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Transit Capacity and Quality of Service Manual

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Submitted by
Kittelson & Associates, Inc.

In association with
Texas Transportation Institute
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Information on this report is available from the TCRP, 2101 Constitution Ave. N.W., Washington, D.C. 20418
Telephone: 202/334-3502 Fax: 202/334-2006

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REPORT ORGANIZATION

This manual treats each Part as a separate document. Therefore, the references cited in text refer to the Reference List at the end of each part. For example, (R1) in Part 1 refers to the references at the end of Part 1 and (R1) in Part 4 refers to those references at the end of Part 4. In addition, equation numbers, exhibits, and appendixes in text refer to the specific part they are cited in.

FOREWORD

TCRP Web Document 6, Transit Capacity And Quality of Service Manual, First Edition

The Transit Capacity and Quality of Service Manual (TCQSM) is intended to be a fundamental reference document for public transit practitioners and policy makers. The manual contains background, statistics, and graphics providing orientation to the various types of public transportation, and it introduces a new framework for measuring transit availability and quality of service from the passenger point of view. The manual contains quantitative techniques for calculating the capacity of bus and rail transit services, terminals, and platforms. Sample problems are included.

The material in this document that is relevant to traffic engineers is also included in Chapters 12, "Transit Concepts," and Chapter 27, "Transit Analytical Procedures," of the *Highway Capacity Manual 2000*, which will be issued by TRB on CD-ROM in the year 2000.

Until the publication of TCRP Web Document 6, *Transit Capacity and Quality of Service Manual (TCQSM), First Edition*, the transportation profession lacked a consolidated set of transit-capacity and quality-of-service definitions, principles, practices, and procedures for planning, designing, and operating vehicles and facilities. This is in contrast to the *Highway Capacity Manual* (HCM) that defines quality of service and presents fundamental information and computational techniques related to quality of service and capacity of highway facilities. The HCM also provides a focal point and structure for advancing the state of knowledge. It is anticipated that the TCQSM will provide similar benefits.

The First Edition of the TCQSM is a start toward providing the transportation industry with a transit companion to the HCM. "Transit capacity" is a multifaceted concept that deals with the movement of people and vehicles; depends on the size of the transit vehicles and how often they operate; and reflects the interaction between passenger traffic and vehicle flow. "Quality of service" is an even more complex concept that must reflect a transit-user's perspective and must measure how a transit route, facility, or system is operating under various demand, supply, and control conditions.

TCRP Project A-15, conducted by a team led by Kittelson & Associates, Inc., was a start toward addressing these issues. The objectives of Project A-15 were to (1) define the content of a comprehensive Transit Capacity and Quality of Service Manual, (2) provide transit input to the *Highway Capacity Manual 2000*, (3) develop a prioritized research agenda for completing the TCQSM, (4) complete those portions of a TCQSM for which information was available and produce an interim document, and (5) conduct research on one or more high-priority research topics growing out of the research agenda. These objectives were accomplished by the project, which produced a first edition TCQSM. The first phase of project A-15 included market research on what potential users would like to see in a TCQSM, assembled and edited existing information on transit capacity, and conducted original research on measuring transit quality of service. The TCQSM also introduces an “A” through “F” classification framework for measuring availability and quality of transit and paratransit service at the transit stop, on the route segment, and for the system.

The TCRP is initiating a continuation project to conduct research to fill user-identified gaps in the *First Edition.* The Transportation Research Board has also established a Task Force on Trasit Capacity and Quality of Service, A1E53, that will be responsible for the guiding the long term-development and evolution of the manual. The continuation work will be coordinated with the activities of the Task Force, and a second edition of the TCQSM will be published at the conclusion of the continuation. Information on how to submit comments will be available on the TCRP A-15 website in the fall of 1999. Select “TCRP, All Projects, A-15” from the TCRP website: http://www4.nas.edu/trb/crp.nsf.

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Alan Danaher, P.E., AICP, Principal Engineer, Kittelson & Associates, Inc. was the principal investigator and the primary author of Part 4. Co-investigators were Tom Parkinson, P. Eng., President, Transport Consulting Limited, the primary author of Parts 1, 3, and 6; Paul Ryus, P.E., Senior Engineer, Kittelson & Associates, Inc., the primary author of Parts 2 and 5; and Lewis Nowlin, Assistant Research Scientist, Texas Transportation Institute. Wayne Kittelson, P.E., Principal, Kittelson & Associates, Inc.; John Zegeer, P.E., Principal, Kittelson & Associates, Inc.; and Daniel Fambro, Professor, Texas A&M University, provided review.

Material for Part 2 was developed from a number of sources, including Chapter 12 (Transit) of the 1985, 1994, and 1997 editions of the *Highway Capacity Manual,* authored by Herbert S. Levinson. Timothy Lomax and Bill Eisele of the Texas Transportation Institute contributed to Chapter 3 (Busways and Freeway HOV Lanes). Chapter 4 (Exclusive Arterial Street Bus Lanes) is a condensed version of research developed by Kevin St. Jacques and Herbert S. Levinson and presented in TCRP Report 26. Clay Barnett of the Texas Transportation Institute contributed to Chapter 6 (Demand-Responsive). Appendix A was developed by Lewis Nowlin of the Texas Transportation Institute. The contributions of Peter Haliburton of Kittelson & Associates, Inc. are also acknowledged.

