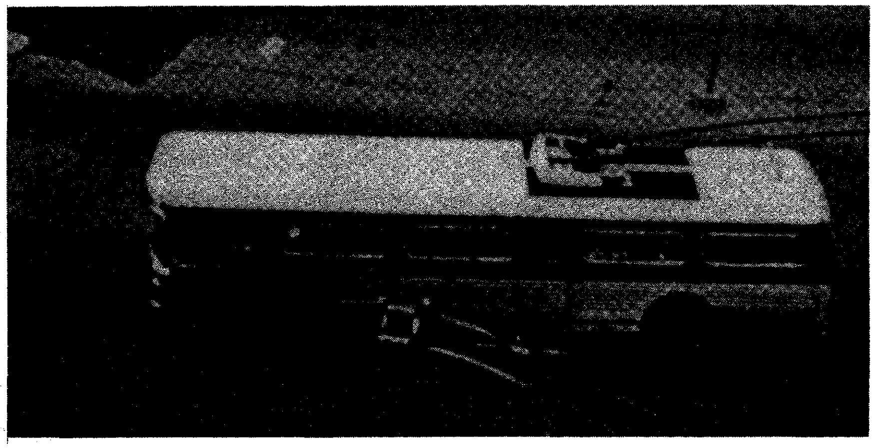
Developed in the early 1900s as an experiment, the electric trolley bus mode gained popularity in the 1930s and 1940s as a replacement for old streetcar systems for several reasons (1):

- Many streetcar systems had reached the end of their economic life and many transit operators chose to replace the street railway lines with a less capital-intensive mode.

- The trolley bus in many instances possessed performance capabilities superior to those of either the streetcar or the motor bus.

- The ability to utilize existing electric power facilities and technology was also a factor. The sizable investment in the power distribution system could be utilized for the electric trolley bus since the substations, feeder lines, and some of the overhead wire components required little or no modification.

- The cost savings realized from conversion from the streetcar mode were usually significant because of the elimination of the fixed guideway and associated maintenance functions. These cost savings, however, were partially offset by the maintenance costs of the power distribution system.



The electric trolley bus mode gained popularity in the U.S. and Canada as a replacement for old streetcar systems.

The utilization of electric trolley buses in the United States and Canada peaked during the early 1950s, when 50 systems were in operation. Beginning in the late 1940s, and continuing through the mid 1960s, almost all electric trolley bus systems in the United States were converted to diesel motor bus operations. During the late 1960s, and early 1970s, a majority of the Canadian systems were similarly converted. The major reasons for the conversion of this mode were (1):

- The changing pattern of the urban infrastructure, partly caused by the widespread use of the automobile, caused much low-density surburban development to occur. Transit operators could not justify the capital investment required to either extend electric trolley bus routes into suburban areas or relocate routes to conform to changes in land use and street patterns.

- During the 1950s, most electric trolley bus systems had reached or passed their anticipated economic life, which was considered to be 20 to 25 years. The poor financial position of many transit operators during this period precluded the borrowing of funds for system renewal.

- The economics of operating transit systems forced the various managements to seek any and all ways to reduce costs in order to remain profitable. The costs of maintaining the fixed-power distribution system, the separate maintenance facilities and forces, plus spare parts inventories for more than one type of propulsion became targets for fiscal conservation on the part of operators.

During the 1960s it appeared that trolley buses could not retain any significant role in urban public transportation. However, several developments around 1970 led to a change in attitude toward this mode. The influencing developments have been (2):

- Introduction of public financial assistance to transit, which led to increased attention to quality of service, rather than minimum cost, as the only criterion in mode selection.

- Emphasis on improving the environment led to recognition of the excellent features of trolley buses with respect to noise and air pollution.

- Reduced dependence on oil through use of electric propulsion became an important factor; recent trolley bus models with thyristor chopper control may allow absolute reduction in energy consumption over buses.

As a result of these new developments, the conversion of electric trolley bus systems to diesel bus systems has been stopped and new trolleys have been purchased by several U.S. and Canadian cities for the first time since 1956.

Today, 4 of the 14 systems which once operated in Canada and 5 of the 49 systems which were implemented in the U.S. remain in operation. Characteristics of these systems are presented in Table 4-3.

Table 4-3
Characterstics of Electric Trolley Bus Transit Systems in Operation in the U.S. and Canada

System	Operating Authority	First Year of Operation	Number of Routes	Directional Miles of Roadway	Number of Vehicles	Urbanized Area Population
Canada						
Edmonton	Edmonton Transit System	1939	9	NA	80	451,000
Hamilton	Hamilton Street Roadway	1950	3	NA	50	312,000[1]
Toronto	Toronto Transit Commission	1947	8	104.0	151	2,998,947[2]
Vancouver	British Columbia Hydro & Power Authority	1948	13	82.0	321	1,269,183[2]
United States						
Boston	Massachusettes Bay Transportation Authority	1936	4	NA	50	2,678,762
Dayton	Miami Valley Regional Transit Authority	1933	8	133.2	65	595,059
Philadelphia	Southwestern Pennsylvania Transportation Authority	1923	5	42.1	110	4,112,933
San Francisco	San Francisco Municipal Railway	1935	15	110.1	345	3,190,698
Seattle	Municipal of Metropolitan Seattle	1940	10	110.0	115	1,391,535

Note: NA indicates data not available
[1]Center city population.
[2]Metropolitan area population.
Source: References 1, 3, 4, and 5.

Ridership and Employees Per Passenger

Annual patronage and the employees per million passengers for selected electric trolley bus systems in the U.S. and Canada are presented in Table 4-4. As the figures indicate, the average number of employees per passenger for electric trolley bus systems (at 21.3 employees per million passengers) is somewhat lower than the average of 26.9 employees per million passengers for diesel motor bus transit (Table 3-10).

Table 4-4
Employees Per Passenger for Electric Trolley Bus Systems

System	Annual Patronage (millions)	Trolley Bus Employees	Employees Per Million Passengers
Canada			
Toronto	30.5	NA	----
United States			
Boston	2.6	120	46.2
Dayton	9.5	115	12.1
Philadelphia	13.7	333	24.3
San Francisco	115.4	1,162	10.1
Seattle	19.9	274	13.8
Range			10.1-46.2
Avg., Non-Weighted			21.3

Note: NA indicates data not available.
Source: References 4 and 5.

Cost of Electric Trolley Bus Transit

Capital Costs (1)

The capital costs associated with implementing electric trolley bus systems primarily consist of the purchase of the vehicles, the construction of the power distribution system, and maintenance and storage facilities. Vehicle costs (presented in Table 4-1) range from $146,000 to $178,000 for standard configuration trolleys. The cost of a power distribution system and the cost of maintenance and storage facilities are difficult to estimate without at least a conceptual layout.

Operating Cost (4, 5)

Estimated operating costs per passenger and per passenger-mile for electric trolley bus systems currently operating in the U.S. are presented in

Table 4-5. As this table indicates, operating costs vary from one system to the next. 1983 operating costs per passenger transported ranged from $0.41 to $1.37, and operating costs per passenger-mile ranged from $0.12 to $0.87.

Table 4-5
Estimated 1983 Operating Cost Per Passenger and Per Passenger-Mile for Electric Trolley Bus Systems

System	Annual Passengers (millions)	Annual Passenger-Miles (millions)	Annual Operating Cost ($ millions)	Operating Cost ($) Per Passenger	Operating Cost ($) Per Pass.-Mi.
Canada					
Toronto	30.5	149.0	NA	----	----
United States					
Boston	2.6	4.1	$ 3.56	$1.37	$0.87
Dayton	9.5	22.7	6.91	0.72	0.30
Philadelphia	13.7	23.5	8.68	0.63	0.37
San Francisco	115.4	158.4	47.11	0.41	0.30
Seattle	19.9	115.8	14.29	0.72	0.12
Range				$0.41-$1.37	$0.12-$0.87
Avg., Non-Weighted				$0.77	$0.39

Note: NA indicates data not available.
Source: References 4 and 5.

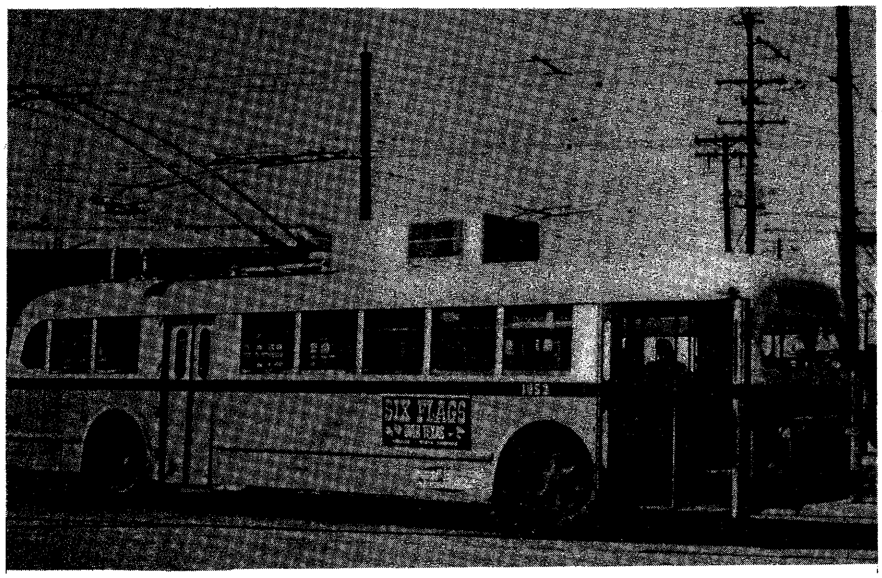
Application of Electric Trolley Bus Transit in Texas (3)

The only city in Texas to implement an electric trolley bus system was Dallas. During World War II, the Dallas Railway and Terminal Company (DR&T) invested $1 million in electric public transportation. A total of 25 PCC streetcars and 30 44-seat Brill electric trolley coaches were ordered and, in November 1945, the city's first trolley bus route went into service. Route #34 - Vickery totaled 5.6 miles and utilized 16 of the new vehicles. A second line, #24 - Capitol, began operations in February 1946. Then, in May 1947, the #17 - Mt. Auburn (4.8 miles) and the #18 - Parkview (5.3 miles) were converted from streetcar to electric trolley bus service. These 2 lines were through-routed with Routes #24 and #34, and 24 additional Brill trolley coaches were acquired.

The early 1950s brought considerable expansion of the electric trolley bus operation in Dallas after DR&T realized that its still extensive street car system had no real future. The original 25 PCCs were still in service, but no additional vehicles had been purchased.

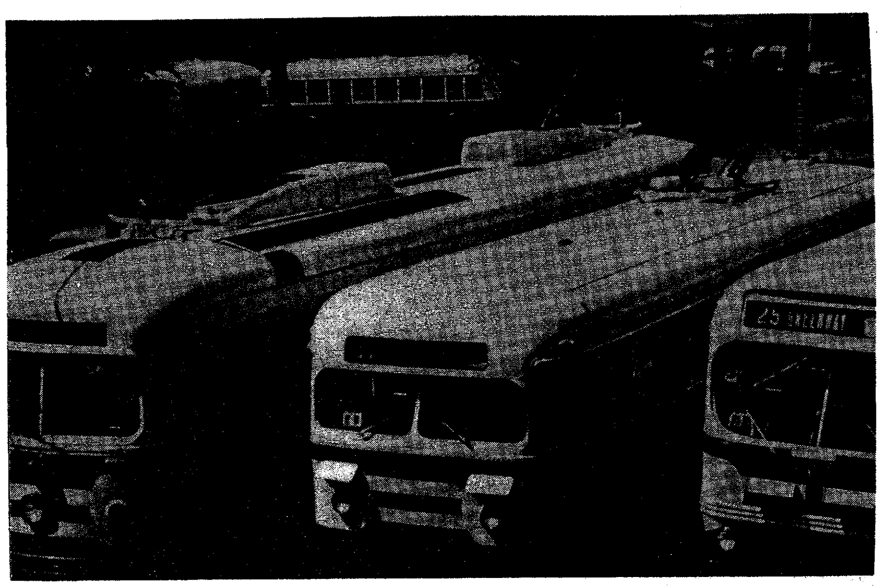
In 1955, DR&T became the Dallas Transit Company under the control of transit entrepreneur Harry Weinberg. The 4 remaining streetcar lines were abandoned the next year, and this event brought about the final expansion of the trolley bus network. Weinberg improved the trolley service with the addition of air conditioning to 49 of the 80 trolley buses, and Dallas became the only city to enjoy air conditioned trolley service.

In the 1960s, electric trolley bus service deteriorated and, in 1964, the system was taken over by the city. Federal funds to finance new equipment were sought immediately and, in 1966, the Dallas Transit System (DTS) acquired 330 new General Motors diesel motor buses. No thought, however, was given to modernizing or renewing electric trolley bus equipment as the city had grown miles beyond the end of the trolley wires. As the new diesel buses arrived, they were put into service on various trolley bus runs, and fewer and fewer trolley coaches were seen. On July 28, 1966 electric trolley bus operations ceased in Dallas.



The only city in Texas to implement an electric trolley bus system was Dallas (left).

Three generations of public transit in Dallas are pictured (right): streetcar, electric trolley bus and diesel motor bus.



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3. Sebree, Mac and Ward, Paul. The Trolley Coach in North America. Cerritos, CA: Ira L. Swett, 1974.

4. Lyons, William M. National Urban Transportation Statistics, 1983 Section 15 Annual Report. Washington, D.C.: U.S. Department of Transportation, December 1984.

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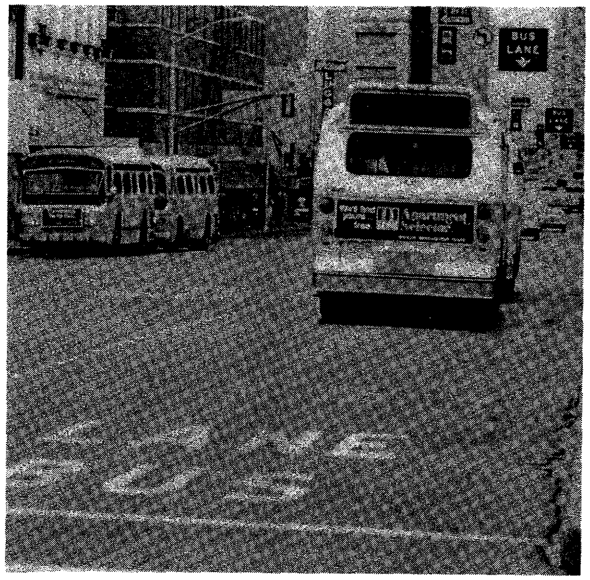
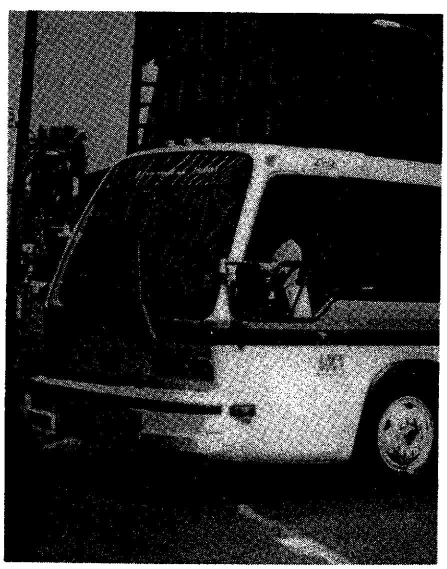


Chapter 5



Motor Bus Transit

• 5 •

Motor Bus Transit

Motor bus transportation carries about 66% of all transit passengers in the United States (1)*. It accounts for over 54% of the passenger-miles transported (1). Nearly 75% of America's population resides in counties served by transit bus operators, and every metropolitan area that has any form of transit service provides bus service.

Eighteen cities in Texas offer municipal bus transit service. An additional 8 cities have limited, special bus systems (2). Figure 5-1 shows the location of the Texas bus systems.

This chapter presents general motor bus transit characteristics, traditional bus transit operations, and bus rapid transit operations.

Motor Bus Transit Characteristics

A motor bus is a rubber-tired, self-propelled, manually steered transit vehicle with fuel supply carried on board the vehicle (1). Regular bus service consists of buses operating along fixed routes on fixed schedules. With vehicles varying in capacity from minibuses (20 to 35 passengers) to articulated buses (up to 125 passengers) with the capability to operate on most streets, arterials and expressways, motor buses provide a range of services with varying levels of service, performance, costs and impacts (3).

Vehicle Technology

Most buses have two axles and a total of six rubber-tired wheels. Some models have three axles and up to 10 wheels. Because of their wide use and short life (8 to 12 years, typically), buses are produced in far greater numbers than any other type of transit vehicles (3).

Transit buses can generally be divided into three broad categories: minibuses, standard, and high capacity (4). Figure 5-2 shows the typical transit vehicles available to systems.

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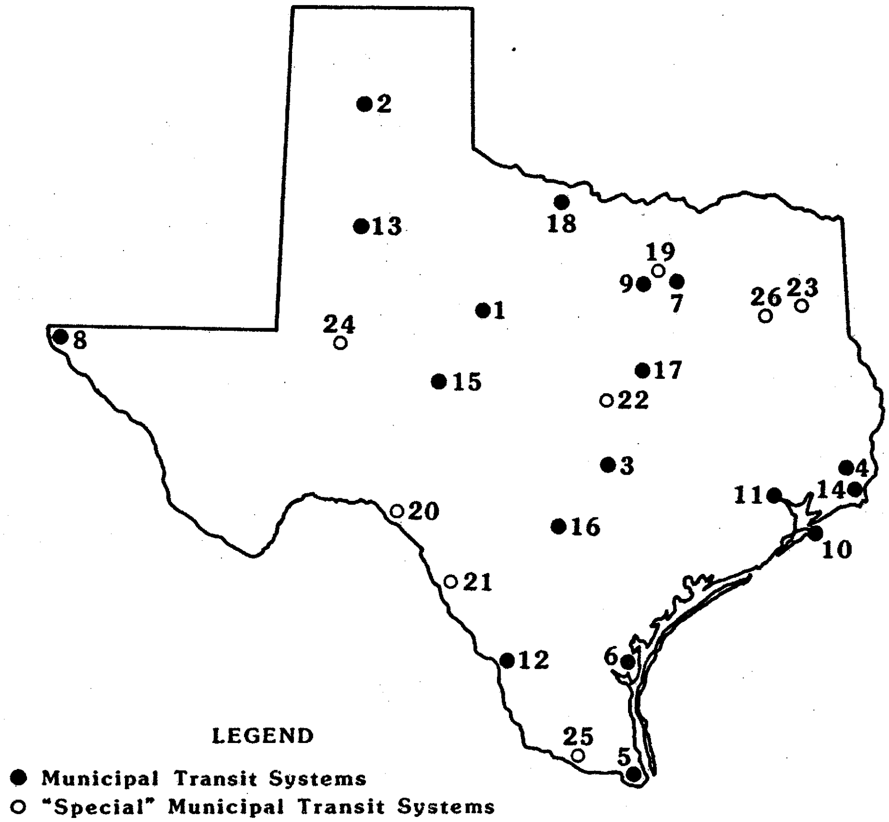
*Numbers in parentheses refer to references listed at the end of the chapter.

Municipal Transit In Texas

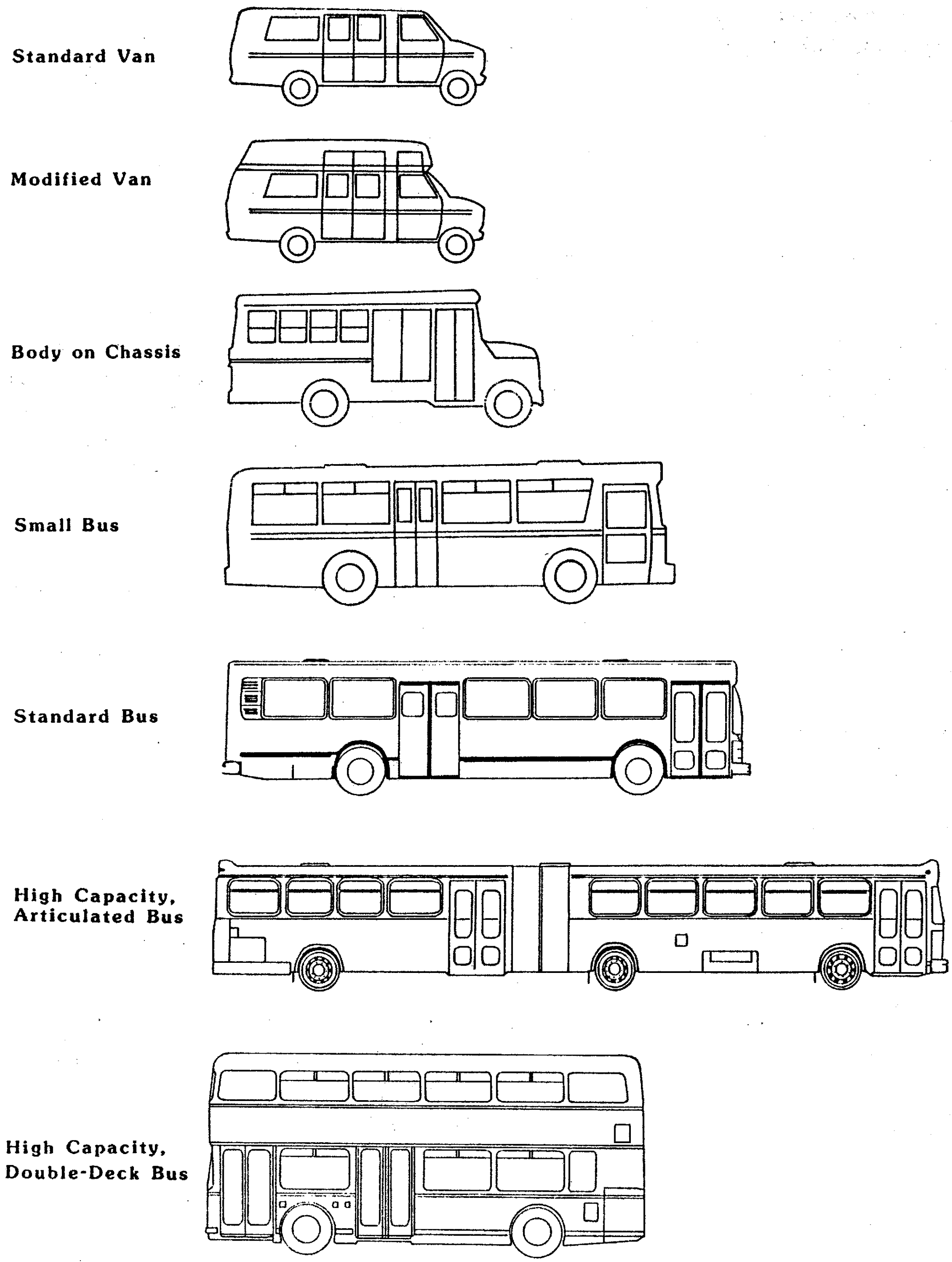


MUNICIPAL SYSTEMS		"SPECIAL" MUNICIPAL SYSTEMS *
1 Abilene	10 Galveston	19 Trailways
2 Amarillo	11 Houston	20 Del Rio
3 Austin	12 Laredo	21 Eagle Pass
4 Beaumont	13 Lubbock	22 Killeen-Fort Hood
5 Brownsville	14 Port Arthur	23 Longview
6 Corpus Christi	15 San Angelo	24 Midland
7 Dallas	16 San Antonio	25 McAllen-Pharr-Edinburg
8 El Paso	17 Waco	26 Tyler
9 Fort Worth	18 Wichita Falls	

* Offer Limited or Special Municipal Transit Service.

Source: Reference 2.

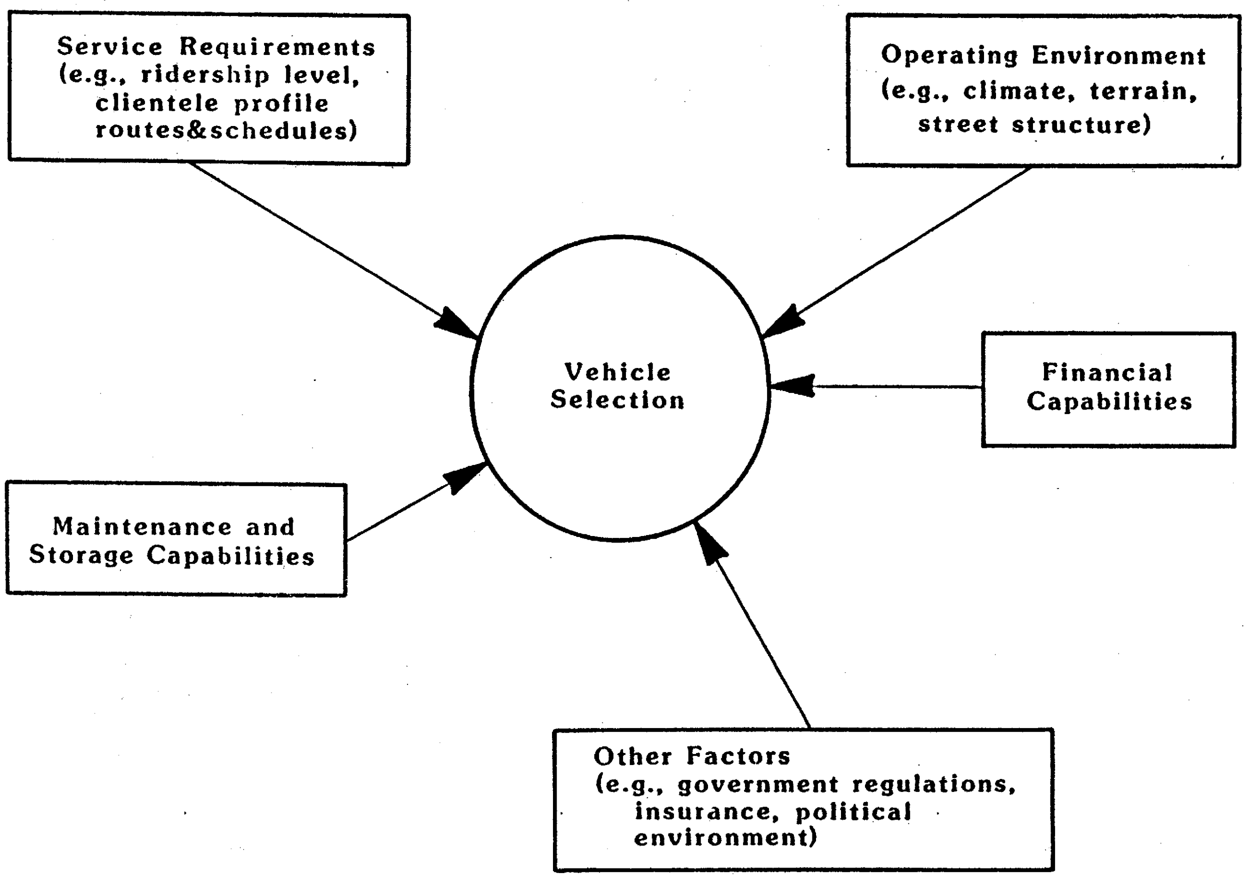
Figure 5-1
Locations of Municipal Bus Transit Systems in Texas



Source: References 3, 5 and 6.

Figure 5-2
Examples of Motor Bus Vehicles

Figure 5-3 shows the general considerations in selecting a transit vehicle. Table 5-1 presents vehicle characteristics for smaller buses; Table 5-2 presents this information for standard buses; and Table 5-3 gives the information for high-capacity buses.



Source: Reference 5.

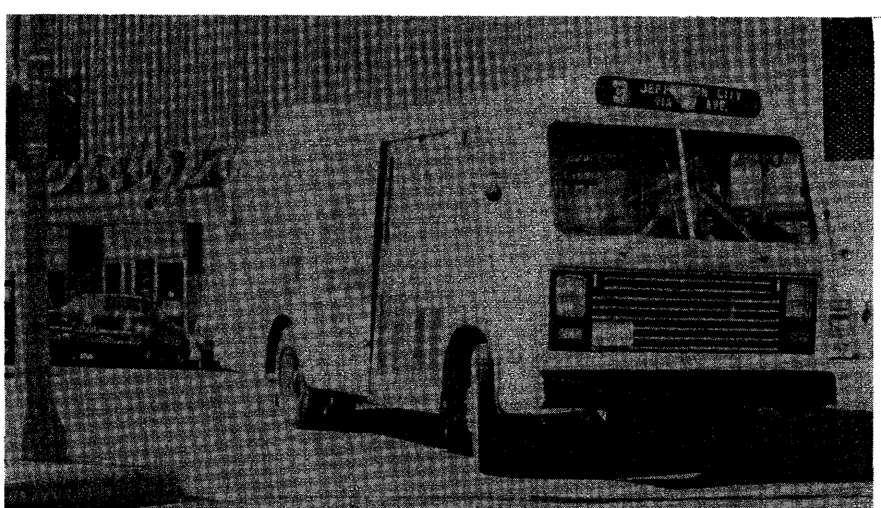
Figure 5-3
Factors Affecting Transit Vehicle Selection

Table 5-1
Physical and Performance Characteristics
of Selected Transit Motor Buses - Small Buses[1]

Characteristic	Bluebird Citybird 77CBPP2904	Chance RT-50	TMC Citycruiser T-30	Skillcraft Transmaster L31	Steyr City-Bus
Length (feet)	31.1	26.5	31.67	34.0	19.0
Width (inches)	96.0	96.0	96.0	96.0	80.0
Height (inches)	115.5	120.0	114.0	101.0	98.5
Wheelbase (inches)	180.0	168.0	180.0	252.0	129.9
Minimum Turning Radius (feet)	33.0	28.5	33.0	36.0	21.75
Front Door Width (inches)	28.0	48.0	31.0	32.0	47.25
Rear Door Width (inches)	34.0	---	31.0	---	---
Design Capacity seats/standees	31/20	25/15	31/30	31/19	15/13
Propulsion System	DDA6V-53 turbo charged	Caterpillar Diesel 3208-175(V8)	DDA6V-53T	DDA453T or 8.2 liter turbo	Diamler-Benz OM616 Diesel (4 cylinders)
Manufacturer	Bluebird Body Co.	Chance Mfg. Company	Transportation Mfg. Corp.	Skillcraft Industries, Corp.	Transbus of America Corp.

[1]Heavy duty transit vehicles under 35 feet in length with seating capacity for 15 to 35 passengers.

Source: References 5 and 6.



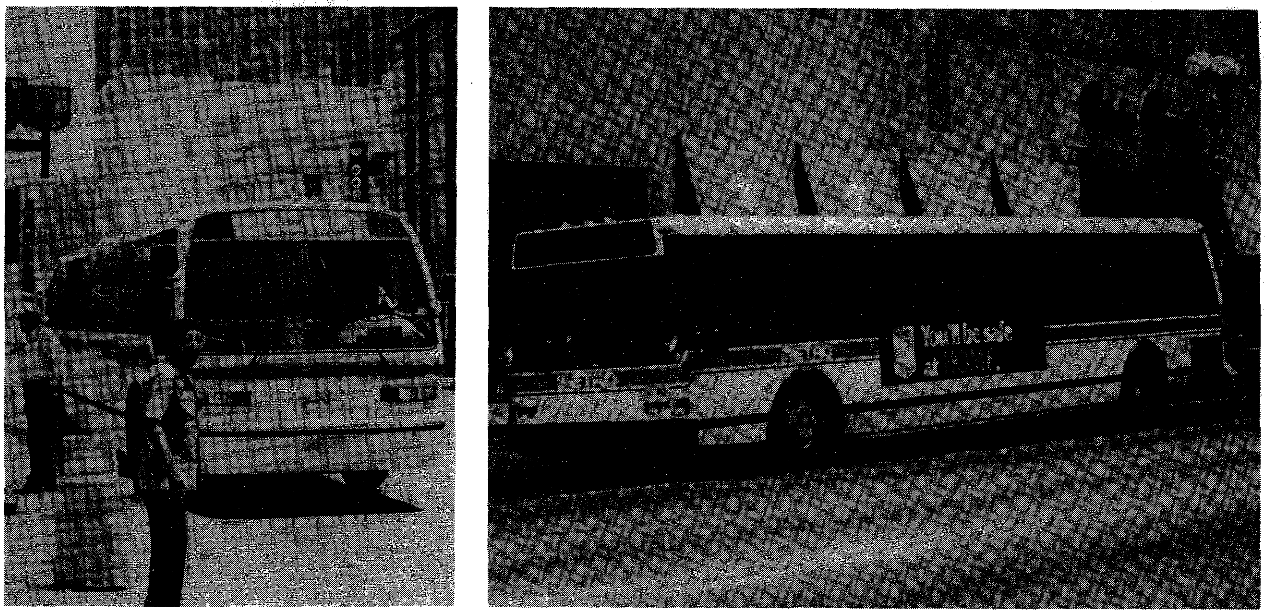
Transit service in Port Arthur is provided in Chance minibuses.

Table 5-2
Physical and Performance Characteristics of Selected Transit Motor Buses - Standard Bus

Characteristic	General Motors RTS04	Grumman Flxible 870	General Motors of Canada "New Look" Bus	Flyer Industries D900	Neoplan N416	Eagle Model 05	M.A.N. Americana	Motor Coach Ind. MC-9	Gillig Phantom
Length (feet)	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
Width (inches)	96.0 or 102.0	96.0 or 102.0	95.75 or 101.8	102.0	96.0	96.0	96.0 or 102.0	96.0	96.0
Height (inches)	118.5	121.5 Maximum	121.5 Maximum	120.5	117.0	133.5	120.0	133.0	119.0
Wheelbase (inches)	298.7	299.0	284.0	285.0	267.0	285.5	N/A	285.0	282.0
Minimum Turning Radius (feet)	44.0	43.9	42.0	42.0	NA	42.5	43.75	46.5	
Front Door Width (inches)	30.0	36.0	30.0	38.0	30.0	NA	NA	NA	37.0
Rear Door Width (inches)	44.0	32.0	26.5	26.5	42.0	NA	NA	NA	26.0
Design Capacity (Seats/Standees)	47/24	48/24	53/27	51/26	47/35	53/NA	NA	49/NA	40/NA
Engine Type	6V-92TA Detroit Diesel-Allison	Detroit Diesel 6V71TA	Detroit Diesel 6V71N	Detroit Diesel 6V71N	Detroit Diesel	6 or 8 cylinder	M.A.N. D2566	Detroit Diesel 8V-71	Detroit Diesel 6V92TA
Manufacturer	GMC Truck & Coach Div.	Grumman Flxible Corp.	Diesel Div. Gen. Motors of Canada, Ltd.	Flyer Ind. Ltd.	Neoplan U.S.A.	Eagle Internat'l Inc.	M.A.N. Truck & Bus Corp.	Motor Coach Ind.	

Note: NA indicates data not available.

Source: References 7, 8, 9, 10, 11, 12 and 13.



The General Motors RTS (left) and Grumman Flxible (right) are two popular standard capacity buses recently purchased and operated by the transit systems in Texas.

Table 5-3
Physical and Performance Characteristics
of Selected High Capacity Transit Motor Buses.

Characteristic	Neoplan N122/3 (DD)	Leyland Metro (DD)	M.A.N. SG310 (ART)	Ikarus 286 City Bus (ART)
Length (feet)	39.4	36.5	60.0 or 55.0	55.0 or 60.0
Width (inches)	102.0	98.0	102.0	102.0
Height (inches)	174.0	174.0	125.0	124.0
Wheelbase (inches)	270.0	NA	287.4	280.0
Minimum Turning Radius (feet)	NA	71.3	43.3	40.0
Front Door Width (inches)	53.1	47.2	47.75	48.0
Rear Door Width (inches)	53.1	47.2	47.75	48.0
Design Capacity (Seats/Standees)	84/14	80/NA	72/NA	67/40
Manufacturer	Neoplan	British Leyland	American M.A.N. Truck & Bus Corp.	Crown Coach Corp.

Note: (DD) = double-deck bus
(ART) = articulated bus
Source: References 8, 12 and 13.

In the United States, the average transit vehicle seats 44.9 passengers (14). Sixty-eight percent of these buses are 40' in length. Less than 2.5% of the vehicle fleet is articulated buses. Nearly 19% are 35'. Just over 6% of the national vehicle fleet is less than 35' (14). Table 5-4 shows the characteristics of the over 59,000 vehicle motor bus fleet in the United States in 1980 (1). Table 5-5 shows the motor bus fleet inventory for Texas. Over 92% of the 2,619 vehicles in Texas have the capacity to carry over 25 passengers. In Texas, nearly half (43.5%) of the fleet is under 5 years of age. An additional 25% is from 5 to 9 years old. 31.5% of the fleet is over 10 years old (2).

Table 5-4
Motor Bus Characteristics of the U.S. Urban Fleet
as of December 31, 1980

Characteristic	Motor Bus
Number of Vehicles	59,411
Number of Vehicles Equipped with Air Conditioning	42,891
Number of Vehicles Equipped with Two-Way Radios	38,469
Number of Vehicles Equipped with Wheelchair Lifts or Ramps	6,133
Average Age, Years	8.8
Average Length	38'3"
Average Number of Seats	45.6
Propulsion Power	Diesel: 96.1% Gasoline: 3.3% Propane: 0.6%
Length/Gross Weight of a Typical Vehicle	40' 34,000 lbs.
Average Operating Speed in Revenue Service	11.8 mph

Source: Reference 1.

Table 5-5
1984 Texas Motor Bus Vehicle Mix

	Vans (<15 passengers)	Small Coach (16-25 passengers)	Standard Coach (over 25 passengers)
Number	104	103	2412
Percent	4.0	3.9	92.0

Source: Adapted from references 2 and 15.

Vehicle Propulsion

Motor bus vehicles run on one of three sources of power: diesel, gasoline or propane. As Table 5-4 shows, the vast majority (96.1%) of buses use diesel power.

Street Operations

In part, motor bus technology owes its popularity to its ability to operate on most city streets, arterials and freeways. The vast majority of buses operate in mixed traffic on streets. A small but growing number of cities have reserved and/or separated lanes for use by buses and other high occupancy vehicles (3).

Operators can place buses on any street, as demand requires. Buses may stop at many points, which can change. These factors make rapid introduction, changes and bus route and stop extensions easy (3).

Traditional Bus Transit Operations

Fixed Route Characteristics

Transit buses traditionally operate on fixed routes, on fixed schedules, making periodic stops for passenger boarding and deboarding. Operationally, fixed route buses act much the same way the streetcars they replaced did.

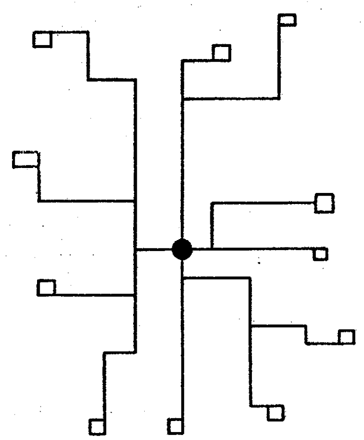
Design and Operating Characteristics

Four basic fixed route operating schemes exist for transit: radial, grid, radial criss-cross and trunk line with feeders (4). Most systems, however, operate some combination of these schemes. Figures 5-4 through 5-7 graphically depict these four networks.

The radial network usually focuses trips to downtown and reflects the road pattern established by the old streetcar lines. As new suburbs grow, the bus route extends to serve them. As economic activities decentralize, this network encounters difficulty in providing adequate service for more than a small percentage of desired trips.

Grid-type bus route networks feature relatively straight, parallel routes spaced at regular intervals and crossed by a second group of routes with similar characteristics. They generally require an even-spaced network of arterial streets suitable for bus operations (4). The system's greatest advantage/disadvantage is that to reach most places a rider requires one transfer.

The radial criss-cross combines features of the grid-type and radial networks. It criss-crosses the lines and provides additional focal points for lines to converge.



Source: Reference 4.