Part 3 is a condensed version of TCRP Report 13, *Rail Transit Capacity*. The contributions of Ian Fisher are acknowledged.

Part 6, the Glossary, was compiled from a number of sources. Definitions have been obtained from numerous sources with acknowledgment and thanks to the many individuals and committees involved—in particular, Benita H. Gray, editor of the 1989 TRB Urban Public Transportation Glossary from which almost half of the entries originated. The TRB glossary is out of print. Other major sources are: APTA web site glossary (April 1998); National Transportation Statistics Glossary; Washington State DOT Glossary; TCRP A-8 Rail Transit Capacity Glossary; and the APTA Glossary of Reliability, Availability, and Maintainability Terminology for Rail Rapid Transit, 1993. The contributions of Ian Fisher in compiling and cross-referencing the glossary are acknowledged.

PHOTO CREDITS

Graham Carey: Exhibit 2-34 (Essen).

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Ian Fisher: Exhibit 1-12.

Peter Haliburton: Exhibits 1-25 (Miami), 2-47 (Miami), and 4-19 (Miami).

Peter Koonce: Exhibit 1-39 (Seattle), 1-41 (New York), and 1-42 (New York).

Tom Parkinson: Exhibits 1-6 (Vancouver), 1-7, 1-10, 1-11, 1-21 (Calgary and San Francisco), 1-25 (New York), 1-30 (Toronto), 1-33 (Newark), 2-5, 2-40 (Ottawa), 2-58, 3-19, 3-54 (low-floor), and 3-61.

Lee Rodegerdts: Exhibit 1-21 (Baltimore and Los Angeles) and 1-37 (Johnstown).

Paul Ryus: Exhibits 1-6 (all but Vancouver), 1-9, 1-21 (Denver and Portland), 1-25 (Atlanta and Vancouver), 1-30 (San Diego), 1-33 (Miami), 1-36, 1-37 (Switzerland and Prague), 1-39 (Wuppertal), 1-41 (Oregon City), 1-42 (all but New York), 2-2 (Seattle), 2-3, 2-4, 2-24, 2-28, 2-30, 2-32, 2-45 (Denver), 2-46, 2-57, 3-54 (all but low-floor), 4-3 (all but landscaping), 4-5 (all but Newark), 4-9 (Denver), 4-16, 4-17 (Berkeley), 4-19 (Portland), 4-23, 4-25, and 4-26.

Tom Schwab: Exhibit 4-3 (landscaping).

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PART 1
INTRODUCTION AND CONCEPTS

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1. TRANSIT IN NORTH AMERICA

INTRODUCTION

Choice riders typically accommodated for work trips, particularly in larger cities.

Transit plays two major roles in North America. The first is to accommodate *choice* riders – or those riders who choose to use transit for their trip-making even though they have other means of travel, in particular a motor vehicle. Many commuters choose transit over other modes due to an unwillingness to deal with traffic congestion in their motor vehicle during peak periods. Use of transit also provides times for productive reading or work time on the transit vehicle, as well. Accommodation of choice riders on transit is dominant in the peak periods for work trips. As such, transit increases the number of people that can be carried by urban transportation systems and helps reduce, or at least constrain, the growth of the more than 4.36 billion person-hours[R4] lost to urban traffic congestion annually in the United States. In this role, transit is essential for mobility in the central business districts (CBDs) of some major cities, which could not survive without it. Accommodating choice riders is especially noteworthy in those cities where central business district densities are high and parking is costly and limited in supply.

Transit serves captive riders as well.

The other major role of transit is to provide basic mobility for those segments of the population too young, too old, or otherwise unable to drive due to physical, mental or financial disadvantages. About 35% of the population in the United States and Canada do not possess a driving license[R4] and must depend on others to transport them, in autos, on transit, or on other modes— walking, cycling, taxis, etc. This is the principal role for those transit services provided specifically for people with disabilities and the dominant role in many smaller transit systems. Such transit users have been called *captive* riders.

In the major cities in North America, transit services serve higher numbers of both choice and captive riders. The variation in transit modal share among urban areas reflects differences in population, CBD employment, extent of bus and rail transit services, and geographic characteristics.

Increased emphasis on moving persons in addition to vehicles on urban transportation systems.

Transit trips can be both time and cost competitive to the auto under certain operating conditions, where exclusive right-of-way operation, or on-street transit lanes or signal priority can be provided. With the trend towards *Transportation System Management* solutions to urban transport problems, there has been increased the focus on moving persons and not simply vehicles on transportation systems. This has increased awareness on the part of local jurisdictions on the benefits transit priority treatments can play in attracting transit ridership and reducing overall traffic congestion. With the higher transit ridership levels in larger cities, transit can provide more efficient use of energy and improve air quality.

Different transit service configurations.

Transit service can be provided in several operating configurations. *Fixed-route* service occurs where there is sufficient population and/or employment density to support higher transit volumes. Paratransit service occurs where transit trips are served on demand with regular routing and scheduling of service, typically in lower density areas and to accommodate elderly or disabled riders. New service concepts combining characteristics of both fixed-route and paratransit, such as deviated-route service, are being tested to provide some regularity of service and to improve transit accessibility for all riders.

Other forms of public transportation.

Other traditional forms of transportation provide an important component of overall public transit. Taxis can serve as short feeders to transit and an emergency role for commuters who must return home outside the hours of commute service. They also serve as an effective alternative, particularly when trips are subsidized, for elderly and disabled persons. School buses in the United States provided 152 billion passenger-kilometers (94 billion passenger-miles) of service in 1993,[R4] over four times the amount provided by all transit buses. The fleet of 550,000 school, church, and institutional buses in the U.S. is nine times larger than the 61,000 transit bus fleet. In Europe, most large Canadian cities, and a few United States cities, school trips are combined with transit, providing considerable savings for the school boards and additional revenues and economies of scale for the transit agency.

Importance of good pedestrian connections to transit.

Transit passengers must of necessity be pedestrians at one, or usually, both ends of their trips. Thus it is important that land uses surrounding transit stops incorporate good pedestrian linkages. In recent years there has been an emergence of neo-traditional developments that provide for higher urban densities, thus promoting transit ridership as well as improving local pedestrian connections to transit. Streets also must be able to be traversed safely to facilitate pedestrian access to and from transit stops.

THE DOMINANCE OF LARGE SYSTEMS

North American transit experience.

North American transit systems carry a majority of all peak-hour travelers to the downtown areas in many of the older major cities, but in other metropolitan areas handle a smaller proportion of CBD trips. Transit systems carry more than two-thirds of all peak-hour travelers to or from the New York, Chicago, and Toronto CBD areas, and more than one-third of all peak-hour travelers entering or leaving most other CBDs of major North American cities. At the very high end, in the densely occupied core of lower Manhattan in New York City, 84% of morning commuters arrive by public transportation.(R14)

Buses carry 86 percent of all peak-hour person-trips through the Lincoln Tunnel into New York City,(R16) about half of all peak-hour travelers on the Long Island and Gowanus Expressways in New York City, and for more than a quarter of all passengers on radial freeways approaching or leaving other large-city CBDs. Buses carry an even higher proportion of peak-hour travelers on many city streets. More than 80 percent of all peak-hour travelers are carried by buses on Hillside Avenue and Madison Avenue in New York City, Market Street in Philadelphia, and Main Street in Dallas. Buses accommodate more than one-half of all peak-hour person-trips on downtown streets in many other cities.(R11) Sixty percent of morning peak hour trips into lower Manhattan on Fifth Avenue took place by bus in 1992.(R8)

These observations do not necessarily represent maximum possible bus volumes or total traffic volumes. They do, however, clearly indicate that while buses account for a relatively small proportion of the vehicles in a traffic stream, they carry a sizable part of the total person flow. Rail rapid transit offers higher capacities and its fixed-route nature makes it more visible and attractive in dense areas. Light rail is gaining broader use in North America: Boston, Calgary, Philadelphia, Portland, Sacramento, St. Louis, San Diego, San Francisco, and Toronto are examples of cities with successful light rail lines.

STATISTICS

National Transit Database.

The U.S. Federal Transit Administration (FTA) maintains an extensive database of statistics covering the larger agencies it funds. In 1995 the National Transit Database included statistics on 392 bus operators, 367 demand responsive service agencies, and a range of less numerous modes.(R7) However, the database does not include many smaller bus systems that are exempted from its reporting requirements. Thus, the American Public Transit Association (APTA) reports a much larger total number of bus systems–2,250.(R1)

Canadian Urban Transit Association data.

Statistics on Canadian transit systems are collected by the Canadian Urban Transit Association (CUTA) from its member systems. These data indicate that there were 89 transit systems in Canada in 1995,(R5) although many of the smaller systems are omitted.[1] Most Canadian ridership figures are reported as linked trips, meaning that each transit trip is counted only once even if transfers are required. In contrast, FTA data counts unlinked trips, meaning that a passenger is counted every time they step aboard a transit vehicle

1 As an example of under-reporting, in the Province of British Columbia, BC Transit provides conventional transit service in a total of 26 service areas. However, only the two largest systems, in Vancouver and Victoria, are accounted for in CUTA's data.

even if they are making a continuous trip. As a result, U.S. passenger trip counts overstate the number of actual person trips by transit between origins and destinations, compared to the linked trips used in transportation planning models. Canadian systems are also not required to report passenger kilometers and so generally do not do so.

The FTA, for the purposes of the National Transit Database, categorizes transit systems by urbanized area population and by the number of vehicles operated in maximum service. Population is used below for comparison purposes. Exhibit 1-1 illustrates the number of transit systems, transit vehicles, and passenger trips in each of the three FTA population categories (under 200,000 population, 200,000 to 1 million, and over 1 million).

Exhibit 1-1
U.S. Transit Systems by Size Grouping (1997)[R5,R7]

Population	# of Agencies*	# of Vehicles	% of Total	Passenger Trips	% of Total
Under 200,000	460	6,308	8.6%	237,204,800	3.1%
200,000 to 1 million	86	11,370	15.4%	685,709,800	8.9%
Over 1 million	65	55,970	76.0%	6,778,716,800	88.0%
National Total	**611**	**73,648**	**100.0%**	**7,701,631,400**	**100.0%**

*Sum of agencies reporting to FTA. Most smaller agencies are not required to report to the FTA; APTA reports the number of U.S. public transit systems in 1998 as 5,973.