Figure 5-4
Radial Bus Route Network

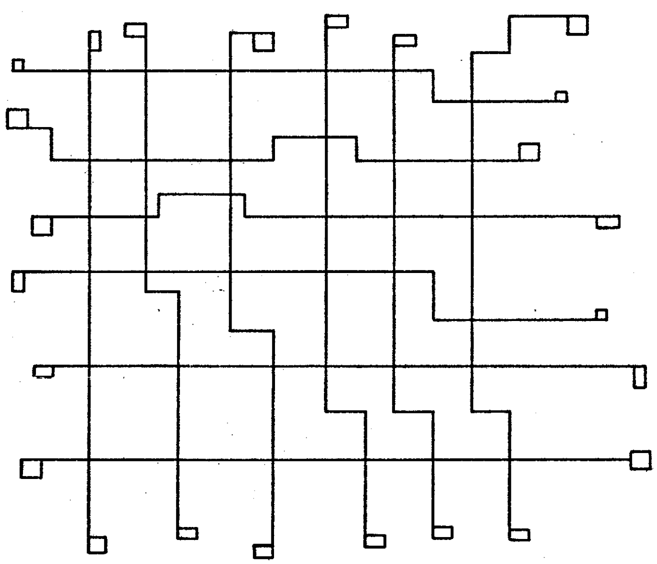


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Figure 5-5
Grid Bus Route Network

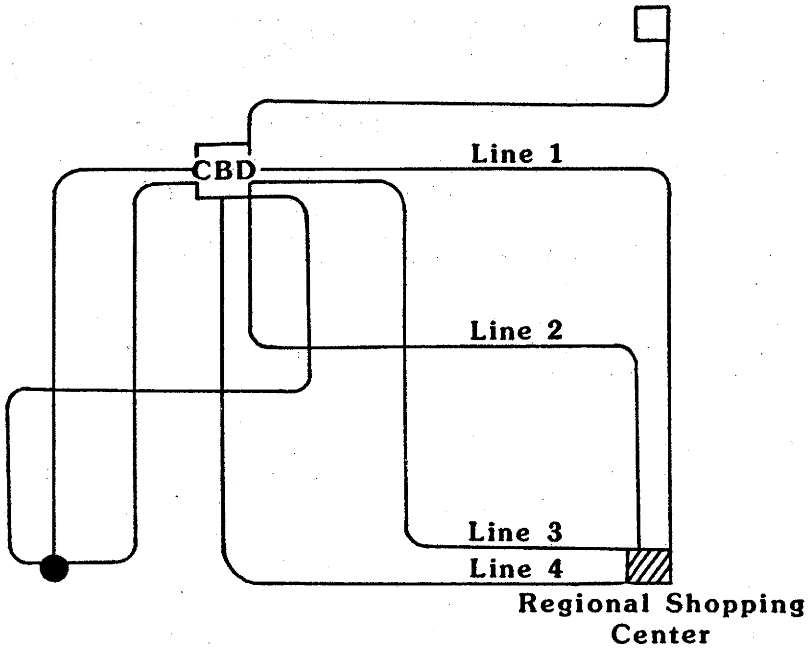

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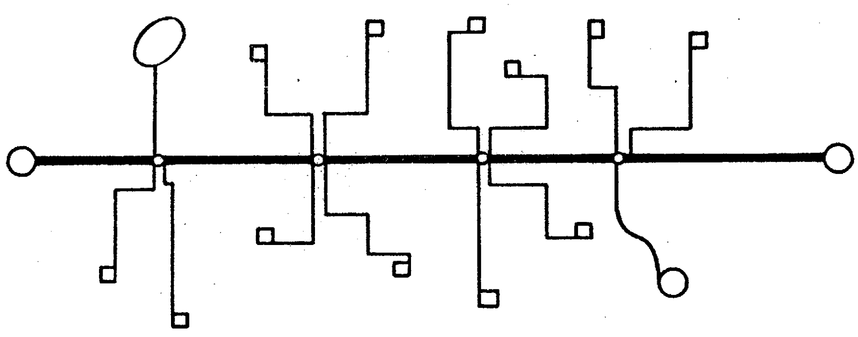
Figure 5-6
Radial Criss-Cross Bus Route Network



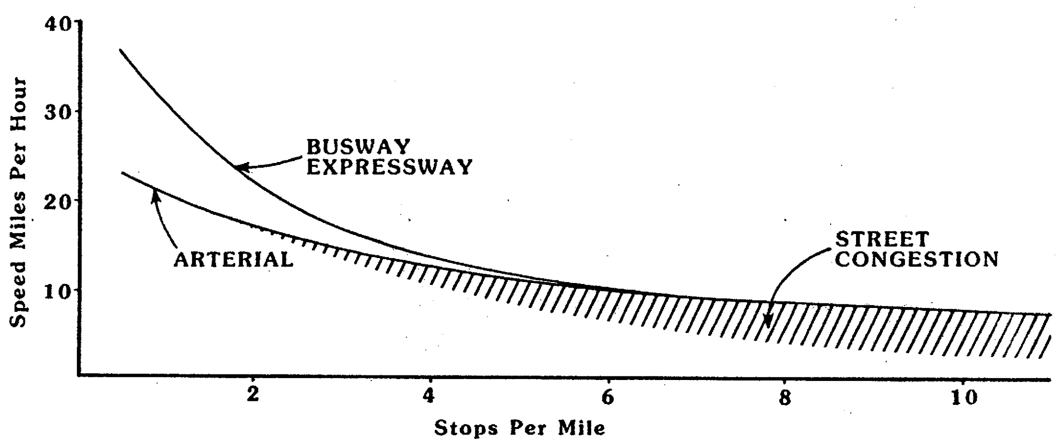
Source: Reference 4.

Figure 5-7
Trunk Line With Feeders

The trunk line with feeder typically focuses on a strong transit artery which serves a major travel corridor. Because of the topography, geographical barriers, street patterns, or other reasons, under this system it is preferable to provide "feeder" service to the major trunk line rather than to run bus lines all the way to the ultimate major destination. Its major advantage is that a system of feeders can support a higher level of service on the trunk line than if it were supported only by passengers walking to stops. Its disadvantage is, however, the necessity for most patrons to change vehicles (4).

In addition to these four networks, some transit properties use timed-transfers. These require coordinated route planning and scheduling. With timed-transfers, the entire system, or its major portions, is laid out to allow vehicles to meet in timed sequence to allow convenient passenger transfer movements. Most transfers occur without having to travel downtown and also occur at places designed for transfer activities. Timed-transfers, while difficult to design and schedule, have been used effectively in many systems (4).

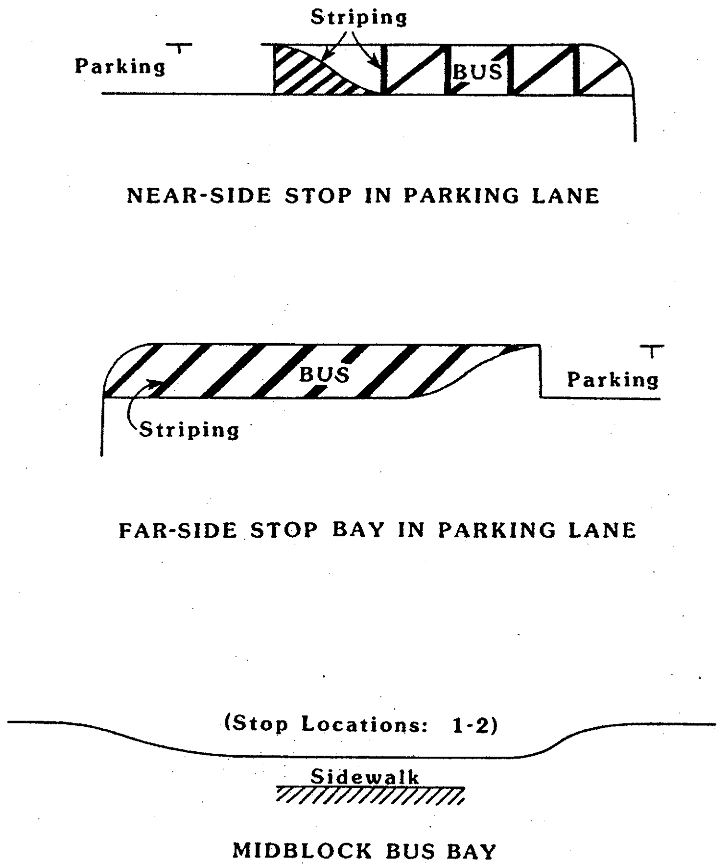
Bus route stop planning involves three aspects: spacing, locations and shelters. Bus stop spacing represents a compromise between short access to stops and higher operating speeds of lines with few stops. On the average, bus stops should be spaced from 1,300' to 2,000' and no less than 1,000' (3). More frequent stops degrade the service and make the provision of physical amenities difficult. Figure 5-8 shows the relationship between bus speeds and stop frequency.



Source: Reference 8.

Figure 5-8
The Effect of Stop Frequency on Average Bus Speeds

Three types of locations serve as bus stops: near-side, far-side and midblock. Near side stops occur at an intersection before crossing the intersecting street. Far side stops occur at an intersection beyond the cross street. Midblock stops occur away from an intersection. The choice of stop location reflects traffic signal coordination, passenger access including transfer, vehicular and pedestrian traffic conditions at intersections, and geometrics of bus turning and stopping (3). Figure 5-9 shows typical bus stop designs. Sidewalks need to be wide enough for waiting and boarding patrons and pedestrians. Bays should be designed so buses can pull out easily. Typical curbside stops with shelters cost $4,300 each, although the costs range from $3,300 to $8,700 per stop (8).



Source: Reference 3.

Figure 5-9
Typical Designs of Bus Stop Areas

Operations and Performance Characteristics

Headways. Policy, either explicit or implicit, establishes the minimum level of service to be provided or frequency of service necessary to handle the passenger demands for bus service. Typically, headways range from 60 minutes to less than 10 in the systems.

Speed. With such frequencies and bus stop spacing and routing specified earlier in this chapter, local buses on arterial streets typically achieve operating speeds of 10-15 mph (8). Table 5-6 shows average motor bus speeds in large urbanized areas.

Table 5-6
Average Motor Bus Speeds in Large Urbanized Areas

Type of Service	Speed (mph)	
	Peak Period	Non-peak Period
Local Bus on Collector Street	5	7
Local Bus in Reserved Lane on Collector Street[1]	8	10[3]
Local Bus on Arterial Street	10-11	13-15
Local Bus in Reserved Lane on Arterial Street[2]	15	17[5]
Express Bus on Freeway	30	45
Express Bus in Reserved Lane on Freeway[4]	45	45[3]
Express Bus on Exclusive Busway[5]	20-60	20-60

[1]Data reflect speeds of buses in normal flow lanes, contraflow lanes, and median lanes, and on bus streets in downtown areas.
[2]Data reflect speeds of buses in normal flow lanes, contraflow lanes, and median lanes outside downtown area.
[3]Value is estimated since facility is not usually operated during nonpeak periods.
[4]Assumes no stops while on freeway portion of route.
[5]Average speed depends upon frequency of stops and geometrics of facility.
Source: Reference 8.

Fare structures and collection procedures impact operating speeds. Flat fares offer simplicity, understandability, marketability and ease of collection. To enhance security, transit operators have initiated "exact fare" policies where drivers do not make change. This also "speeds up" passenger loading.

Attributes

Traditional bus transit service possesses the following unique characteristics which require consideration in system planning (8).

- Because traditional motor bus transit service utilizes the existing roadway system, the initial capital costs associated with implementing service are primarily limited to the acquisition of vehicles and the provision of maintenance and storage facilities.

- Because there is not need a for major fixed facility construction, the implementation period is relatively short.

- The level-of-service offered will be directly affected by the traffic in which the vehicles operate.

- Unlike operation on exclusive lanes, maximum transit vehicle speeds will be constrained by traffic conditions, safety considerations and posted speed limits.

- Motor buses can be operated wherever paved roadways exist. A no-transfer ride can be provided between a large number of origins and destinations and the same bus can perform collection and distribution functions in addition to providing line-haul service.

Capital and Operating Costs

Motor bus capital and operating costs continue to rise annually. Generally, transit deficits are the result of rising labor costs, energy prices and consumption rates, service expansion, declining utilization of services and reduced fare per passenger carried. The rising unit labor costs per vehicle-mile of service is the most important single source of escalating transit deficits from 1970 to 1980. Escalating compensation per labor-hour accounted for slightly more than 25% of the growth in transit deficits while declining labor productivity accounted for an additional 18% (16). Accounting for 10% of the deficit were increasing costs for vehicle propulsion energy. Another 16% of the deficit resulted from expansion nationwide of transit service. Deterioration in transit utilization accounted for another 2% of the deficit. Substantial decline in average fare per passenger carried contributed the remaining 28% of the deficit (16). Table 5-7 shows the factors affecting rising transit deficits. Table 5-8 shows 1980 national motor bus operating revenue and expenses.

Table 5-7
1980 National Bus Financial Characteristics

Number of Systems	1,022
Vehicles Operated	59,411
Vehicle-Miles Operated (millions)	1,677.2
Passenger Trips (millions)	5,731.0
Operating Revenue (millions)	1,899.0
Operating Expense (millions)	4,893.0
Operating Revenue/Vehicle Mile	1.13
Operating Expense/Vehicle Mile	2.92
Passenger Trips/Vehicle Mile	3.42

Source: Adapted from reference 1.

Table 5-8
Factors Contributing to Rising Transit Deficits

Factor	Relative Contribution[1]
Rising Unit Labor Costs	43%
Reduced Fare Revenue per Passenger Carried	28%
Service Expansion	16%
Increases in Energy Prices and Consumption Rates	10%
Declining Utilization of Service	2%

[1]Because of rounding, totals do not equal 100%.

Source: Adapted from reference 16.

With all 18 Texas transit systems offering fixed-route service, the systems exhibit similar vehicle-mile operating and revenue figures. Table 5-9 shows 1983 Texas operating statistics. Texas' passengers per vehicle-mile of 2.01 is less than 60% of the national average of 3.42. Both statistics include regular route and transfer passengers.

Table 5-9
1983 Texas Transit Operating Statistics

Passengers	154.2 million
Vehicle-Miles	76.9 million
Farebox Revenue	$61.9 million
Other Revenue (Charters, Sales Tax, Advertising, etc.)	$29.9 million
Operating Expenses	$207.6 million
Number of Serviceable Buses	2,322
Passengers/Vehicle-Mile	2.01
Pass. Revenue/Vehicle-Mile	$1.19
Operating Expenses/Vehicle-Mile	$2.80

Source: Adapted from reference 2.

Federal expenditures for public transportation are not the only ones increasing. State assistance is also increasing. Table 5-10 shows the federal and state capital assistance to the Texas systems. In the 1983-84 fiscal year, public transit operations cost over $100 million in Texas. This includes $13 million in state capital assistance. The state provides no operating assistance to the eighteen municipal Texas systems.

Table 5-10
Texas Transit Capital Improvement Expenditures

Government Level	Expenditures (millions)
Federal	$ 82.1
State	13.3
Local	7.2
Total	$102.6

Source: Adapted from reference 2.

Texas Transit Service

All 18 transit systems in Texas offer fixed route bus service. Table 5-11 gives the general operating characteristics for the Texas systems.

Table 5-11
1983 Texas Transit Operating Characteristics

City	Number of Serviceable Buses	Annual Vehicle-Miles (thousands)	Annual Ridership (thousands)	Average Fare (cents)[1]
Houston	628	28,000	51,600	41
Dallas	592	15,500	36,000	57
San Antonio	466	14,700	34,500	25
Fort Worth	141	3,300	5,200	49
El Paso	135	4,200	8,900	38
Austin	90	3,000	4,400	35
Corpus Christi	41	1,300	1,500	36
Lubbock	41	1,000	2,200	29
Amarillo	30	700	800	24
Beaumont	26	700	1,500	24
Wichita Falls	9	300	200	69
Waco	19	400	600	33
Abilene	17	500	400	27
Laredo	26	900	3,200	35
San Angelo	12	300	400	21
Galveston	15	400	900	43
Brownsville	25	700	1,600	38
Port Arthur	9	200	300	38
Total	2,322	76,900	154,200	37

[1]This is farebox revenue divided by passengers.
Source: Adapted from reference 2.

Table 5-12 shows the Texas operating data by size of the city served by transit. Large cities (over 500,000 population) include Houston, Dallas and San Antonio. Medium cities (between 200,000 and 500,000 population) include Fort Worth, El Paso, Austin, and Corpus Christi. Small Cities (under 200,000 population) include Abilene, Amarillo, Beaumont, Brownsville, Galveston, Laredo, Lubbock, Port Arthur, San Angelo, Waco and Wichita Falls.

Table 5-12
1983 Texas Transit Data Categorized by Size of City Served

Item	City Category	Percent of Statewide Total
Passengers	Large	79.2
	Medium	12.9
	Small	7.1
Vehicle Miles Operated	Large	76.7
	Medium	15.4
	Small	7.9
Operating Expenses	Large	82.8
	Medium	11.9
	Small	5.3
Buses in Service	Large	72.6
	Medium	17.5
	Small	9.9

Source: Adapted from reference 2.

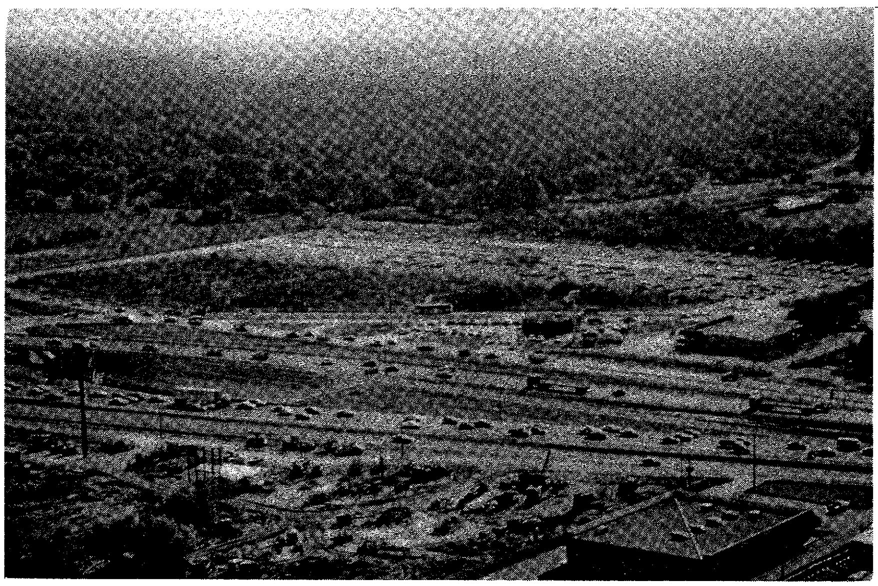
Analysis of Table 5-12 shows that the three largest cities' systems carry 79.2% of the passengers and generate 82.8% of the state's operating expense.

Park-and-Ride Service

Park-and-Ride service is a mode of travel by transit when a passenger drives (or is driven) to a transit station, parks his/her automobile (or is dropped off) at the station's park-and-ride lot and completes his/her trip by transit. The park-and-ride concept is an effective way of combining the automobile and public transit by using each mode in the geographic area to which it is best suited. Because the automobile is used for the initial collection part of the journey, park-and-ride is able to draw trips from a relatively large market area to a point where there is enough concentrated demand to support public transit. For this reason, park-and-ride is especially suited to low density areas which may not otherwise be able to support fixed-route transit service. Although the park-and-ride concept is applicable to both bus and rail transit, this report addresses its application to bus transit.

Design and Operating Characteristics

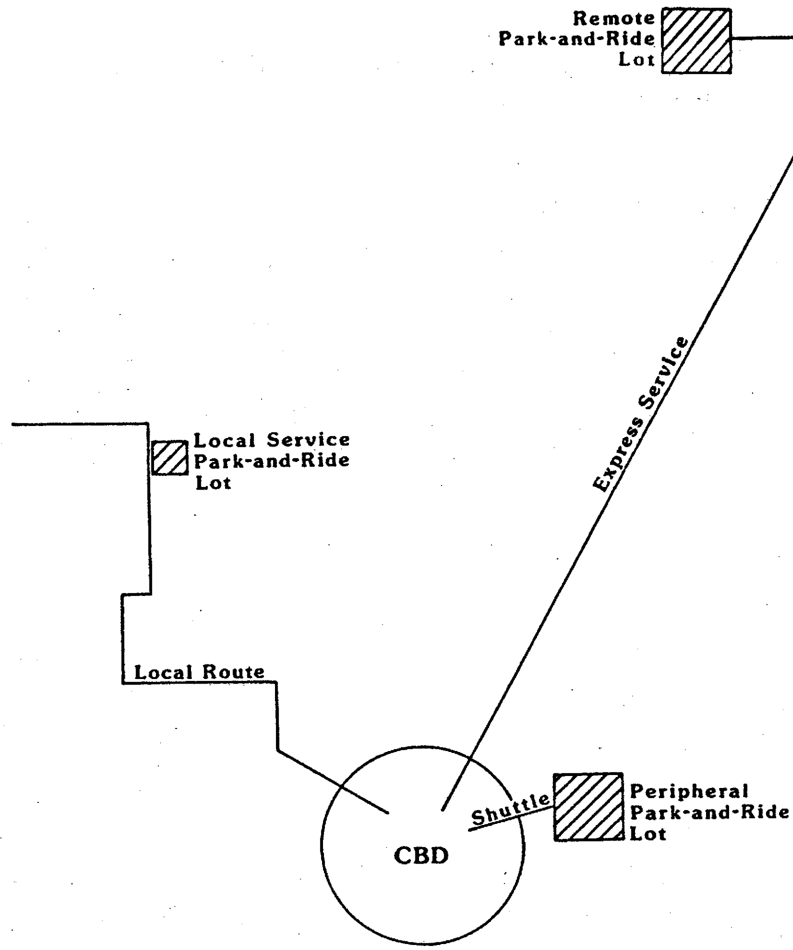
The location and type of park-and-ride lot, as well as type of transit service provided to the lot, define bus park-and-ride services. Park-and-ride services serve three types of journeys: long-haul, neighborhood and short-haul. Remote park-and-ride services provide for a shift from automobile to transit from a suburban or satellite community to an activity center by intercepting the automobile trip near its origin (18). Thus, the remote park-and-ride serves the long-haul trip. In Texas, the majority of park-and-rides serve remote lots.



The majority of park-and-ride lots in Texas are remote facilities, such as this lot in Houston.

Local service park-and-rides, on the other hand, provide an additional stop designated along an existing local bus route. Demand comes from neighborhoods adjacent to the lots. Fort Worth has an extensive "Park-and-Go" lot system. San Antonio, has, however, discontinued several of its local service park-and-rides (19).

Peripheral park-and-rides serve major activity centers; these lots lie on the edge of the activity center they serve. Unlike remote operations, this service comprises the shorter end of the trip. The commuter travels the long-haul trip by automobile and changes to the bus mode usually within 1.5 miles of the ultimate destination. Local or shuttle bus service provides the link between the lot and activity center (18). Dallas' Reunion lot, carrying 1,100 riders daily, serves as one peripheral park-and-ride lot in Texas (20). Figure 5-10 shows the three park-and-ride service types.



Source: Reference 17

Figure 5-10
Types of Park-and-Ride Service

As opposed to the service categorized by type of trip served, park-and-ride lots may be classified by lot type as well. They may be single-use or joint-use facilities. Single-use lots, like North Shepherd in Houston, have been specifically constructed to serve as parking for park-and-ride patrons. Joint-use lots serve more than one parking purpose. They utilize unused portions of existing parking lots. The Windsor Park Mall facility in San Antonio serves as one Texas example of a joint-use lot.

Park-and-ride lots offer several types of transit service. Generally some type of express bus provides service to remote bus park-and-rides. The express bus may have one or more destinations and may operate in mixed traffic, on exclusive busways, and/or on high occupancy vehicle lanes. Three types of express service to park-and-ride lots exist: full, limited and link express. Full express provides non-stop service from origin to destination. Limited express provides non-stop service along a portion of a route and link express provides service with stops at a selected few locations (18).

Local transit operations serve local service park-and-ride facilities. This service provides riders with several destinations along the local route. Shuttle or local service buses operate between peripheral lots and the activity center.

Attributes

Park-and-ride service can achieve reductions in parking demand, energy consumption, air pollution and traffic congestion. When large numbers of drivers leave their automobiles at park-and-ride facilities and take the bus, they reduce demand for parking spaces at their destination. Research shows that about half of the park-and-ride patrons formerly made the entire trip by private automobile. Thus, park-and-ride users reduce the demand for parking at the terminal end of the trip by about 50% (18). The park-and-ride lots that served the contraflow lane in Houston reduced the demand for downtown parking by about 2,000 spaces, which is roughly equivalent to 10 to 20 acres of downtown parking in Houston (18).

By leaving their automobiles at park-and-ride lots and riding transit, commuters save fuel. Because of the relatively low percentage of total trips that can be accommodated by park-and-ride service, however, the relative magnitude of park-and-ride fuel savings is low relative to total state and national transportation fuel consumption.

By reducing vehicle-miles traveled, park-and-ride commuters also decrease air pollution. Studies show, however, that a vehicle with a cold engine emits more pollution than a warmed-up engine; therefore, air pollution emissions increase from vehicles making short trips. This tends to offset slightly the expected reduction in air pollution. Table 5-13 shows the air pollution and energy impact of a park-and-ride lot along a congested 6 and 8 lane freeway for an origin to destination distance of 10 miles.

Table 5-13
Impact of a Park-and-Ride Lot on Freeway Energy Consumption, Air Quality, and Congestion Per 3-Hour Peak Period

Freeway Evaluation Factor	Freeway Conditions	
	Without Park-and-Ride	With Park-and-Ride
Person-hours of travel	6,029	4,754 (-21%)
Average speed (mph)	43	53 (+23%)
Gasoline consumption (gals.)	11,037	10,630 (- 4%)
Pollutants emitted (kilograms)		
Hydrocarbons	536	475 (-11%)
Carbon Monoxide	3,552	2,872 (-19%)
Nitrous Oxide	746	759 (+ 2%)

Notes: Based on implementing a 1200-space, fully-utilized park-and-ride lot along a congested 6 and 8 lane freeway a distance of 10 miles from downtown. Based on FREQ computer simulation analysis.

Source: Reference 18.

In addition to its impact on parking demand, energy consumption, and air pollution, park-and-ride service shares those attributes common to local bus operations. Not only using the facility itself, park-and-ride service utilizes the local arterial street network for collection, distribution and terminal access. It can operate in a variety of modes: from high-speed line-haul service on exclusive bus lanes to collection and distribution functions on local arterial street networks (8). Because motor bus modes possess the capability to utilize so many street and network configurations, bus operations can benefit from staged improvements with increasing capital intensive projects being phased in as demand and congestion warrant. Bus operations in mixed traffic on freeways from park-and-rides exhibit the following characteristics.

- Because existing vehicles and fixed facility service park-and-ride lots, initial capital costs consist of vehicle acquisition, maintenance and storage. Joint-use lot costs typically are limited to lease arrangement costs and passenger shelter/terminal area. Single use lots include the former costs plus rights-of-way, and lot design and construction costs.

- Since fixed facility construction is minimal, the service may be implemented in a relatively short time.

- Service initiation involves little or no community disruption.

- Because it provides for a convenient mode, this service provides a single transfer ride to concentrated destinations. For local park-and-ride service, the bus can provide collection and distribution functions.

- Freeway operating speeds limit operating speeds for buses serving park-and-ride lots and traveling in mixed flow traffic.

- Because of the ability to use under-utilized parking lots, the park-and-ride mode has an inherent flexibility. As demand increases, separate use lots can replace joint-use lots.

- Few park-and-ride lots sustain all day transit service. Buses usually serve commuters during peak traffic hours. Some lots do have limited midday service available, however (21).

Capital and Operating Costs

Compared to light and rail rapid transit, bus park-and-ride service requires little capital investment. For single use lots, capital costs consist of right-of-way acquisition and/or land lease, utility adjustments, bus loading/passenger waiting area construction, parking lot construction, illumination provision, signing, landscaping and provision of amenities (trash receptacles, newsstands, vending machines, public telephones, among others).

In Texas, costs per parking space in single use lots range from $2,000 to $4,700 per space (8, 22). Multiple use lots vary on a cost per space basis because of the numerous private-public lease agreements. Typically, annual maintenance and operating costs for park-and-ride service is $20 per space (8).

The flexibility inherent in the bus park-and-ride operation also makes obtaining reliable operating cost data difficult. Because buses used in park-and-ride service may also be used in off peak hours on normal bus routes, transit operators generally do not distinguish between revenue and operating costs for these buses.

Examples of Park-and-Ride Operations in the United States

Table 5-14 presents characteristics of bus park-and-ride operations in selected U.S. cities. Table 5-15 shows mode of arrival to park-and-ride lots in selected U.S. cities. On the average, 62% drive alone to the site and another 21% are carpoolers or kiss-and-ride patrons. On the average 8% walk to the lot while 4% use local bus service.

Table 5-14
Characteristics of Park-and-Ride Facilities in Selected U.S. Cities

Park-and-Ride Location	Parking Spaces Provided	% of Spaces Utilized	Route Distance to CBD		Type of Lot Utilized
			Miles	Minutes	
Seattle Blue Streak	525	100	7.0	---	multiple use
Hartford, Conn.	250	60	7.0	13-18	multiple use
Richmond, Va.	337	100	11.0	18-23	single use
Lincoln Tunnel, N.J.	1600	99	2.5	---	single use
St. Louis	1000	100	5.0	17	---
Louisville, Ky.	170	---	8.5	---	---
Rochester, N.Y. (avg. of 25 lots)	67	---	18.2	49	---
Washington, D.C.	800	---	---	---	---
Milwaukee, Wis.					
Mayfair	300	50	10.0	21	multiple use
Bayshore	150	77	7.0	10	multiple use
Treasure Island South	100	50	10.0	20	multiple use
Treasure Island North	100	30	12.0	22	multiple use
Country Fair	50	50	14.0	20	multiple use
Spring Mall	100	30	10.0	15	multiple use

Source: Adapted from reference 23.

Table 5-15
Mode of Arrival to Park-and-Ride Lots in Selected U.S. Cities

City	Drove Alone	Rode with Other Park-and-Ride or Kiss-and-Ride User	Walked	Local Bus	Other
Miami, FL	53	23	--	12	12
Dade County, FL	45	16	36	2	1
Milwaukee, WI	46	33	12	9	--
Washington, DC	76	18	3	3	--
Hartford, CT	66	30	4	--	--
Pittsburgh, PA	63	20	8	6	3
Los Angeles, CA	74	17	4	4	1
Seattle, WA	76	18	3	3	--
Shirley Highway, VA	70	14	--	--	16
Unweighted Average	63	21	8	4	4

Source: Adapted from reference 18.

Texas Park-and-Ride Applications

Texas' first bus park-and-ride serves the state's only subway. In 1963, Leonard's Department Store opened a parking lot one mile from the Fort Worth CBD at the terminal of the subway (18). With three joint-use park-and-ride lots, Corpus Christi Transit System recently joined the cities of Dallas, El Paso, Fort Worth, Houston and San Antonio in providing bus park-and-ride service (Table 5-16). Table 5-17 shows the bus park-and-ride ridership as a percent of the market area population. National data suggest that properly placed park-and-ride lots on congested travel corridors may attract up to 2.5% to 3.0% of the total market area population (18).

Table 5-16
Park-and-Ride Lots in Texas, 1985

City	Number of Lots	Number of Spaces	Spaces Used
Austin	8	435	173+
Corpus Christi	3	NA	82
Dallas/Garland	15	6,229	4,167
El Paso	4	286	156
Fort Worth	35	NA	840+
Houston	17	17,207+	7,835+
San Antonio	9	1,475	672

Note: NA indicates data not available.
Source: Transit systems in Austin, Corpus Christi, Dallas, El Paso, Fort Worth, Houston, and San Antonio.

Table 5-17
Texas Cities' Park-and-Ride Ridership Based on Market Area Population

City	Ridership as a Percent of Market Area Population
Houston	0.7% to 2.0%
Dallas Area	0.4% to 1.3%
San Antonio	varies up to 1.2%
Austin	0.3% to 0.6%
Fort Worth	0.05% to 0.3%
El Paso	0.07% to 0.4%

Source: Reference 18.

Table 5-18 shows the mode of arrival at park-and-ride lots.

Table 5-18
Mode of Arrival at Park-and-Ride Lots

Arrival Mode	El Paso	San Antonio	Dallas/ Garland	Houston	Fort Worth	Non-Weighted Average
Drove alone	40%	64%	66%	68%	57%	59%
Rode with other park-and-ride user	5	3	9	11	8	7%
Dropped off	31	19	20	15	26	22
Walked	21	4	0	5	8	8
Another bus	3	10	--	--	--	3
Other	--	--	5	1	1	1

Source: Reference 18.

The primary market area, or watershed, for park-and-ride service is the geographical area from which the users originate. The size of the park-and-ride watershed depends upon the type of the facility: remote, local or peripheral. Surveys have indicated that the watershed areas for peripheral lots extend across urban areas without any recognizable pattern, whereas, remote and local service facilities have relatively localized watershed areas. This difference is due to the basic nature of each type of facility. Peripheral lots are essentially parking lots on the edge of a major activity center and, as such, are used by people whose final destination is near the lot. Remote and local service lots that are near the "origin" end of the trip, on the other hand, are used by people who live close to the lot and whose destination is near the bus route's terminus (18).

Nearly 60% of Texas park-and-ride patrons drive alone to the lots. An additional 7% carpooled to the lot while 22% were dropped off as kiss-and-ride users. Eight percent walked while 3% took a bus. Compared to the country as a whole, more Texans carpooled or were dropped off at the lot than were their national counterparts. Texas park-and-ride patrons traveled by bus or walked in percentages similar to their national counterparts. Table 5-19 shows the Texas and national average mode of arrival at park-and-ride lots.

Table 5-19
Comparison of Mode of Arrival to Park-and-Ride Lots: United States and Texas

Arrival Mode	Texas Average	U.S. Average
Drove alone	59%	63%
Rode with other park-and-ride or kiss-and-ride user	29	21
Walked	8	8
Another Bus	3	4
Other	1	4

Source: Adapted from references 18 and 24.

Houston experience indicates that ridership at bus park-and-rides increases significantly when provided in conjunction with express bus service over a reserved bus lane. It appears that bus modal splits at least in the range of 25% are associated with those lots served by a busway (as compared to modal splits of 15% for lots not served by a busway).

The current Texas properties operating bus park-and-ride indicate plans to expand significantly their park-and-ride service. The remaining transit systems do not indicate any plans to initiate park-and-ride service (2).

Bus Rapid Transit Operations

Four specific modes of bus operation provide high-speed primary bus transit service. These include operation in mixed traffic on freeways, operation over reserved bus lanes on freeways, operation over exclusive busways and preferential operations on surface arterials.

Mixed Traffic Operation on Freeways

The least capital intensive of the four bus rapid transit operations, bus operations in mixed-flow traffic on freeways is the most common type of rapid transit service provided by bus (8). Using existing freeways, buses make their line-haul portion of each trip with or without intermediate stops. Thus, buses operate at speeds higher than possible on arterial streets in mixed traffic. Trip collection and distribution occurs using stops along surface streets, at local bus stops or park-and-ride facilities.

Design and Operating Characteristics

Bus routing and frequency of stops are the two system characteristics most important to the definition of express bus service. An express bus must follow a route length of at least 5-10 miles, connect a limited residential neighborhood and/or parking lot(s) with a major employment, transportation or recreational center and make no more than one or two intermediate stops on the line-haul segment of the trip (25). Here the conventional rubber-tired motor bus operates over conventional freeway lanes that are open to all motor vehicle traffic. Preferential bus access to the freeway may or may not be protected. For a service to be a mixed-flow freeway operation, it must meet the following conditions:

- Conventional diesel-powered, rubber-tired transit vehicles of single-level, articulated or double-deck design serve as the vehicles;
- Operations must occur in mixed traffic, the line-haul being over a divided, limited-access, fully grade-separated facility; and
- Passengers pay fares (or show pre-paid pass) on-board (8).

Attributes

Bus operations in mixed traffic on freeways possess certain characteristics requiring planning consideration:

- Since existing freeways serve as guideways for the trip, initial capital costs for construction are minimal. Initial costs include vehicle acquisition, storage and maintenance. If bus priority access to the freeway is desired, then capital costs of the control equipment need inclusion in cost estimates;
- Since this treatment requires no major capital investment, this treatment offers relatively short implementation time and very little community disruption;
- The vehicle providing line-haul service can also act as its own feeder and as distribution vehicle. With this flexibility, buses can offer their patrons a no-transfer ride; and
- Freeway traffic conditions limit the speeds at which the buses can operate.

Capital and Operating Costs

Since the mixed traffic operation of buses on freeways utilizes existing facilities, this mode has little initial investment. Priority entrance ramps to freeways cost from $20,000 to $120,000 depending upon the site (26). Annual operating cost per priority entrance ramp, including random enforcement and maintenance, is approximately $2,500 (26).

Existing U.S. Operations

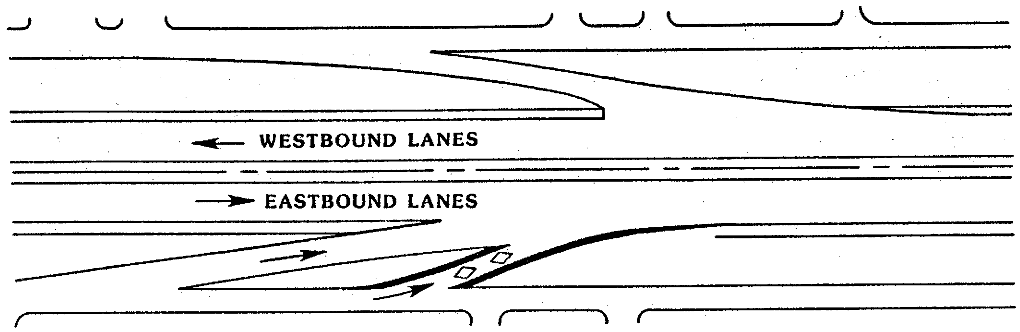
Because of its ease of implementation, bus use of freeways in mixed flow traffic constitutes the most common mode of rapid bus operations. By 1973 at least 18 major metropolitan areas had express bus service in mixed traffic on freeways (8). Since then, numerous cities have implemented this mode of transit operation. Table 5-20 shows several U.S. cities at which buses operate in mixed flow traffic on freeways.

Table 5-20
Express Bus Utilization in Selected U.S. Cities

City	Project	Months of Service	Daily Bus Trips	Daily Patronage Total	Average Number of Passengers/ Bus Trip[1]
Richmond	Parham P&R	12	--	1,100	--
Hartford	Corbins P&R	9	26	600	23.1
	Burr P&R	3	26	480	18.5
Louisville	P&R/Express Bus	avg. of 16	32	588	18.4
Cincinnati	P&R/Express Bus	avg. of 6	26 P&R 52 total	1,097	48.0
Denver	Current Area P&R/Exp. Bus	N/A	276	5,903	21.4
Seattle	Blue Streak (1 P&R lot)	18	545	11,189	38.7
Milwaukee	Fwy. Flyer	variable	--	2,800	--
Miami	I-95 Mixed	4	52	1,160	22.3
	NW 7th Ave.	18	52	1,552	29.8
Minneapolis	I-34W P&R/Exp. Bus	38	225	7,100	31.6
Dallas	Spring Creek Express Bus	22	27	405	15.0
	N. Central P&R	3	73	1,608	28.0
Washington, D.C.	P&R/Express Bus				
	New Routes	--	34	1,320	38.8
	Expanded	--	30	1,600	53.3

[1]This is for the peak period.
Source: Adapted from reference 23.

Fewer cities, however, offer priority access to buses entering the freeway traffic. For example, Los Angeles, Dallas, San Diego, Milwaukee, Minneapolis, Houston and San Francisco have, at some locations, modified the metered freeway entrance ramps to allow high-occupancy vehicles (buses, vanpools and sometimes carpools) to bypass the meter (8, 26). Figure 5-11 shows a typical priority entrance ramp.



Source: Reference 26.

Figure 5-11
Priority Entrance Ramp for Buses in Mixed Flow Operation on Freeways

Texas Applications

Nine Texas systems operate express bus service in mixed flow traffic on freeways. These include Austin, Corpus Christi, Dallas, El Paso, Fort Worth, Houston, San Antonio and Wichita Falls (2). They charge fares from $.75 to $2.25 per one-way trip. Thus, patrons pay a premium for express service over regular route service where $.37 is the average fare charged (2).

Few Texas cities, however, provide priority entrance ramps for buses in conjunction with their express bus service. Dallas and Houston provide the only priority entrance ramps (26). In 1977, Dallas initiated the first priority entrance ramp for high-occupancy vehicles in Texas. Located on North Central Expressway at Mockingbird Lane, the ramp is used exclusively for buses. Dallas opened its second ramp on R. L. Thornton Freeway (I-30) at Ferguson for use by buses and carpools with three or more occupants. Houston has two such ramps at Southwest Freeway (US 59) and Bellaire and at Southwest Freeway and Hillcroft. Buses and vanpools use the priority ramps in Houston. Table 5-21 shows the volumes for these priority and non-priority entrance ramps.

Table 5-21
Ramp Volume Summary for Selected Priority Entrance Ramps in Texas

Site	Average Non-Priority Volume (vehicles/hour)	Average Priority Volume (vehicles/hour)			Avg. Total Passenger Volume (persons/hour)
		Bus	Van	3+ Carpools	
Mockingbird (Dallas)	1445	12	--	--	2550
Ferguson (Dallas)	1040	18	5	21	2478
Bellaire (Houston)	875	9	12	--	1734
Hillcroft (Houston)	1019	15	41	--	2495

Source: Reference 26.

The travel time savings resulting from these ramps is from .75 minutes per person where traffic is not metered to 4.92 minutes per person with ramp meters (26). Delay savings of this magnitude show the initiation of priority entrance ramps for bus operations with mixed flow traffic on freeways to be cost-effective with benefit-cost ratios ranging from 3 up to 43 to 1 (26).

Reserved Freeway Bus Lane Operations

The concept of reserved freeway lanes for bus operations requires either the dedication of existing traffic lanes to transit vehicle use, or the installation of additional traffic lanes either in a median area, adjacent to the outside shoulder or in one of the shoulder areas. With collection and distribution services on city streets, the buses usually operate the line-haul portion on the freeway lanes. Part of the line-haul trip may take place on mixed flow lanes with reserved lanes being provided along congested freeway sections (8).

Involving minimum construction are two types of reserved bus lane operations: contraflow lanes and concurrent flow lanes. In a concurrent flow configuration, buses travel in the same direction as the other traffic. Using appropriate signing, pavement markings, and traffic cones or posts, transit and highway personnel designate the reserved, concurrent flow lane. Typically installed on the inside shoulder adjacent the median, reserved concurrent flow lanes operate without conflict of automobiles and trucks crossing the lane upon entry from right-hand entrance ramps (8).

Reserved bus lanes may also operate as contraflow lanes within freeway rights-of-way. Contraflow is a technique in which a lane in the off-peak direction is used for peak direction travel. Contraflow lanes are used when the off-peak direction has relatively light volumes and the removal of a lane would not seriously affect the off-peak flow of traffic. For planning purposes, minimum peak/off-peak directional splits for contraflow operation are 60/40. The minimum freeway cross section applicable to contraflow is a 6 lane facility which would allow 2 lanes in the off-peak direction while the contraflow lane is in operation. From the use of traffic cones to lane control signals, contraflow lane designation uses a range of traffic engineering measures to initiate potential problems associated with operations "in the wrong direction." Contraflow lanes operate on the inside lane adjacent the median (8).