Concentration of transit ridership.

As can be seen, a small number of systems carry 88% of the total U.S. transit ridership. This group, in turn, is dominated by the New York region, which accounts for nearly 63% of the total U.S. ridership. Taken from a different point of view, however, it can also be seen that the majority of U.S. transit agencies operate in areas under 200,000 population. This fact is reinforced by Exhibit 1-2, which lists the number of U.S. public transit agencies operating various transit modes. The greatest number of agencies by far are the demand response and fixed route bus modes, both of which are suited for areas with smaller populations that have no need for high-capacity transit modes, yet still require basic transportation services.

Exhibit 1-2
U.S. Public Transit Systems by Mode (1998)[R1]

Mode	# of Agencies
Aerial tramway	1
Automated guideway transit	5
Fixed route bus	2,250
Cable car	1
Commuter rail	16
Demand response bus	5,214
Ferryboat*	25
Heavy rail	14
Inclined plane	5
Light rail	22
Monorail	2
Trolleybus	5
Vanpool	55
TOTAL**	**5,973**

*Excludes international, rural, rural interstate, island, and urban park ferries.
**Total is not sum of all modes since many agencies operate more than one mode.

Modal ridership and trip lengths.

Exhibit 1-3 summarizes United States transit ridership by transit mode along with the average trip length for each mode. Of note are the long average trip lengths for passengers using the commuter rail and demand responsive modes, and the short trips that characterize electric trolleybus and *other rail* services.

Exhibit 1-3
Transit Ridership in the United States by Mode (1996)[R7]

Mode	Annual Unlinked Pass. Trips (millions)	Millions of pass-km	Millions of pass-mi	Avg. Trip Length (km)	Avg. Trip Length (mi)
Bus	4,505.6	27,040	16,802	6.0	3.7
Heavy rail	2,156.9	18,556	11,530	8.6	5.3
Commuter rail	352.2	13,438	8,350	38.2	23.7
Light rail	258.7	1,537	955	5.9	3.7
Electric trolleybus	117.2	296	184	2.5	1.6
Demand responsive	54.5	629	391	11.5	7.2
Ferry	43.4	410	255	9.4	5.9
Other rail*	20.6	34	21	1.7	1.0
Total	7,509.1	61,940	38,488	8.2	5.1

*Includes automated guideway transit (AGT), cable cars, inclined planes, and monorails.

BUS SERVICE TYPES

Introduction

The bus is the most commonly used form of public transport in North America, accounting for 63 percent of all passenger trips by transit in the U.S., and 55 percent of transit trips on the five largest Canadian transit systems. There were an estimated 2,250 bus systems in the U.S. in 1998.[R1] Exhibit 1-4 provides a list of the most-utilized bus systems in the U.S. and Canada, ranked by 1997 annual ridership. The figures shown are consolidated for all bus modes operated by each agency and thus include trolleybuses and contracted services. Note the very high ridership for the San Francisco Municipal Railway relative to its fleet size. This can be ascribed to the compactness of the service area and a high number of transfers resulting from the grid nature of the route structure.

Top ten U.S. and top five Canadian bus systems.

Exhibit 1-4
Top 10 U.S. and Top 5 Canadian Bus Systems Based on Annual Ridership (Including Trolleybus and Contracted Services)[R1,R7]

Transit Agency	1997 Annual Unlinked Passenger Trips (millions)	1996 Buses Operated in Maximum Service
UNITED STATES		
MTA-New York City Transit	542,624	3,078
Los Angeles County MTA	337,870	1,794
Chicago Transit Authority	288,217	1,589
MUNI (San Francisco)	169,919*	636*
SEPTA (Philadelphia)	147,725	1,141
New Jersey Transit	142,547	1,734
WMATA (Washington, DC)	139,929	1,178
MBTA (Boston)	102,922	880
MTA of Harris County (Houston)	88,144	994
MARTA (Atlanta)	78,169	564
CANADA		
Toronto Transit Commission	354,742	NA
MUCTC (Montréal)	346,560	NA
BC Transit (Vancouver)	176,034	NA
Ottawa-Carleton RTC	98,660	NA
Calgary Transit	57,077	NA

*1995 data. NA: not available

Local, limited-stop, and express bus service.

Bus services fall into three major operating categories. *Local services* provide service to all stops along a route and consequently provide relatively slow service and are best for short-distance trips. *Limited-stop services* are frequently overlaid over a local route or routes and provide a higher speed service by stopping only at major destinations, such as key transfer points and major activity centers. *Express services* tend to be used for longer distance trips and provide local service near the end points of the route, with the intervening distance covered without passenger stops. Local passengers are often prohibited from riding the local portions of express services in core areas of the city where other local services are available.

Bus use of roadways.