Most contraflow and concurrent flow lanes operate during weekday peak hours with the reserved lanes open to mixed traffic during off-peak hours and on weekends. Table 5-6 shows bus operating speeds on reserved freeway lanes. Actual operating experiences of buses on the North Freeway contraflow lane in Houston suggest operating speeds of 55 mph are possible (25). Table 5-22 presents some characteristics of concurrent flow bus operations and Table 5-23 gives this for contraflow lane operation.

Table 5-22
Selected Characteristics of Concurrent Flow Reserved Freeway Lanes
in the United States: 1978

Characteristic	Boston	Honolulu	Miami	Northern New Jersey	New York City	Portland	San Diego	San Francisco	San Francisco	San Francisco
Freeway Utilized	IH 93	Moanalua Freeway	IH 95	IH 95	Gowanus Freeway	Banfield Freeway	Route 163	Bay Bridge	IH 580	IH 280
Length of Reserved Lane (miles)	1.0	2.7[1]/1.4[2]	7.5	2.0	1.0	3.3	0.5	0.5	3.5	2.0
Hours of Operation	AM peak	24 hours	both peak periods	AM peak	AM peak	both peak periods	PM peak	both peak periods	24 hours	24 hours
Year of Implementation	1974	1974	1976	1976	1976	1975	1974	1970	1976	1975
Traffic Control Measures	Lane markings, signing, and portable barriers	Signing and striping	Signing and striping	Signing	Signing and striping	Signing and striping	NA	Toll plaza bypass	Signing and buffer lane	Signing
Number of Buses per Peak Hour	24 in peak period	11 in peak period	26	400	120	20	22	330	10	15

[1]Inbound
[2]Outbound

Source: Adapted from references 8 and 21.

Table 5-23
Selected Characteristics of Contraflow Reserved Freeway Lanes
in the United States: 1979

Characteristic Freeway Utilized	Houston IH 45	New York City Long Island Expressway	Northern New Jersey IH 495	San Francisco US 101
Length of Reserved Lane (miles)	9.6	2.0	2.5	5.0
Hours of Operation	Both peak periods	AM peak	AM peak	PM peak
Year of Implementation	1979	1971	1970	1972
Traffic Control Measures	Traffic posts, signing, & signals	Traffic cones and signing	Traffic signs and directional signals	Signs and traffic posts
Number of Buses per Peak Hour	144 in peak period	120	500-600	105
Number of Passengers per Peak Hour	5,000 in peak period	6,000	20,000+	4,000

Source: Adapted from references 4, 8 and 25.

Attributes

Bus operations over reserved freeway lanes possess certain characteristics requiring consideration when planning.

- Since this operation utilizes existing freeway facilities with relatively low-cost traffic engineering measures for lane designation, bus operations over reserved freeway lanes have low capital costs. Initial costs include vehicle acquisition, storage and maintenance.

- This relatively low capital cost means little community disruption, and relatively short implementation time.

- Vehicles providing line-haul service can also act as their own feeder and distribution vehicle. With this flexibility buses can offer patrons a no-transfer ride.

- Successful implementation of contraflow operation requires highly imbalanced peak hour traffic flows. Even so, implementation of a contraflow lane reduces available capacity in the off-peak direction resulting in lower off-peak direction speeds. The volume of passenger traffic on the contraflow must be large enough to result in a savings to off-set this loss.

- Safety considerations, not mixed flow traffic, limit the speeds at which buses may operate (8).

Capital and Operating Costs

Capital costs for reserved freeway lanes range from $6,500 to $1.1 million per lane mile (8). Table 5-24 presents typical costs. The range in costs reflect park-and-ride construction and/or sophisticated lane control equipment. Excluding park-and-ride construction, contraflow lane construction in Houston costs approximately $227,000 per mile (25).

Table 5-24
Typical Implementation Costs for Reserved Freeway Lane Operation

Item	Range of Costs per Mile[1]	Typical Cost per Mile[1]
Reserved Lane on Freeway		
Basic Lane Separation and Signing		
(theoretical minimum application)	$12,000 - $35,000	$ 22,000
Contraflow Freeway Lane		
Based on Actual Projects	$8,700 - $109,000	$ 54,000
Concurrent Flow Freeway Lane		
Additional At-Grade Lane	$500,000 - $1,100,000	$1,100,000
Additional Lane in Cut	--	2,700,000
Additional Lane on Fill	--	3,050,000
Miscellaneous		
Concrete Lane Barrier	--	$ 196,000

[1]Costs are based on 1970 data adjusted to reflect 1979 prices.
Source: Adapted from reference 8.

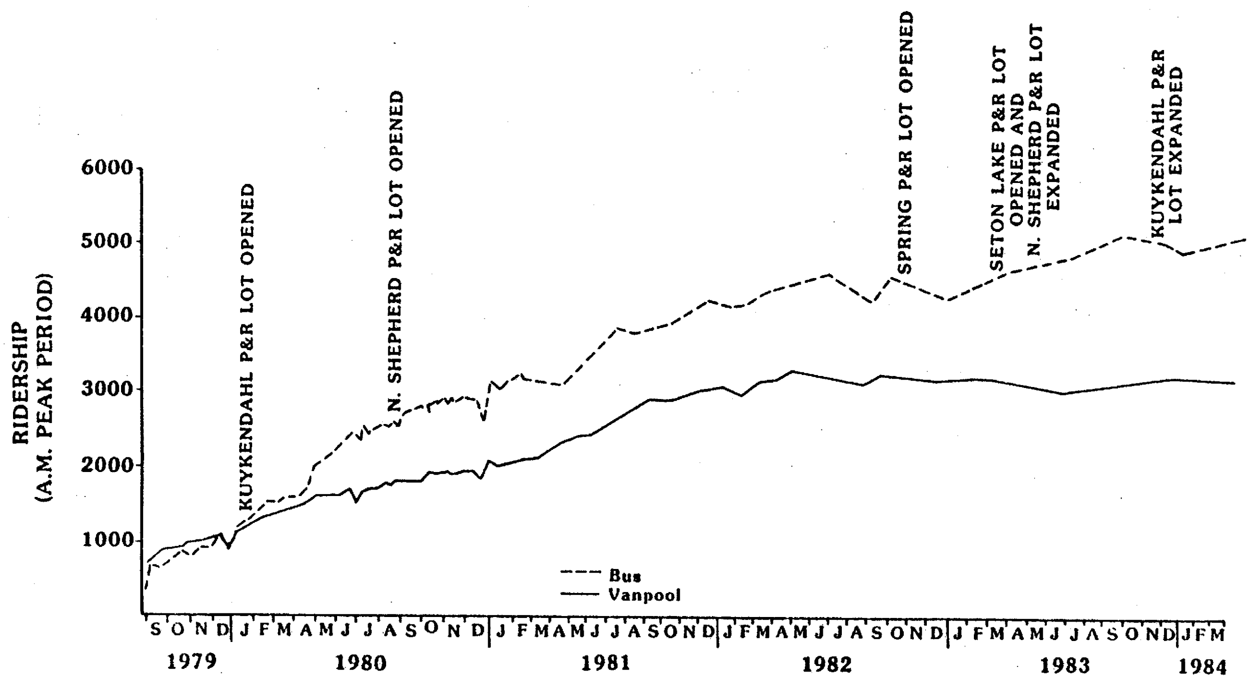
Operating costs for reserved bus freeway lanes include daily bus fleet operating and maintenance costs plus the costs associated with routine operations of the freeway lanes. Costs associated with routine operations of the lane include maintenance and repair costs, and for facilities operating parts of the day, expenses associated with lane set up and closure. The North Freeway contraflow lane in Houston experienced average operating costs and enforcement of $50,200 per month or $5,230 per lane-mile (25). This includes the cost of daily installation and removal of yellow plastic safety pylons to separate contraflow lane traffic from the opposing traffic flow.

Existing U.S. Operations

Operating since 1970, reserved freeway bus lanes reflect a new concern for maximizing passenger trips carried versus vehicles carried on freeways. The 2.5 mile I-495 contraflow lane between the New Jersey Turnpike and the Lincoln Tunnel serves as the first contraflow freeway bus lane in the U.S. (29). Tables 5-22 and 5-23 give operating and design characteristics of reserved lane bus operations in selected U.S. cities. No known reserved freeway bus lane operations exist outside the United States (8).

Applications in Texas

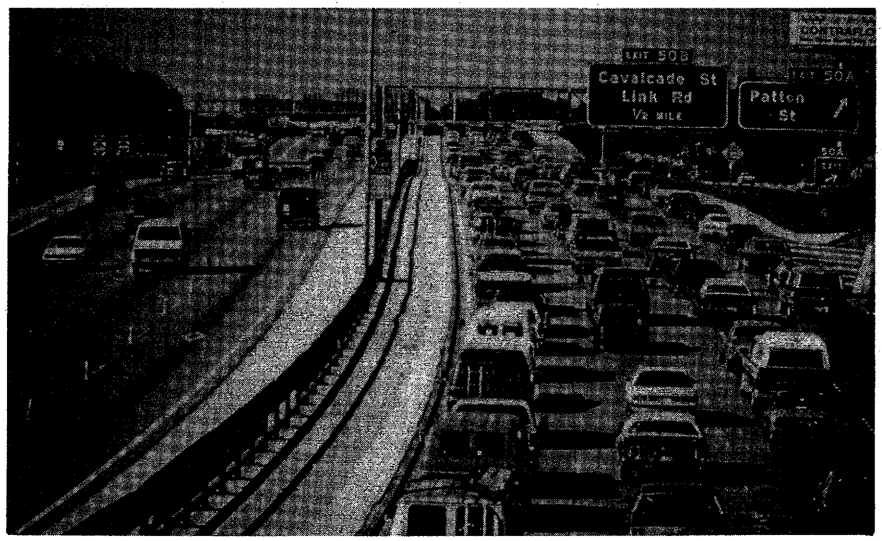
The North Freeway Contraflow lane in Houston operated from 1979 to 1984. The longest contraflow lane in the United States, the North Freeway contraflow was replaced with an exclusive busway, Phase I of which opened in December 1984. While the contraflow lane was in operation, the number of buses and vanpool users increased more than 400% which resulted in the contraflow lane having the person carrying equivalent of over two adjacent freeway lanes during peak hours (30). Figure 5-12 shows the bus and vanpool ridership on the contraflow.



Source: Reference 25.

Figure 5-12
Growth in North Freeway Contraflow Lane
Bus and Vanpool Ridership

The contraflow's impact on ridership is impressive. Approximately 35% of bus riders have stated that they would not ride the bus without contraflow service (25). Contraflow appears to impact modal split as well. Defined as the percent of market area population working in the activity center served by the park-and-ride that uses park-and-ride service, modal split at a lot served by contraflow is 43% versus 29% at a lot not served by reserved bus freeway lanes (25).



The North Freeway contraflow lane in Houston (1979-1984) carried as many persons as 2 adjacent freeway lanes during peak periods.

Busway Systems

Exclusive roadways designed, constructed and operated for motor buses, busways offer the highest quality primary transit service of all bus modes. In Texas, these lanes are also known as transitways, HOV (High Occupancy Vehicle) lanes and AVLs (Authorized Vehicle Lanes based on the need for a permit to travel on the lane). Also for use by carpools, vanpools, suburban and/or intercity buses, busways can be constructed on existing freeway or railroad right-of-way, other existing right-of-way or newly acquired right-of-way (8).

Description and Operating Characteristics

Some busways provide for simultaneous operation in both directions. Others operate inbound in the morning and outbound in the evening. Unlike bus freeway lane operations, busways utilize exclusive ramps to access the facility. Generally with ramps located between facility termini to access other routes or terminals, busway facilities can have on-line stations varying considerably in complexity. Thus, service can be express or with stops. Provided off the guideway at terminal facilities or connecting arterial streets, collection and distribution functions usually involve transfer to another bus or mode. Usually busways act as exclusive line-haul facilities for numerous routes accessing a major activity center which bypasses locations of serious peak period congestion (8).

Operating on exclusive rights-of-way, buses average between 20 and 50 mph depending upon frequency of stops and the facility's geometrics. Table 5-6 shows this mode of bus travel to exceed greatly the operating speeds of other bus operations.

With the number of buses per hour ranging from 400 to 1450, with headways of 9.0 to 2.5 recorded, respectively, busway lanes offer equivalent passengers per hour of 20,000 to 72,500 (31). Their limitation lies in that their effectiveness depends upon street distribution of buses in the activity area, i.e., the CBD. Because sections of lines using streets have lower capacity, operating speeds and reliability, these capacities represent a control for the performance and level-of-service offered by busways (3).

Attributes

Busways have certain characteristics which demand consideration in their planning.

- Although they do not involve a new technology with separate installations, busway implementation involves major facility construction and, therefore, takes a relatively long time to implement compared to other bus operations.

- Transitway implementation may result in some community disruption.

- Equaling or exceeding rail system speeds, busway operations provide very high operating speeds.

- Even when located within existing freeway rights-of-way, busways do not reduce capacity of the freeway.

Capital and Operating Costs

Capital costs for busways are difficult to estimate since it is not always possible to tell precisely what is included in the cost values. Table 5-25 summarizes available cost data. In reviewing the cost numbers, it should be noted that additional buses are required, bus maintenance facility expansion is needed, and support facilities (park-and-ride lots, bus transfer facilities) must be developed. The following might be used as guidelines for total cost per busway corridor (31).

• 50 buses at $140,000	$ 7,000,000
• 6000 park-and-ride spaces (5 lots at $5M/lot)	$25,000,000
• 1 bus transfer facility	$ 4,000,000
• 1/2 bus operating facility	$10,000,000
TOTAL	$46,000,000

Assuming that an average corridor might be 15 miles in length, the cost per mile for support facilities would be roughly $3 million (31).

Operating cost for regular route bus transit systems is in the general range of 25 cents to 30 cents per passenger-mile (Table 5-26). The cost per passenger-mile for busway operations (Table 5-27) is approximately half that cost. However, the extent and reliability of the data reported in Table 5-27 are less than desirable. For example, "1984 APTA Operating Statistics" show, for the entire Golden Gate Transit operation, an operating cost of 18 cents

Table 5-25
Estimated Cost of Exclusive Busway/High Occupancy Vehicle Facilities

Location	Distance (miles)	Estimated Cost (millions of dollars)	Cost/Mile (millions)
Houston			
Katy Fwy., Phase 1[1]	5	$ 12	$ 2.4
Katy Fwy., Phases 1-3	11	40	3.6
North Fwy., Phases 1-4[2]	17.6	75	4.3
Gulf Fwy., Phases 1-3[3]	15	80	5.3
Northwest[4]	13.8	100	7.2
Southwest[5]	8.5	85	10.0
Ottawa[6]	18.6	250	13.4
Pittsburgh			
South Patway[7]	4.5	27	6.0
East Patway[8]	6.8	113	16.6
Baltimore (proposed)[9]	12.7	127	10.0
Shirley Highway (1970)[10]	11	43	3.9
Proposed Extension	19	98	5.2
El Monte (1973)[11]	11	56	5.1
Proposed Extension[12]	1	20	20.0
Range			$2.4 - $20.0
Avg., Non-weighted			$ 8.1

[1] 1-lane reversible in freeway median, 1-grade separated access point.
[2] 1-lane reversible in freeway median, 4 grade-separated access points, 1 bus transfer center, 2 park-and-ride lots, 2 vanpool staging areas.
[3] 1-lane reversible in freeway median, 4 grade-separated access points, 1 bus transfer center, 2 park-and-ride lots, 2 vanpool staging areas.
[4] 1-lane reversible in freeway median, 5 grade-separated access points,2 park-and-ride lots.
[5] 2-lane, 1- or 2-way in freeway median, 6-grade separated access points, 2 park-and-ride lots.
[6] 2-lane, 2 direction on exclusive right-of-way, includes 26 stations.
[7] 2-lane, 2 direction on exclusive right-of-way.
[8] 2-lane, 2 direction on exclusive right-of-way, includes $7.5 million for R.O.W., 1/2 of construction cost to relocate RR.
[9] 2-lane, 2 direction on exclusive right-of-way, includes $28M for vehicles.
[10] 2-lane, 1 direction in freeway median.
[11] 2-lane, 2 direction in freeway median, includes costs to relocate RR, construct 3 passenger stations, and build or modify numerous highway, pedestrian and RR structures.
[12] A fully grade separated section extending into downtown Los Angeles

Note: In general, costs are shown in construction year dollars. No attempt has been made to express all costs in current dollars.

Source: Reference 31.

Table 5-26
Estimated 1982 Operating Cost Per Passenger-Mile, Regular Route Transit Service

City	Cents Per Passenger-Mile
Atlanta	24 cents
Chicago	28 cents
Dallas	50 cents
New York City	30 cents
Baltimore	23 cents
Los Angeles	22 cents
Pittsburgh	27 cents
San Antonio	29 cents
Miami	25 cents
Washington, D.C.	31 cents
San Diego	19 cents
San Francisco	16 cents
Philadelphia	38 cents
New Orleans	26 cents
Range	16-50 cents
Non-weighted Average	27.7 cents

Source: Reference 31.

Table 5-27
Estimated Operating Cost Per Passenger-Mile, Bus Transit on HOV Lanes

City and Mode	Cents Per Passenger-Mile	
Buses		
Houston, Contraflow (Contract Carriers)[1]		
Kuykendahl Park-and-Ride	13.1	
Spring Park-and-Ride	11.3	
North Shepherd Park-and-Ride	23.0	
Seton Lake Park-and-Ride	7.9	
Average, Houston (non-weighted)		13.8
Los Angeles, El Monte, SCRTD		5.5
San Francisco, Golden Gate Transit		9.7
Carpools/Vanpools (typical)		5-10
Bus Data		
Range		5.5 - 23 cents
Average non-weighted		11.8 cents

[1]Based on the initial contracts signed by Metro for approximately $95 per bus hour. Subsequent contracts have been considerably lower than that value.

Source: Reference 31.

per passenger-mile. The costs shown for the Houston contraflow lane appear to be reliable, however (31).

Existing U.S. Busways

Proposed in the 1960s, busways appeared in response to the demand for high-speed transit at lower costs than rail transit modes. Most transitways opened in the late 1970s and in the 1980s. Busways exist in only the largest U.S. cities: Los Angeles, Pittsburgh, Washington, D.C. and Houston.

Table 5-28
Characteristics of Busways in Selected U.S. Cities: 1984

Facility	Location	Length	Peak Hour Number of Buses	Peak Hour Passengers	Daily Passengers
South PATway	Pittsburgh	4.5	60	5,000	49,000
Shirley Busway	Washington D.C.	11.0	200	12,000	80,000
San Barnardino (El Monte)	Los Angeles	11.0	115	5,000	
North Freeway (1985)	Houston	9.6	77	4,096	16,600
Katy Freeway (1985)	Houston	6.0	28	1,763	5,700

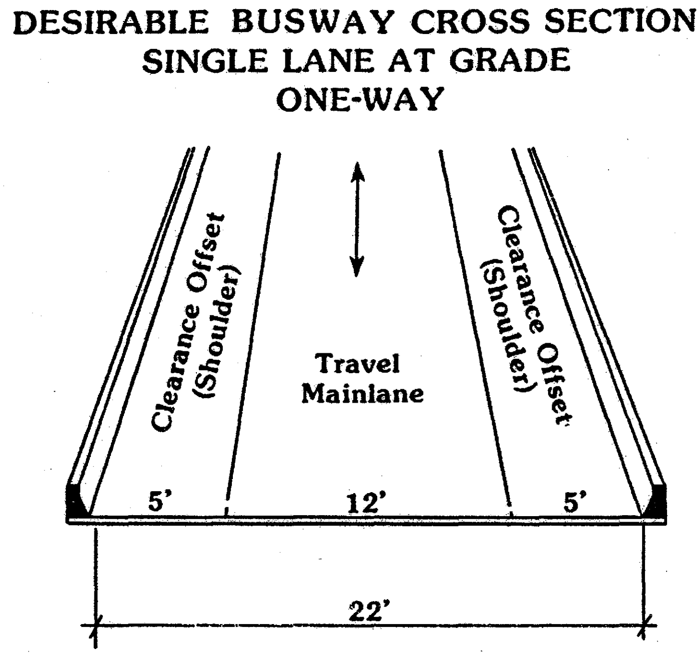
Source: Adapted from references 28, 29, 30, 31, 32 and 34.

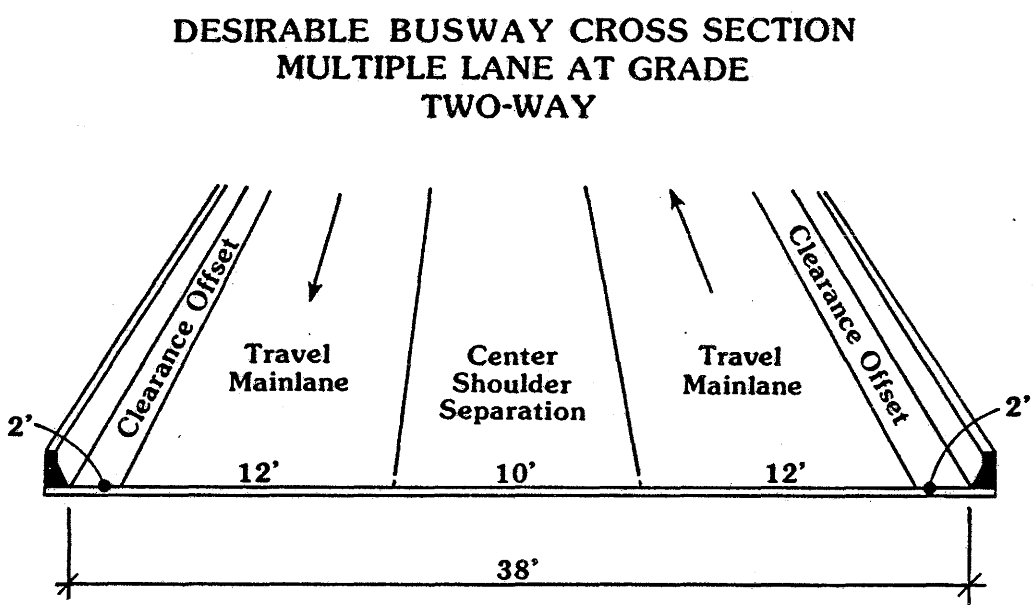
Figure 5-13 shows the desired typical cross-section for a one-lane and two-lane at-grade busway. Figure 5-14 shows an elevated flyover terminal connection to a busway, and Figure 5-15 shows an intermediate access ramp to a busway.

Applications in Texas

Dallas, Houston and San Antonio have proposals for extensive busway construction. Two busways currently operate in Houston: Katy Freeway (I-10) and North Freeway (I-45). Table 5-37 presents general characteristics of these two busways. A total of 70 miles of exclusive barrier-protected busways have been proposed in the Houston area. Approximately half of the projects are currently in various stages of development in the North, Katy and Gulf Freeway corridors (30). All of these projects include the following general characteristics:

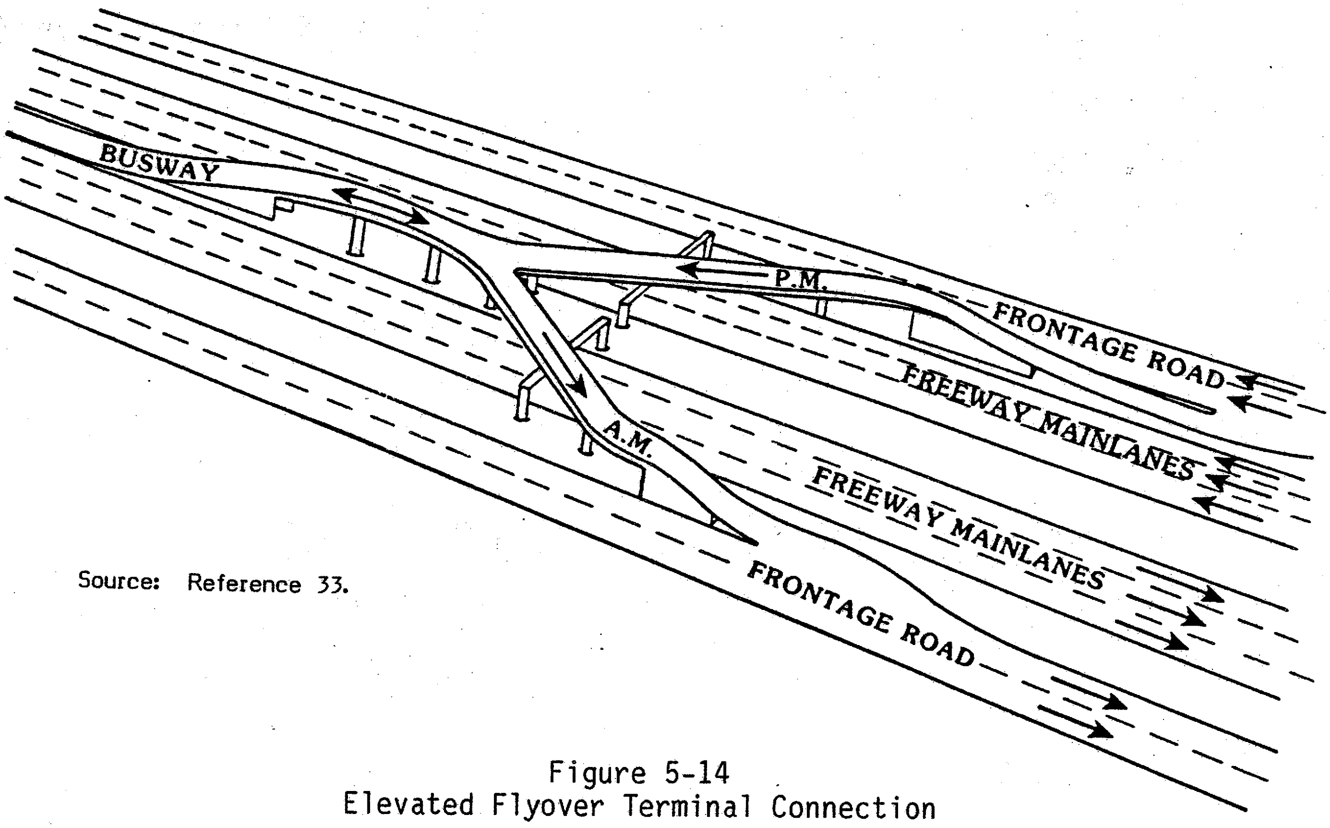
- Single, reversible lane, constructed within the existing median of the freeway and protected by concrete barriers;





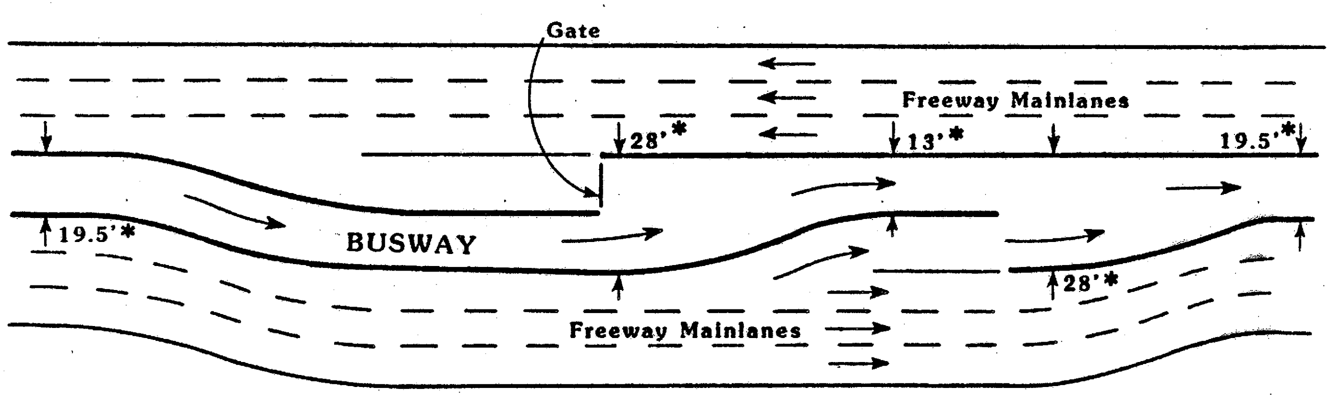
Source: Reference 33.

Figure 5-13
Mainlane Cross-Sections for Single and Multiple Lane, At-Grade Busways



Source: Reference 33.

Figure 5-14
Elevated Flyover Terminal Connection



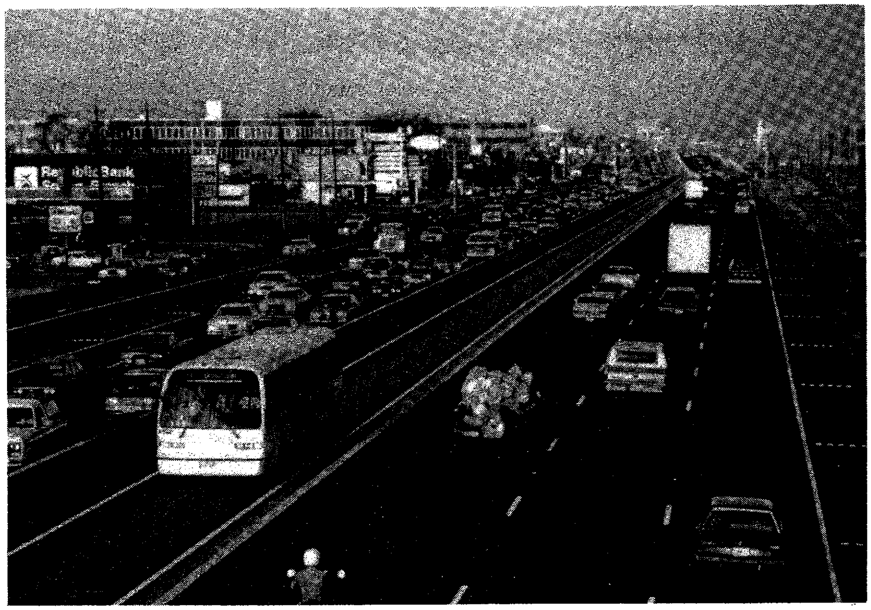
No Scale

* Inside Dimensions

Source: Reference 33.

Figure 5-15
Schematic Layout of Median Slip Ramp Intermediate Access

- Adequate space within the busway for emergency vehicle breakdowns;
- Limited, controlled access; and
- Ancillary transit facilities including park-and-ride lots and vanpool staging lots.



Busways in Houston are constructed within the existing median of the freeway and protected by concrete barriers (above). Support facilities include park-and-ride lots (below).

Configured as such, the proposed busway projects show effective benefit/cost ratios. Table 5-29 presents the benefit/cost ratios for Texas' proposed busways. Additionally, Austin's Capital Metro plans future busways along the Loop 360/US 290 corridor and the US 183 corridor (37).

Table 5-29
Estimated Benefit/Cost Ratios for Proposed Transitway Projects in Texas

City, Freeway, and Improvement		Benefit/Cost Ratio
Houston	Southwest Freeway, I-59 (W. Bellfort to Spur 527)	
	1-lane reversible	11.7
	2-lane reversible	7.5
	3-lane, 2 direction	5.4
	Eastex Freeway, I-59	
	1-lane reversible	6.8
	2-lane reversible	4.1
	West Loop, I-610 (US 290 to Fournace)	
	1-lane reversible	13.7
	2-lane, 2 direction	7.2
	Katy Freeway, I-10 (SH 6 to Washington)	
	1-lane reversible	10.3
Dallas	East R.L. Thornton Freeway, I-30	
	1-lane reversible	3.3
	Stemmons Freeway, I-35 E	
	1-lane reversible	5.4
	2-lane, 2 direction	6.8
	North Central Expressway, I-75	
	1-lane reversible	10.0
	2-lane reversible	8.0
	LBJ Freeway, I-635	
	2-lane, 2 direction	6.1
San Antonio	I-10 W Freeway (Huebuen to Callaghan)	
	1-lane reversible	3.4
	I-10 W Freeway (Callaghan to Cincinatti)	
	1-lane reversible	2.8
	I-10 W Freeway (Cincinatti to CBD)	
	1-lane reversible	1.5

Source: Adapted from references 31, 35 and 36.

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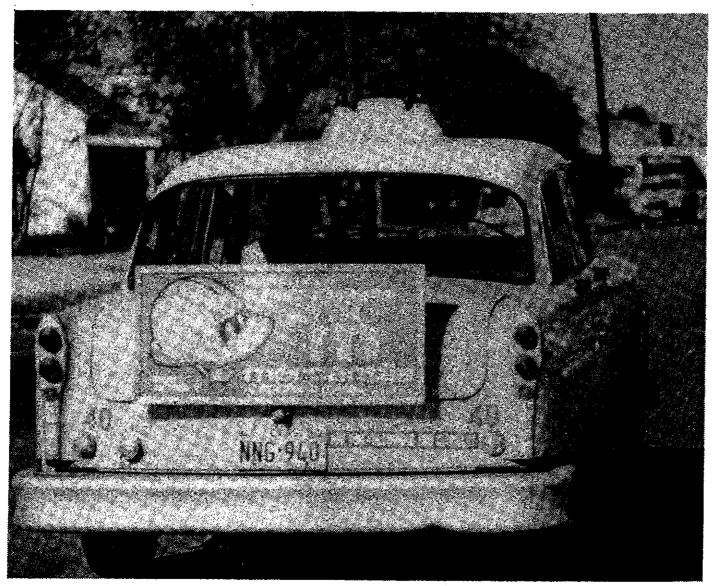
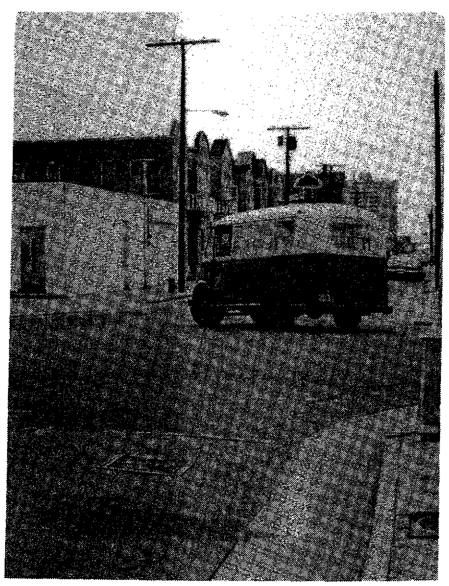
Chapter 6





Paratransit

•6•

Paratransit

The vast majority of regular public transportation services in most urban areas of the United States and Canada are provided by fixed-route rail and diesel motor bus transit systems (discussed in Chapters 3 and 5, respectively). These conventional transit modes play important roles in providing line-haul transit service along high-density corridors; however in certain instances they may be rather inefficient for collection and distribution portions of a trip. Furthermore, fixed-route transit modes cannot efficiently serve dispersed non-corridor travel in low-density urban or rural areas. Different types of transit services are necessary to adequately fill these two needs. In addition, services that are more accessible than fixed-route service to special market segments with limited physical mobility are needed (1)*.

It has been said that fixed-route transit and the private automobile represent the 2 extremes in urban travel. Fixed-route transit systems operate in finitely defined time and space, with little privacy and limited amenities, using paid professional labor, and (generally) public ownership of the capital facilities. The automobile, on the other hand, operates in variable time and space, with complete privacy and significant amenities, with labor contributed as an "in-kind" payment for service, and (generally) using privately owned capital equipment. In recent years, attention has been focused on transit service alternatives which fall between the 2 extremes represented by fixed-route, fixed-schedule transit service and the completely flexible private automobile. These service options have been termed paratransit (1).

A more precise and functional definition of paratransit service is presented below (2):

> Paratransit is urban passenger transportation service usually in highway vehicles operated on public streets and highways in mixed traffic; it is provided by public or private operators, and it is available to certain groups of users or to the general public, but adaptable in its routing and scheduling to individual user's desires in varying degrees.

*Numbers in parentheses refer to references listed at the end of the chapter.

Specialized Services Provided by Paratransit

Paratransit systems can effectively function in a variety of transportation roles including:

- Citywide transit in which the transit demand of an entire city is served;
- Transit feeders for line-haul transit service;
- Low-density urban or rural transit where demand is too low or too unpredictable to be adequately served by conventional fixed-route transit modes; and
- Specialized transportation service for elderly and handicapped persons who are unable to use conventional fixed-route modes.

Three different modes typically used to provide public paratransit service (i.e., service adjustable to the individual user's desires which is open to the general public) are discussed in this chapter. These modes are demand-responsive (dial-a-ride) service, taxicabs, and jitneys.

Unlike rail, electric trolley bus and diesel motor bus transit modes, paratransit modes are characterized by the type of usage, ownership and type of operation, rather than by technology; paratransit vehicles vary only in size and body designs, but they are all (with very few exceptions) highway vehicles powered by internal combustion engines. A significant amount of auxiliary equipment is typically required on paratransit vehicles, including a 2-way radio, wheelchair lifts and ramps, and passenger and wheelchair restraints.

Paratransit systems can effectively function in a variety of roles, such as specialized door-to-door transportation for handicapped persons who are unable to use fixed-route transit.

Demand-Responsive Transportation Service

Description

Demand-responsive transportation refers to a range of public transportation services that fall between fixed-route scheduled bus and conventional taxicab service. Those services are generally characterized by the following.

- Demand-responsive services utilize flexible routing and scheduling.
- Relatively small vehicles (small transit buses or vans) are typically used.
- Customary method of hailing a demand-responsive vehicle is by telephone.
- Transportation service is of a personalized, door-to-door nature.
- Fare collection is on-board.
- Demand-responsive transit systems are typically publicly owned and operated.

Design and Operating Characteristics (4, 5)

A user of demand-responsive transit typically telephones in a request for service to a central location and provides information concerning his origin address, destination address, desired arrival at his destination and the number of persons in his party. The dispatcher then chooses the vehicle that is in the best position to serve the new request, and updates the scheduled stops of that particular vehicle to incorporate the new request. The caller is then given the expected time of pickup based on the updated schedule. The vehicle operator is informed by radio about the revised future stop schedule and amends the route accordingly.

Automation of Scheduling and Dispatching Functions (6). Six basic "methods" of scheduling and dispatching demand-responsive vehicles have been identified based on the degree of automation used.

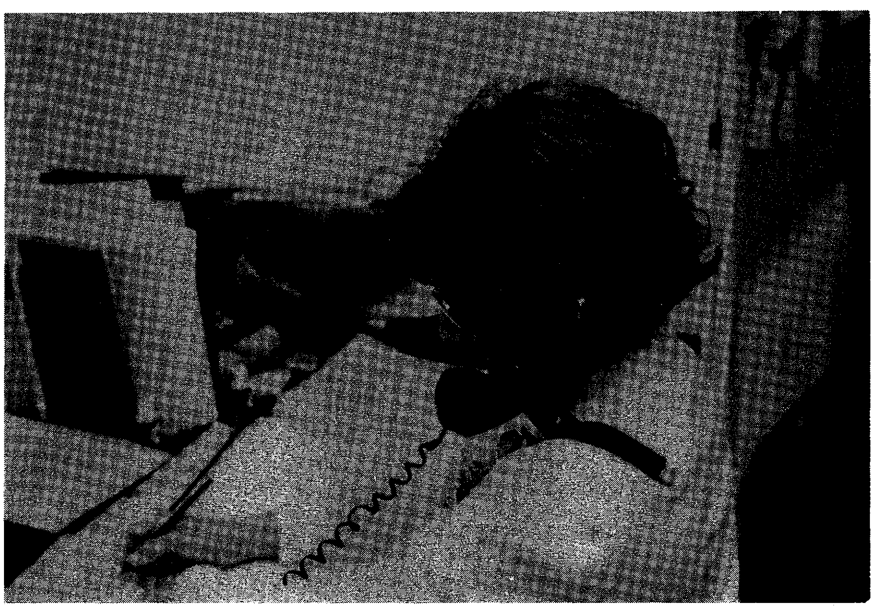
- **Manual System** - Systems that manually schedule and dispatch services are typically small, target market services that are restricted to pre-arranged and/or subscription service.
- **Manual System with Markers or Maps** - This type of system combines manual controls with either voice or digital communications. With this system, requests for service are recorded on slips of paper and different markers are used to identify vehicles and pick-up and drop-off points on a service area map.

- **Computer-Aided System** - With this degree of automation, a computer is used as a control aid for the dispatcher. Vehicle "tours" are stored manually to simplify the record keeping and scheduling process.

- **Computer Decision with Manual Override Systems** - Computer-assisted scheduling systems permit telephone operators to enter each service request into the computer system. Dispatchers can then select one vehicle from a limited number of alternatives presented by the computer.

- **Fully Operated Systems** - These systems use algorithms to assign each request to a vehicle according to some specified objective (such as minimizing ride and wait times). Street addresses of riders are fed into the computer and translated into coordinates for the selection of the most appropriate vehicle for the trip. While computers have proven to be more accurate than humans at scheduling vehicle arrivals, they do not always choose the best routes to minimize passenger travel time.

- **Integrated Computer Control** - At this level of computerized dispatching and scheduling, the computer is able to coordinate transfers between fixed-route and other demand-responsive modes. More communication links can be provided and riders may even "talk" directly to the computer to request service. The computer also has the capability of reminding the control center staff to telephone clients just before pick-up to reduce vehicle wait times.



Requests for demand-responsive transportation are typically telephoned in to a central dispatching location.

Vehicles. The size and types of vehicles used to provide demand-responsive service vary according to the size of the operation. Generally speaking, demand-responsive systems utilize either small capacity transit coaches or vans.

Demand-responsive transit systems typically provide service in small capacity buses or vans.

Travel Ways and Stops (1, 4). Demand-responsive transit vehicles travel on existing street systems in mixed traffic. The routing and stops vehicles make while in operation vary from one system to the next, however. Examples of alternative types of operations are presented below.