Bus services can be operated on a variety of types of roadway, ranging from streets with mixed traffic to exclusive bus-only highways known as busways. Greater degrees of separation from other traffic provide transit vehicles and their riders with faster, more predictable journeys as the interference with other road users is reduced or eliminated. Providing special lanes or roads for buses also serves a marketing function as it indicates an institutional preference given to buses over the private automobile. Bus operation on dedicated right-of-way, however, is not very common relative to mixed traffic operation. In the U.S. in 1995, there were about 830 km (515 mi) of roadway lanes with full-time occupancy restrictions favoring buses. Another 930 km (575 mi) of lanes offered preferential access for buses during at least part of the day. In contrast, about 250,000 km (150,000 mi) of roadway used by buses are shared with mixed traffic.[R1]

Bus services can be provided by a number of vehicle types ranging from minibuses to articulated and double-deck buses. The composition of the U.S. transit bus fleet is shown in Exhibit 1-5.

Exhibit 1-5
Non-Rail Vehicles in Active Transit Service in the U.S. (1996)[R7]

Vehicle Type	Bus	Demand Responsive
Class A Bus (>35 seats)	47,803	95
Class B Bus (25-35 seats)	4,317	117
Class C Bus (<25 seats)	2,020	4,238
Articulated Bus	1,648	4
Trolleybus	897	0
School Bus	3	129
Van	552	8,109
Automobile	6	5,633
TOTAL	57,246	18,325

NOTE: Class A, B, and C bus totals do not include the specialized bus types listed separately.

Standard 12-meter (40-foot) buses with over 35 seats are by far the dominant form of bus operated by United States transit systems and comprise over 80 percent of the national transit bus fleet. Articulated buses of 18 meters (60 feet) in length have been embraced by a smaller number of transit agencies, but their use is growing as agencies seek to improve capacity and comfort with relatively low increases in operating costs. Double-deck buses have been employed for trial applications but have not found widespread transit use in either the United States or Canada.

The requirements of the Americans with Disabilities Act, and parallel policies in Canada, have resulted in most new transit vehicles being designed to accommodate passengers in wheelchairs and scooters, and those who have difficulty with stairs. In 1996, 67.6% of the U.S. transit bus fleet was accessible to wheelchairs. While providing wheelchair lifts has been the most common means to meeting these obligations, a recent trend is the move towards low-floor buses which allow easier boarding for all passengers by eliminating the need for steps and wheelchair lifts. Separate transit systems— often run by volunteers— have been developed to meet the transportation needs of the elderly and persons with disabilities in areas where no regular transit service is available.

While most transit buses are diesel powered, natural gas and electric powered buses (trolleybuses) are also used by some agencies. Trolleybuses operate in seven cities in Canada and the U.S., but comprise less than two percent of the total U.S. transit bus fleet. Exhibit 1-6 shows an example of trolleybuses, as well as other common bus types in use.

Exhibit 1-6
Transit Bus Vehicle Types

Standard (Tallahassee)

Articulated (Portland, OR)

Low-Floor (Victoria, BC)

Trolleybus (Vancouver, BC)

70-Passenger Shuttle Bus (Denver)

Double-Deck (Berlin, Germany)

Segregated Right-of-Way (Busway)

Busways typically provide a two-way roadway in a segregated right-of-way designated for the exclusive use of buses. Maximum operating speeds are typically in the 70-80 km/h (45-50 mph) range. Stations are provided for passenger service. Well-known examples of busways in North America include Pittsburgh's East and South Busways, the downtown Seattle bus tunnel and the connecting surface busway to the south, and the Ottawa Transitway, shown in Exhibit 1-7. The last example is the largest in scale, being 31 km (19 mi) in length and handling up to 10,000 passengers in 190 buses per hour in the peak direction. Outside of downtown Ottawa, the Transitway has its own roadway and stations resembling those of a light rail line. Very frequent bus service on the Transitway is accommodated by dividing the bus routes between a number of stops at each station. While most of the Transitway is fully segregated from other traffic, the downtown segment consists of reserved lanes on a one-way couplet. This section tends to be slow and congested. Plans for a tunnel through downtown have been canceled due to cost.

Exhibit 1-7
OC Transpo Busway (Ottawa, Ontario)

Metro-Dade Transit in Miami opened a 13.2-km (8.2-mi) busway in early 1997. The busway has its own right-of-way; however, as signalized intersections are used where the busway intersects major streets, this facility is treated as an exclusive arterial street bus lane for capacity analysis purposes.

Guided busways represent another form of segregated right-of-way. A combination of curbs on the side of the guideway and an extra set of wheels on the bus that roll against these curbs provide lateral guidance for buses and require less right-of-way. As of 1998, no facilities of this type existed in North America, although one was under consideration in Eugene, Oregon. International applications exist in Australia, England, and Germany.

Exclusive Reserved Lanes (Bus Lanes)

Roadway lanes— either on arterial streets or freeways— reserved for the exclusive use of buses are a form of high-occupancy vehicle (HOV) lane distinguished by a highly restrictive occupancy policy. Exclusive lanes can be provided in the same direction as general traffic (concurrent flow) or in the opposite direction as a contraflow lane. Both types are used in North America. A well-known contraflow facility is the Lincoln Tunnel bus lane from New Jersey to Manhattan in New York City (Exhibit 1-8). In many cases bus lanes are in effect during peak periods only and are available to general traffic at other times of the day. Short reserved lane segments, known as queue bypasses or queue jumpers, are commonly used to allow buses, and sometimes other HOVs, to bypass congestion points such as congested intersections and metered freeway ramps. In 1990 there were over 950 HOV ramp bypasses in North America.[R8]

Exhibit 1-8
Lincoln Tunnel Contraflow Bus Lane

Streets reserved for buses, known as bus malls, are used in a number of cities but their use has waned in recent years. The more prominent remaining examples include the Nicollet Mall in Minneapolis, the Fulton Street Mall in Brooklyn, the 16th Street Mall in Denver (shown in Exhibit 1-9), the 5th and 6th Avenue Mall in Portland, Oregon, and the Granville Mall in Vancouver, British Columbia. However, there are many bus lanes along arterial streets that operate on a daily or 24-hour basis. Examples include the Madison Avenue dual bus lanes in New York City, lanes in Pittsburgh, and lanes in San Francisco.