Route-Deviation Service. The demand-responsive vehicle operates over a fixed route, but will deviate from the route upon request in order to pick up or drop off passengers. After the customer is served, the vehicle will return to the fixed route.

Point-Deviation Service. A specified number of checkpoints are established which generally correspond to major activity centers. Demand-responsive vehicles stop at these checkpoints at scheduled times to pick up or drop off passengers. In between the checkpoints, the vehicles can deviate to pick up or drop off passengers on request at any point provided there is enough time to arrive at the next checkpoint on schedule.

Many-to-One. The demand-responsive vehicle collects clients from multiple locations and transports them to one common destination.

Many-to-Few. The demand-responsive vehicle collects clients from multiple locations for transportation to a limited number of destinations.

Many-to-Many. The demand-responsive vehicle provides service from any origin to any destination.

Figure 6-1 illustrates the difference between the various alternative types of operations.

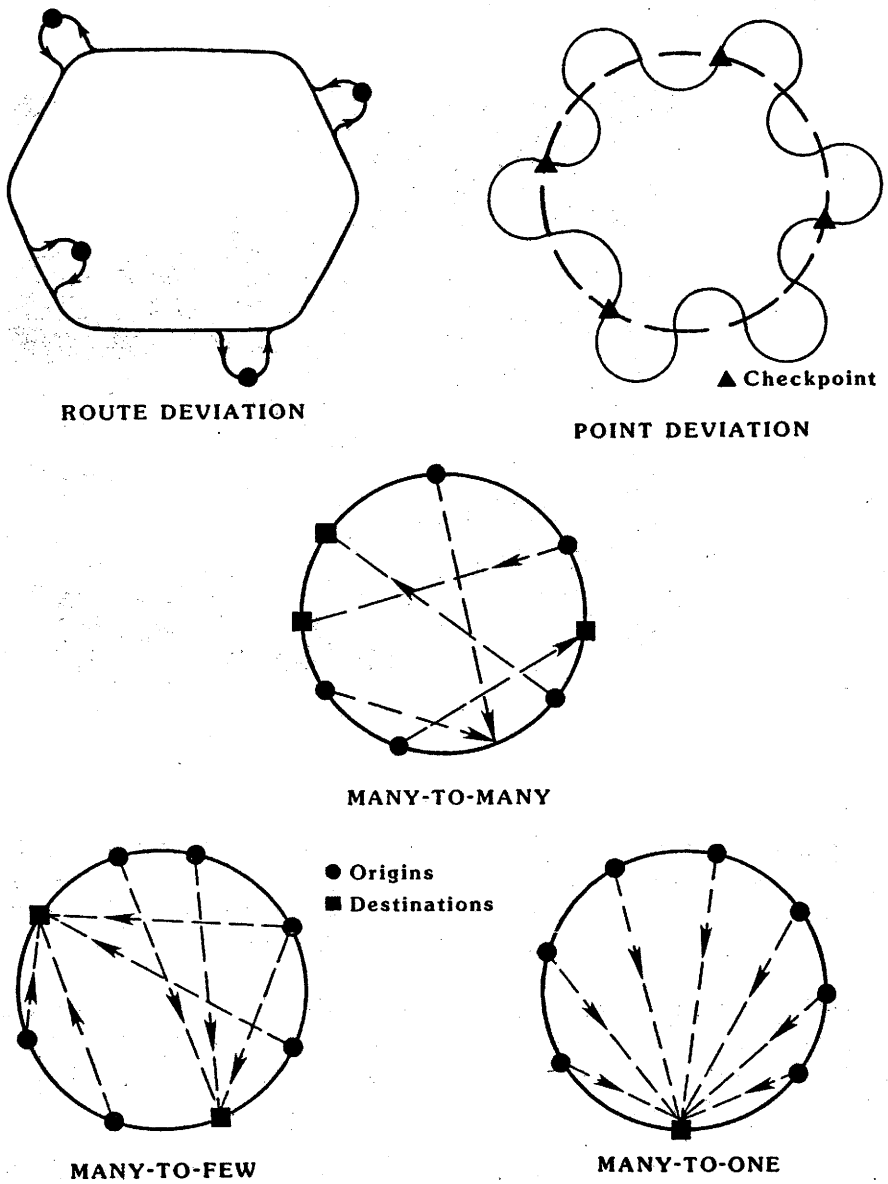


Figure 6-1
Types of Demand-Responsive Transportation Service

Operations and Performance Characteristics. Operating and performance characteristics of speed, headway and capacity which define conventional fixed-route rail, trolley bus and motor bus modes do not apply to demand-responsive transportation systems. Because of the nature of its services (flexible routing and scheduling), the characteristics of speed, headway and capacity will necessarily vary from one vehicle to the next, and from one type of operation to the next. Productivity is measured in other means such as passengers per vehicle hour of service.

Attributes (5, 7)

The following attributes of demand-responsive transit should be considered in system planning.

- Demand-responsive transportation systems operate on the existing roadway network.
- Demand-responsive transportation service operates only when and where required.
- Demand-responsive systems are designed to provide a guaranteed seat, door-to-door service at a reasonable fare with reasonable waiting time and ride time.
- Vehicles are typically low-capacity, easy to handle and suitable for turning around in driveways where necessary.
- A wide range of possible demand-responsive applications are possible from few-to-one through many-to-many, depending upon local needs.
- Implementation of demand-responsive service can be accomplished on an incremental basis based on the demand for service.

Examples of Existing Demand-Responsive Transportation Systems in the U.S.

The conceptual and development work on "modern" demand-responsive (dial-a-ride) service was largely performed in the 1960s by staffs of the Ford Motor Company, General Motors Research Laboratories, Massachusettes Institute of Technology and Northwestern University, although demand-responsive shared-ride taxicab services have existed in some U.S. communities as early as the 1930s. Three of the most notable of the early demand-responsive services were the UMTA demonstration programs in Rochester, New York, Haddenfield, New Jersey and Ann Arbor, Michigan.

By the end of 1983, a total of 231 demand-responsive services were in operation and had submitted financial and operating statistics to the Urban Mass Transportation Administration. Approximately 17% of these systems operated demand-responsive service exclusively, while the remaining 83% offered demand-responsive service in addition to various fixed-route modes (9). The large increase in the provision of demand-responsive service stems largely from the desire to better meet the needs of elderly and handicapped persons through the provision of specialized door-to-door transportation rather than by accessible fixed-route modes.

Characteristics of selected demand-responsive operations in Texas and the U.S. are presented in Table 6-1. Annual patronage and the employees per million passengers for these operations are presented in Table 6-2 and estimated passengers per vehicle-hour are presented in Table 6-3.

Table 6-1
Characteristics of Selected Demand-Responsive Transportation Systems

Location	1980 Urban Area Population (000)	Population Density (ppsm)	Total Revenue Vehicles	Adult Fare ($)	Annual Passengers (000)	Annual Passenger-Miles (000)	Annual Vehicle-Hours (000)
Texas Cities							
Arlington	2,451[1]	1,915[1]	5	NA	29.0	211.7	
Austin	380	2,692	21	.60	106.1	665.7	53.4
Corpus Christi	246	1,756	9	.50	53.9	184.7	14.2
Dallas	2,451[1]	1,915[1]	175	.50	89.2	807.1	82.8
El Paso	454	2,703	15	.50	51.9	378.2	24.0
Fort Worth	2,451[1]	1,915[1]	14	NA	76.3	547.1	23.6
Houston - METRO	2,413	2,300	4	1.00	8.9	71.4	5.8
Houston - GHTC	2,413	2,300	72	NA	456.4	4,752.3	255.6
Lubbock	175	1,867	3	1.00	10.9	73.4	4.8
Midland	72	1,989	15	2.00	129.8	656.3	37.4
Port Arthur	119	1,261	3	.50	7.6	75.5	5.6
San Antonio	945	2,669	41	.50	85.6	532.5	37.5
Waco	134	1,245	2	.60	3.8	12.6	4.0
Other U.S. Cities							
Ann Arbor, MI	209	3,163	15	.60	1,096.9	---	42.1
Cleveland, OH	1,752	2,786	81	.40	578.7	2,043.8	108.7
Columbus, OH	834	2,733	12	.60	51.1	428.2	24.5
Detroit, MI	3,809	3,649	255	NA	1,346.6	9,297.2	364.7
Gary, IN	6,780	---	22	2.50	109.0	1,416.5	58.4
Hartford, CT	510	---	80	NA	341.1	2,271.3	104.5
Jackson, MS	265	1,541	11	.25	67.0	202.4	6.3
Lexington, KY	194	2,554	11	.50	70.0	414.7	21.5
Los Angeles, CA	9,479	5,189	120	NA	570.4	1,678.5	246.6
Miami, FL	1,608	4,730	95	2.00	167.1	1,207.9	385.5
Milwaukee, WI	1,207	2,433	551	1.50	459.4	2,362.6	216.5
Minneapolis, MN	1,788	1,824	77	.75	410.6	2,317.3	134.0
New Bedford, MA	142	3,507	8	.20	22.3	110.2	11.0
Orange Cnty., CA	9,479	---	123	.75	759.9	2,641.3	220.5
Phoenix, AZ	1,409	2,199	155	1.25	518.2	3,038.4	196.5
Portland, OR	1,026	2,940	92	.50	384.3	1,423.4	92.1
Reno, NV	162	2,254	24	.60	111.3	536.1	34.5
Rochester, NY	606	3,015	25	.70	111.5	674.9	NA
Spokane, WA	267	2,493	23	.60	73.8	332.9	43.6
Topeka, KS	126	2,031	5	1.50	17.0	135.9	5.1
Tuscon, AZ	450	2,601	33	.75	288.3	1,164.5	122.5

[1]Population of the Dallas-Fort Worth metropolitan area.

Source: Reference 9, supplimented with information from the various transit operators listed.

Demand-responsive systems provide a guaranteed seat and door-to-door service.

Table 6-2
Employees Per Passenger for Selected Demand-Responsive Transportation Systems in the U.S.

System	Annual Patronage (millions)	Number of Employees	Employees Per Million Passengers
Texas			
Arlington	.029	11	379.3
Austin	.106	28	264.2
Corpus Christi	.054	10	185.2
El Paso	.052	23	442.3
Fort Worth	.076	15	197.4
Houston - GHTC	.456	109	239.0
Lubbock	.011	5	454.5
Midland	.130	24	184.6
San Antonio	.086	27	314.0
Waco	.004	2	500.0
Other U.S. Systems			
Ann Arbor, MI	1.097	39	35.6
Cleveland, OH	.588	171	290.8
Detroit, MI	1.347	245	181.9
Gary, IN	.109	20	183.5
Hartford, CT	.341	63	184.8
Jackson, MS	.067	9	134.3
Minneapolis, MN	.411	70	170.3
New Bedford, MA	.022	12	545.5
Reno, NV	.111	33	297.3
Spokane, WA	.074	34	459.5
Topeka, KS	.017	5	294.1
Range			35.6 - 545.5
Avg. Non-Weighted			282.8

Source: Reference 9.

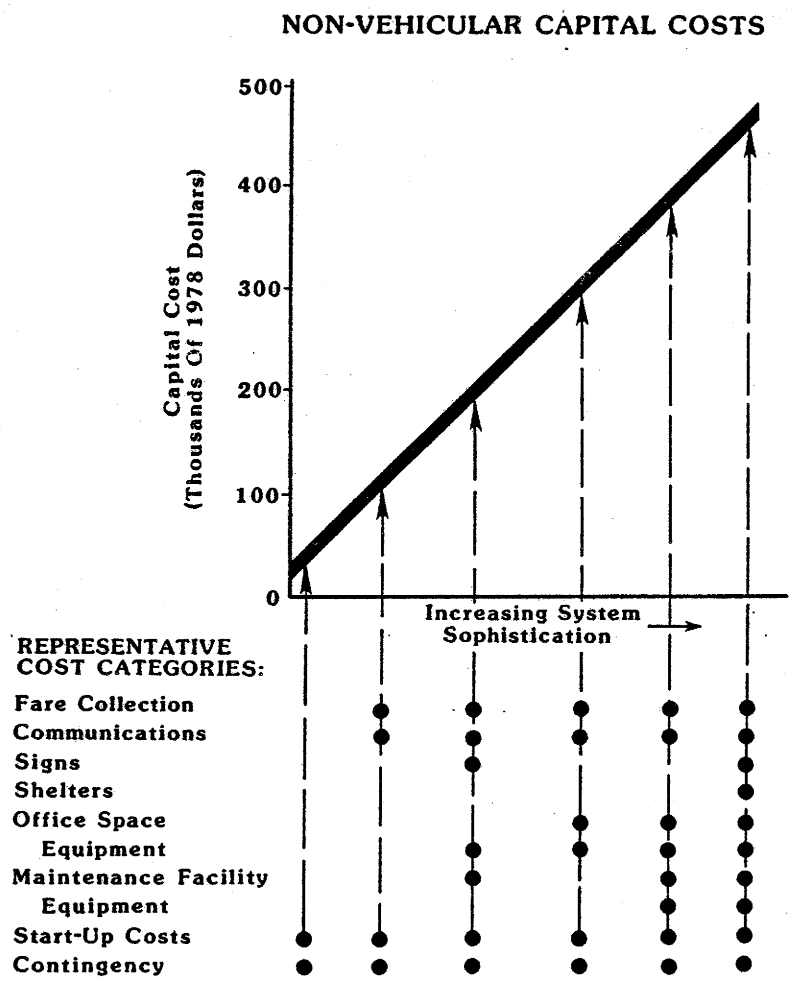
Table 6-3
Estimated 1983 Passengers Per Vehicle-Hour for Selected Demand-Responsive Transportation Systems in the U.S.

System	Annual Passengers (000)	Annual Vehicle-Hours (000)	Passengers Per Vehicle-Hour
Texas			
Arlington	29.0	9.8	2.9
Austin	106.1	53.4	2.0
Corpus Christi	53.9	14.2	3.8
Dallas	89.2	82.8	1.1
El Paso	51.9	24.0	2.2
Fort Worth	76.3	23.6	3.2
Houston - METRO	8.9	5.8	1.5
Houston - GHTC	456.4	255.6	1.8
Lubbock	10.9	4.8	2.3
Midland	129.8	37.4	3.5
Port Arthur	7.6	5.6	1.3
San Antonio	85.6	37.4	2.3
Waco	3.8	4.0	1.0
Other U.S. Systems			
Ann Arbor, MI	1,096.9	42.1	26.1
Cleveland, OH	578.7	108.7	5.3
Columbus, OH	51.1	24.5	2.1
Detroit, MI	1,346.6	364.7	3.7
Gary, IN	109.0	58.4	1.9
Hartford, CT	341.1	104.5	3.3
Jackson, MS	67.0	6.3	10.6
Lexington, KY	70.1	21.5	3.2
Los Angeles, CA	570.4	246.6	2.3
Miami, FL	167.1	385.5	0.4
Milwaukee, WI	459.4	216.5	2.1
Minneapolis, MN	410.6	134.0	3.1
New Bedford, MA	22.3	11.0	2.0
Orange Cnty., CA	759.9	220.5	3.4
Phoenix, AZ	518.2	196.5	2.6
Portland, OR	384.3	92.1	4.2
Reno, NV	111.3	34.5	3.2
Rochester, NY	111.5	---	---
Spokane, WA	73.8	43.6	1.7
Topeka, KS	17.0	5.1	3.3
Tuscon, AZ	288.3	122.5	2.4
Range			0.4 - 26.1
Avg., Non-Weighted			3.5

Source: Reference 9.

Cost of Demand-Responsive Transportation Service

Capital Cost. The capital investment required for implementing demand-responsive transportation systems will vary from system to system depending upon the size, type, and level of sophistication of the operation. Capital assets include vehicles, shelters and signs (if appropriate), communication equipment, fare collection equipment, office space, maintenance facilities, office furnishings, maintenance equipment, start-up costs and contingencies. Actual capital requirements will vary widely because of opportunities for sharing some assets with other services. Figure 6-2 illustrates the non-vehicular capital assets as a function of the types of support equipment that is provided. As a bare minimum, a new service needs \$20,000-\$30,000 to cover start-up costs and a contingency against delays, unexpected difficulties and low initial revenues. At the other extreme, as much as \$500,000 can be in a full set of support equipment (6).



Source: Reference 7.

Figure 6-2
Non-Vehicular Capital Costs Associated With
Implementing Demand-Responsive Transportation Systems

The cost of lightweight accessible demand-responsive vehicles (in 1980) ranged from $16,000 to $29,000 for modified vans and from $14,000 to $35,000 for small buses (10).

Operating Costs (9). Estimated operating costs per passenger, per passenger-mile and per vehicle-hour for selected demand-responsive systems operating in Texas and the U.S. are presented in Table 6-4. As this table indicates, operating costs vary from one system to the next. Excluding the Houston METRO data, 1983 operating costs per passenger transported ranged from $1.44 to $13.93, operating costs per passenger-mile ranged from $0.30 to $3.09, and operating costs per vehicle-hour ranged from $4.78 to $41.68.

A breakdown of the distribution of demand-responsive transportation costs, as presented in Table 6-5, shows the labor intensive nature of this transit mode.

Source of Operating Revenue (9). Sources of operating revenue for 2 demand-responsive systems in Texas and the average for 38 demand-responsive systems in the U.S. are presented in Table 6-6. As indicated by this table, passenger fares typically account for only a small percentage of operating revenue. In Texas, operating deficits are subsidized from federal and local sources only.

Table 6-6
Sources of Operating Revenue for Demand-Responsive Transportation Systems in Texas

Sources of Operating Revenue	Texas Systems		Average for 38 U.S. Systems
	Arlington Handitran	Midland's MIDTRAN	
Passenger Fares	10.1%	11.3%	8.7%
Other Transportation Revenue	0.0%	1.5%	4.0%
Non Transportation Revenue	0.0%	0.0%	4.3%
Federal Public Assistance			
UMTA Section 5	45.0%	44.3%	16.8%
Other	0.0%	0.0%	1.9%
State Public Assistance			
General Revenue	0.0%	0.0%	5.7%
Dedicated	0.0%	0.0%	18.5%
Local Public Assistance			
General Revenue	45.0%	42.8%	17.8%
Dedicated	0.0%	0.0%	20.9%
Other	0.0%	0.0%	1.4%

Note: Percentages as reported do not add up to 100%. Figures in this table were compiled from Section 15 operating data. Becasue Section 15 does not require multi-service transit systems to report operating revenue by mode, the only demand-responsive operating revenue data that could be included in this table were from 38 systems in the U.S. (including 2 in Texas) which operate demand-responsive transportation exclusively.

Source: Reference 9.

Table 6-4
Estimated 1983 Operating Cost Per Passenger, Per Passenger-Mile, and Per Vehicle-Hour for Selected Demand-Responsive Transportation Systems in the U.S.

System	Annual Operating Cost ($000)	Operating Cost ($)		
		Per Passenger	Per Passenger-Mile	Per Vehicle-Hour
Texas				
Arlington	$ 248.0	$ 8.55	$ 1.17	$ 25.30
Austin	938.9	8.85	1.41	17.58
Corpus Christi	320.6	5.95	1.74	22.58
Dallas	628.0	7.04	0.78	7.58
El Paso	375.3	7.23	0.99	15.64
Fort Worth	439.3	5.76	0.80	18.61
Houston - METRO	6,229.9	699.99	87.25	1,074.12
Houston - GHTC	2,034.7	4.46	0.43	7.90
Lubbock	154.3	14.16	2.10	32.15
Midland	677.2	5.23	1.03	18.11
Port Arthur	76.0	10.00	1.00	13.57
San Antonio	770.8	9.00	1.45	20.55
Waco	20.2	5.32	1.60	5.05
Other U.S. Systems				
Ann Arbor, MI	1,577.3	1.44	---	37.47
Cleveland, OH	4,525.3	7.82	2.21	41.63
Columbus, OH	481.7	9.43	1.12	19.66
Detroit, MI	11,444.8	8.50	1.23	31.38
Gary, IN	422.5	3.88	0.30	7.23
Hartford, CT	1,566.1	4.59	0.69	14.99
Jackson, MS	127.7	1.90	0.63	20.27
Lexington, KY	245.4	3.50	0.59	11.41
Los Angeles, CA	3,931.2	6.89	2.34	15.94
Miami, FL	1,578.5	9.45	1.31	4.09
Milwaukee, WI	2,974.4	6.47	1.26	13.73
Minneapolis, MN	3,596.5	8.76	1.55	26.84
New Bedford, MA	228.5	10.25	2.07	20.77
Orange Cnty., CA	5,126.4	6.75	1.94	23.24
Phoenix, AZ	879.5	1.70	0.29	4.78
Portland, OR	1,851.2	4.82	1.30	20.10
Reno, NV	387.1	3.48	0.72	11.22
Rochester, NY	709.3	6.36	1.05	---
Spokane, WA	1,028.1	13.93	3.09	23.58
Topeka, KS	127.7	7.51	0.94	25.04
Tuscon, AZ	1,276.2	4.43	1.10	10.42
Range[1]		$1.44 - $14.16	$0.29 - $3.09	$4.09 - $41.68
Avg., Non-Weighted[1]		$ 6.77	$ 1.26	$ 18.39

[1]Houston data not included.
Source: Reference 9.

Table 6-5
1983 Transit Operating Expenses by Object Class for Selected Demand-Responsive Transportation Systems in the U.S.

System	Operating Expenses $000	Percent of Operating Expenses by Object Class							
		Labor	Services	Fuel and Lube	Tires and Other	Utilities	Casualty and Liability	Purchased Trans-portation	Other
Texas									
Arlington	248.0	74.1	9.3	12.0	2.1	2.0	0.0	0.0	0.5
Austin	938.9	59.3	1.2	5.9	6.0	1.4	1.2	24.0	1.0
Corpus Christi	194.0	80.5	0.0	14.1	5.4	0.0	0.0	0.0	0.0
Dallas	628.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
El Paso	355.1	73.1	0.0	19.9	5.7	0.0	0.0	0.0	1.3
Fort Worth	439.3	59.9	3.8	11.1	5.3	0.0	0.7	14.6	4.5
Houston - METRO	6,229.9	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0
Houston - GHTC	2,034.7	67.5	11.5	14.3	0.8	0.5	3.9	0.3	1.1
Lubbock	154.3	64.9	5.5	7.7	6.9	3.0	5.9	0.0	6.0
Midland	677.2	71.6	6.3	12.1	5.7	1.1	2.4	0.0	0.7
Port Arthur	76.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0
San Antonio	692.3	63.1	0.4	11.4	5.8	0.0	-0.1	18.8	0.6
Waco	20.2	83.1	0.0	12.1	2.3	0.0	2.4	0.0	0.0
Other U.S. Systems									
Ann Arbor, MI	571.1	80.3	0.0	14.4	0.0	0.0	0.0	5.3	0.0
Cleveland, OH	4,525.3	65.0	1.3	9.8	7.9	3.2	2.6	9.6	0.6
Columbus, OH	477.7	5.0						94.9	0.1
Detroit, MI	9,926.8	51.5	3.0	6.4	6.1	2.5	1.5	28.6	0.4
Gary, IN	422.5	71.7	7.2	13.5	5.5	0.0	1.7	0.0	0.9
Hartford, CT	1,586.3	51.3	2.0	9.8	7.6	2.5	2.7	22.7	1.4
Jackson, MS	127.7	74.0	5.9	7.0	6.2	1.6	2.5	0.0	2.6
Lexington, KY	245.4	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0
Los Angeles, CA	3,931.2	1.9	0.4	0.0	0.0	0.0	0.0	97.7	0.0
Miami, FL	1,578.5	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0
Milwaukee, WI	2,974.4	4.9	3.1	0.0	0.3	0.0	0.0	89.8	2.0
Minneapolis, MN	3,596.4	72.0	1.1	4.4	4.4	1.2	1.3	3.6	12.0
New Bedford, MA	228.5	75.9	2.5	9.5	1.4	2.9	5.9	0.0	1.9
Orange Cnty., CA	5,126.4	12.1	0.7	0.0	0.8	0.1	0.0	86.3	0.0
Phoenix, AZ	879.5	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0
Portland, OR	1,851.2	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0
Reno, NV	387.1	76.5	4.6	10.9	3.0	1.3	3.3	0.0	0.3
Rochester, NY	709.3	0.0	1.7	0.0	0.2	0.0	0.0	97.9	0.2
Spokane, WA	941.5	0.0	4.1	5.5	3.3	0.0	2.2	0.0	7.1
Topeka, KS	110.3	70.4	0.0	16.1	6.9	0.0	4.3	0.0	2.4
Tuscon, AZ	1.276.2	44.1	13.2	4.5	0.3	0.4	1.3	36.2	0.0

Source: Reference 9.

Application of Demand-Responsive Transportation Service in Texas

As indicated in Table 6-1 through 6-5, 13 municipal transit systems in Texas offer demand-responsive transportation service. In addition to these systems, a significant, but little understood source of demand-responsive transportation services is provided by federal, state and local human services agencies. It is virtually impossible to identify the exact number of such agencies within the state or the extent of the services they provide. The Texas State Department of Highways and Public Transportation (11) identified 493 human services agencies which provided demand-responsive transportation in Texas in 1983. A brief survey questionnaire was completed by 419 (85%) of the 493 agencies identified; it was determined that these 419 agencies has operated a total of 2,745 vehicles in 1983, 259 of which were specially equipped to transport elderly and handicapped clients.

Human services agencies in Texas have become involved in providing transportation not out of desire, but out of necessity in order to transport their clients to needed goods and services. Because such a large number of agencies are involved in the transportation field, interest in coordinating the services of these agencies has been expressed. It is important to note, however, that transportation expenditures for human services programs administered by federal agencies such as the Department of Health, Education and Welfare, the Department of Labor, the U.S. Department of Agriculture, Action, etc. are "support service" expenditures. In fact, with the exception of the Department of Transportation programs, no other federal programs identify transportation as a primary program service. For example, the U.S. Department of Labor provides funds for employment and training programs under CETA (Comprehensive Employment Training Act) and also makes funds available for transportation as a support service to assist CETA clients in obtaining and maintaining employment and/or training. Therefore, any thought of coordinating transportation services among federal human services programs will necessarily deal with coordinating support services authorized by law and regulation to more effectively carry out primary program services (12).

Coordination of services is sometimes possible, however, as demonstrated by the MIDTRAN system operated by the City of Midland. Originally, MIDTRAN was a fixed-route, fixed-schedule bus system with only limited demand-responsive service when implemented in January 1980. Due to a lack of ridership, the fixed routes were abandoned 4 months later in favor of providing strictly demand-responsive and subscription bus transportation. Today, the system continues to provide monthly subscription service for weekday commuters, and a demand-responsive service throughout the City of Midland as well as Midland County. In addition, MIDTRAN has also coordinated with most of the human services agencies in Midland to provide demand-responsive service for their clients (11, 13).

Taxicab Service

Having its beginnings from for-hire horse-drawn coaches in Western cities and rickshaws in Far Eastern cities, the taxicab is the oldest form of urban public transportation. By comparison, taxis require lower demand than any other public transport mode. Taxis can therefore operate in many smaller communities which are unable to support any other form of public transportation.

Taxicab companies are privately owned and operated and most receive no public subsidy. In recent years, however, attention has been focused on the possibilities associated with using taxi companies as providers of publicly supported demand-responsive transportation. This gradual movement of the private taxi company into the public transit domain can be attributed to the following factors (14):

- The widespread diffusion of demand-responsive transit systems for commuting level transit, combined with the growing desire for more cost-effective methods of delivering demand-respsonsive transportation, have given taxi companies the opportunity to enter the transit market; and

- The steadily worsening financial prospects of conventional taxi services have given taxi companies the motivation to diversify into new markets, such as the delivery of demand-responsive transportation services under contract to human services agencies.

Description

Taxicabs offer a level of transportation service which falls in between that of fixed-route, fixed-schedule bus service and the private automobile. As such, taxis are generally defined by the following.

- Taxicabs are capable of accessing any point in an urban area.

- Taxicabs can respond to demand either by hailing or telephone.

- Transportation service is of a personalized, door-to-door nature.

- Passengers typically pay a fare for service based on the distance (and sometimes duration) of the ride.

- Some wait time is associated with taxicab trips after request for service is telephoned in; virtually no wait time is required if cab is hailed from a stand or off the street.

- Taxicab companies and operators are private enterprises under government control.

Design and Operating Characteristics

The type of service offered by conventional taxicab operations is unique in that it is completely individualized; a passenger can request service whenever and wherever he or she desires. This characteristic enables taxis to fulfill important roles in cities of all sizes. For example, certain types of trips can be provided by taxis far more efficiently and effectively than by any other transit mode. These trips include (2, 8):

- Emergency trips where time is critical (hospital, parts delivery, package delivery);

- Transportation of elderly or handicapped persons to and from medical centers, shopping facilities, etc.;

- Important business trips where time is crucial;

- Trips to areas not accessible by fixed-route transit;

- Late night work-to-home trips, particularly when concern for safety is a factor; and

- Trips to and from airports, bus stations, etc. where transporting luggage is necessary and no limousine or transit service is available.

Shared-Ride Taxi Concept (15). Another type of taxi service which is gaining popularity across the nation is the shared-ride taxi concept. This concept refers to a client sharing a ride with another passenger or group of passengers with similar or close destinations. This type of arrangement (which is prohibited by most Texas municipal ordinances) can function well at shopping centers, bus terminals, airports, and any other place where the demand for taxis often exceeds the number available.

Often the taxi driver will group passengers with similar destinations in his taxi. This matching of potential shared taxi riders can also be done by the dispatcher, by advanced scheduling of demands, or by grouping calls as they are received, into sections such as neighborhoods.

Overall, approximately 50% of the total recorded vehicle miles are "empty" or "non-paid" miles for everyday taxi operations (15). By increasing the load factor, the shared-ride taxi concept provides an opportunity to decrease operating costs and contribute to the overall improvement of service. This could result in the ability of the operator to service a higher level of demand with lower operational costs and less waiting time. The gain in efficiency and economy should then be passed on to the clients by way of lower fares.

Several obstacles must be overcome before a shared-ride taxi service can be implemented, however. The allocation of fares among passengers is a major problem which must be resolved and well publicized in advance of initiating service. One approach is to divide the total fare by the number of passengers to yield an average fare. Another method is to charge a flat rate fare and divide the fare by the total number of passengers each passenger has ridden with, regardless of distance.

Another problem to be addressed concerning the shared-ride taxi concept is the legality under local city ordinances. A review of existing taxi regulatory ordinances in many Texas cities indicates the need for revision before the shared-ride taxi concept can be implemented.

Subsidized Taxi Operations (16). Taxicab operations in a number of areas across the United States have been given the opportunity to compete for publicly funded services. Subsidy techniques for utilizing taxis in publicly funded programs generally take one of 2 forms:

- Provider-side subsidies, in which funds are disbursed to the providers for the provision of certain specified transportation services; or

- User-side subsidies, in which funds are distributed to the users in the form of reduced-rate tickets or charge slips.

Provider-side subsidies have been used in areas such as Pittsburgh, El Cajon, California, Westport, Connecticut, and Portland, Oregon. Provider-side subsidies are typically service contracts where the provider is reimbursed on the basis of in-service hours, miles or some other measure of the transportation service delivered.

User-side subsidies, which are typically administered through reduced-rate tickets or charge slips, have been employed extensively for special user group programs, particularly those which serve elderly and handicapped clients. General public applications have been limited, however. User-side subsidized taxi operations can be found in Milwaukee, Kansas City, Missouri and Montgomery, Alabama among other areas.

Company Organization (5, 8). Taxicab organizational arrangements typically take the form of either fleets or owner/operator vehicles.

- **Fleets** - Taxicab fleets hire drivers who are compensated by some form of output-related incentive system, usually a commission on the gross receipts of their cabs. Ownership/management of the fleet may use any one of several arrangements (individaul, partnership, corporation, etc.). As the name implies, a fleet must consist of more than one vehicle, yet be operated as a single entity. Fleets typically provide vehicle maintenance and repair facilities as well as dispatching services, although occassionally these services are supplied by a separate enterprise, an association or a management company.

- **Owner/Operators** - Owner/operators are private entrepreneurs who own their own vehicles, retain their gross receipts and from them pay the full operating costs.

In addition to fleet proprietors and owner/operators, several other service enterprises and associations exist in the taxi industry. For example, some taxi "companies" provide dispatching services to both fleets and owner/drivers. Other taxicab "associations" are comprised of fleets and owner/operators banded together for economic or political reasons. Some associations purchase gasoline, oil, insurance and other goods and services for their members at bulk prices. Other associations represent fleet owners in labor negotiations and present the owner's position to regulatory agencies.

Taxicab Regulation (2, 5, 8). Taxicab operations are regulated by public bodies (usually local governments) with respect to some or all of the following items:

- Number of taxicabs permitted in the jurisdiction (entry);
- Driver training;
- Area in which each taxi company can operate;
- Fares and charges;
- Financial responsibility in case of accidents and other risks associated with the business; and
- Service standards related to vehicles, drivers and methods of operation.

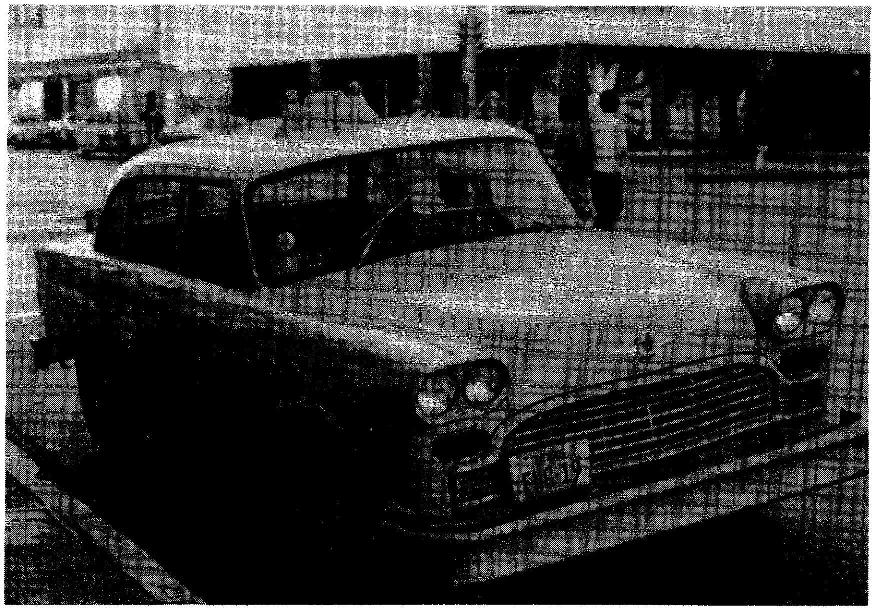
Specific regulations vary considerably from one community to the next with no 2 taxicab ordinances alike. For example, control of entry varies from no control (Washington, D.C.) to a fixed number of licenses (New York City). Driver training requirements also vary from no special training at all to the completion of training courses which include safety aspects, intervention in emergencies, courtesy and familiarity with the local street system. The regulation of taxicab fares is yet another area where differences exist. Most cities require taxis to calculate fares using taximeters and specify meter rates in their fare structures. Other cities have zone rates or flat rates, and a few cities have combinations of meter and zone rates.

For meter rates, the fare is typically calculated in terms of "flag drop" (an initial flat fee) plus a specified number of cents for each additional mile or fraction thereof. In addition to recording distance-based charges, taximeters in most large urban areas also contain "live clocks" which automatically record the time the operator is delayed in the course of transporting a passenger (because of traffic or other factors) and adds this cost into the total trip cost.

Vehicles (2, 5). Taxicabs are usually some form of automobile, either standard production models (that carry a maximum of 5 passengers in addition to the driver) or specially designed vehicles which can hold up to 7 passengers comfortably and feature convenient entry/ exit. Taxicabs are always designated by color scheme, by signs on the doors or on the roof, or by some special symbol.

Travel Ways and Stops (2). Taxicabs offer their services by stationing themselves at taxi stands (specially designated areas usually in the vicinity of major trip generators such as airports and hotels) or by cruising streets with a sign showing that the vehicle is available. Modern taxi systems have a dispatcher who is in radio contact with the entire fleet to assist in the distribution of vehicles within the service area and to handle telephone requests for service.

Taxicab service is theoretically available at any time from/to any place within its jurisdiction. Service at certain hours or in certain areas may be unavailable, however.



Taxicab service may be provided in either standard production sedans or specially designed vehicles (left).

Operations and Performance Characteristics. Because of the door-to-door nature of its services, the operating and performance characteristics of speed, headway and capacity which define fixed-route fixed-schedule public transportation modes do not apply to taxicab transportation service.

Attributes

Taxicabs provide quite different types of service and fulfill different roles in urban transportation than do conventional transit modes. The following characteristics of taxicab service should be considered in service planning (2).

- Taxicabs operate on the existing roadway network.
- Fully personalized, door-to-door service (including a guaranteed seat) is provided.
- Taxis are very convenient for transporting luggage.
- The necessity to have a driver for individual trips makes taxis inherently more labor-intensive and more costly (to the user) than other modes.
- Unlike private automobiles, taxis require virtually no parking; only taxi stands occupy certain street or off-street areas.
- Service, in most cases, is easily available.

Supply of Taxicab Services

Because taxicab services are privately owned and operated, because an owner-operator company may consist of only one vehicle, and because many illegal (unlicensed) operations may exist, it is virtually impossible to determine the exact number of taxicab operations in existence. Furthermore, because the taxi industry is part of the private sector, comparatively little research has been performed with regard to the supply of service, industry characteristics, etc. However, some understanding of the industry can be gained by reviewing the limited amount of data which is available.

Current Industry Statistics. On June 17, 1985, the International Taxicab Association reported the following statistics concerning the U.S. taxi industry (17).

- Number of Taxi Companies = 4,000
- Number of Taxis = 141,000
- Total Employees = 240,000
- Gross Annual Revenues = $4.42 billion

In addition, the International Taxicab Association also reported that the average taxi in the U.S.:

- Travels 49,000 miles per year;
- Is occupied 55% to 60% of the time;
- Carries the average passenger 4 miles; and
- Grosses $31,348 per year (17).

In Texas, a 1983 survey by the State Department of Highways and Public Transportation identified 378 taxi companies. 173 (46%) of these 378 companies reported operating a total of 5,151 vehicles in 1983, 49 of which are specially equipped to transport handicapped clients.

Coordination with Other Transportation Providers. Within the State of Texas, taxicabs perform a vital function. In fact, taxi services are the form of public transportation available in many rural and small urban areas of the state. In other areas, however, the trend toward subsidizing municipal transit sytems and human services agency transportation providers with federal, state and/or local funds has placed taxi operators at a competitive disadvantage. Some taxi operators have reported that this situation has made it increasingly more difficult for them to earn a reasonable profit. In several areas of Texas, this problem has been resolved by taxi companies contracting with local transit systems or human services agencies to provide transportation for their clients. For example (11):

- In San Antonio, VIA Metropolitan Transit Authority provides demand-responsive, curb-to-curb service for mobility impaired persons through its VIAtrans service. To supplement VIAtrans vans, VIA also contracts with a local taxi company to provide transportation for semi-ambulatory clients. In 1983, 21,521 taxi trips were made.

- The Austin Transit System reports that it will continue to contract with taxi companies for demand-responsive service when their vehicles are fully utilized or whenever the taxi service proves more cost effective.

- In the Killeen area, 3 of the 12 taxi companies reported that they provide transportation under contract with various human services organizations for certain categories of clients.

- The Yellow-Checker Cab company of Wichita Falls report that continued operation of its company may depend on receiving contracts with human services agencies to furnish transportation for their clients.

Taxicab Operating Costs

Average estimated taxicab operating costs for the Dallas/Fort Worth area and the nation as a whole are presented in Table 6-7. These costs per mile figures would be expected to be considerably higher today, however, in view of rising fuel prices, labor costs, etc.

Table 6-7
Estimated Operating Costs (Cents Per Mile) of Taxicab Operations

Operating Expense	National Averages 1978	Dallas/Fort Worth Area Averages 1978	Dallas/Fort Worth Area Averages 1979
Labor (drivers)	22.0	32.0	40.0
Vehicle Operation			
Fuel	5.0	5.4	8.0
Tires	0.5	0.4	0.5
Maintenance			
Labor	3.0	3.5	4.5
Parts	2.0	3.5	4.5
Insurance	3.0	2.8	4.3
Other	8.0	5.5	7.5
Total Operating Cost (¢/mi.)	43.5	53.1	69.3

Source: Reference 18.

Jitney Service

The jitney concept is generally said to date from July 1, 1914 when L.P. Draper of Los Angeles picked up a passenger while driving his Ford Model T touring car, transported the passenger a short distance and accepted a nickel as fare payment. The term "jitney" (for 5¢ fare) was coined and the concept spread quickly. For example: On January 1, 1915 no jitneys were in service in Dallas, but by March 22, 259 were in operation (19).

Jitney operations within the United States reached a peak in May 1915 with an estimated 62,000 vehicles in service. Within a short period of time, jitneys were diverting perhaps as much as 50% of the peak-hour streetcar passengers. In 1917, approximately 1,400 vehicles were operating over major thoroughfares in San Francisco. By the 1920s, political pressure from the street railways as well as the transit industry as a whole resulted in legislation that regulated most jitneys out of existence. Today, only 2 U.S. cities (Atlantic City and San Francisco) continue to maintain jitney operations of a significant size on a fully legal basis (19). Smaller or quasi-legal jitney operations are also found in other areas such as San Diego, Indianapolis and Miami. One other jitney-type service exists in Chattanooga, Tennessee, but these vehicles are licensed as taxicabs (20).

Description (5, 21)

Today, jitney service refers to a form of public transportation which is generally defined by the following.

- Jitneys are privately owned and operated public transportation conveyors that provide shared-ride services along authorized, semi-fixed routes.
- Service is generally not formally scheduled, but headways are short.
- Jitneys offer a guaranteed seat.

Design and Operating Characteristics

Private Ownership and Operation (20). In most every instance, drivers engaged in jitney service are independent entrepreneurs who assume the risks and enjoy the benefits of their business ventures. Most drivers own their vehicles, although some are lessors. The goal of both owners and lessors alike is to transport as many passengers as possible within time and regulatory constraints in order to maximize income.

In Atlantic City, jitneymen are owners of their vehicles. They retain all passenger revenues and work at their own convenience within the constraints of shift schedules prepared by the local jitneymen's association. San Francisco jitneymen also own the vehicles they drive. In Chattanooga, about 72% of the cruising cabs are owner operated and all establish their own work schedules; almost half elect to operate the jitney mode on a full-time basis.

Vehicles (2, 5, 20). Jitney vehicles can be passenger automobiles, vans or minibus-type vehicles with seating capacities that range from 5 to 15 seats, excluding the driver. Generally speaking, jitney operators select the vehicles (new or used) they feel will be most likely to attract passengers and least expensive to buy and operate. Local or state regulations may restrict the selection of vehicles, however, by specifying maximum capacity and/or vehicle characteristics.

In Atlantic City, about 80% of the jitney fleet are old Metro buses manufactured by International Harvestor before 1966; the remainder are Willis Chassis with Brill-built bodies, General Motors Step Vans, Dodges or Chevrolets. All are characterized by 10 seats facing forward (state law limits the capacity to 10 seats and prohibits standees). San Francisco's jitneys are primarily 12-passenger Dodge, Ford, Chevrolet or International vans with seating arranged either in rows or around the perimeter of the van. Chattanooga cruising cabs are standard 5-passenger sedans of all makes. Jitneys are distinguishable by either signs or color schemes.

Jitney service in Atlantic City is provided in refurbished International Harvestor buses (left) while Chattanooga's cruising cabs are standard 5-passenger sedans (right).

Travel Ways and Stops (2, 5, 20). Jitneys typically serve heavily traveled corridors. Vehicles operate along fixed routes under rules established by the local associations. Specific methods of traveling a particular route vary from one operation to the next. For example, jitneys may cruise continuously during certain morning and evening hours and may be dispatched from a stand the rest of the day. Some jitneys may travel the entire length of an authorized route, while others may serve only portions of the route. Another common practice is for drivers of shorter routes (these under 5 miles) to cruise continuously and drivers of longer routes to operate from stands or terminals.

Passengers typically access a jitney route by foot. Passengers may be picked up at street stands (or terminals), at designated jitney stops or at any point along the route. Once on board, passengers pay a modest fare and can disembark at any location along the route. Minor route deviations are sometimes made to provide personalized service to elderly or partially handicapped passengers or other persons with special needs. Deviations are also made to avoid traffic congestion and to take shorter routes when no on-board passengers are affected. While most jitney regulations specifically restrict or forbid deviations, these regulations are seldom enforced on many routes.

Jitney passengers may be picked up at designated jitney stops (above) or at any point along the route (below).

Operating and Performance Characteristics (5, 20). While in operation, jitneys travel as rapidly as possible given traffic conditions, safety considerations and posted speed limits. Overall, jitney speeds are only slightly lower than speeds attained by private automobiles following the same routes.

Jitneys do not operate according to a fixed schedule. Headways are controlled, however, by fixing the maximum number of vehicles allowed in service at any particular time. The local jitneymen's association typically matches the number of vehicles allowed with anticipated passenger demands. This results in very short headways. For example, headways as short as 60 seconds have been observed in Atlantic City and headways of 57 seconds during the morning peak and 79 seconds during the evening peak have been recorded in San Francisco. Other deviations in Chattanooga and San Francisco have placed average headways in the range of 2 to 4 minutes.

The passenger carrying capacity of jitney operations is directly related to the size of the vehicle and the length of the route service; larger capacity vehicles which operate on shorter routes have higher passenger carrying potential than smaller vehicles which operate on longer routes.

Attributes

The following general characteristics of jitney operations demand consideration in jitney service planning (2, 5).

- To be successful, jitney services must operate along moderately or heavily traveled corridors; they cannot serve very low density routes.
- Jitney services have operated profitably (in both a financial and social sense) in at least 2 different environments:
  - Low income areas which are inadequately served by bus and taxi (San Francisco, Pittsburgh, Miami), and
  - Tourist resorts (Atlantic City).
- Operating in large numbers and stopping frequently at most any location along the usually busy streets they serve, jitneys can be major contributors to traffic congestion.
- Almost all jitneys operate on a self-supporting basis, while transit systems operating in the same cities usually receive public financial assistance.
- Jitneys are typcially judged as fast and frequent service, but reliability, regularity of service, safety standards, comfort, passenger information, etc. may not be as high as for conventional transit modes.

Financial and Operating Statistics (20)

Only limited financial and operating statistics are available for the jitney operations in the United States. Table 6-8 presents typical major cost items for jitney vehicles. Table 6-9 presents data on passengers per vehicle mile, passenger-miles per vehicle-mile and passenger-miles per seat-mile for various trip modes along one jitney route in Atlantic City and one in Chattanooga. In Chattanooga, the 8 trips along the Patten to Citico route averaged:

- 3.84 miles in distance traveled per trip;
- 0.60 passengers per vehicle-mile;
- 1.47 passenger-miles per vehicle-mile; and
- 0.366 passenger-miles per seat-mile.

The Caspian to Jackson route in Atlantic City averaged:

- 3.76 miles in distance traveled per trip;
- 2.35 passengers per vehicle-mile;
- 3.81 passenger-miles per vehicle-mile; and
- 0.423 passenger-miles per seat-miles.

Table 6-8
Typical Major Item Costs
(1978 Dollars)

Item	Gasoline			Diesel	
	Private Auto	Jitney Sedan	Jitney Van	Minibus Transit	Full-Size Bus Transit
Fuel ($/gal)	0.60	0.60	0.60	0.46	0.46
Tires ($/mile)	0.003	0.006	0.017	0.20	0.027
Oil ($/mile)	0.002	0.002	0.008	0.003	0.003
Driver ($/veh-hr)	1.50	3.00	3.00	6.50	6.50
Dispatch Cost ($/veh)	0.0	0.0	0 or 150	3,256	3,256
Annual Insurance ($/veh)	400	962	1,200	2,000	3,839
Annual Admin. ($/veh)	0.0	120	120	9,853	9,853
Annual Maint. & Garage ($/veh)	200	500	500	9,369	9,369
Annual Advt. & Traf. ($/veh)	240	100	100	514	514
Annual Taxes & Lic. ($/veh)	40	70	85	1,000	2,672
Annual Deprec. ($/veh)	540	900	1,200	3,400	5,667
Off-peak/Peak Factor	0.50	0.78	0.78	0.50	0.50

Source: Reference 20.

Table 6-9
Jitney Productivity by Trip

Route	Trip Number	Trip Distance (Vehicle-Miles)	Passengers per Vehicle-Mile	Pass.-Miles per Vehicle-Mile	Pass.-Miles per Seat-Mile
Patten to Citico, Chattanooga	1	3.97	0.38	1.48	0.370
	2	3.21	0.31	0.71	0.176
	3	4.79	0.52	1.10	0.275
	4	4.17	0.36	1.03	0.259
	5	3.17	0.95	1.84	0.461
	6	3.58	1.26	2.78	0.696
	7	3.12	0.48	1.36	0.339
	8	4.73	0.53	1.42	0.353
	Average	3.84	0.60	1.47	0.366
Caspian to Jackson, Atlantic City	1	4.08	3.06	5.01	0.556
	2	3.13	2.72	4.40	0.488
	3	3.13	2.08	3.95	0.439
	4	4.08	2.82	4.27	0.474
	5	4.08	1.10	1.45	0.161
	6	4.08	2.33	3.77	0.418
	Average	3.76	2.35	3.81	0.423

Source: Reference 20.

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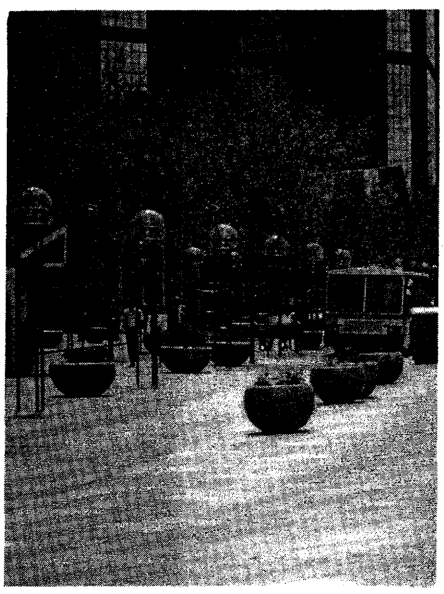
Chapter 7



Public Transit Planning

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Public Transit Planning

The cities of today are an accumulation of different urban patterns. Each of these patterns was influenced not only by the previous form of the city and by its site, but also by contemporary economic, social, political and technical systems of its inhabitants. Within all these patterns, travel has prevailed as a constant condition of urban life. Throughout history, the need of the traveler for improved transportation has been much the same. Travel is not purchased as an end-product, but rather to make other products and services available. Economical, safe, pleasant, convenient and fast transportation are but a few of the many goals of urban life (1).*

The Urban Transportation System

The transportation system may be defined as the circulatory system of a city. It brings people and goods into the community and provides the means by which they can move freely from one area or activity to another. A wide variety of factors interact to affect the type, nature and configuration of urban transportation systems. The following are indicative of these factors (1, 2, 3).

- **Urban Economy and Income Levels** - History has shown that as urban economics flourish and income levels increase, auto ownership increases and transit ridership decreases.

- **Total Population** - The larger the population of an urbanized area, the greater the total number of trips that will be made; hence, a more extensive transportation system is required. Theoretical research supported by observations of transportation systems in major cities indicates that, with an excellent urban arterial street system, a city can grow to a population of about 250,000. If an extensive system of freeways is superimposed over the network of arterial streets, the resulting urban transportation system can support a metropolitan population of up to 2,000,000. To support a larger development, a high capacity mass transportation system or extensive ride-sharing system becomes necessary to transport large volumes of

*Numbers in parentheses refer to references listed at the end of the chapter.

persons to and from major employment centers during peak commuting periods.

- **Locations of Major Employment/Activity Centers** - Urbanized areas with small employment centers distributed evenly throughout the area are best served by the automobile, while cities with large work forces concentrated in the CBD and perhaps 1, 2 or 3 other major activity centers require some sort of mass transit to help move the large volumes of weekday commuters to and from employment centers.

- **Industrial Activity** - Extensive intraregional and interregional transportation systems tend to be found in areas with extensive industrial development.

- **Geographical Constraints** - Bridges, mountain passes and tunnels which are constructed to move persons and goods over bodies of water or through or around mountainous terrains can frequently be the cause of bottlenecks in an urban transportation system. In some cases, such as bridges, additional capacity through the bottleneck location can be obtained through widening or double-decking the present facility or constructing new facilities. In many instances, however, additional capacity must be achieved by more effective utilization of existing facilities, such as preferential treatment for high occupancy vehicles.

Evolution of Urban Transportation Planning

Urban transportation planning, as it has been practiced during the last 20 years or so, has its roots in the highway planning of the 1930s. Early highway planning concentrated on developing a network of all-weather highways which connected the various portions of the nation. Soon, problems of serving increased traffic growth surfaced. Additional problems such as land development, disruption and dislocation, environment degradation, citizen participation, concern for providing transportation for the elderly, handicapped and economically disadvantaged and concern about energy conservation also had to be addressed. The result is that current urban transportation planning practices are considerably more sophisticated, complex and costly than their highway planning precedent; current practices evolved as a result of the wide range of issues cities have been forced to deal with. This chapter traces the evolution of the urban transportation planning process that pertains to public and mass transportation (4).

Federal Involvement in Public Transportation

Over the years, the actions of the federal government have significantly affected the planning and development of public transportation in the United States. Several of the more important acts which relate to the regulation, planning, and funding of public transit are summarized in the following paragraphs (5, 6).

Holding Company Act of 1935. Perhaps the first major piece of legislation affecting public transportation was the Holding Company Act of 1935. This Act placed severe restrictions on public utilities or related holding companies which owned and operated public transit systems. Many of the public utilities companies had begun as street railway operations, but soon found it more profitable to sell their excess electrical power. By 1935, public transportation service comprised only small parts of their total businesses, and unprofitable ones at that. The utility companies had nevertheless been able to provide a reasonable level of transit service because of their overall operation and their ability to raise capital easily. With the passage of this act, however, most utility companies quickly sold their public transit holdings. This legislation is generally considered to have added to the financial problems and demise of the private transit industry.

The Housing and Urban Development Act of 1961. This act represents the federal government's first effort in providing financial assistance to public transit. Although the act was primarily aimed at housing and urban renewal, it did contain the following provisions which related to public transportation:

- $25 million was authorized for transit demonstrations;
- Transit planning was required to be a part of federally funded urban planning programs (701 planning funds); and
- $50 million in loans were made available through the Home Finance Administration for mass transportation projects.

While modest, this program is credited for establishing a precedent for the major public transportation programs that followed.

Federal Aid Highway Act of 1962. Under this act, urbanized areas with populations of 50,000 or more were required to implement a cooperative, comprehensive and continuous transportation planning process which included public transportation. Projects which failed to meet this requirement would no longer be eligible to receive federal funds after 1965.

The Urban Mass Transportation Act of 1964. The Urban Mass Transportation Act of 1964 was passed in response to the increasing inability of private transit operators to make a profit and remain in business.

This act created (within HUD) the Urban Mass Transportation Administration. The act also provided the first capital grants for transit and authorized funding of up to $1.2 billion over a 7-year period. The purposes of the act were:

- To assist in the development of improved mass transportation services;
- To encourage the planning and establishment of areawide urban mass transportation systems to improve mobility; and
- To provide assistance to state and local governments in financing both public and private transit systems.

High Speed Ground Transportation Act of 1965. A 3-year, $90 million research and development program for the purpose of investigating the feasibility of high speed ground transportation in densely developed urban corridors was authorized under this act passed in 1965.

Urban Mass Transportation Act of 1966. The 1966 Act amended the earlier Act of 1964 and provided funds for first time planning, engineering, design, management training, and new system studies. Also included in this law were strict local planning requirements and labor protective provisions -- Section 13(c). In addition, the 1966 Act established a research, development and demonstration program and provided funding for technical studies and training. Finally, the 1966 amendment increased the funding program to $150 million annually between 1967 and 1969.

Department of Transportation Act of 1966. This act created the Department of Transportation by bringing together a number of modal agencies. Mass transit remained a part of HUD although a study was initiated to determine where mass transit should be located. In 1968, under the President's Reorganization Plan 2, most of the functions and programs established by the 1964 UMT Act were transferred from HUD to DOT. In addition, the Urban Mass Transportation Administration (UMTA) was put on an equal footing with the Federal Highway Administration (FHWA). Still another aspect of the 1966 Act was the establishment of Section 4(f) environmental protection measures.

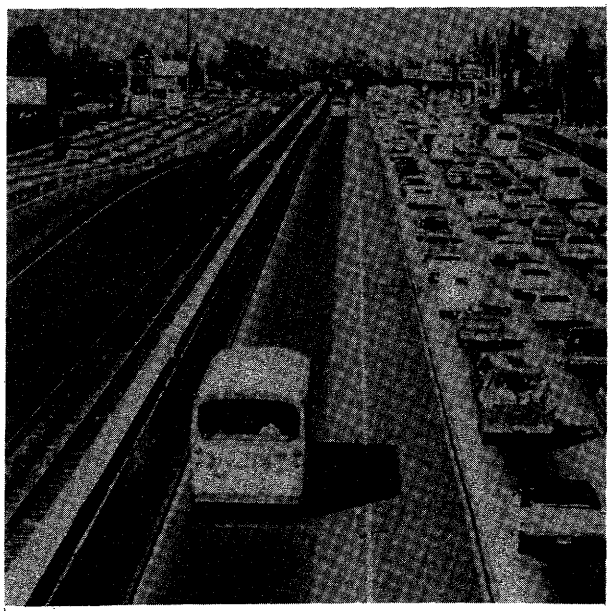
Federal Aid Highway Act of 1968. With the passage of this act, the Traffic Operations Program to Increase Capacity and Safety (TOPICS) and the Fringe Parking Program were created. Both of these programs contained major elements which pertained to highway oriented transit improvements. Bus bays and bus shelters are examples of eligible improvements under the TOPICS program. Parking facilities that are located and designed in conjunction with existing or planned public transportation facilities are eligible items under the Fringe Parking Program (contained in Section 137).

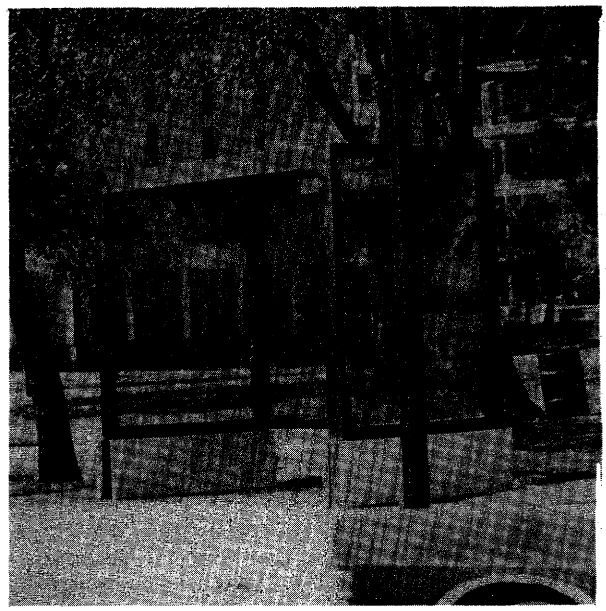
National Environmental Policy Act of 1969. This act, while not directly related to public transportation, has nevertheless significantly affected the development, funding and implementation of urban transportation facilities. Because of this act, the preparation of environmental impact statements is mandatory for all major federally funded projects.

The Urban Mass Transportation Assistance Act of 1970. This legislation amended the 1964 Act and offered long-term financing for expanded public mass transportation projects. The 1970 Act outlines a federal commitment for the expenditure of at least $10 billion over a 12-year period and specifically authorized $3.1 billion for capital grants to state and local governments.

Federal Aid Highway Act of 1970. The significance of the passage of this act was the establishment of the Federal Aid Urban System. The selection of specific routes to be placed on the Federal Aid System must be a cooperative effort between local officials and state highway departments based on an urban transportation planning process. Special provisions (under Section 142) were included that authorized funds apportioned to the states from the Highway Trust Fund to be used for public transportation related purposes.

The purpose of Section 142 was to encourage the development, improvement and use of public mass transportation systems which operate motor vehicles (not rail vehicles) on Federal Aid Highways for the purpose of increasing the people moving capacity of the federal aid system. Improvements which are eligible on any federal aid system include the construction of exclusive or preferential bus lanes, highway traffic control devices, bus passenger loading areas (including shelters), and both fringe and transportation corridor parking facilities to serve bus and other public mass transportation passengers.





Improvements eligible on any federal aid highway system include the construction of preferential bus lanes (left) and bus passenger loading areas, including shelters (right).

In addition, the Department of Transportation could (beginning in 1975) approve the purchase of buses and (beginning with fiscal year 1976) approve the construction, reconstruction and improvement of fixed rail facilities, including the purchase of rolling stock for fixed rail.

Federal Aid Highway Act of 1973. Enactment of this 1973 legislation represented a major change in policy by permitting certain basic program authorizations to be used for the full range of public transportation capital costs, including rail rapid transit. For the first time, policy and funding levels for both the Federal Aid Highway Program and the Urban Mass Transportation Program were enacted. An additional $3 billion from general funds was appropriated which increased the contract authority for the Urban Mass Transportation Capital Grant Program to $6.1 billion. The federal share of net project costs (that cannot be reasonably financed out of revenues) was also increased from two-thirds to 80%. Furthermore, the act authorized $780 million per year for the Federal Aid Urban System to be spent on either highway or public mass transportation projects for fiscal year 1974, and $800 million for each of the next two fiscal years. Finally, the act permits state and local governments, with the concurrence of the Secretary of Transportation, to substitute (in an urban area) a rail transit project or other transit improvement for a non-essential Interstate Highway project with financing from general revenues.

Also established under this act was the Rural Highway Public Transportation Demonstration Program (Section 147). The purpose of Section 147 was to encourage the development, improvement, and use of public mass transportation systems operating vehicles on highways for the transportation of passengers within rural areas and small urban areas, and between such areas and urbanized areas, in order to assist rural populations in reaching important community destinations such as employment, health care, retail centers, education, and public services. It authorized $15 million for the fiscal year ending June 30, 1975, and $60 million for the fiscal year ending June 30, 1976, of which $50 million shall be out of the Highway Trust Fund. The act directed the Department of Transportation to carry out demonstration projects for public mass transportation on highways in rural areas and small urban areas.

The National Mass Transportation Assistance Act of 1974. As one of the most significant pieces of legislation affecting urban public transportation this act amended the 1964 UMTA act and authorized for the first time the use of federal funds for transit operating assistance. Almost $4 billion of the $11.8 billion authorized over the six year period was allocated to urban areas by a formula based on population and population density. These formula allocated funds could be used for either capital or operating assistance. Of the remaining $7.8 billion, $7.3 billion was available for capital assistance at the discretion of the Secretary of Transportation, and the remaining $500 million of that amount could also be used for rural mass transportation.

Federal Aid Highway Acts of 1975 and 1976. The 1975 Act authorized $7.8 billion in funds, the largest amount in the history of the federal-state highway program. Similar funding levels were continued for two more years in the 1976 bill. The 1976 Act also created a 19-member National Transportation Policy Study Commission to study the nation's transportation needs.

The Surface Transportation Assistance Act of 1978. This act authorized over $51 billion for surface transportation improvements through fiscal year 1982, including over $37 billion for highways and almost $14 billion for mass transportation.

This act continued the 15-year trend of increasing federal involvement and support of public transportation. Some of the more important provisions of the act included a discretionary grants program (Section 3), a formula grant program for urbanized areas (Section 5), and a formula grant program for areas other than urbanized areas (Section 18). (Note: Sections 3, 5 and 18 of this act are discussed in more detail in a subsequent section of this chapter.)

Surface Transportation Assistance Act of 1982. This act placed caps upon the federal transit assistance which could be used for operating subsidies and reduced the Federal share of transit capital assistance funds under Section 3 from 80% to 75% of the net project costs.

Section 9 of the Surface Transportation Assistance Act is a block grant program which authorizes funds for Fiscal Years 1984 through 1986. Funds appropriated under this program are apportioned to urbanized areas in accordance with a statutory formula which incorporates population and population density. In addition, for urbanized areas with populations of 200,000 or more, specific operating statistics are also incorporated into the formula. These statistics are:

- Fixed guideway directional route miles;
- Fixed guideway and nonfixed guideway vehicle revenue miles;
- Fixed guideway and nonfixed guideway passenger miles; and
- Fixed guideway and nonfixed guideway operating expenses.

The term "fixed guideway" means a public transportation facility which utilizes and occupies a separate right-of-way or rails for the exclusive use of public transportation service including, but not limited to, fixed rail, automated guideway transit, and exclusive facilities for buses and other high occupancy vehicles. Also included in this definition are public transportation facilities which use a fixed catenary system and utilize a right-of-way usable by other forms of transportation.

Fiscal Year 1986 U.S. DOT Appropriations Bill (7). On September 26, 1985 the U.S. Senate Appropriations Subcommittee on Transportation approved a Fiscal year 1986 U.S. DOT appropriations bill that would cut overall transit funding by about 11% while freezing operating assistance at current levels.

If approved, this bill will set Section 3 capital discretionary funding at the fully authorized level of $1.1 billion. In addition, the Section 9 formula capital program would be cut from $2.5 billion to $2.1 billion and the Interstate Transfer Program would be reduced from $250 million to $200 million.

The measure also includes language ordering UMTA to reapportion lapsed Section 5 funds from earlier years which is expected to partially offset the reductions made in the formula capital program.

The U.S. DOT appropriations bill will be considered by the full Appropriations Committee where there may be challenges to the bill's overall funding level.

Other Rules and Regulations

In addition to the major acts passed in recent years, the U.S. Department of Transportation has also issued a number of rules and regulations which established policies related to previous legislation. Some of the more important issuances are summarized below (5, 8).

Charter and School Bus Operations, UMTA, April 1, 1976. These regulations were adopted to ensure that public capital and operating assistance made available under UMTA statutes are not used in support of charter bus operations. The regulations forbid the grantee of UMTA projects from operating charter service outside the urban area in which it provides regular service.

A second part of these regulations puts limitations on the transportation of school students by federally assisted operators when they are in direct competition with private school bus operators. Both parts of the regulation are aimed at prohibiting unfair competition to the private operator by federally funded public transportation authorities.

Joint Regulations, Transportation System Management, 1975. In September 1975, the Department of Transportation issued regulations governing urban transportation planning under FHWA and UMTA. The regulations specified that the urban transportation planning process shall include the development of a transportation system management (TSM) element and a long-range element. This marks the first time that a formal requirement for TSM has been included in the urban transportation planning process.

The purpose of the transportation system management element was:

- To provide for the short-range transportation needs of the urbanized area by making efficient use of existing transportation resources and providing for the movement of people in an efficient manner; and

- To identify traffic engineering, public transportation regulation, pricing, management, operational, and other improvements to the existing urban transportation system not including new transportation facilities or major changes in existing facilities.

The task of developing and coordinating the TSM plan was designated the responsibility of the Metropolitan Planning Organizations (MPO) for each urbanized area.

Urban Transportation Programming For Elderly and Handicapped, UMTA/FHWA, April 30, 1976. Regulations were issued effective May 31, 1976, concerning project approvals under various UMTA grant programs. The regulations required that the planning process show special efforts in providing facilities and services that can be used by the elderly and handicapped (E & H) persons. The annual element of the transportation improvement program must contain projects or project elements for the E & H and, specifically, wheelchair users and the semi-ambulatory persons. By September 1, 1977, reasonable progress must have been made in implementing previously programmed projects. Project approval was contingent on acceptable performance on the above items.

Non-Discrimination Against the Handicapped - Section 504 of the Rehabilitation Act of 1973. The Department of Transportation issued this regulation to carry out the intent of Section 504 of the Rehabilitation Act of 1973, which specified that handicapped persons shall not be "excluded from the participation in, be denied the benefits of, or be subjected to discrimination under any program or activity receiving federal financial assistance." The regulation establishes guidelines for development of accessibility to fixed rail stations and vehicles, transit buses, and non-urban public transportation. Essentially, levels of accessibility are set along with timetables for their achievement. Provisions for the possibility of waivers from the requirements as well as alternative service during the transition to accessibility were also included.

Major Urban Mass Transportation Investments, UMTA, September 22, 1976. On September 22, 1976, UMTA issued a policy statement concerning transportation investments in major urban areas. The policy recognized the inability of UMTA to fund all capital grant applicants, particularly those requesting new fixed guideway systems. The policy stressed the need to consider combinations of transit modes and technologies appropriate to the service requirements of specific corridors. It required major fixed guideway systems to be implemented incrementally with priority given to the most immediate needs of the locality.

Paratransit Services, UMTA, October 20, 1976. A proposed policy was issued by UMTA on October 20, 1976, concerning paratransit services. The thrust of the policy was to provide a mechanism for UMTA to assist the various paratransit services without subjecting paratransit operators to the regulations and provisions normally associated with UMTA grants. In particular, Section 3(e), which aims to avoid competing services and Section 13(c) which pertains to labor protection would not be applied.

Considerable federal legislation has been aimed at providing for the special transportation needs of elderly and handicapped persons.

The Planning Process (5, 9, 10)

In September 1975, the U.S. Department of Transportation issued regulations governing the urban transportation planning process under the Federal Highway Administration and the Urban Mass Transportation Administration. The intent of these regulations is to engage regional planning agencies and local operating agencies in cooperative efforts to make more productive use of existing transportation facilities. The regulations specified that the urban transportation planning process shall include the development of a transportation system management (TSM) element and a long-range element. The basic steps of this planning process are illustrated in Figure 7-1. The process begins with the establishment of interagency agreements between the area's Metropolitan Planning Organization (MPO) and transit and highway agencies. These agreements specify cooperative procedures for implementing transportation planning and programming. The prospectus (or Operations Plan) details the effort in drafting a Unified Work Program (UWP).

Inter-Agency Agreement **Prospectus** **Unified Work Program (UWP)**	**Policy**
Transportation Plan: **Long-Range Element** **Transportation System Management (TSM) Element**	**Planning**
Transportation Improvement Program (TIP) **Annual Element of TIP**	**Programming**
Transportation Improvements	

Source: Reference 5.

Figure 7-1
The Transportation Planning Process

Unified Work Program

The Unified Work Program is a written document which outlines all upcoming planning activities for urban transportation that are anticipated during a one or two year period. It serves as the basis for coordinating and consolidating planning activities to ensure the efficient use of resources. It delineates specific responsibilities at all levels of government. It also includes all elements of the long-range planning effort (initial, continuing and refinement phases). Finally, the UWP must contain descriptions of planning activities for highway, transit, aviation and railway modes.

Transportation Plan

The transportation plan consists of both the long-range and TSM elements. The development of this plan must be in conjunction with the area's comprehensive long-range land use plan and must be consistent with urban development objectives and the area's overall social, economic, environmental, system performance and energy conservation goals and objectives.

Long-Range Element. The purpose of this element is to provide for the long-range transportation needs of an urbanized area by identifying new policies and facilities or changes in existing facilities by mode. The time frame for the long-range element is 15 years or more.

Transportation System Management (TSM). The purpose of the TSM element is to provide for the short-range transportation needs of an urbanized area through the most efficient use of existing transportation resources. The TSM element includes identifying traffic engineering, public transportation, regulatory, pricing, management, operational and other needed improvements to the existing urban transportation system, not including new transportation facilities or major changes in existing facilities.

The TSM concept views existing streets and highways, rail, parking and pedestrian facilities and the transportation vehicles (both public and private) as individual elements which comprise a single urban transportation system. The objective of TSM is to organize these individual elements into one efficient, productive and integrated transportation system which not only serves local community needs and objectives, but also the broader national goals and objectives of environmental protection, energy conservation and equity for persons dependent on public transportation.

No formal standards or measures to meet the requirement of developing a TSM element are specified by UMTA or FHWA. Rather, the TSM element is strictly a local responsibility to be accomplished as part of a continuing and cooperative transportation planning and implementation process. The MPO in each urbanized area in cooperation with the state and operators of publicly owned transportation services is responsible for the development and periodic updating of the TSM element.

Examples of actions which are considered eligible for the TSM element include:

- Projects which are designed to ensure the efficient use of the existing roadway network through:
  - Traffic engineering and operational improvements which are designed to reduce traffic congestion and facilitate the flow of traffic such as the construction of reversible flow traffic lanes, traffic control signalization, traffic control and surveillance systems (computerized and noncomputerized), driver advisory information, ramp control, etc.;
  - Preferential treatment for transit and other high-occupancy vehicles, such as preferential or exclusive arterial and freeway lanes, traffic bypass lanes, bus preemption of traffic signals, etc.;
  - Provision of the appropriate facilities for pedestrians and bicyclists such as bicycle lanes, parking areas for bicycles, pedestrian malls, elevated pedestrian walkways or skyway systems, etc.;
  - Provisions for fringe and transportation corridor parking, construction of off-street parking (when a TSM project requires the removal of critical on-street parking), central and outlying intermodal transfer facilities, etc.;
  - Local transit route and schedule improvements such as express bus and park-and-ride service; and
  - Demand spreading and pricing policies such as staggered and flexible work hours, reduced off-peak transit fares, peak-period commuter tolls, etc.
- Projects implemented to reduce vehicle use in heavily congested urbanized areas through:
  - Ride-sharing activities that encourage carpooling, vanpooling and other forms of ride-sharing, and the diversion, exclusion and metering of automobile access to specific areas;
  - Area licenses, parking surcharges and other forms of congestion pricing;
  - The establishment of auto-restricted zones and the closure of selected streets to vehicular traffic or to through traffic;
  - Restrictions on downtown truck delivery during peak traffic hours; and
  - On-street parking restrictions.
- Projects designed to improve transit services through:
  - Provision of better collection, distribution and internal circulation services (including route-deviation and demand responsive services) within low density areas;

- Greater flexibility and responsiveness in routing, scheduling and dispatching of transit vehicles;

- Provision of express bus service in coordination with local collection and distribution services;

- Provision of extensive park-and-ride services from fringe and transportation corridor parking areas;

- Provision of shuttle transit services from CBD fringe parking areas to downtown activity centers;

- Encouragement of jitneys and other flexible para-transit services and their integration in the metropolitan public transportation system;

- Simplified fare collection systems and policies;

- Provision of shelters and other passenger amenities; and

- Better passenger information systems and services.

- Projects which increase internal transit management efficiency and effectiveness through:

  - Improved marketing techniques;

  - Developing cost accounting and other management tools to improve decision-making;

  - Establishing maintenance policies that assure greater equipment reliability, and

  - Using surveillance and communications technology to develop real time monitoring and control capability.

These TSM projects may be financed by UMTA and FHWA planning funds under the UWP planning effort.

Transportation Improvement Program (TIP). The Transportation Improvement Program covers a time frame of 3 to 5 years and outlines transportation improvement projects for an urbanized area. Also included in the TIP is an annual element which is a listing of projects proposed for implementation during the first program year. The Transportation Improvement Program serves as a vital link between the urban transportation planning process and the projects proposed for federal assistance.

For each urbanized area, the Transportation Improvement Program should:

- Identify transportation improvement projects recommended as a result of the cooperative planning process for advancement during the program period;

- Indicate the area's priorities;

- Group projects of similar urgency and anticipated staging into appropriate staging periods;

- Include realistic estimates of total costs and revenues for the program period; and

- Include for information purposes a discussion of how the long-range and TSM elements of the transportation plan were merged into this program.

The Transportation Improvement Program should be developed and updated annually by the area's MPO in cooperation with state and local officials as well as regional and local transit operators.

Estimating the Demand for Transit (5,11)

Estimating the demand for urban transit service is but one component of overall urban travel demand forecasting. Accurate estimates of future travel are essential inputs for a variety of transportation planning functions, such as identifying transportation needs, preparing long-range plans and evaluating transportation alternatives. Travel forecasts may be developed as part of the continuing planning process for an urbanized area or to satisfy short-range planning requirements for a specific project. Potential travel demand uses can be outlined as follows:

- Demand forecasting for design purposes
  - For project-specific design
  - For general design guidelines
- Demand forecasting for project evaluation
  - For comparison of alternatives
  - For feasibility analysis

Thus, the demand estimation effort may be large or narrow in scope, depending on the purpose or project.

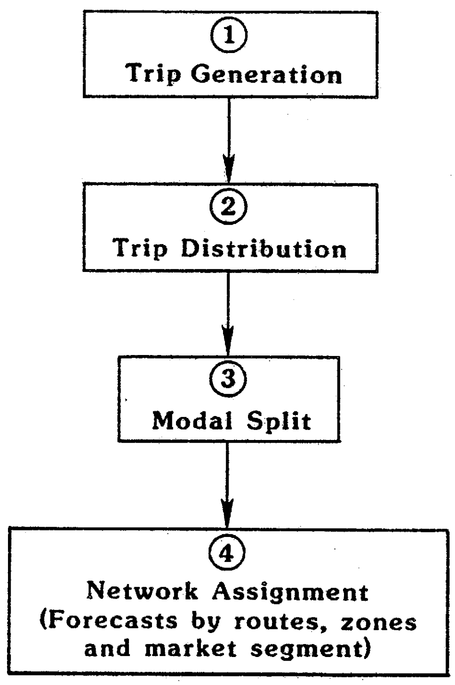
Travel Forecasts (5)

The task of developing travel forecasts can require substantial data, mathematical models and associated computer use. An important preliminary step is data collection which typically consists of surveys of actual and latent (present but not active) travel and market segment characteristics. A market segment is a group of individuals or households with similar travel behavior.

Methodology. Urban travel demand forecasting generally involves describing the transportation network area by zones, travel, population, characteristics, etc., using a 4-step approach to calculate forecasts. The traditional 4-step approach (Figure 7-2) can include the use of mathematical models to predict travel (number of trips) on a network. The basic variables of travel considered include:

- Frequency of trips (per day);
- Origin/destination;
- Mode;
- Time of trip;
- Number of autos owned;
- Residential location; and
- Employment location.

These variables, along with activity variables (such as trip purpose), economic variables (such as out-of-pocket costs), and service-related variables (such as travel time), are used in the travel forecasting process.



Source: Reference 5.

Figure 7-2
Traditional Four-Step Approach of
Urban Travel Demand Forecasting

Service Characteristics (5). Mathematical models which predict travel are based on consumer behavior patterns. Decisions made by consumers will affect the urban transportation system. The basic decisions to be made by individuals are whether, where, when and by which mode and route to make a trip. These decisions are influenced by many factors. Trip purpose is one factor which is typically used in modeling. Other factors to be considered include service-related characteristics, such as those presented in Table 7-1.

Table 7-1
Service Characteristics

Characteristic	Description
Time	• Total trip time can be divided into the following components: - access time: • excess time (walk time, wait time) • in-vehicle time (time in auto or bus to mainline transit) - line haul time: • excess time (transfer time) • in-vehicle time (mainline transit time, auto driving time) • Reliability - subjective estimate of variance in trip time
User Cost	• Out-of-pocket costs - Fares, fuel, parking, oil, toll charges, etc. • Transportation overhead - cost of acquiring, maintaining, etc.
Safety	• Probability of fatality • Probability of accident • Perceived security
Comfort and Convenience	• Walking distance (less than 1/4 mile) • Number of changes of vehicle • Physical comfort - temperature, humidity, cleanliness, ride quality, exposure to weather • Psychological comfort • Amenities

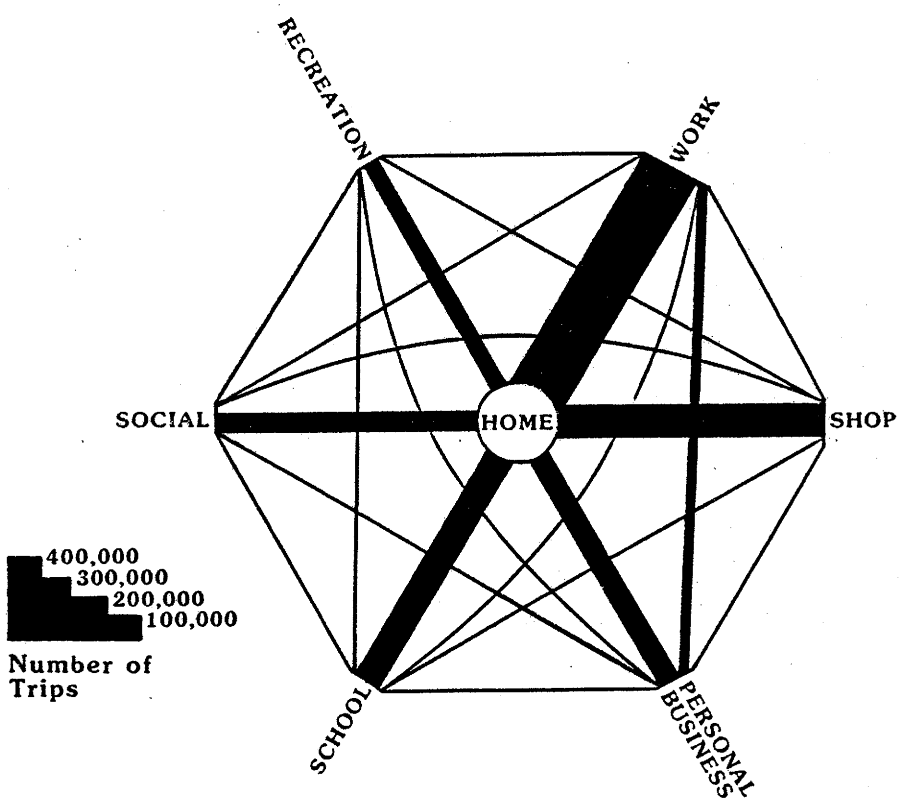
Source: Reference 5.

When forecasting the demand for conventional transit service along a single route, the primary service variables typically used include travel time, wait time and fare. For large scale projects, such as corridor service, additional variables are required to give an estimate of demand. For example, the competition between auto and bus or rail is an important aspect to be included in the forecast methodology (modal split analysis).

Trip Characteristics (12). Trip making is a function of the various purposes of trips and when they are made.

Trip Purpose. All trips are made for a reason: for example, a trip to work or school, a trip to the doctor or a trip to a shopping center. Thus, trip purpose patterns reflect the daily activities of urban residences. The following is a summary of trip purpose patterns observed in the United States and Canada (12).

- The home or dwelling unit is the primary origin or destination of most trips (Figure 7-3). In general, more than 75% of all urban trips are to or from home.
- Transportation studies in urban areas of the U.S. and Canada (conducted in the 1960s and 1970s) revealed that 30% of all trips are to and from work, 18% to and from shopping, 21% to and from social or recreational purposes, 12% for business purposes, 10% to and from school, and the remaining 9% are for other reasons.
- The number of daily work trips per person does not vary substantially from city to city in the U.S. It averages 0.7 trip/person, despite the variations in total trip making. This indicates that work trips are relatively inelastic and that it is the nonwork trips that increase with rising income and auto ownership.



Source: Reference 10.

Figure 7-3
Trip Purposes Within Typical Urban Area

Table 7-2 presents the average percentage of nationwide urban travel by mode and trip purpose. As the percentages indicate, the use of transit is comparable to the use of other transportation modes for all trip purposes except social and recreational.

Table 7-2
Percentage of Urban Trips By Mode and Trip Purpose for Urban Areas in the U.S.