Exhibit 1-9
Denver 16th Street Bus Mall

Shared Reserved Lanes (HOV Lanes)

Where capacity permits, buses can successfully operate in high-occupancy vehicle (HOV) lanes. HOV lanes are preferential lanes that are available only to vehicles carrying a number of passengers above a set threshold occupancy. In practice the occupancy requirement varies widely, depending on local policies, and ranges from a minimum requirement of two occupants per vehicle to the exclusive bus lanes previously mentioned. Some jurisdictions also permit motorcycles or taxis to use HOV lanes— as well as all emergency vehicles. While, in theory, occupancy requirements can be raised in order to maintain a desired level of service and increase person-moving capacity, reductions in occupancy requirements have been much more common in order to reduce the negative public perception caused by "empty-lane syndrome."(R8)

Mixed Traffic

Mixed traffic bus operation (Exhibit 1-10) accounts for over 99 percent of total bus route distance in North America. While operating buses in general traffic lanes is straightforward for planning and political purposes, it does result in buses being subject to delays caused by traffic. Mixed traffic operation complicates capacity calculations for both bus and automobile flow since it exposes buses to automobile traffic congestion and slows automobiles as buses stop and start to serve passengers.

Exhibit 1-10
Mixed Traffic Operation (Los Angeles)

Demand-Responsive

Demand-responsive transit service is typically operated by vehicles seating fewer than 25 passengers, such as the one shown in Exhibit 1-11, that are dispatched in response to passenger request. In general, operation is not according to a fixed route or schedule. Vehicles are normally dispatched to pick up a number of passengers at various locations and take them to their respective destinations, possibly picking up additional passengers along the way. Demand-responsive service is most commonly employed to serve the travel needs of persons who, through physical inability, are not able to use the conventional transit system. The operation of *complementary* demand-responsive systems, which supplement fixed route accessible bus services, is mandated by the Americans with Disabilities Act. This type of service is also often used in low-density suburban and rural areas where there is insufficient demand to justify the operation of conventional transit service. Demand-responsive service is highly vehicle intensive. An average demand-responsive vehicle operating in the U.S. in 1995 provided 4,125 passenger trips per year. By comparison, buses and trolleybuses together carried 106,620 passenger trips per vehicle in 1995 in the U.S.

Exhibit 1-11
Demand-Responsive Small Bus

Route Deviation

A variant of demand responsive service, route deviation service can use a wide range of equipment from full-sized buses to small vans. The service operates on fixed routes with rules that permit deviation on demand— usually limited to deviation within about four blocks and no more than two deviations per trip. Deviations are usually expected not to add more than five minutes to the scheduled one-way trip time and may be limited to sections of the route and/or to specific times of day or certain days of the week.

Rural and Intercity

Rural services are often contracted or privately run.

Transit services outside urban areas are often provided by private bus services (Exhibit 1-12). However, in some areas of the U.S., public transit agencies provide service in rural areas and between regional population centers. Such is the case in New Jersey where the state transit operator (New Jersey Transit) provides service throughout the state. Heavy-duty highway-type coaches or minibuses are often used for such services, depending on demand, rather than regular transit buses. Service to outlying areas is often infrequent and is designed to accommodate persons traveling for medical, shopping and other personal business needs rather than commuting. It is not uncommon for rural bus service to operate fewer than five days a week with schedules designed to allow for a same-day return trip on those days that service is provided.

Exhibit 1-12
Typical Rural Bus Service (Maple Ridge, BC)

Observed Bus and Passenger Flows

Streets and Highways

Exclusive busways.

Observed bus volumes on urban freeways, city streets, and bus-only streets clearly show the reductive effects of bus stops on bus vehicle capacity. The highest bus volumes experienced in a transit corridor in North America, 735 buses per hour through the Lincoln Tunnel and on the Port Authority Midtown Bus Terminal access ramps, in the New York metropolitan area, are achieved on exclusive rights-of-way where buses make no stops (and where an 210-berth bus terminal is provided to receive these and other buses).[R13] Where bus stops or layovers are involved, reported bus volumes are much lower. Exhibit 1-13 shows bus flow experience for a number of North American cities.