Mode of Travel	Business	Recreational	Shopping	Misc.	Home	Total
Auto Drivers	32.3	9.5	8.0	13.4	36.8	100.0
Auto and Taxi Passengers	17.2	24.5	7.4	7.9	42.5	100.0
Transit Passengers	29.5	7.2	6.8	12.5	44.0	100.0
Total	27.9	12.0	7.5	11.8	40.8	100.0

Source: Reference 5.

Table 7-3 presents the percentage of urban travel by mode and trip purpose for the Houston metropolitan area. Again, the use of transit for many trip purposes (such as travel to and from work and school) is comparable to other transportation modes.

Table 7-3
Percentage of Urban Trips By Mode and Trip Purpose for the Houston Metropolitan Area - 1984

	Trip Purpose (%)						
Mode of Travel	Work	Work Related	School	Shopping or Meal	Other[1]	Home	Total
Auto Driver (n=10,475)	18.7	10.8	3.1	13.8	20.8	32.8	100.0
Auto Passenger (n=2,867)	9.2	5.1	11.6	15.8	22.7	35.6	100.0
Transit Bus (n=192)	22.4	6.3	16.6	2.6	14.6	38.0	100.0
School Bus (n=426)	0.7	0.9	50.2	0.0	2.4	45.8	100.0
Taxi (n=5)	20.0	20.0	0.0	20.0	20.0	20.0	100.0
Other (n=136)	37.5	24.3	4.4	11.8	7.3	14.7	100.0
Total (n=14,101)	16.3	9.2	6.5	13.6	20.5	33.9	100.0

[1]Includes social, recreational, personal, etc.

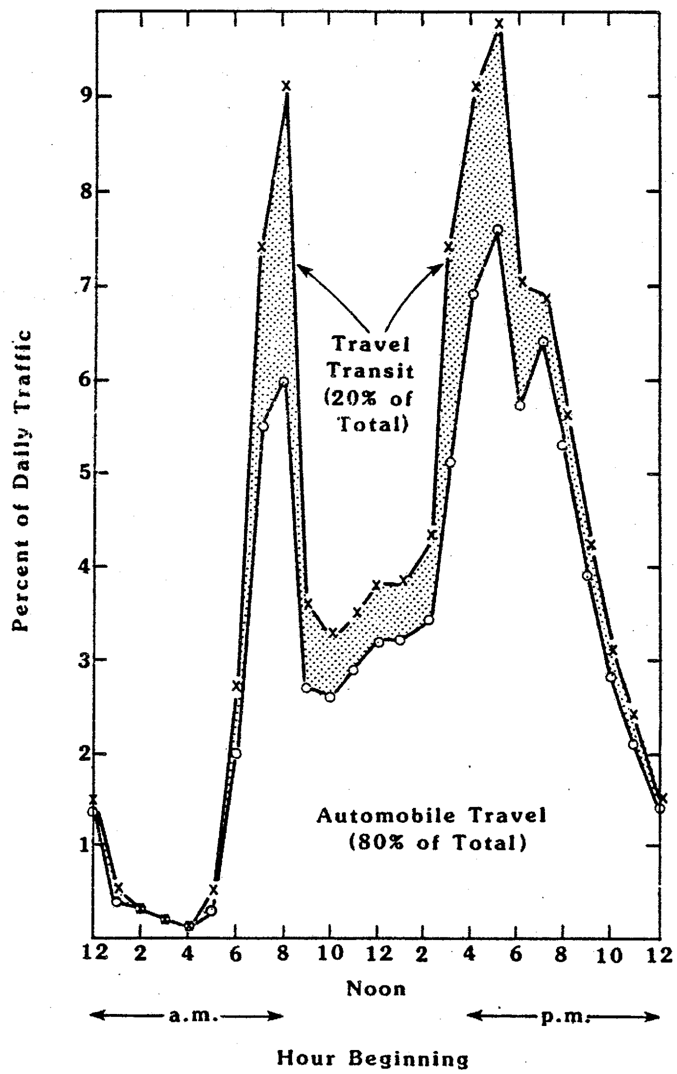
Source: Preliminary data from the 1984 Houston-Galveston Area Council Regional Travel Survey.

Hourly Variations. The hourly variations of urban travel during the typical weekday are a reflection of the basic purposes for which the trips are made and the capabilities of the various travel modes. In general, vehicular travel on highways is normally less peaked than public transportation modes (especially rail transit) for the following reasons:

- More travel takes place during evenings and off peak times for non-work purposes; and

- Road capacity constrains peak-period travel on many streets and highways.

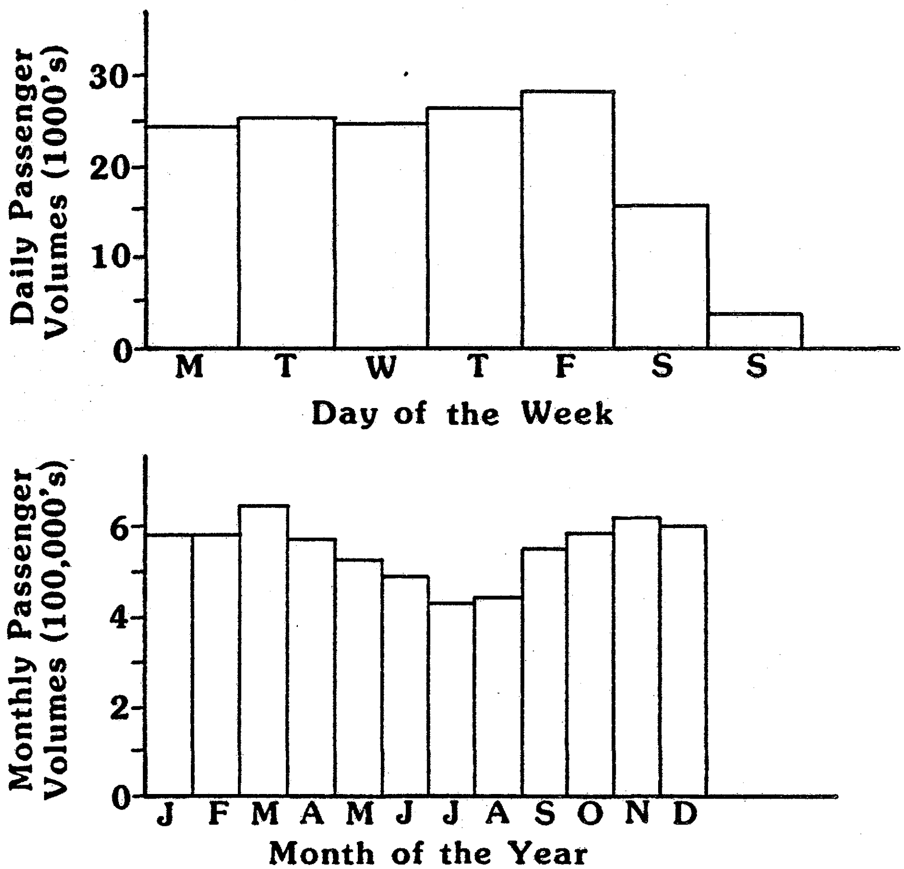
Typical hourly urban travel patterns for both automobiles and transit are illustrated in Figure 7-4. An important aspect of this figure is the large demand which occurs over short periods (peak periods) of time. For transit, this means that a larger number of vehicles and operators are required to handle the surges in demand.



Source: Reference 12 compiled from data on Chicago, Detroit, Pittsburgh, Toronto and Washington, D.C.

Figure 7-4
Typical Hourly Variation of Travel by Mode

Weekly and Monthly Variations. Travel demand, particularly transit travel demand, also varies by day and month. As illustrated in Figure 7-5, transit demand on weekends is slow, with Saturday higher than Sunday because of shopping trips. In addition, demand during the summer months is lower (school vacation, other vacations, etc.) and winter months are slightly higher (reluctance to drive cars or walk in bad weather, etc.).



Source: Reference 5.

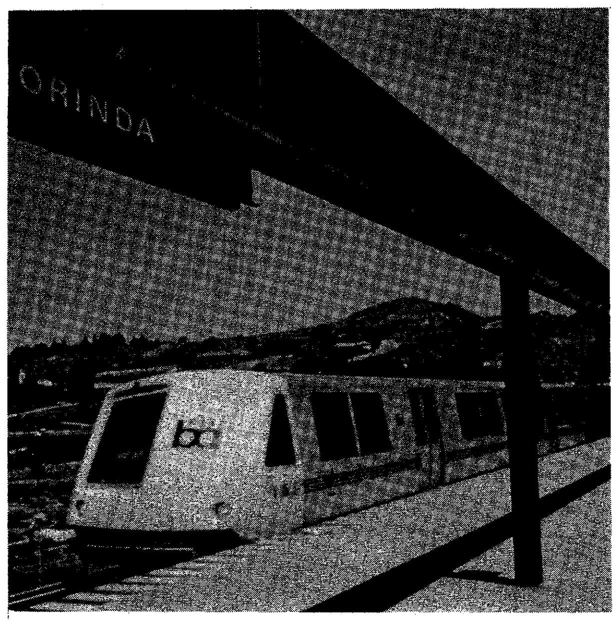
Figure 7-5
Typical Daily and Monthly Transit Demand

Trip Lengths. Trip lengths vary by mode. As indicated by Table 7-4, ranges in trip lengths by mode show some difference basically because of their service characteristics. For example, the increased length of rail transit modes results from the limited service coverage, greater distance between stations and the downtown focus of these trips.

Table 7-4
Typical Trip Length Ranges

Travel Mode	Trip Length (miles)
Auto (driver)	4.0 - 7.2
Auto (passenger)	3.6 - 7.2
Bus	2.5 - 4.3
Rapid Transit	5.8 - 7.9
Regional Rail	14.6 - 18.5

Source: Reference 12.



Due to limited service coverage and greater distance between stations, trip lengths for regional rail (left) are longer than for rail rapid transit (right) or other modes.

Trip Maker Characteristics (5, 13). The average transit user is frequently thought of as a poor and/or elderly person who has no other means of transportation. While transit does indeed serve a public transportation function for transit dependent individuals or "captive riders" (as illustrated in Table 7-5), transit has also demonstrated the ability to attract and serve young, highly educated persons employed in white-collar positions who would rather use transit than other modes. Park-and-Ride service, for example, serves weekday commuters who do not fit the typical captive rider description. Table 7-6 summarizes personal characteristics of park-and-ride users in Texas cities.

Table 7-5
Summary of Selected Characteristics of Bus Riders in
Port Arthur and Midland, Texas 1982

Characteristic	Port Arthur Weekday Riders	Port Arthur Saturday Riders	Midland Weekday Riders[1]
Age	(n=218)	(n=189)	(n=71)
Median (years)	32	29	46
Sex	(n=221)	(n=189)	(n-=81)
Male	29%	22%	15%
Female	71%	78%	85%
Highest Level of Education			
Less than high school	53%	53%	14%
High school graduate	35%	35%	41%
Some college, college graduate	12%	12%	45%
Occupation	(n=190)	(n=162)	(n=71)
Unemployed	7.9%	11.7%	1.48
Homemaker	13.2%	15.4%	18.3%
Student	33.6%	39.5%	2.8%
Retired	8.9%	6.8%	5.7%
Household Worker	3.2%	3.7%	8.5%
Laborer	3.2%	6.8%	1.4%
Operative	3.2%	2.3%	5.6%
Service Worker	14.2%	9.9%	5.6%
Craftsman	2.6%	1.2%	5.6%
Clerical	4.2%	1.9%	28.2%
Sales	3.7%	1.2%	2.8%
Managerial	0.5%	------	8.5%
Professional	1.6%	0.6%	5.6%
Annual Household Income	(n=145)	(n=146)	(n=71)
Less than $10,000	62%	57%	46%
$10,000 - $20,000	29%	20%	21%
$20,000 - $30,000	5%	15%	10%
More than $30,000	4%	8%	23%
Travel Mode if No Transit			
Service Available	(n=239)	(n=200)	(n=84)
Drive myself	10%	10%	26%
Ride with someone else	37%	29%	33%
Taxi	23%	23%	28%
Walk	15%	12%	5%
Couldn't make trip	12%	12%	13%
Other	3%	4%	5%

[1]Saturday service was not available in Midland.

Source: Reference 13.

Table 7-6
Summary of Selected Characteristics of Park-and-Ride Users in Texas

Characteristic	El Paso	San Antonio	Dallas/ Garland	Houston	Fort Worth	Non-Weighted Average
Age Groups	(n=108)	(n=365)	(n=402)	(n=2289)	(n=107)	(n=328)
Less than 18	2%	3%	0%	0%	0%	1%
18 - 21	5	10	5	8	4	6
22 - 31	37	38	26	45	35	38
32 - 41	28	23	28	27	23	26
42 - 51	17	11	20	12	20	16
52 - 61	11	11	10	7	14	11
62 and over	0	4	1	1	4	2
Sex	(n=108)	(n=354)	(n=408)	(n=2348)	(n=111)	(n=3329)
Male	40%	45%	42%	42%	37%	41%
Female	60	55	58	58	63	59
Highest level of education	(n=109)	(n=362)	(n=371)	(n=2222)	(n=106)	(n=3170)
Less than high school	3%	5%	2%	1%	7%	4%
High school graduate	23	22	24	19	33	25
Some college	45	41	27	24	22	32
College graduate	25	23	33	42	10	27
More than college	4	9	14	14	18	12
Occupation	(n=108)	(n=343)	(n=396)	(n=2254)	(n=106)	(n=3207)
Unemployed	0.9%	0.0%	0.0%	0.1%	0.0%	0.2%
Homemaker	0.9	0.0	0.5	0.3	0.0	0.3
Student	8.4	14.6	2.5	1.4	0.0	5.4
Retired	0.9	0.3	1.0	0.1	0.9	0.7
Household Worker	0.0	0.0	0.0	0.0	0.0	0.0
Laborer	2.8	0.0	.8	0.0	0.0	0.7
Operative	0.9	1.2	1.5	0.6	4.7	1.8
Service Worker	2.8	8.5	1.3	0.4	5.6	3.7
Craftsman	0.9	2.0	1.5	1.0	9.4	2.9
Clerical	38.0	32.9	39.6	35.2	35.8	36.3
Sales	4.6	3.2	4.3	3.7	0.9	3.4
Managerial	13.0	17.8	18.7	17.1	14.1	16.2
Professional	25.9	19.5	28.3	40.1	28.3	28.4
Previous Mode of Travel	(n=109)	(n=361)	(n=416)	(n=2378)	(n=112)	(n=3376)
Drove alone	61%	57%	50%	49%	63%	56%
Carpool/vanpool	28	20	11	17	15	18
Local bus	8	20	11	8	8	11
Didn't make trip	3	3	25	24	9	13
Other	0	0	3	2	5	2

Source: Reference 14.

For transit demand estimation, the discussion will include travel surveys, latent demand and modal split analysis.

Travel Surveys (5).

Travel surveys represent the tools of data collection. The specific level of effort devoted to these surveys will depend on the objectives of the overall planning effort.

Survey Design. Certain organizational steps are necessary in preparation for travel surveys. At a minimum, the following groups and agencies should be included in planning and developing the travel surveys.

- Affected state and local governmental agencies;
- Federal agencies that might be involved;
- Local and regional planning groups not included in the previous groups;
- Transit properties to be included in the survey;
- Transit unions through the transit properties;
- Sources for hiring temporary help, if such assistance is necessary; and
- The news media, to assist in publicizing the survey.

Input from these groups can be used in developing a survey schedule and in organizing the survey effort.

Data Requirements. The type, amount and detail of data required will depend on the analysis for which it is gathered. A few general considerations include:

- Goals and objectives of the study;
- Types of analysis and planning models to be employed;
- Types of survey constraints that exist;
- Data tabulation;
- Sample sizes, statistical considerations; and
- Types of surveys.

Available Data. In order to avoid duplicating efforts, a review of existing sources of data such as those presented in Table 7-7 is recommended. In the course of the investigation, the type, quantity and reliability of the data sources should also be considered.

Table 7-7
Typical Sources of Data Used in Forecasting Urban Travel

Data Type	Source
Social and Economic	U.S. Bureau of the Census City or County Clerk State Department of Labor State Department of Internal Revenue City or County Planning Board
Motor Vehicle	State Highway Department, DOT or Motor Vehicle Dept. U.S. Census (Journey-to-Work) Local Traffic Department Earlier Travel Surveys State Registration Records Gasoline Tax Collection Records
Public and Mass Transportation Travel	Local Transit Companies State Highway Department (or State DOT) Local Planning Agency U.S. Census (Journey-to-Work) Earlier Travel Surveys Regional Transit Authority
Travel by Intercity Modes (air, rail, bus)	Federal Agencies such as: The Civil Aeronautics Board The Federal Aviation Admin. The Interstate Commerce Comm. The Federal Railroad Admin. State Regulatory Agencies Earlier Travel Surveys Private Carriers
Land Use Characteristics	City Directories Local, Regional, and State Planning Agencies Tax Assessor's Records

Source: Reference 5.

Examples of existing data for Texas cities which can be obtained from the U.S. Bureau of the Census (15) are presented in Tables 7-8 and 7-9.

Table 7-8
Percentage of Households With None, One, Two, and Three or More Private Vehicles Available for Selected Texas Cities

City	Number of Households	Automobiles, Trucks or Vans Available			
		None	1	2	3 or more
Abilene	33,938	5.4%	35.3%	37.0%	22.3%
Amarillo	56,216	6.0	33.4	37.8	22.8
Austin	133,932	8.4	41.4	34.0	16.2
Beaumont	43,082	11.5	35.3	35.6	17.6
Brownsville	22,882	14.9	41.9	30.0	13.2
Corpus Christi	76,661	7.9	36.3	35.1	20.7
Dallas	355,071	10.8	41.8	31.8	15.6
El Paso	128,167	11.3	36.8	32.9	19.0
Fort Worth	144,018	9.4	38.7	34.4	17.5
Galveston	24,013	18.9	44.4	25.7	11.0
Houston	602,719	9.5	41.8	33.0	15.7
Laredo	23,903	19.3	39.1	26.6	15.0
Lubbock	60,783	5.1	35.9	38.5	20.5
Midland	25,558	4.3	32.2	39.7	23.8
Port Arthur	22,130	13.4	37.4	33.7	15.5
San Angelo	26,576	7.0	35.7	35.6	21.7
San Antonio	258,979	12.4	38.3	32.0	17.3
Waco	37,567	10.8	39.9	32.5	16.8
Wichita Falls	33,647	7.2	36.8	36.0	20.0

Source: Reference 15.

New Data. Data which needs to be obtained from the travel surveys can be identified after the examination of analysis requirements and existing data. The specific information needed will depend on the particular planning effort. Examples of data typically collected include:

- **Transit-Related Data** - Frequency of trips (per day), origin/destination, access mode to transit, route, time of trip, etc.;
- **Trip Making Characteristics** - Transfer, fares, method of fare payment, home address, etc.;
- **Socio-Economic Data** - Age, sex, occupation, level of education, household size, number of autos owned, drivers license, etc.; and
- **Reasons for Using Transit** - No other means of transportation, more convenient, saves time, saves money, etc.

Development of the Survey. The following factors should be considered in the development of the survey.

Questionnaire Design. The survey questionnaire should be clear, concise, and easy to complete. Pretesting the questionnaire by distributing it to a random sample of a few transit users is usually advisable to be sure

Table 7-9
Means of Transportation to Work for Residents of Selected Texas Cities in 1979 (Percentage of Mode)

City	Workers 16 years and Older	Means of Transportation to Work			
		Drive Alone	Carpool/ Vanpool	Public Transportation[1]	Other[2]
Abilene	46,301	74.9%	15.8%	0.7%	8.6%
Amarillo	70,585	74.7	19.8	0.9	4.6
Austin	173,662	67.1	19.7	0.4	12.8
Beaumont	50,333	73.8	18.8	0.2	7.2
Brownsville	28,204	66.9	23.4	0.2	7.7
Corpus Christi	101,809	72.5	20.7	1.4	5.4
Dallas	455,067	67.5	19.6	8.3	4.6
El Paso	161,036	68.0	20.5	4.2	7.3
Fort Worth	178,104	69.2	22.0	3.6	5.2
Galveston	28,677	58.3	23.4	4.5	13.8
Houston	806,697	58.3	23.4	4.5	13.8
Laredo	29,638	63.1	22.8	4.6	9.5
Lubbock	83,289	73.4	18.4	1.2	7.0
Midland	35,028	75.7	18.3	0.6	5.4
Port Arthur	20,209	69.6	22.5	1.5	6.4
San Angelo	34,880	71.1	18.1	0.6	10.2
San Antonio	315,549	67.6	20.2	6.0	6.2
Waco	41,262	74.5	17.1	1.5	6.9
Wichita Falls	46,002	67.9	17.0	1.1	14.0

[1]Includes bus, subway, or elevated train, railroad and taxi.
[2]Includes bicycle, motorcycle, walked only, other means and worked at home.

Source: Reference 15.

that the data to be collected is easily understood by the respondents. The method of processing the data from the completed questionnaires should also be considered in the survey design.

Accuracy Checks. Data sources independent from the travel survey should be used to check the accuracy and completeness of the travel data. Passenger counts or other statistics available from the transit property are typically used for this purpose.

Personnel Requirements and Survey Costs. Manpower requirements for all phases of the survey (development, distribution, editing, coding, computer inputing of data, analysis of data, etc.) should be carefully considered as should the various costs associated with the survey effort.

Publicity. The cooperation of the public is essential for a successful survey. People should be informed of the survey and its importance by a communication effort appropriate to the level of financial and manpower resources available for the overall project. Media efforts typically used include placing notices on transit vehicles and at transit stops and advertising through the radio, television and newspapers.

Types of Surveys

Survey techniques for the data collection effort consist of the following:

- Personal interview;
- Telephone interview;
- Mailing or hand distribution of mail-back questionnaires; and
- Hand distribution of questionnaires, followed by hand collection of completed forms.

There are advantages and disadvantages associated with each technique. The basic consideration in deciding which to use is the trade-off between the cost per completed survey versus the number or percent of responses required. For example, personal and telephone interview surveys will normally be more complete and accurate (and expensive) while mail-back forms will have a much lower response rate, but cost less. Selecting the most appropriate technique for each specific data collection effort will depend on costs, time and personnel requirements.

Two basic survey types are used in travel surveys. The first type is comprehensive and involves collecting data where trips begin and end to obtain information on all trips by all modes. Examples of comprehensive surveys include dwelling unit (or household surveys), employee surveys, employer surveys and shopping center surveys.

The second type of survey involves collecting data while users are making the trips. The on-board transit user survey is an example of this type.

Latent Transit Demand

Latent demand represents the potential trips that could be made by persons who cannot or will not make these trips because of inconvenience, or absence of service, or by persons who would make more trips than they are making now. Latent demand includes the potential ridership shift from auto to transit. Poor, elderly, handicapped, auto-less, young persons and those who do not make trips due to intolerable traffic congestion are other examples of latent demand groups.

The surveys used to identify latent demand must be comprehensive in nature and identify characteristics of the non transit users and the unattractive aspects of transit service. Experience indicates that actual usage of new service is often less than that indicated by survey responses, however.

Mode Split Analysis

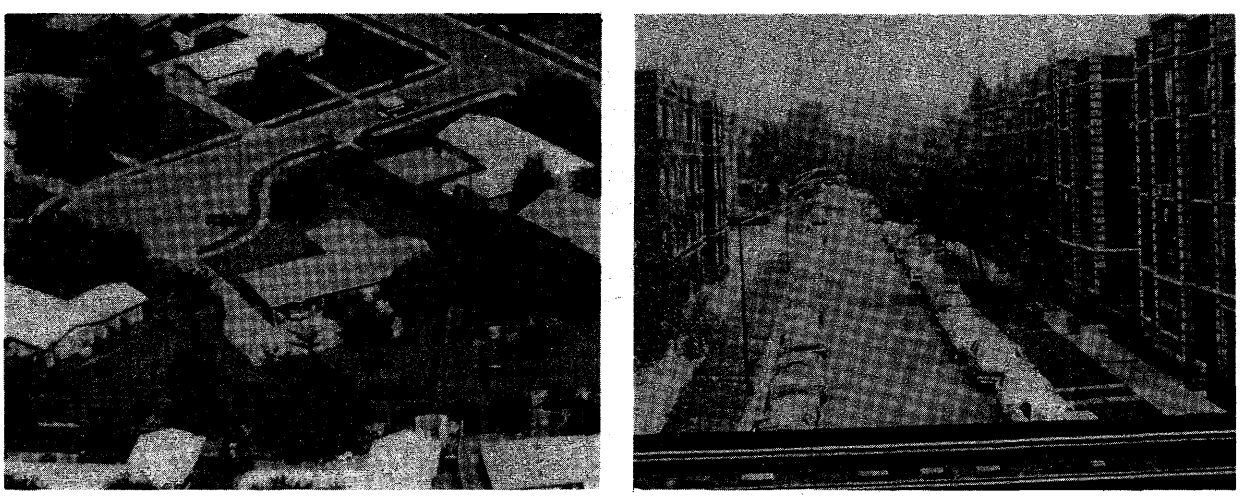
Modal split analysis, which is one step in the traditional four-step forecasting procedure, consists of estimating the percentage of travel which will occur on various alternative modes. Basic methodologies are based on analysis of how demand might change with transit service improvements to routes, schedules, etc. and policies such as congestion pricing, auto-free zones, etc.

Demand Function. In quantifying demand, the relationship between consumer desires and service variables of alternative modes (auto, transit, etc.) is estimated. This relationship is termed the demand function. Trip, tripmaker and service characteristics are variables in the function. Such variables as auto availability, parking charges, fares, travel time, etc. can be considered. Other variables such as consumer perception of safety, comfort, etc. cannot be quantified as easily as service characteristics. In essence, the function identifies what mode will be used by certain users.

Models. Two basic types of models exist. One model is the trip-end modal split model which estimates portions of total person-trips by auto-transit, etc. before the trips are distributed by route from zone to zone. That is, trips are assigned to modes before the trip distribution step. Another model is the trip-interchange model which estimates trips after trip distribution, yielding internal transit and auto trips.

Population Density and the Demand for Transit (3)

In the planning and development mass transit systems to serve larger urbanized areas it should be recognized that population density is at least somewhat related to transit utilization. As indicated in Table 7-10, the average population density for the large Texas cities is less than 1/4 the average for the other U.S. cities. Furthermore, the average density for Texas cities is less than 1/2 of that for other U.S. cities with rail rapid transit.



The average population density for Texas cities (left) is less than 1/2 of that for other U.S. cities with rail rapid transit (right).

Table 7-10
Population Densities of Selected U.S. Urbanized Areas, 1980 Census

Urbanized Area	City Population (000)	Land Area (sq. mi.)	Population Per Square Mile
Texas Cities			
Dallas	904	333.0	2,714
Fort Worth	385	240.0	1,604
Houston	1,595	556.4	2,866
San Antonio	786	262.0	3,000
Avg. Non-weighted			2,562
Other U.S. Cities			
Atlanta	425	79.1	5,372
Baltimore	787	80.3	9,800
Boston	563	47.2	11,928
Chicago	3,005	228.1	13,174
Cleveland	574	79.0	7,266
Denver	492	110.6	4,448
Los Angeles	2,967	464.7	6,385
Miami	347	34.3	10,166
New York City	7,072	301.5	23,456
Philadelphia	1,688	136.0	12,411
Pittsburgh	424	55.4	7,653
San Francisco	679	46.4	14,633
Washington, D.C.	638	62.7	10,175
Avg., Non-weighted			10,528

Source: Reference 3.

Operating Subsidies (3)

In planning transit systems (particularly mass transportation systems), funds must be available on an on-going basis to subsidize operations. On a national basis, for urban areas over one million in population, transportation revenues represent about 36% of operating expenses. The remainder is made up from local, state, and federal operating subsidies.

The magnitude of the deficits can be substantial. On an annual basis, operating expenses exceed fare box revenue by approximately $1 billion in New York City (Table 7-11).

For large properties in Texas, substantial deficits may also occur. For example, Houston plans to serve roughly 200 million annual passengers. In Texas, a typical cost per passenger is $1.40. If 40% of operating expense is recovered, the annual deficit will be in the range of $150 to $200 million. Table 7-12 provides recent data for selected major transit properties in Texas. Thus, significant on-going subsidies will be associated with long-range transit plans and need to be recognized in the public transit planning process.

Table 7-11
Estimated Operating Revenues and Expenses for Selected Major Transit Properties, Fiscal Year 1985

Transit Property (all transit modes)	Total Revenue (millions of $)	Percent of Total Revenue From				Operating Expenses (millions of $)
		Fare Box	Local Assistance	State Assistance	Federal Assistance	
Atlanta (MARTA)	$ 114	27.4%	47.2%	0%	7.0%	$ 98
Boston (MBTA)	342	27.7	26.0	36.5	6.8	286
Chicago (CTA)	528	50.2	39.1	0	9.0	532
Cleveland	116	33.9	56.2	0.6	7.6	105
New York City (NYCTA)	2,206	47.5	21.6	19.4	3.8	2,196
Philadelphia (SEPTA)	387	38.4	10.1	30.8	14.4	363
San Francisco (BART)	138	44.2	49.8	1.8	0	125
Washington, D.C. (WMATA)	423	32.4	45.6	4.4	14.9	336

Source: Reference 3.

Table 7-12
Operating Revenue and Expenses For Major Texas Transit Properties, Fiscal Year 1983

Revenue and Expense ($ millions unless otherwise noted) Fiscal Year 1983	Dallas		Fort Worth		Houston		San Antonio	
Passenger Fares	$20.1	48%	$2.5	34%	$19.8	10%	$ 8.6	21%
Other Operating Revenue	3.0	7%	0.4	6%	1.0	1%	2.8	7%
Auxiliary Transportation Revenue	0.4	1%	0.1	1%	0	0%	0.2	1%
Non Transportation Revenue	0.0	0%	0.1	1%	21.4	10%	2.4	6%
Local Operating Assistance	8.7	21%	2.0	28%	157.3	79%	21.2	53%
Federal Operating Assistance	9.6	23%	2.2	30%	0.7	0%	4.9	12%
TOTAL Revenue	$41.8	100%	$7.3	100%	$200.2	100%	$40.1	100%
TOTAL Expense	$41.7		$7.3		$101.3		$31.5	
Transportation Revenue/Total Expense	56%		41%		21%		37%	
Expense Per Passenger (dollars)	$1.15		$1.40		$1.95		$0.92	

*This has declined to less than 45% since the creation of DART.
Sources: Reference 3.

Summary

Urban transportation planning plays an important role in the overall effort of meeting the transportation needs of urban areas. As the planning process has come to include a wide range of issues, impacts, and alternatives, and has come to involve a larger number and greater diversity of participants and has become increasingly more complex. While planning for transit services is but one component of the overall transportation planning effort, it has become an increasingly important one -- particularly in those urban areas of Texas and the U.S. which are actively pursuing methods of restoring (or maintaining) acceptable levels of mobility to provide for continued economic growth and a better quality of life for its residents.

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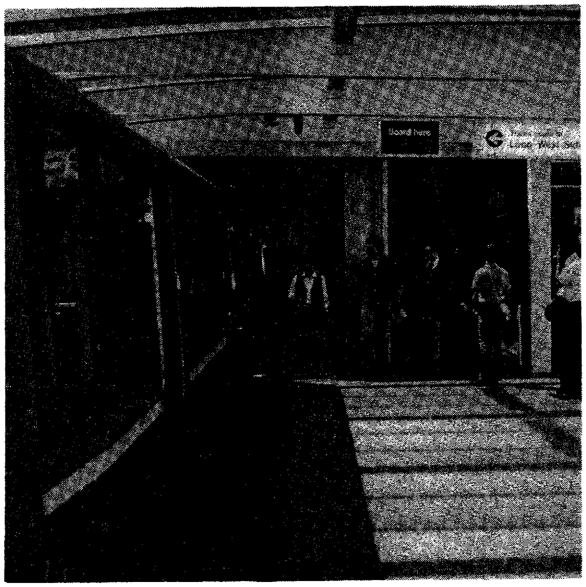
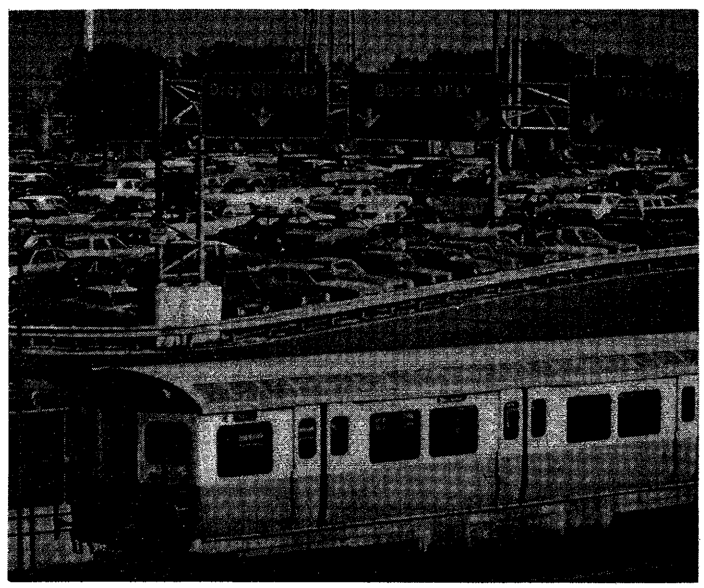
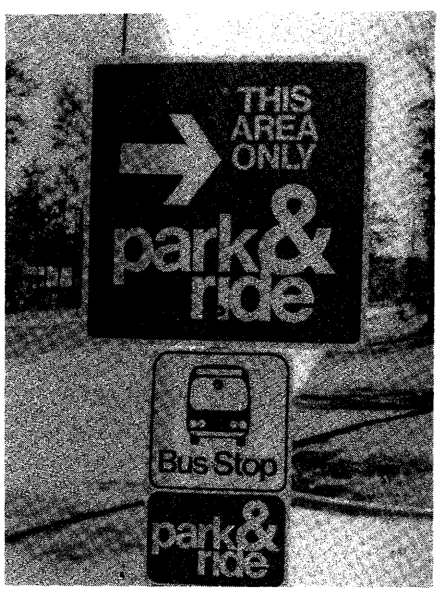




Chapter 8



Managing and Operating Transit Systems

•8•

Managing and Operating Transit Systems

Ownership And Management

Prior to the 1960s, municipal transit systems were predominately privately owned and operated by profit-making business enterprises. During the decades that followed, however, the majority of the nation's transit systems became unprofitable business enterprises. Public ownership became the general rule, and federal, state and local funding sources were used to provide capital and operating assistance. This shift of the transit industry from the private sector to the public sector (documented in Chapter 2) has resulted in several different ownership and operation options being available to municipal transit systems. In general, 6 basic ownership and operation alternatives exist today. These include:

- Private ownership and operation without public subsidy;
- Private ownership, operation with public subsidy;
- Public ownership, management contract with a private corporation;
- Public ownership, city operation;
- Public ownership, independent public operation; and
- Regional transit authority.

Ownership and operation structures for the transit systems in Texas cities are presented in Table 8-1. Of particular interest in this table is the existence of 6 regional transit authorities. Present legislation allows for the possible creation of transit authorities and the assessment of a local sales tax (not to exceed one cent) in metropolitan areas with populations over 230,000, upon local voter approval. In order that smaller urbanized areas be allowed to benefit from increased funds for transit at the local level, considerable interest has been expressed for the enactment of legislation that will permit any urbanized area over 50,000 in population to exercise a local option to create a transit authority and to assess a local sales tax in appropriate increments up to a maximum of one cent.

Table 8-1
Ownership and Management of Transit Systems in Texas

Private Ownership and Operation Without Public Subsidy: • Harlingen • McAllen • Eagle Pass
Private Ownership, Operation With Public Subsidy: • None
Public Ownership, Management Contract With Private Corporation: • Beaumont • Lubbock • Galveston • Port Arthur • Laredo • Waco
Public Ownership, City Operation: • Abilene • Midland • Amarillo • San Angelo • El Paso • Tyler[1] • Wichita Falls
Public Ownership, Independent Public Operation: • None
Regional Transit Authority: • Austin • Houston • Corpus Christi • Ft. Worth • Dallas • San Antonio

[1]Wholly owned and operated by the city using only local funds.

Transit Policy Making and Goal Setting (1)*

Policy making and goal setting functions for transit are typically the responsibility of a governing body. This group makes basic decisions concerning budgets, executive personnel, grants, loans, union contracts, salaries, legal matters, levels-of-service, expansion of the system, acquisition of new equipment and facilities, fare structures, and financial matters. Once these policies are established and adopted, the management staff is given the authority and responsibility for implementation. The governing board gives general supervision and holds the management staff accountable for operating the transit system in accordance with board policies and guidelines. In a publicly owned transit system, the governing body (usually the city council or a governing board in the case of a metropolitan transit authority) is responsible for policy formulation and adoption. In a private company, the board of directors performs this function.

*Numbers in parentheses denote references listed at the end of the chapter.

The carrying out of these policies and administration of operations are responsibilities of the chief executive officer. In a municipality, this typically would be the city manager or mayor, with direct responsibility being delegated to a department head. In those cases where a non-profit corporation has been created by the legislative body of the public agency, direction of the transit system is awarded to a general manager. This arrangement is similar to the management structure of a private corporation, with its board of directors as the governing body and the general manager as the chief executive officer.

Daily Operation (1)

The organizational structure for carrying out the policies and the administration of operations is much the same for both privately or publicly owned transit systems. Most transit systems are organized according to the following functional departments.

- Transportation;
- Scheduling;
- Maintenance;
- Purchasing;
- Engineering;
- Personnel;
- Comptroller-Treasurer;
- Public Relations (Marketing);
- Legal, Claims; and
- Planning.

Whether these functional departments operate as separate entities or are combined depends on the size of the transit system and magnitude of its operations.

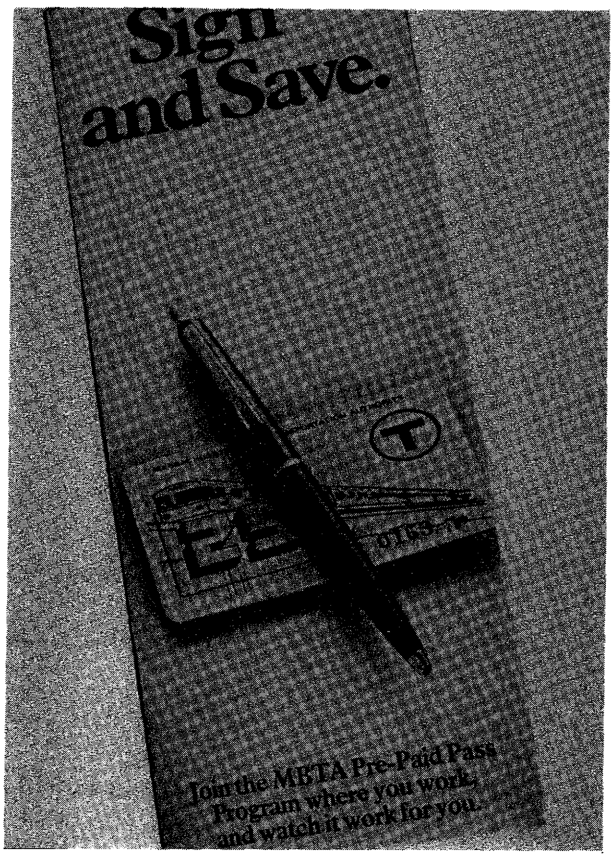
Fares and Service Levels

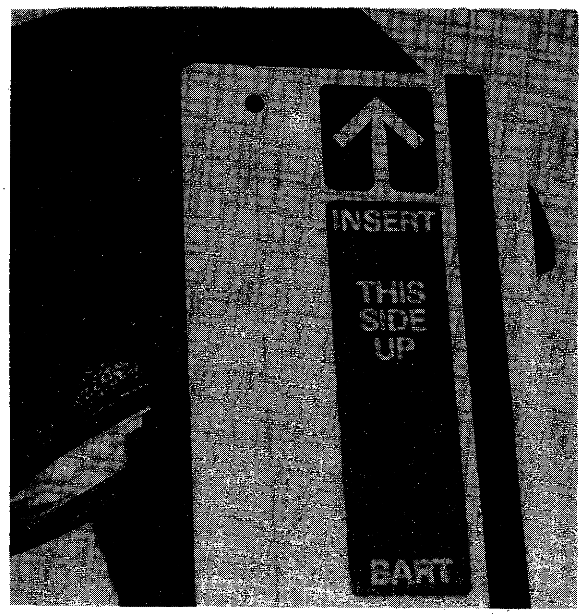
Fare Structures

Fare structures often vary considerably from one type of transit operation to the next. The total fare structure for a transit system may include different rates for each of the following:

- Base fare
- Zone charge

- Transfer fee
- Express fares
- Park-and-ride fares
- Discount fares for:
  - Children
  - Students
  - Senior Citizens
  - Handicapped persons
- Weekly and monthly passes
- Commuter passes
- Ticket books





Monthly and weekly passes, commuter passes and ticket books are examples of fare pre-payment plans offered by many transit systems.

Differences in fare structures sometimes make fare comparisons difficult. One frequently used basis for comparison is the average fare. The average fare is calculated by dividing the total passenger revenue by the ridership. The trend of average fares nationwide by mode is presented in Table 8-2.

Table 8-2
Trend of Average Fares by Mode for the U.S. Transit Industry

Transit Mode	Average Fare (Revenue) Per Linked Passenger-Trip[1]				
	1940	1950	1960	1970	1980
Light Rail	$.07	$.12	$.22	$.27	$.38
Rail Rapid	.05	.10	.16	.23	.51
Electric Trolley Bus	.06	.10	.18	.24	.37
Motor Bus	.07	.10	.18	.29	.38
TOTAL	.07	.10	.18	.28	.38

[1]Includes adult fares, child fares, elderly and handicapped fares, transfer charges and zone charges; includes reduced-fare and free-fare trips.

Source: Reference 2.

A comparison of the 1983 nationwide average adult base fare for transit service by mode is presented in Table 8-3; specific fare structures for Texas transit properties are presented in Table 8-4. As indicated by the fare structures in Table 8-4, most of the cities in Texas do not have zone or transfer charges.

Table 8-3
Comparison of Average 1983 Adult Fares for Selected Public Transit Modes in the U.S.

Mode	Average Adult Fare[1]
U.S.	
Light Rail (n=7)	$ .81
Rail Rapid (n=9)	.79
Regional Rail (n=3)	3.90
Electric Trolley Bus (n=4)	.64
Motor Bus (n=197)	.60
Demand-Responsive (n=69)	.81
Texas	
Motor Bus (n=19)	.55
Demand-Responsive (n=10)	.82

[1]Unweighted average of adult base fare as reported by the transit systems; each transit system counted equally.

Source: Reference 3 and unpublished survey data collected by the Texas State Department of Highways and Public Transportation (SDHPT).

Table 8-4
1984 Fare Structures (Dollars) for Selected Motor Bus Transit Systems in Texas

Location	Base Fares					Fare/ Zone	Transfer Charge	CBD Shuttle	Park-and Ride
	Children	Students	Adults	E&H	Express				
Abilene	Free[1]	.35	.50	.25	----	----	Free	----	----
Amarillo	Free[1]	.35	.45	.20	----	----	.15	----	----
Austin	Free[2]	.25	.50	.25	----	----	.05	NA	NA
Beaumont	Free[2]	.15	.50	.15	----	----	.10	----	----
Brownsville	Free[3]	.25	.50	.15	----	----	----	----	----
Corpus Christi	.25[4]	.25	.50	Blind Free E&H .15	----	----	Free	----	.75;1.00
Dallas	Free[3]	.25	.50	E .15; H .25	----	.50 Avg.	Free	.25	1.00
El Paso	Free[1]	.25	.50	.15	1.00	----	NA	.25-.50	1.00
Ft. Worth	Free[2]	.35	.75	.35	.75	----	NA	Free	NA
Galveston			.60						
Houston	.10[4]	.20	.50	.20	.95	.10 .15 .30	1st Free 2nd exp.	10	Varies
Laredo	Free[3]	.25	.50	.10	----	----	NA	----	----
Lubbock	Free[1]	.50	.75	.35	----	----	Free	----	----
MIDTRAN	.75[4]	2.00	2.00	E Free H .50	----	----	Free	----	----
Port Arthur	NA	NA	.50	NA	NA	NA	NA	NA	NA
San Angelo	Free[2]	.30	.40	.20	----	----	Free	----	----
San Antonio	.20[5]	.25	.40	.20	.75	.10	Reg. Free Exp. 35	.10	Varies
Tyler	.25	.25	.75	----	----	----	----	----	----
Waco	Free[1]	.30	.60	.30	----	----	Free	----	----
Wichita Falls	.35[5]	.35	.75	.35	1.00	----	.25	----	----

[1]for children up to 6 years old
[2]for children up to 5 years old
[3]for children up to 4 years old
[4]for children up to 12 years old
[5]for children up to 11 years old

Note: NA indicates data not available.

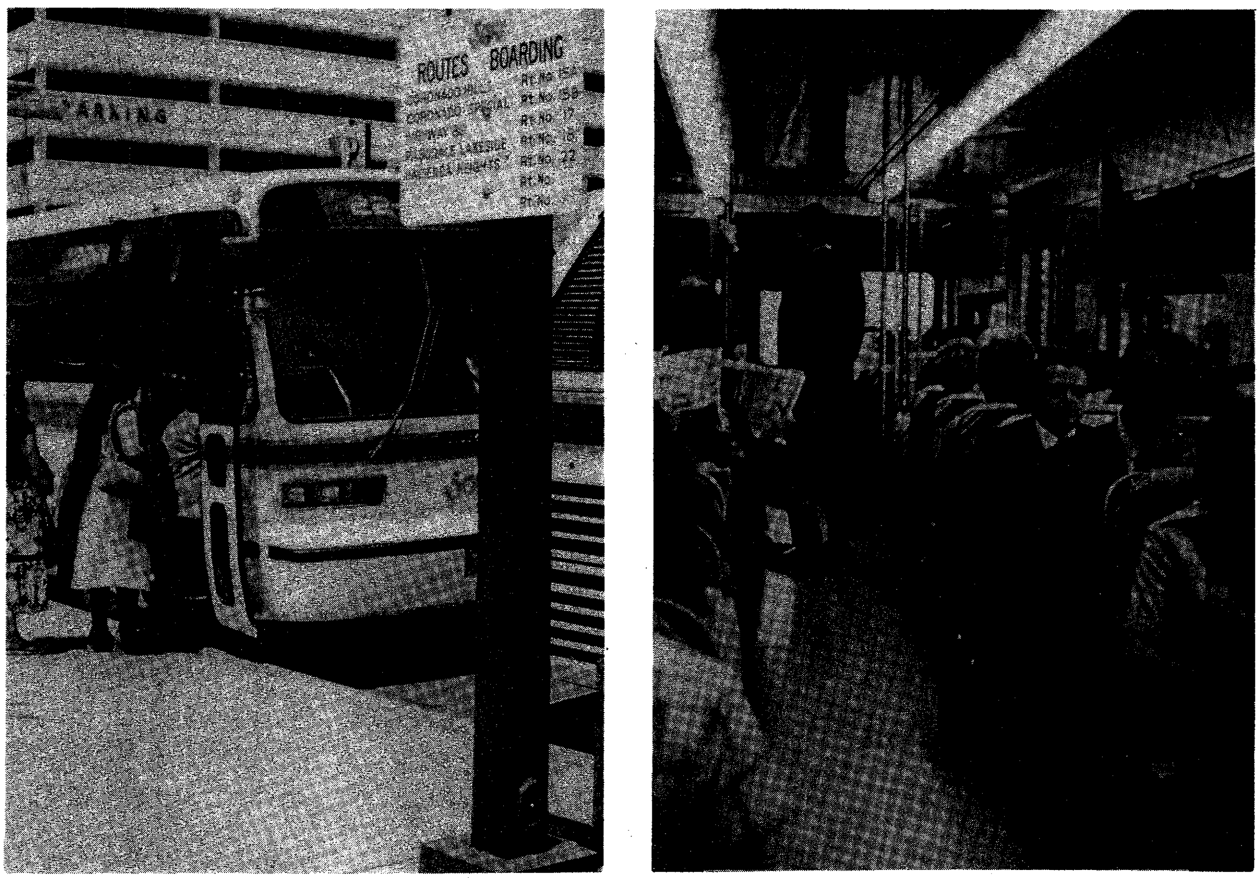
Source: Unpublished SDHPT survey data.

Level of Service (4, 5, 6)

The level-of-service provided by a transit system is frequently defined by some or all of the following attributes:

- Service area and route spacing (accessibility);

- Days and hours of service;
- Frequency of service (headway);
- Travel time;
- Directness of service (transfers);
- Delay (in-vehicle wait time);
- Reliability (schedule adherence);
- Passenger density; and
- Passenger comfort (acceleration, temperature, noise, etc.).



The frequency of service and passenger density are two important measures of level-of-service.

No single measure can adequately describe the level-of-service provided by a transit system. In addition, each transit system has certain characteristics which makes its operation unique. Thus, across-the-board comparisons of service levels among transit systems are difficult. However, because improvements to the first 3 items on the list above result in an increase in the transit service supplied, measures such as the following can be used to provide some indication of transit service levels:

- Vehicles operated in maximum scheduled service;
- Annual vehicle miles;
- Annual vehicle hours;
- Annual vehicle revenue capacity miles;
- Annual vehicle revenue miles; and
- Annual vehicle revenue hours.

Table 8-5 presents statistics on the transit service supplied by Texas transit properties during calendar/fiscal year 1983.

Table 8-5
Transit Service Supplied During Calendar/Fiscal Year 1983
(Directly Operated and Purchased Service[1])

Texas Transit System	Vehicles Operated in Max. Scheduled Service	Annual Vehicle Miles (000)	Annual Vehicle Hours (000)	Annual Vehicle Revenue Capacity Miles (000)	Annual Vehicle Revenue Miles (000)	Annual Vehicle Revenue Hours (000)
Abilene	12	446.6	31.4	23,514.0	446.6	31.4
Amarillo	14	751.0	51.1	28,589.7	733.8	48.5
Austin	79	3,258.6	249.1	148,143.7	3,055.2	238.3
Beaumont	14	599.1	46.3	34,150.2	599.1	46.3
Brownsville	14	689.4	60.0	31,501.2	644.7	58.1
Corpus Christi	36	1,704.6	127.7	50,170.7	1,368.1	103.8
Dallas	590	15,928.6	1,115.1	864,246.4	14,139.5	984.1
El Paso	90	4,262.3	325.1	277,796.7	4,246.9	318.6
Ft. Worth	98	3,261.8	261.3	156,279.8	3,135.7	249.6
Galveston	9	435.3	37.6	24,941.5	415.7	36.1
Houston	516	29,121.2	1,908.8	109,010.0	23,473.7	1,342.5
Laredo	18	799.6	799.6	42,377.1	775.9	83.6
Lubbock	27	1,050.4	75.8	5,991.3	1,026.2	74.5
Midland	14	359.8	37.4	6,151.9	359.8	37.4
Port Arthur	6	321.6	23.0	9,323.2	314.3	22.0
San Antonio	380	15,430.4	1,088.9	713,155.0	13,188.1	934.1
Waco	12	379.6	32.7	16,091.2	379.6	32.7
Wichita Falls	5	301.5	20.1	12,475.2	297.0	19.5

[1]Includes all modes operated and purchased by transit system.

Source: Reference 6.

Fare and Service Elasticities (4, 7)

The elasticity of demand is one measure of the relative responsiveness of transit ridership to changes in fares or service levels. As a quantitative measure of relative change, the elasticity of demand may be defined by the following formulas.

$$n_f = \frac{\%\ \text{change in ridership}}{\%\ \text{change in fares}} \quad \text{and} \quad n_s = \frac{\%\ \text{change in ridership}}{\%\ \text{change in service}}$$

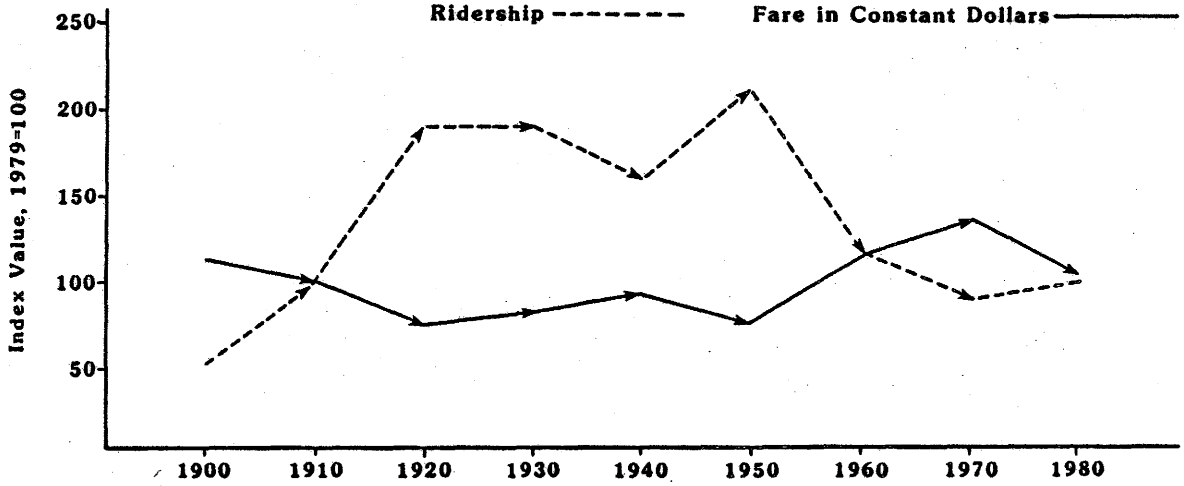
Because the elasticity measures a ratio of percentage changes, it is therefore dimensionless and can be used to compare demand elasticity among different transit systems and time periods.

Two broad approaches for estimating fare and service elasticities are described below (7).

- **Quasi-Experimental Approaches** - Quasi-experimental approaches identify and analyze actual changes in services or current fares (i.e., these expressed in current dollars without adjustments for inflation). Quasi-experimental approaches include: (1) estimating from demonstrations or practical experiments, and (2) monitoring actual changes in services or current fares.

- **Non-Experimental Approaches** - Non-experimental approaches rely on a data base either devoid of any actual changes in current fares or service levels or where actual changes are part of historical trends. Non-experimental approaches include: (1) conventional time-series analysis of annual transit operating statistics, (2) aggregate direct-demand and mode-split models based on cross-sectional data, and (3) disaggregate behavioral mode-choice models based on cross-sectional data.

Fare Elasticity (2, 4, 7). According to economic theory, the demand for goods decreases when the real price of those goods increases. The same long term effect can be seen when reviewing the transit ridership in relation to the real price of transit fares. In every decade of the 20th century, when the real price of a transit trip (adjusted for inflation) has gone up, transit ridership has gone down. Conversely, when the real price of a transit trip has gone down, transit ridership has gone up (Figure 8-1). While the aggregate statistics in this figure would indicate that transit fares are elastic, many other factors affect transit ridership. For example, studies have shown that in particular locations, or during certain time periods, the price of a transit trip has a relatively unimportant effect on ridership change. In addition, other factors such as the availability and price of gasoline, percent of population in urban areas, population density, congestion, downtown parking costs, unemployment rates and quantity and quality of transit service also affect ridership. Therefore, more detailed analyses are necessary in order to gain a better understanding of the effect of fare pricing on ridership levels.



Source: Reference 2.

Figure 8-1
The Relationship of Fares to U.S. Transit Ridership (All Modes)

One pricing impact formula that is generally accepted by the transit industry is the Simpson and Curtin Formula which states:

$$\% \text{ Ridership Loss} = 0.88 + 0.30 \times (\% \text{ Fare Increase})$$

In an analysis of 77 fare increases during a period of 20 years, the average shrinkage ratio for the 77 fare increase events was calculated at -0.36. Therefore, the Simpson and Curtin Formula, which has been used extensively by transit managers in the financial planning and analysis of fare policies, has reverted over the years into the general rule of thumb that transit ridership will increase (decrease) 0.3% for every 1% decrease (increase) in fares over their previous level. In other words, if fares are increased by 10%, ridership will decrease by about 3%.

Although the Simpson and Curtin Formula is generally correct in highlighting the fact that transit ridership is inelastic (i.e., not very responsive to fare changes), several studies have shown that there is a wide variation in the transit fare elasticities estimated. The existence of such a wide variation has prompted research into the area of presenting evidence of disaggregate ridership response to fare changes. A summary of the principal findings on aggregate and disaggregate fare elasticities is presented below. A summary of the means and standard deviations of the fare elasticities for various market groups are shown in Table 8-6.

- **Transit demand is relatively inelastic to fare changes.** Transit fare elasticities range in value from -0.04 to -0.87 with a mean of -0.28 $\pm$ 0.16 (67 cases). These results, from demonstrations and other quasi-experiments, are not appreciably different from the Simpson and Curtin rule of thumb. However, the fare elasticities developed from non-experimental direct-demand and mode-choice models are noticeably higher, especially for those models using cross-sectional data.

Table 8-6
Summary of Fare Elasticities, Means and Standard Deviations

Aggregate Fare Elasticities		
Estimation Method		
Quasi-experimental	-0.28 ± 0.16	(67 cases)
Time-series	-0.42 ± 0.24	(28 cases)
Cross-sectional	-0.53 ± 0.35	(28 cases)
Type of Fare Change		
Fare increase	-0.34 ± 0.11	(14 cases)
Fare decrease	-0.37 ± 0.11	(9 cases)
Fare Change to Fare-Free		
Within CBD only	-0.52 ± 0.11	(4 cases)
System-wide	-0.30 ± 0.17	(6 cases)
City Size		
Populations greater than 1 million	-0.24 ± 0.10	(19 cases)
Population 500,000 to 1 million	-0.30 ± 0.12	(11 cases)
Populations less than 500,000	-0.35 ± 0.12	(14 cases)
Disaggregate Fare Elasticities		
Transit Mode		
Bus	-0.35 ± 0.14	(12 cases)
Regional Rail	-0.31	(1 case)
Trip Length		
London: Bus		
• Trips less than 1 mile	-0.55	(1 case)
• Trips between 1 and 3 miles	-0.29	(1 case)
London: Rapid Rail		
• Trips between 1 and 3 miles	-0.25	(1 case)
• Trips greater than 3 miles	-0.60	(1 case)
Route Type		
Radial arterial	-0.09 ± 0.02	(3 cases)
Intrasuburban	-0.31 ± 0.05	(3 cases)
System-wide	-0.24 ± 0.08	(3 cases)
CBD oriented	-0.40 ± 0.04	(3 cases)
Non CBD oriented	-0.62 ± 0.09	(3 cases)
System wide	-0.55 ± 0.08	(3 cases)
Intra CBD	-0.52 ± 0.11	(4 cases)
System wide	-0.43 ± 0.08	(3 cases)
Time Period		
Peak	-0.17 ± 0.09	(5 cases)
Off peak	-0.40 ± 0.26	(5 cases)
All hours	-0.29 ± 0.19	(5 cases)
Trip Purpose		
Work	-0.10 ± 0.04	(6 cases)
School	-0.19 to -0.44	(3 cases)
Shop	-0.23 ± 0.06	(5 cases)
Income Group		
Less than $5,000	-0.19 ± 0.10	(2 cases)
$5,000 to $14,999	-0.25 ± 0.11	(4 cases)
More than $15,000	-0.28 ± 0.13	(4 cases)
Age Group		
1-16 years	-0.32 ± 0.01	(2 cases)
17-24 years	-0.27 ± 0.03	(2 cases)
25-44 years	-0.18 ± 0.10	(2 cases)
45-64 years	-0.15 ± 0.03	(2 cases)
More than 65 years	-0.14 ± 0.02	(2 cases)

Source: Reference 7.

- **Elasticities for fare increases do not differ from those for fare decreases.** Although limited evidence from Atlanta and Madison suggests that larger fare elasticities result from fare increases than from fare decreases, the large sample of fare changes does not confirm this view.

- **Fare-free elasticities are slightly smaller than comparable reduced fare elasticities.** With the exception of the fare-free elasticities for intra-CBD service, the fare-free elasticities are smaller than comparable elasticities for reduced-fare programs.

- **Small cities have larger fare elasticities than large cities.** Fare elasticities vary by city size and are appreciably larger in small and medium-size cities than in large cities.

- **Bus travel is more elastic than commuter and rail rapid travel.** Bus fare elasticities are twice as large as rail rapid fare elasticities where both modes are available. Fare elasticities for commuter-rail service appear to lie between the values observed for bus and rapid rail service, but the limited evidence makes this claim uncertain.

- **Off-peak fare elasticities are double the size of peak-fare elasticities.** Regardless of the mode considered, fare elasticities for off-peak transit service are twice as large as those observed for peak-period service. Weekend fare elasticities are comparable to weekday off-peak elasticities. Cross-elasticities of demand from peak to off-peak hours are relatively small, less than +0.20 in the case of the recent off-peak fare-free demonstrations in Denver and Trenton.

- **Short-distance trips are more elastic than long-distance trips.** Bus trips less than one mile in length exhibit fare elasticities almost 100 percent larger than trips between one and three miles in length.

- **Intrasuburban trips are four times more elastic than radial trips on arterials.** The experience in London shows intrasuburban trips to be more elastic than radial trips to and from the central city. No accurate fare elasticity comparisons are possible for express and local service due to scarcity of measurements.

- **Fare elasticities rise with income and fall with age.** The Trenton and Denver off-peak fare-free demonstrations show that fare elasticities rise with income and fall with the age of the transit rider.

- **Of all trip purposes, the work trip is the most inelastic.** Shopping and school trips are two to three times more elastic than the work trip.

- **Travel by the elderly is slightly more elastic than average.** Although travel by the elderly is inelastic, it is more elastic than travel by the average transit rider.

- **Promotional fare elasticities are slightly larger than short-term fare elasticities following permanent fare revisions.** The fare elasticities estimated from ridership changes following the introduction of promotional fares are larger than those observed for permanent fare changes. Fare elasticities resulting from changes in the prices paid for fare prepayment instruments are similar to the fare elasticities observed for permanent cash-fare changes.

In summary, estimates of fare elasticities are not sufficiently precise to accurately predict the detailed effects of a fare change on ridership in a particular city or corridor. However, in all cases, the percent change in ridership is considerably less than the percent change in fares. Therefore, a fare reduction will reduce total revenue and a fare increase will increase total revenue.

Service Elasticity (7). In contrast to the relative abundance of data on fare elasticities, the data on service elasticities are scarce. A summary of the means and standard deviations of the service elasticities developed in one research effort is presented in Table 8-7. Although the number of case studies is not large enough to support conclusions based on rigorous statistical testing, the following generalizations are possible (7).

- **Ridership response to service changes is inelastic.** All services exhibit elasticities of demand with absolute values lower than 1.00. Thus, the proportional increases (decreases) in services are greater than the proportional increases (decreases) in passengers and revenues.

- **Off-peak ridership is more responsive than peak ridership.** Service elasticities are invariably 50 to 100 percent higher for the off-peak periods than for the peak periods.

- **Ridership is more responsive in lower-service areas.** Service elasticities are higher in low-service areas than in high-service areas during all time periods. Thus, the proportional change in patronage is much less than the proportional change in service when frequent or fast service exists.

- **Ridership response is similar across modes.** Bus and regional rail headway elasticities are similar, as are bus and rail rapid in vehicle time elasticities. The limited number of cases available, however, prevents making final conclusions concerning modal differences in service elasticities.

- **Headway and vehicle-miles elasticities are similar.** There are no apparent numerical differences between the quasi-experimental bus headway elasticities (-0.47) and bus-miles elasticities (+0.30 to 0.85), a conclusion that is supported by comparison with the non-experimental elasticities in Table 8-6.

- **Ridership is more responsive to improvements in headways than in vehicle time.** The quasi-experimental service elasticity for in vehicle bus travel time during peak periods (-0.29) is much lower than the equivalent quasi-experimental headway elasticity of (-0.42).

- **Most non-experimental travel-time elasticities are questionable.** There are discrepancies in the relative values of in-vehicle and out

Table 8-7
Summary of Service Elasticities, Means and Standard Deviations

Headway Elasticities		
Bus (Quasi-Experimental)		
Peak	-0.37 ± 0.19	(3 cases)
Off-Peak	-0.46 ± 0.26	(9 cases)
All Hours	-0.47 ± 0.21	(7 cases)
Regional Rail (Quasi-Experimental)		
Peak	-0.38 ± 0.16	(5 cases)
Off-Peak	-0.65 ± 0.19	(5 cases)
All Hours	-0.47 ± 0.14	(5 cases)
Vehicle Miles Elasticities		
Regional Rail (Non-Experimental)		
All Hours	-0.47 ± 0.11	(4 cases)
Bus (Quasi-Experimental)		
All Hours	$+0.63 \pm 0.24$	(3 cases)
Bus (Non-Experimental)		
Peak	$+0.33 \pm 0.18$	(3 cases)
Off-Peak	$+0.63 \pm 0.11$	(3 cases)
All Hours	$+0.69 \pm 0.31$	(17 cases)
Rail Rapid (Non-Experimental)		
Peak	+0.10	(1 case)
Off-Peak	+0.25	(1 case)
All Hours	+0.55	(1 case)
Total Travel Time Elasticities		
Bus (Non-Experimental)		
Peak	-0.13 ± 0.13	(2 cases)
All Hours	-0.92 ± 0.37	(2 cases)
Bus and Rail Rapid (Non-Experimental)		
Off-Peak	-0.59	(1 case)
In Vehicle Time Elasticities		
Bus (Quasi-Experimental)		
Peak	-0.29 ± 0.13	(9 cases)
Off-Peak	-0.83	(1 case)
Bus (Non-Experimental)		
Peak	$+0.68 \pm 0.32$	(7 cases)
Off-Peak	-0.12	(1 cases)
Rail Rapid (Non-Experimental)		
Peak	$+0.70 \pm 0.10$	(2 case)
Bus and Rail Rapid (Non-Experimental)		
Peak	$-0.30 + 0.10$	(2 cases)
All Hours	-0.27	(1 case)
Regional Rail (Non-Experimental)		
All Hours	-0.59 ± 0.28	(9 cases)
Total Out of Vehicle Time Elasticities		
Bus and Rail Rapid (Non-Experimental)		
All Hours	-0.59 ± 0.15	(3 cases)
Walk Time Elasticities		
Bus (Non-Experimental)		
Peak	-0.26	(1 case)
Off-Peak	-0.14	(1 case)
Wait Time Elasticities		
Bus and Rail Rapid (Non-Experimental)		
Peak	-0.20 ± 0.07	(4 cases)
Off-Peak	-0.21	(1 case)
All Hours	-0.54	(1 case)
Transfer Time Elasticities		
Bus and Rail Rapid (Non-Experimental)		
Peak	-0.40 ± 0.18	(3 cases)
Number of Transfers Elasticities		
Bus (Non-Experimental)		
Off-Peak	-0.59	(1 case)

Source: Reference 7.

of-vehicle travel-time elasticities from the non-experimental or mode-choice models. As a general rule, the elasticities estimated from direct-demand and mode-choice models based on non-experimental data sources are less reliable and contain more discrepancies than the elasticities obtained from quasi-experimental data.

- **Service elasticities are not available for changes in many important service variables.** Although transportation analysts have confirmed the importance of other service attributes on transit ridership, demand elasticities have not been estimated for such service attributes as seat availability and service reliability. Few demand elasticities exist for number of transfers.

Use of Fare and Service Elasticities (7). Although the elasticity concept provides only a limited amount of information concerning how ridership adjusts to fare and service variations, it is useful as a summary of the type of behavior -- especially potential traffic diversions -- that characterizes the demand for transit. In addition to providing the numerical values necessary in estimating passenger response to future fare and service variations, disaggregate demand elasticities can provide an indication of how ridership and revenues can be increased by manipulating both fare and service levels. It can thus be used for transit operational and financial planning and for the formulation of general transportation policy options.

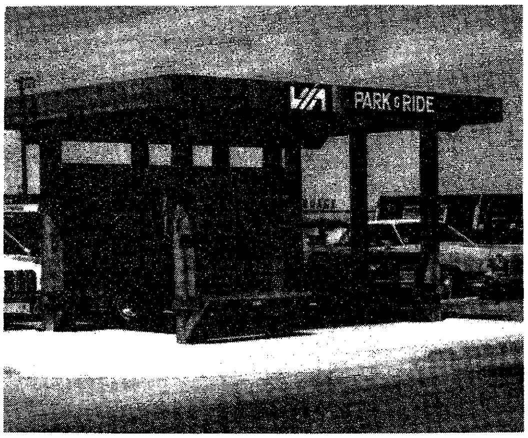
Fiscal Needs

As documented in Chapter 2, the cost-operating revenue situation has steadily deteriorated for transit systems in the United States; transit operating expenses have exceeded passenger farebox revenues for many years (1983 deficits in operating income for Texas transit properties are presented in Table 8-8). This situation has led the transit industry to seek other sources of funds to cover operating deficits and to finance capital investments in rolling stock and fixed facilities.

Table 8-8
Net Operating Income Per Passenger, Vehicle Mile and Vehicle Hour for Texas Transit Properties During Calendar Year 1983

Total Operating Revenue Per Passenger	$ .60
Total Operating Expenses Per Passenger	1.40
Net Operating Income Per Passenger	(.80)
Total Operating Revenue Per Vehicle Mile	$1.19
Total Operating Expenses Per Vehicle Mile	2.80
Net Operating Income Per Vehicle Mile	(1.61)
Total Operating Revenue Per Vehicle Hour	$16.81
Total Operating Expenses Per Vehicle Hour	39.48
Net Operating Income Per Vehicle Hour	(22.67)

Source: Reference 8.



Without federal, state and local financial assistance, the transit systems of Texas could not operate.

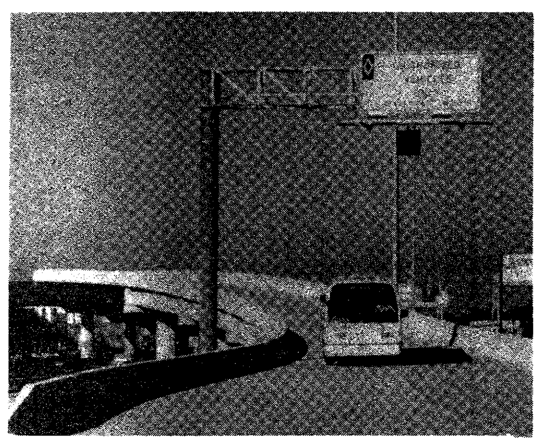
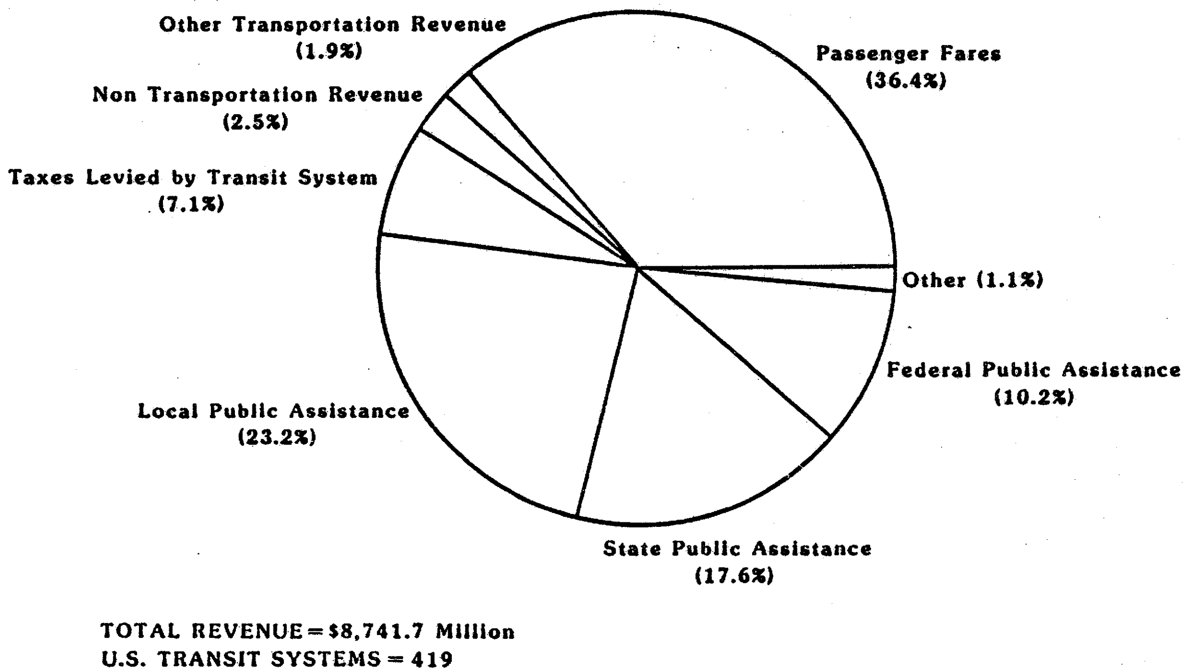


Figure 8-2 illustrates the sources of operating revenue and assistance for 419 transit systems in the United States during calendar/fiscal year 1983. As this figure indicates, federal, state and local public assistance accounted for 51% of the total $8,741.7 million in operating revenue.



Source: Reference 2.

Figure 8-2
Sources of Operating Revenue and Assistance
for U.S. Transit Operations
(Calendar/Fiscal Year 1983)

In Texas, federal, state and local public funds financed 100% of the $66.9 million invested in capital improvements during 1983 (Table 8-9). In addition, federal and local public assistance accounted for 57% of the total revenue required to finance $215.5 million in transit operating expenses (State funds cannot be used for operating assistance). This translates into a public expense of $1.23 per passenger or $2.48 per vehicle mile (Table 8-10).

Table 8-9
Texas Transit Finances for Calendar Year 1983

REVENUES		
Operating Revenue and Assistance		
Farebox	$61,852,308	
Charter	5,935,517	
Other Operating Income	23,954,394	
Federal Operating Assistance	26,922,051	
Local Operating Assistance	96,850,132	
TOTAL		$215,514,402
Capital Assistance		
Federal	$61,012,333	
State	4,405,058	
Local	1,521,835	
TOTAL		$ 66,939,266
TOTAL REVENUE AND ASSISTANCE		$282,453,628
EXPENSES		
Total Operating Expense		$215,514,402
Total Capital Expense		66,939,266
TOTAL EXPENSE		$282,453,628

Source: Reference 8.

Table 8-10
Total Public Expense for Transit in Texas,
Calendar Year 1983

Net Public Operating Cost	$123,772,183
Net Public Operating Cost Per Passenger	$ .80
Net Public Operating Cost Per Vehicle Mile	$1.61
Public Capital Cost	$ 66,939,226
Public Capital Cost Per Passenger	$ .43
Public Capital Cost Per Vehicle Mile	$ .87
Total Public Expense	$190,711,409
Total Public Expense Per Passenger	$1.23
Total Public Expense Per Vehicle Mile	$2.48

Source: Reference 8.

Federal Capital and Operating Assistance

In recent decades the federal government has been the primary source for a variety of funds available to the public transit industry of the United States. The major source of financial assistance is the Urban Mass Transportation Administration (UMTA) of the U.S. Department of Transportation. Another important source is the Federal Highway Administration (FHWA). The following provides a brief description of the various grants and funds available (1,9).

UMTA Section 3-Discretionary Capital Funds. Section 3 of the UMTA Act of 1964, as amended, provides discretionary capital grants or loans to public transportation operating agencies in urban areas greater than 50,000 population. Federal funds may be used to cover 80% of the net cost of construction, modernization or extension of fixed guideways; the acquisition, construction and improvement of mass transit facilities and equipment; the introduction of new technology into public transportation; and joint development and urban initiative projects. Routine bus purchases, formerly under Section 3, are to be funded from Section 5 apportionments.

UMTA Section 5-Urban Mass Transit Formula Grants. Section 5 of the Urban Mass Transportation Act of 1964, as amended, created a new mass transportation assistance program for urbanized areas whereby funds are apportioned on the basis of statutory formulas. Urbanized areas may use Section 5 funds for capital and/or operating assistance projects under the requirements of the act. Apportioned funds are made available on the basis of population and population density. Funding is available on a 80% federal, 20% local match for capital projects and on a 50% federal, 50% local match for grants used for operating costs.

Within Section 5, there is also a separate formula program for the purchase of buses, bus-related equipment and the construction of bus-related facilities. These funds will also be apportioned on the basis of population and population weighted by density.

In addition, Section 5 contains a new commuter rail/fixed guideway category to replace the former Section 17 and 18 commuter rail programs. Two-thirds of the funds appropriated will be apportioned on a commuter rail train mile/route formula, and one-third will be apportioned on a fixed guideway route mile basis. Apportioned funds may be used on any commuter rail or fixed guideway system in the urbanized area.

For urbanized areas with populations of 200,000 or more, the Governor, responsible local officials and publicly owned operators of mass transportation services will designate recipients of funds under Section 5. In urbanized areas of under 200,000 population, the Governor, or his designee, is the recipient. (Note: In Texas, the governor has designated the State Department of Highways and Public Transportation as the recipient.)

UMTA Section 6 - Research, Development and Demonstration Project Funds. Section 6 of the Urban Mass Transportation Act of 1964, as amended, provides for discretionary research, development, and demonstration projects in all phases of urban mass transportation including the development, testing and demonstrations of new facilities, equipment, techniques, and methods to improve public transportation. The Urban Mass Transportation Administration approves grants under this section on a project-by-project basis.

UMTA Section 8 - Planning and Technical Study Funds. Section 8 (formerly Section 9) of the Urban Mass Transportation Act of 1964, as amended, makes funds available for public transportation planning and other technical studies. The Urban Mass Transportation Administration apportions grant funds directly to cities with a population over 200,000. Funds are made available on a discretionary basis to cities with a population of less than 200,000. Activities assisted under this section may include: (1) Studies relating to management, operations, capital requirements, and economic feasibility; (2) Preparation of engineering and architectural surveys, plans and specifications; (3) Evaluation of previously funded projects; and (4) Other activities. Funding is available for projects under this section on an 80% federal, 20% local match.

UMTA Section 16 - Funds to Meet the Special Transportation Needs of the Elderly and Handicapped. Section 16(b)(1) of the Urban Mass Transportation Act of 1964, as amended, provides for grants and loans to states and local public bodies and agencies to assist them in providing mass transportation for elderly and handicapped persons.

Section 16(b)(2) provides for grants and loans to private non-profit organizations for the transportation of elderly and handicapped clients. Private non-profit organizations applying for capital assistance must provide service within a recognized "urban area" (a municipality having a population of not less than 5,000 persons according to the 1970 census). This does not preclude operation in a rural area as long as the origin and/or destination of the service is in an urban area. Section 16(b)(2) funds are available on an 80% federal, 20% local match.

UMTA Section 18 - Formula Grant Program for Areas Other Than Urbanized Areas. Section 18 of the Surface Transportation Act of 1978 provides formula grants for public transportation in non-urbanized areas (small urban areas with less than 50,000 population and rural areas). These funds can be used for capital or operating assistance. The capital assistance is based on an 80% federal and 20% local participation while the operating assistance provides for a maximum 50% federal share.

Section 20 - Human Resource Programs. Section 20 authorizes the Secretary of Transportation to undertake, or provide financial assistance by grant or contract for, national and local programs that address human resource needs as they apply to public transportation activities. Such programs include, but are not limited to, employment training programs; outreach programs to increase minority and female employment in public transportation activities; research on public transportation manpower and training needs, and training assistance for minority businesses. Such assistance may include assistance in seeking business venture capital, obtaining security bonding, obtaining management and technical services and contracting with public agencies organized for such purposes.

FHWA Section 142 - Public Transportation. Policy and implementing guidance for undertaking public transportation projects is provided in Section 142 Title 23 U.S.C. - the basic law. Section 142 of Title 23 addresses two categories of public transportation projects which are eligible for

Federal funding. The first category, covered in 142(a)(1), deals with highway public transportation projects and special use highway facilities. The second category, covered in 142(a)(2), deals with nonhighway public transportation projects.

Highway public transportation projects and special use highway facilities are those highway related projects which will further the use of bus mass transportation systems.

These are 4 classes of eligible highway public mass transportation projects under this section:

- Exclusive or preferential bus lanes;
- Eligible highway traffic control devices;
- Bus passenger loading areas and facilities; and
- Fringe and transportation corridor parking facilities.

The second category under Section 142 of public transportation projects eligible for Federal-aid participation are the non-highway public mass transit projects. These are defined in broad terms as: "projects which develop or improve public mass transit facilities or equipment." Eligible non-highway public mass transit projects must be included in, and related to, a program for the development or improvement of an urban public mass transit system which includes either or both:

- The construction of fixed rail facilities; and
- The purchase of passenger equipment.

A non-highway public mass transit project need not be physically located or operated on a route designated as part of the Federal-aid urban system, but fixed facilities must be located within established urban boundaries. Eligible projects may include the construction of fixed rail facilities and the purchase of passenger equipment such as buses, fixed rail rolling stock, and other transportation equipment.

The construction of bus garages and bus maintenance and repair facilities may be an eligible project if a part of an overall program of planned transit development which provides for the purchase of buses or other passenger rolling stock. Eligible non-highway public mass transit projects may be approved and funded with apportioned urban system funds. The federal participation ratio will be at the same ratio as a regular highway project on the federal-aid urban system. The Urban Mass Transportation Administration is the federal agency with responsibility for approving non-highway mass transit projects.

Other Federal Programs. In addition to UMTA and FHWA programs, other funds for special transportation purposes are available for planning, operating, and capital improvements from the Department of Health, Education, and Welfare (HEW), the Department of Housing and Urban Development (HUD), and the Department of Labor (DOL). HEW funds are usually in association with another program such as assistance to aging Americans or various social welfare and educational programs. The U.S. Department of Labor (DOL), through its Manpower Administration and the Office of Economic Opportunity, can provide services, purchase services or reimburse individuals or agencies for services that are associated with a DOL program.

Funds Available from the State of Texas (10)

State of Texas Public Transportation Fund. From 1969 to 1975, the Texas Mass Transportation Commission worked to "encourage, foster and assist in the development of public mass transportation, both intracity and intercity, in this State....".

In 1975, the 64th Legislature combined the Texas Mass Transportation Commission with the Texas Highway Department to form the State Department of Highways and Public Transportation (SDHPT). The Public Transportation Program created by Senate Bill 761 authorized the SDHPT to undertake a broad range of activities from purchasing and constructing public transportation systems to recommending necessary legislation to advance the interests of the State of Texas in public and mass transportation. Senate Bill 762 provided an implementation mechanism by establishing the Public Transportation Fund (PTF), a special dedicated fund in the State Treasury.