Exhibit 1-13
Observed Peak Direction Peak Hour Passenger Volumes on U.S. and Canadian Bus Transit Routes (1995-97)[R6,R13,R17]

Location	**Facility**	**Peak Hour Peak Direction Buses**	**Peak Hour Peak Direction Passengers**	**Average Passengers per Bus**
New Jersey	Lincoln Tunnel	735*	32,600	44
Ottawa	West Transitway	225	11,100	49
New York City	Madison Avenue	180	10,000	55
Portland, OR	6th Avenue	175	8,500	50
New York City	Long Island Expy.	165	7,840	48
New York City	Gowanus Expy.	150	7,500	35
Newark	Broad Street	150	6,000	40
Pittsburgh	East Busway	105	5,400	51
Northern Virginia	Shirley Highway	160	5,000	35
San Francisco	Bay Bridge	135	5,000	37
Denver	I-25	85	2,775	33
Denver	Broadway/Lincoln	89	2,325	26
Boston	South/High Streets	50	2,000	40
Vancouver, BC	Granville Mall	70	1,800	26
Vancouver, BC	Highway 99	29	1,450	50

*no stops

Bus malls.

When intermediate stops are made, bus volumes rarely exceed 120 buses per hour. However, volumes of 180 to 200 buses per hour are feasible where buses may use two or more lanes to allow bus passing, especially where stops are short. An example is Hillside Avenue in New York City. Two parallel bus lanes in the same direction, such as along Madison Avenue in New York, and the 5th and 6th Avenue Transit Mall in Portland, Oregon, also achieve this flow rate. Up to 45 buses one-way in a single lane in 15 minutes (a flow rate of 180 buses per hour) were observed on Chicago's former State Street Mall; however, this flow rate was achieved by advance marshaling of buses into 3-bus platoons and by auxiliary rear-door fare collection during the evening peak hours to expedite passenger loading.

Several downtown streets carry bus volumes of 80 to 100 buses per hour, where there are two or three boarding positions per stop, and where passenger boarding is not concentrated at a single stop. (This frequency corresponds to about 5,000 to 7,500 passengers per hour, depending on passenger loads.)

Historic streetcar volumes.

These bus volumes provide initial capacity ranges that are suitable for general planning purposes. They compare with maximum streetcar volumes on city streets in the 1920s which approached 150 cars per track per hour, under conditions of extensive queuing and platoon loading at heavy stops.[R3] However, the streetcars had two operators and large rear platforms where boarding passengers could assemble.

Terminals

Peak-hour bus flows observed at 13 major bus terminals in the United States and Canada range from 2.5 buses per berth at the George Washington Bridge Terminal in New York to 19 buses per berth at the Eglinton Station, Toronto.(R9)

Buses occupy loading areas at bus terminals for much longer periods of time than they occupy loading areas at on-street bus stops.

The high berth productivity in Toronto reflects the special design of the terminal (with multiple positions in each berthing area); the wide doors on the buses using the terminal, and the free transfer between bus and subway, which allows use of all doors, and separate boarding and alighting areas. The relatively low productivity at the New York terminals reflects the substantial number of intercity buses that use the terminals (which occupy berths for longer periods of time) and the single-entrance doors provided on many suburban buses.

This experience suggests an average of 8-10 buses per berth per hour for commuter operations. Intercity berths typically can accommodate 1-2 buses per hour.

Bus Priority Treatments

Much attention has been paid to expediting transit flow by providing various forms of priority treatment. Such treatments are aimed at improving schedule adherence and reducing travel times and delays for transit users. They may attract new riders, increase transit capacity, and/or improve the transit quality of service.

A growing number of cities have established exclusive bus lanes and other bus priority measures to improve person-flow over city streets and highways. Bus priority measures are an essential part of transportation system management (TSM) programs that attempt to maximize transport system efficiency consistent with social, economic, and environmental objectives.

Because buses may stop within priority lanes to pick up and discharge passengers, the ability of these lanes to carry people will be affected by loading and unloading time requirements set forth earlier. Guidelines presented in Part 2 can be used to estimate capacities. The following sections summarize the pertinent operational features, planning considerations, and guidelines for specific freeway and arterial treatments.

Operational Overview

Exhibit 1-14 presents operational characteristics of significant busway and freeway HOV lanes. A complete listing of these treatments can be found in the TRB *HOV Systems Manual.*(R19)

Effective distribution of buses in CBD areas remains an important challenge, and communities are giving this issue increased attention. Freeway-related treatments generally provide good access to the CBD perimeter, but do not substantially improve service within the downtown core. Terminals are not always located near major employment concentrations and may require secondary distribution. Because curb bus lanes are not always effective, there have been several efforts to install contraflow bus lanes in downtown areas. Signal pre-emption for buses is another measure effectively used to minimize bus delay and increase level of service. As a capital-intensive solution to CBD bus distribution, a 2.1-km (1.3-mi), five-station bus tunnel opened in downtown Seattle in 1991. Bus routes using the tunnel are operated with a special fleet of dual-mode buses which run on electric power in the tunnel and diesel power on the surface portions of their routes. Both ends of the tunnel connect to freeway ramps.

Many bus priority measures have produced important passenger benefits, especially those relating to freeways. Some have achieved time savings of 5 to 30 minutes— savings that compare favorably with those resulting from rail transit extensions or new systems. The contraflow bus lane leading to the Lincoln Tunnel in New Jersey, for example, provides a 20-minute time saving for bus passengers.