Public Transportation Fund Guidelines. Three basic grant programs comprise the Public Transportation Fund: the Formula Program; the Discretionary Program and the Secondary Discretionary Program. Within the PTF, 60% of the total funds appropriated are allocated to the Formula Program for the 7 cities in the state with populations in excess of 200,000. The remaining 40% is allocated to the Discretionary Program for the following:

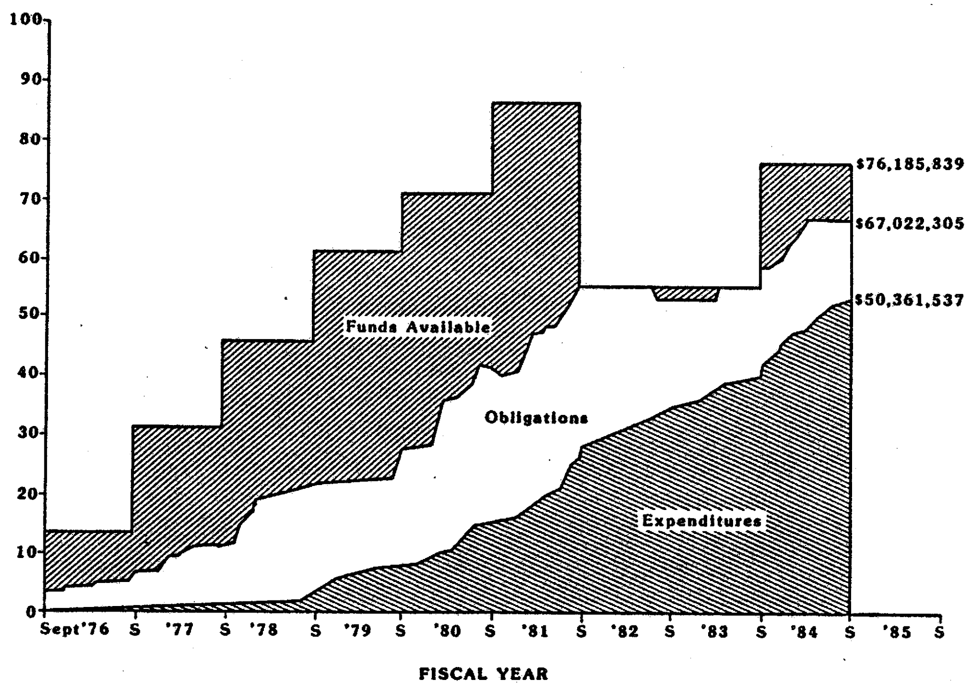
- Urbanized areas with populations under 200,000;
- Urban areas with the authority to own and operate a transit system;
- Ridesharing projects in urbanized areas of any size; and
- Any urbanized or urban area that can certify that federal funds are unavailable for a proposed project.

All funds which have not been obligated 180 days after the close of the fiscal year for which the funds are originally appropriated are automatically transferred to a Secondary Discretionary Program. These funds then become available for any city eligible under the Formula or Discretionary Programs.

Under each of the three programs, funds are available to provide 65% of the local share requirement of federally-funded projects for capital improvements. Through the Discretionary Program, a designated recipient who certifies that federal funds are unavailable for a proposed project may receive 50% of the total cost of a capital project. Also through the Discretionary Program, urbanized area recipients may receive 80% of the total cost of the acquisition of vans to be used in commuter ridesharing.

Public Transportation Fund Usage. The Public Transportation Fund may be used for a wide range of capital projects. Examples of State capital improvements include land purchases, rail right-of-way acquisition, facility design and construction, transit improvements to otherwise satisfactory highways, vehicle purchases, service and maintenance equipment, purchase of private transit systems, professional services contracts, passenger amenities, rehabilitation of facilities, project sponsor force account and miscellaneous supporting services. The SDHPT has participated in each of these types of projects through the Public Transportation Fund, including the purchase of over 2,000 transit vehicles; the acquisition of land for administration, maintenance, park-and-ride lots and rights-of-way; the construction of 16 major transit facilities; improvements for high occupancy vehicle lanes; and rehabilitation of historical buildings for transit use.

The utilization of the Public Transportation Fund by local governments has not been as active as the Legislature was assured it would be by transit operators or as anticipated by SDHPT. During the first six fiscal years of the program, approximately 61% of the available funds were obligated by the State Highway and Public Transportation Commission. Due to delays between applications and receipt of capital improvements, only 32% was expended. At the close of fiscal year 1981, Public Transportation Fund had a balance of $58 million. The 67th Legislature transferred $30 million from the PTF to the general fund and reapportioned the remaining $28 million. After the ninth year of the fund's existence (as of September 30, 1984), 88% of the available funds have been obligated and 65% have been expended (not including the $30 million dollars previously mentioned) (see Figure 8-3).



Source: Reference 10.

Figure 8-3
State of Texas Public Transportation Funds Available

In Texas, state funds cannot be used for transit operating assistance, but may be used to assist local governments in matching funds for federal capital programs. Most of the capital grants are Section 3 and Section 5 grants funded by the Urban Mass Transportation Administration on an 80% federal 20% local match basis. A grant applicant may apply to the State of Texas to provide as much as 65% of the local share requirement (13% of the total project cost). New federal legislation enacted in 1982 altered the matching ratio for one program to 75% federal, 25% local. Therefore, in some cases, the state may provide up to 16.25% of the total capital improvement cost. Should no federal funding be available, an applicant may apply for up to 50% state funding on a capital project (3).

Sources of Funds at the Local Level

At the municipal level, transit operating and capital assistance for transit properties in the smaller cities of Texas is typically provided by general revenue funds. The regional transit authorities in Houston, San Antonio, Corpus Christi, Dallas, Fort Worth and Austin, on the other hand, are funded locally by way of a 1/4 to 1% sales tax. In 1983, almost 79% of the total operating funds for Houston's transit system and 53% of the total operating funds for San Antonio's system were generated from the local sales taxes levied by the transit systems (Table 8-11). The significance of the

Table 8-11
Sources of Operating Revenues for the Houston and San Antonio Metropolitan Transit Authorities as Compared to Those for the Remaining Texas Transit Systems

Source of Revenue	1983 Operating Revenue $(millions)		
	Houston	San Antonio	Other 16 Systems
Passenger Fares	$ 19.8 (9.9%)	$8.6 (21.4%)	$22.3 (27.5%)
Other Transportation Revenue	1.0 (0.5%)	3.0 (7.6%)	3.1 (3.0%)
Non-Transportation Revenue	21.4 (10.7%)	2.4 (6.0%)	2.8 (3.5%)
Sales Tax Levied by the Transit System	157.3 (78.6%)	21.2 (52.9%)	-----
Federal Public Assistance	.6 (0.3%)	4.9 (12.1%)	26.7 (33.2%)
State Public Assistance	-----	-----	-----
Local Public Assistance			25.7 (31.9%)
Total Revenue	$200.1 (100%)	40.1 (100%)	80.6 (100%)

Note: Metropolitan transit authorities had not been created in Austin, Corpus Christi, or Fort Worth as of 1983; the Dallas MTA was created in August 1983 but did not report sales tax revenue for 1983.
Source: Reference 6.

taxing ability of the regional transit authorities is twofold. First, in many metropolitan areas the burden of public subsidy for transit operating deficits is shifted from the federal level to the local level. Second, the amount of revenue which can be generated from a local sales tax is far more significant than that which is typically generated from any other source. For example, in 1983, the 1% sales tax revenue received by Houston's transit system totaled approximately $157.3 million (Table 8-11). This amount is almost twice that of the total $80.6 million in revenue received by the remaining 16 public systems in Texas (excluding San Antonio).

Summary

During calendar year 1983, public transportation financial assistance to Texas totaled almost $175 million (Table 8-12). Of this amount, approximately 63% was provided by federal sources, 6% by the State of Texas and the remaining 31% by local sources.

Table 8-12
Financial Assistance to Texas in 1983

Project	Sections 3 & 5 Capital	Section 5 Operating	Section 8 Technical Studies	Section 18	Section 20 Human Resource Program	Texas 50% Program	Total
Federal Assistance to:							
Municipal Systems	$82,999,304	$23,155,689	$ -0-	$ -0-	$266,664	$ -0-	$106,421,657
Technical Studies	-0-	-0-	2,814,000	-0-	-0-	-0-	2,814,000
Elderly & Handicapped Transportation Section 16(b)(2)	787,055	-0-	-0-	-0-	-0-	-0-	787,055
Non-Urbanized Area Transit Section 18	-0-	-0-	-0-	36,800	-0-	-0-	36,800
State Department of Highways and Public Transportation	-0-	-0-	295,000[2]	-0-	-0-	-0-	295,000
TOTAL FEDERAL	$83,786,359	$23,155,689	$3,109,000	$36,800	$266,664	$ -0-	$110,354,512
TOTAL STATE	9,951,538	-0-	73,750[3]	5,980	-0-	87,875	10,119,143
TOTAL LOCAL	11,305,054[4]	42,260,282	703,750[5]	3,220	66,666	87,875	54,426,847
TOTAL PROJECTS	$105,042,951	$65,415,971	3,886,500	46,000	333,330	175,750	174,900,502

[1]If a designated recipient certifies that Federal funds are unavailable for a proposed project and the State Highway and Public Transportation Commission finds the project vitally important to the development of public transportation in the State, then the Commission may supply 50% of the total cost of the project.
[2]This technical study grant is set out separately because it was made directly to a state agency for planning and study purposes.
[3]This is the 20% match for the technical studies grant made to SDHPT.
[4]Local participation includes the local match of $196,764 for the 16(b)(2) Program.
[5]This is the local match for technical studies.

Source: Reference 8.

<u>**References**</u>

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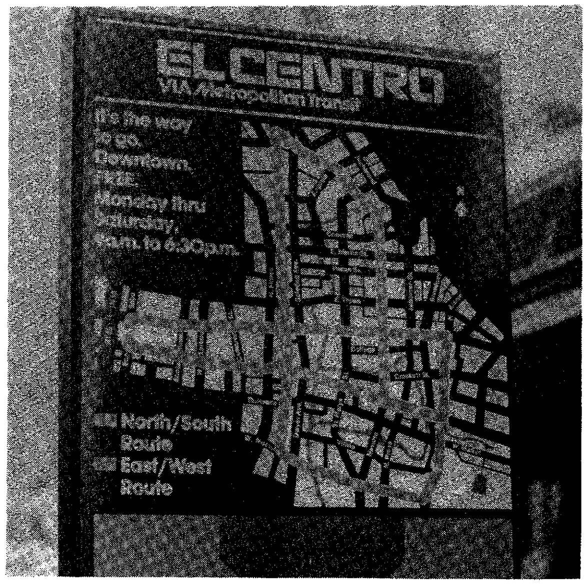
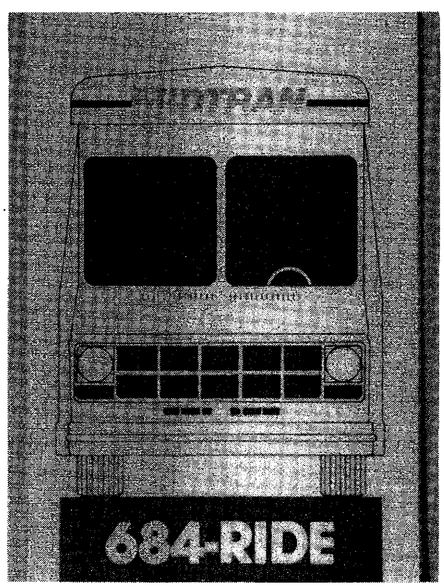
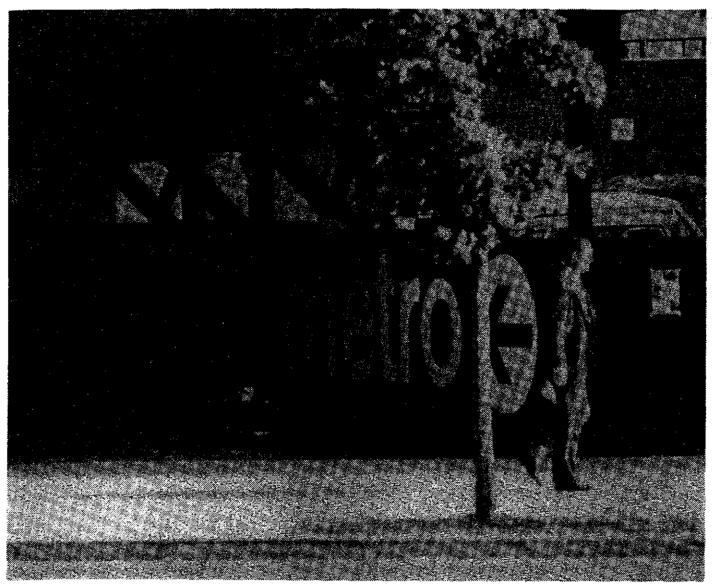


Chapter 9





Marketing Transit Services

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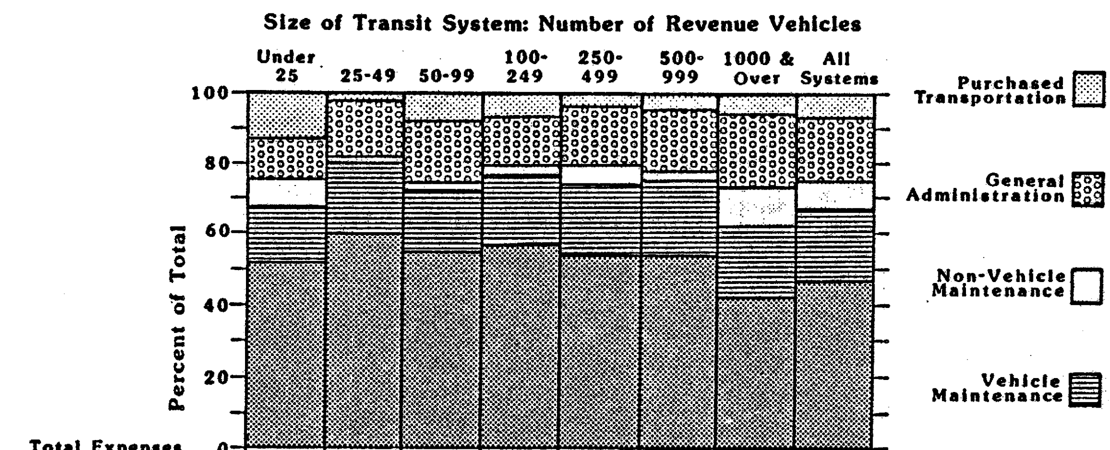
Marketing Transit Services

Traditionally, the formal organization of public transit systems has been operations-oriented rather than consumer-oriented. Consequently, the organizational structure has treated operations as the central function followed by maintenance, clerical work and administrative functions. Marketing has typically been neglected. This is not surprising, particularly in the developmental stages of most modes when the tasks of scheduling persons and equipment, overcoming the limitations of equipment and facilities and various other tasks of insuring the equipment was on the street and rolling were matters of high priority. Even today, the majority of a tranit system's activities and expenses are necessarily devoted to the 2 principal functions of vehicle operations and vehicle maintenance (Figure 9-1). Yet, if a transit service is to be geared to carry out the objectives of a consumer-oriented service, marketing should be an integral element about which the organization structure is built. A model organization structure illustrating this principal is presented in Figure 9-2.

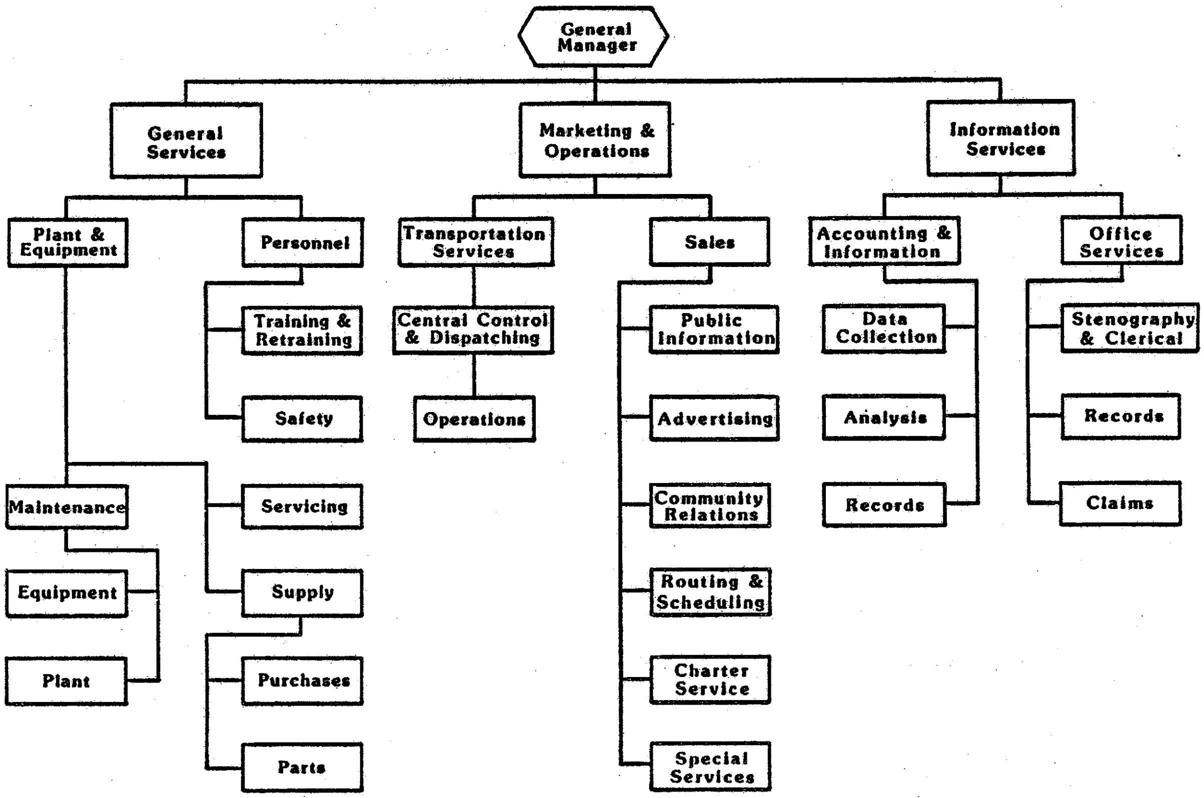


	Under 25	25-49	50-99	100-249	250-499	500-999	1000 & Over	All Systems
Total Expenses $ (Millions)	176.1	156.8	313.0	565.0	734.4	824.3	5598.9	8368.6
# of Systems Reporting these Data	161	82	68	56	24	12	16	419
Total # of Systems	166	84	73	56	27	12	17	435

Source: Reference 1. **Fiscal Year Ending Between 01/01/83 and 12/31/83**

Figure 9-1
U.S. Transit System Operating Expenses (All Modes)
by Transit System Size

*Numbers in parentheses refer to references listed at the end of the chapter.



Source: Reference 2.

Figure 9-2
Functional Organization of Transit System Management

Marketing Philosophy (2, 3)

Today, marketing activities of many transit systems are beginning to reflect the consumer-oriented approach. The marketing of public transportation encompasses more than advertising; it is developing and providing products (transportation services) which satisfy consumer needs and desires. Each transit property must adopt a marketing strategy that is appropriate to its situation and level of resources. The organization of a transit property to develop and promote its services, rather than simply produce the service, requires that a management position have direct responsibility and authority to coordinate the transit marketing efforts.

Marketing Plan (3)

The development of a transit marketing plan (a written document which contains a review of the transit marketplace, an analysis of the current situation, a statement of goals and objectives and a program to achieve the objectives) is the best way to prepare and develop an overall transit operating program. A transit marketing plan encourages planning for the long-term rather than relying solely on day-to-day "crisis management."

The basic requirements of developing a transit marketing plan are:

- Determine precisely what the market's mobility needs are in terms of service, price, and other attributes;
- Determine what opportunities for expanding volume exist in the marketplace. Who are the best prospects, and what must be done to obtain their patronage;
- Initiate a program to fulfill the consumer's needs consistent with available operational resources. (This may require some substantial changes in the present operating program and capital investment);
- Inform the public of what transit is doing. Use advertising and publicity to communicate the message. Use promotion to induce initial trial; and
- Evaluate the effectiveness of the efforts and initiate corrective action where appropriate.

These requirements can be translated into 7 basic activities in which marketing plays a role:

- Market research;
- Service planning and development;
- Facility and equipment design and maintenance;
- Rider informational systems;
- Sales communication and promotion; and
- Ongoing evaulation and monitoring.

Market Research (3, 4)

As in the marketing of any product or service, transit properties must organize and integrate service and promotional activities so that they respond to the consumer's needs, desires and habits. Market research provides the necessary consumer input upon which decisions are made. Effective market research seeks to answer questions such as the following.

- Who are the prospective patrons?
- What is transit's competition (other modes of travel)?
- What are the trip making characteristics of consumers in the marketplace?

- What should be the characteristics of the transit service?
- What should be the performance of the transit service?
- How do consumer use, habits and decisions affect the service offered?
- What benefits do consumers seek from transit service?
- How should the communications to consumers be expressed?

Market research also involves defining the marketplace. As a minimum, delineating the area, describing existing transportation systems, outlining the existing roadway network, defining population data and trends, and describing the area's land use are essential in order to determine the existing conditions in the area which transit serves.

Finally, and perhaps most importantly, market research seeks to define the market for transit service. Defining the market involves examining several important characteristics of transit patrons, including:

- Travel characteristics (such as trip origins and destinations, trip purpose, mode choice, and travel patterns);
- Travel desires (such as attitudes toward transit and reasons for mode choice);
- Socio-economic characteristics (such as age, sex, occupation, and income).

Among other things, defining the market for transit service involves identifying the socio-economic characteristics of transit patrons.

This information can be obtained from existing sources or from surveys (on-board, telephone, home-interview, transit stop interview) of transit users and potential users. Systematic and large scale market research can identify consumer groups or market segments which offer the greatest potential for increasing ridership. With this procedure (often referred to as market segmentation), emphasis can be placed on developing and promoting particular services which are likely to appeal to certain market segments.

Service Planning and Development (2, 3, 4)

Transit service planning and development should be closely tied to the market research findings regarding travel characteristics, travel desires, and socio-economic characteristics of the users and potential users. Functional service specifications should be developed to translate consumer needs and desires into functional service requirements. Examples of service specifications are:

- Type of service (fixed-route, demand-responsive, local, express, shuttle, park-and-ride, etc.);
- Timing of service (by time of day and day of week);
- Routing (to major activity centers, residential neighborhoods, etc.);
- Direction of haul; and
- Performance characteristics.

In relation to these general service specifications, a few basic considerations that have proven successful in transit service design include the following (2).

- Successful service design is the skillful aggregation of a number of individual travel needs. The concept of a "mass" movement of people only exists in the largest metropolitan areas. A successful transit service is built based on the complete understanding that the product must be designed to meet individual travel needs. Accordingly, service must be timed to accommodate specific user desires.
- Fixed-route service which repeats in standard time segments is more understandable and attractive to the consumer. "Clock headways" which repeat each 15, 30, or 60 minutes, as an example, are often much preferable to those with variable pickup times.
- Service frequency must be realistic in terms of traffic conditions and running times. The ideal service design will allow running time that makes the passenger feel that the vehicle is moving safely and expeditiously.
- Transfers should be avoided whenever possible. When transfers are inevitable, waiting time should be kept to a minimum. Through routing of fixed-route sytems can eliminate many transfer situations and should be utilized whenever possible.

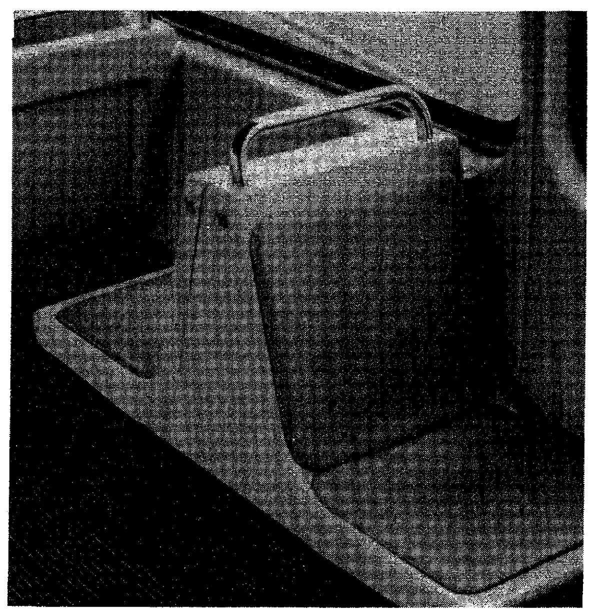
- Major activity centers should be identified and attempts made to tailor service specifically to their start and end times. Additionally, early contact with such centers can result in modification of start and end times to better correspond with peak requirements and vehicle capability.

- Newly initiated service requires at least 90 days, and preferably 180 days, to demonstrate actual potential. Shorter periods of time do not allow for accurate measures of demand and use.

- Public input is often the most usable single factor in designing new service.

Facility and Equipment Design and Maintenance (3)

Transit vehicles, stops and terminals are the aspects of transit with which riders come in direct contact. Well designed and maintained equipment and facilities are essential to create a positive image and to encourage initial and continued use of transit. Therefore, another important function of marketing is to review and evaluate the condition of these items and determine what improvements should be made. Marketing research can identify many correctable items. In general, as many passenger amenities as feasible should be provided.



Well designed and maintained transit equipment and facilities are important in creating a positive public image.

Pricing Transit Services (3, 5, 6)

When transit systems were privately owned and operated business enterprises, the fares charged of passengers were commensurate with the amount of service provided while at the same time allowing transit operators to realize a profit after operating costs were covered.

With today's publicly subsidized transit operations, fare pricing strategies are quite different. Faced with stiffer competition from the automobile, transit fares must be levied such that the user perceives a monetary savings from choosing transit over the automobile.

In developing a transit service pricing strategy, the marketing program should make use of a variety of special fare incentives to promote the attractiveness of transit. Reduced fares, for example, can be instituted to provide increased mobility to low-income and/or elderly persons. Free-fare zones may be established in downtown areas to stimulate business activity and decreased use of automobiles. Premium fares, on the other hand, may be charged to cover extraordinary costs of providing "deluxe" services to special market segments, such as commuter park-and-ride service.

Special pricing policies can also be tied to promotional efforts, like Nickle Day, Unfare Hours, Tuesday Shopper Special, etc. In addition, discounted monthly passes or unlimited ride passes can provide daily customers with the convenience of a one-time monthly charge plus a cash saving "bonus" for frequent transit use.

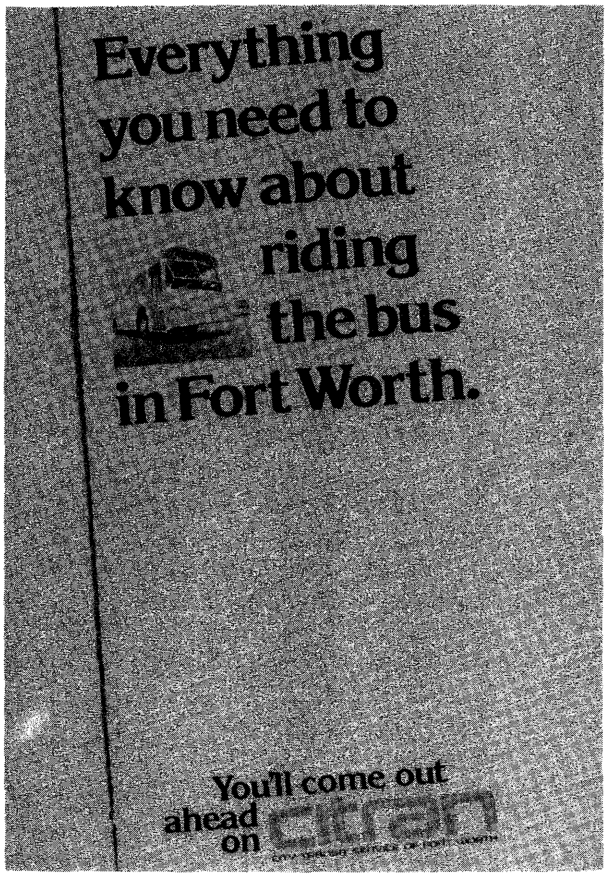
Informational Systems (3, 5)

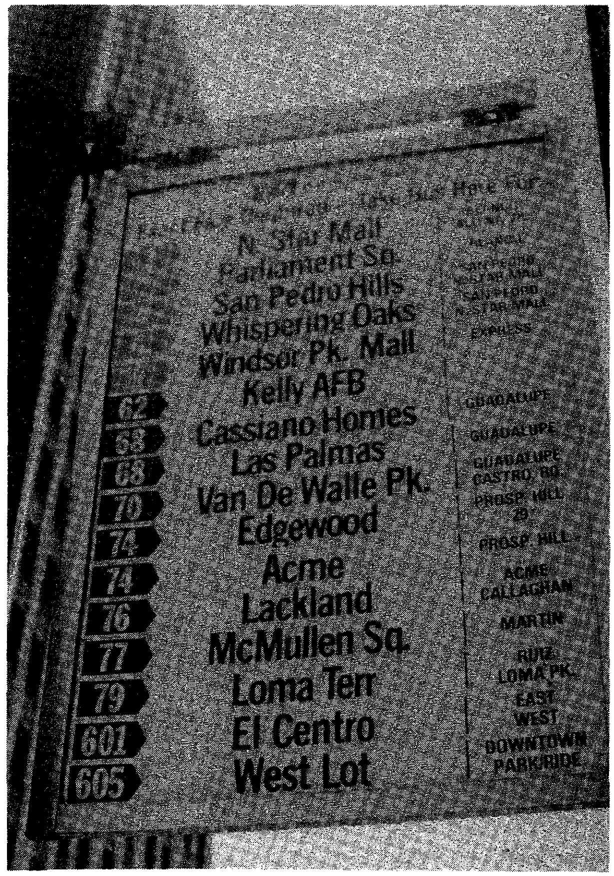
Rider information must be provided to acquaint new and potential users with the service available, and to notify current users of any changes or service adjustments that have been (or will be) implemented.

User informational aids and systems are employed to communicate information about the transit services to the public. They emphasize the "how to", while sales communications (such as advertising) stress the "why to" use transit. In many instances, however, informational aids and advertising will function jointly such as in a newspaper ad which attempts to "sell" the reader on riding transit and also provides specific schedule information and, perhaps, a route map.

The effective program of informational aids will necessarily be tailored to the needs of the broadest range of potential and current users. Typically, such a program will include:

- Signs or logos on transit equipment;
- Telephone information centers;
- Pocket schedules;
- System maps; and
- Transit stop signs that display information.





Transit system maps and transit stop signs that display route information are two components of an effective program of informational aids.

In addition, if resources allow, the following techniques can also help to reach and educate the general public:

- Door-to-door distribution of informational material;
- Information kits distributed to school children; and
- Informational packets distributed to shopping centers, apartment complexes, health care facilities, libraries, etc.

In general, transit informational systems are most effective when strong, simple, consistent information is provided uniformly. Visual communications are especially important, and it is imperative that identification markings on vehicles, timetables, route maps, facilities, etc. be consistent and of high graphic quality.

For the current transit patron, travel on system routes other than his regular one will be encouraged because he/she is reinforced and assisted by familiar markings and identifications. To the occasional or potential rider, consistent markings and identifications make the system easier to understand and use which encourages ridership.

Determination of which techniques are appropriate to local needs can be made through analysis of the market research findings. With few exceptions, an effective research effort can pinpoint information needs of each market segment and identify weaknesses in a current user information aids program.

Sales Communication Promotion (3, 5, 7, 8)

Sales communication is probably the most familiar marketing element. It is also one of the most important since it encompasses techniques that are highly effective in communicating transit system information to target market segments and persuading them to use transit services. Once the market has been researched and service planning completed, the communications effort begins. Typically it starts with a review of the research findings to determine who the audiences are as well as what is to be said, how, where and when. While there can be many secondary communications goals, the primary purposes almost always are to:

- Establish public awareness of the programs, operations, and problems of the transit system;
- Enhance the public's perception and attitudes toward the transit system services; and
- Create public awareness of the special benefits that accrue to the individual, the community and the nation from patronizing public transit.

The purpose of these goals is to improve the public's attitudes toward transit and to encourage its use.

The need to upgrade transit's overall public image is critical since serious damage was inflicted on transit's image during its period of decline. Consequently, many potential users view transit as undesirable or unattractive. (Their view may be right or wrong which only reinforces the need for marketing research on consumer attitudes to upgrade the system.) Moreover, transit is often viewed as "mass transit" for the disadvantaged, elderly, poor, etc. The potential customer may not see these citizens as his or her peers. The potential user may also perceive the available transit service as unresponsive to his or her needs even though they may have been improved substantially. Finally, a generation has grown up that is largely unfamiliar with transit services and their benefits.

Promotional campaigns can take many forms and utilize virtually every type of news media, financial resources permitting. Special programs can also be developed to promote transit, such as:

- Art contests for school children;
- Information display centers for shopping malls, exhibit halls, etc.;
- Slide/film presentations to civic groups, school children, senior citizen groups and other market segments;
- Open house; and
- Free or reduced ticket trial service.

Promotional campaigns can also involve the private sector. For example, a relatively recent practice is the promotion of transit use by employers through the sharing, or in some cases, total subsidization of transit fares for their employees. In a survey of 355 Katy Freeway Authorized Vehicle Lane bus users in Houston, 19% of the respondents indicated that their employers paid all of their bus fare expense and an additional 38% indicated that their employers subsidized part of their transit fare (7). Transit passes can greatly facilitate this type of effort by enabling firms to include transit into their fringe benefit, employee relations and recruiting packages. This approach complements and is justified by the extensive provision of free or reduced-cost parking for employees.

Promotion of transit service by local merchants can also be effective. In some areas, such as Bridgeport, CT, Spokane, WA and Orange County, CA, merchants have been organized to offer discounts to bus riders. Merchant coupons can be distributed on-board or as part of a fare pre-payment program.

Specific transit/private sector promotions can be creatively designed for many purposes and offer many opportunities. For example:

- Merchant associations, shopping centers, local banks or other major institutions may fund free ride days;
- Fast food restaurants may offer free food coupons for distribution to transit riders, or accept free ride coupons for distribution with food purchases; and
- Merchants can be organized to offer gift certificates for monthly drawings among transit pass purchasers.

Ongoing Service Evaluation and Monitoring (3)

A final important activity in the marketing effort involves: (1) Obtaining information on the degree to which marketing program has succeeded and (2) Determining which marketing elements contributed to the program's overall success or failure. This task can be accomplished by means of a type of consumer research known as "penetration research" which measures the effect of the marketing program on consumers' awareness of attitudes toward and responsiveness to the program as a whole.

Penetration research consists of conducting a series of studies over time. First, a base study is performed immediately before the introduction of any service changes and/or the sales promotion program to document existing conditions. This study is then followed at intervals by other studies - each of which are designed to track the progress of the marketing effort.

The analysis of the "before" and "after" studies, including the criteria by which results are judged, should be established according to the marketing goals. In general, the analysis must document answers to the following questions:

- What effect has the plan had on consumers in the appropriate target group?
- What effect has the plan had on other consumers who were not originally considered to the strategic research?
- Has any observed positive shift in consumers' attitudes occurred in those identified as being of strategic importance?
- Which aspects of the plan appear to contribute most to shifts in attitudes and/or behavior, (e.g., service elements vs. communications)?
- Has the plan resulted in increased ridership from diverted auto users?

The number and timing of penetration studies depends on the marketing plan and the level of resources available. It is highly desirable to conduct at least one follow-up study, but, in general, two follow-up studies are the recommended minimum. One of these should be conducted shortly after full implementation of the marketing plan (but after a sufficient amount of time has elapsed to have had a measurable effect), and one after the plan has been in effect long enough to have registered its full impact.

The early measurement of marketing impacts is useful because it makes it possible to modify the marketing program by: (1) Improving or revising elements of the original service improvement plan and/or the communications campaign; (2) Permitting a consideration of additional changes to interest non-key prospects; and (3) Evaluating the effectiveness of the communications campaign in terms of creative content, levels of media weight and media mix.

Monitoring transit service is necessary to assure that ridership goals are being met or that ridership trends are moving in the desired direction. Monitoring is also employed to determine if service is properly matched to the usage level. Since penetration research and system monitoring have an ongoing dialogue with the consumers that transit seeks to serve, these techniques provide input which can be applied to better planning and execution of each successive marketing effort.

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GLOSSARY OF TERMS

Articulated Bus or Articulated Electric Trolley Bus - An extra-long bus or trolley bus with the rear body section connected to the main body by a joint mechanism which allows the vehicle to bend in curves and yet have a continuous interior.

Articulated Rail Vehicle - An extra-long rail vehicle with 2, 3 or 4 bodies connected by joint mechanisms which allow bending in curves and yet have a continuous interior. Very common on light rail transit systems.

Automated Guideway Transit - Any guided transit mode with fully automated operation (no driver). Comprises people movers and intermediate capacity transit systems.

Bus or Motor Bus - A manually-steered, rubber-tired vehicle which operates on the existing roadway system usually in mixed traffic.

Bus Rapid Transit - The concept of providing a rapid transit type of service using buses. A number of facilities may be utilized to provide rapid transit service including exclusive lanes, contraflow lanes, concurrent flow lanes, or priority ramps for buses.

Busway - A traffic lane for dominant or exclusive use by buses. It may be a concurrent flow lane, contraflow lane or exclusive lane. In many instances, carpools and vanpools are also allowed to operate on busways.

> **Concurrent Flow Lane** - A lane on an urban street or freeway reserved for bus use only, separated from other lanes by pavement markings, signs and/or rubber cones, (but not by fixed physical barriers). Concurrent flow lane traffic travels in the same direction as adjacent traffic.
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> **Contraflow Lane (CFL)** - A lane to the left of the centerline, separated from other lanes by pavement markings, signs and/or rubber cones, where buses operate in the opposite direction from the other traffic; contraflow "borrows" a lane in the off-peak direction for peak direction travel.
>
> **Exclusive Lane** - A lane (or lanes) for bus use only, physically separated (by curbs or barriers) from other traffic.

Cablecar - A rail transit mode with single cars without motors propelled by a continuously moving cable located in an underground slot between rails.

Capacity (Transit) - The maximum number of vehicles or persons which can be transported on a transit line past a fixed point in one direction per unit of time (usually 1 hour).

Capacity (Vehicle) - The total number of persons (sitting and standing) a vehicle can accommodate. In some cases it may refer to the number of seats only.

Commuter Rail - See Regional Rail.

Demand-Responsive Transit - Paratransit service consisting of minibuses or vans directed from a central dispatching office to pick-up or drop-off individual passengers according to their desires expressed via telephone (dial-a-ride).

Electric Trolley Bus Transit - Rubber-tired buses which operate on streets, usually in mixed traffic. Trolley buses are propelled by electric motors which receive power through an overhead network of trolley contact wires.

Express Service - Transit line with long spacings between stops or stations that has high operating speed, and serves primarily long trips.

Heavy Rail Transit - See Rail Rapid Transit.

High Occupancy Vehicles (HOV) - Vehicles of any type (automobiles, vans, buses, etc.) which carry a prescribed minimum number of passengers (usually 3-4). Concept used for reserved "HOV lanes."

Highway Transit - Transit modes with highway (steered) vehicles; includes all bus modes, electric trolley buses and paratransit modes.

Internal Circulation (Service) - Transit service provided within an activity center where parking is scarce and travel distances are two lengthy to be served only by walking.

Interurban - Electric rail transit service between cities and towns in close proximity to each other.

Jitney (Service) - Paratransit service provided in passenger cars, vans, or minibuses driven by their owners along semi-fixed routes.

Kiss-and-Ride - Mode of travel by transit when a passenger is driven to and from a transit station by another person.

Level-of-Service (LOS) - Overall measure of all service characteristics that affect users.

Light Rail Rapid Transit (LRRT) - Light rail transit that operates on exclusive rights-of-way on its entire length.

Light Rail Transit (LRT) - An urban railway mode that operates on reserved right-of-way or in mixed-traffic. Its electrically propelled dual-rail vehicles operate singly or in trains. Power supply is from an overhead wire system.

Local Service - Transit line operation in which all vehicles stop at all stations.

Mass Transportation - The movement of large numbers of people within a corridor-particularly during peak travel hours.

Paratransit - Modes of passenger transport consisting of small to medium capacity highway vehicles offering service adjustable in varying degrees to individual user's desires.

Park-and-Ride - Mode of travel when a passenger drives to a transit station, parks his/her automobile at the station's park-and-ride lot, and completes the trip by transit. Possible with any transit mode.

People Mover System - Medium-sized vehicles operating automatically as single units or coupled trains on exclusive rights-of-way with special guideways. Vehicles are usually rubber-tired, electrically propelled.

Premetro - Light rail transit designed with provisions for easy conversion to rail rapid transit (METRO).

Public Transportation - The provision of mobility service to the general public. Primarily serves persons that do not have any other means of transportation.

Rail Rapid Transit (RRT) - Dual-rail vehicles (operating in 5 to 10 car trains) propelled by electricity transmitted through a side-running third rail. Because of its power supply, rail rapid transit must operate on fully-protected, exclusive rights-of-way.

Regional Rail (RGR) - Regional passenger service usually provided by railroad companies which consists of electrically or diesel-powered trains sharing mainlane railway trackage and rights-of-way with intercity passenger and freight service.

Regular Bus Service - See Local Bus Service.

Right-of-way (ROW) - Any path or way on which transit vehicles travel.

Rolling Stock - Collective term for a fleet of transit vehicles.

Rubber-Tired Rapid Transit (RTRT) - The same as rail rapid transit, except that the vehicles ride on and are guided by rubber tires on a specially designed guideway with wooden, concrete or steel running surfaces.

Streetcar - Street transit mode consisting of electrically powered rail vehicles usually operating in mixed-traffic.

Street Transit - Generic class of modes operating on streets with mixed traffic. Examples: motor bus, electric trolley bus, streetcar.

Subway - Rail transit operated in tunnels.

Taxi - Standard or specially designed passenger automobile operated by a professional driver and hired by one or a few users for individual trips.

Train Consists - A grouping of 2 to 5 rail transit cars into 1 or 2 trains.

(Urban) Public Transit - Transport systems for intraurban or intraregional travel available for use by any person who pays the established fare.