Exhibit 1-14
Operating Characteristics of Selected North American Busways and Freeway HOV Facilities (January 1998) (R19)

Facility	# of Lanes	Length in km (mi)	HOV hours[1]	Eligibility
BUSWAYS				
Ottawa, Ontario (5 busways)				
Southeast Transitway	1 each dir.	10 (6.2)	24 hours	Buses only
West Transitway	1 each dir.	8.5 (5.3)	24 hours	Buses only
Southwest Transitway	1 each dir.	3.6 (2.2)	24 hours	Buses only
East Transitway	1 each dir.	6.6 (4.1)	24 hours	Buses only
Central Transitway	1 each dir.	3.5 (2.2)	24 hours	Buses only
Pittsburgh, PA (2 busways)				
East Patway	1 each dir.	9.9 (6.2)	24 hours	Buses only
West Patway	1 each dir.	6.6 (4.1)	24 hours	Buses only
Seattle, WA (Bus Tunnel)	1 each dir.	2.1 (1.3)	24 hours[2]	Buses only
Minneapolis, MN (Univ. of Minnesota)	1 each dir.	1.8 (1.1)	24 hours	Buses only
Dallas, TX (SW Texas Medical Center)	1 each dir.	1.0 (0.6)	24 hours	Buses only
BARRIER-SEPARATED TWO-WAY HOV LANES				
Los Angeles, CA (I-10 El Monte)	1 each dir.	6.4 (4.0)	24 hours	3+ HOVs
Seattle, WA (I-90)	1 each dir.	2.5 (1.6)	24 hours	2+ HOVs
BARRIER-SEPARATED REVERSIBLE FLOW HOV LANES				
Northern Virginia (I-95/I-395 Shirley Hwy)	2	24 (15)	24 hours	3+ HOVs
Houston, TX				
I-10 (Katy Freeway)	1	21 (13)	5-12, 2-9[3]	3+ HOVs
I-45 (Gulf Freeway)	1	21 (13)	5-12, 2-9	2+ HOVs
US 290 (Northwest Freeway)	1	21.6 (13.4)	5-12, 2-9	2+ HOVs
I-45 (North Freeway)	1	21.6 (13.4)	5-12, 2-9	2+ HOVs
US 59 (Southwest Freeway)	1	20 (12)	5-12, 2-9	2+ HOVs
CONCURRENT-FLOW HOV LANES				
Miami, FL (I-95)	1 each dir.	52 (32)	7-9 am SB, 4-6 pm NB	2+ HOVs
Atlanta, GA (I-75)	1 each dir.	19.3 (12.0)	24 hours	2+ HOVs
Honolulu, HI (H-2)	1 each dir.	13.1 (8.1)	6-8, 3:30-6	2+ HOVs
Montgomery County, MD				
I-270	1 each dir.	25.8 (16.0)	peak periods	2+ HOVs
US 29 (shoulders)	1 each dir.	4.8 (3.0)	peak periods	Buses only
Ottawa, Ontario				
Hwy. 417 Kenta	1 EB only	4.8 (3.0)	7-9 am	Buses only
Hwy. 17 Orleans	1 WB only	4.8 (3.0)	7-9 am	Buses only
CONTRAFLOW HOV LANES				
New Jersey, Hwy. 495 (to Lincoln Tunnel)	1 EB only	4 (2.5)	6-10 am	Buses only
Dallas, TX	1 each pk. dir.	8.3 (5.2)	6-9, 4-7	2+ HOVs
Boston, MA	1 each pk. dir.	9.6 (6.0)	6-10, 3-7	3+ HOVs
Montreal, Quebec	1	6.9 (4.3)	6:30-9:30 NB, 3:30-7 SB	Buses only
HOV QUEUE BYPASSES				
Oakland, CA (Bay Bridge Toll Plaza)	3	1.4 (0.9)	5-10, 3-7	3+ HOVs
San Diego, CA ("A" Street ramp to I-5)	1	0.6 (0.4)	24 hours	Buses only
Los Angeles, CA (250 freeway ramps)	1	0.2 (0.1)	when demand warrants	2+ HOVs
Chicago, IL (I-90 toll plaza)	1 EB only	0.8 (0.5)	peak periods	Buses only

NB: northbound, SB: southbound, EB: eastbound, WB: westbound
[1]Part-time periods are weekdays only unless otherwise noted.
[2]Buses operate through tunnel 5 am-11 pm weekdays, 10 am-6 pm Saturdays; closed other times.
[3]Also 5 am-5 pm westbound Saturdays, 5 am-9 pm Sundays.

Successful priority treatments are usually characterized by one or more of the following: (a) an intensively developed downtown area with limited street capacity and high all-day parking costs, (b) a long-term reliance on public transport, (c) highway capacity limitations on approaches to downtown, (d) major water barriers that limit road access to the CBD and channel bus flows, (e) fast nonstop bus runs for considerable distances, (f) bus priorities on approaches to or across water barriers, (g) special bus distribution within the CBD (often off-street terminals), and (h) active traffic management, maintenance, operations, and enforcement programs.[R12]

RAIL TRANSIT

Introduction

Rail transit systems in North America carry five billion passengers each year. A total of 53 agencies operate 207 routes of the four rail transit modes with a total length of 8,200 km (5,100 miles), providing 29 billion passenger-kilometers (18 billion passenger-miles) of service annually.

Two systems dominate. The largest operator, Sistema de Transporte Colectiva in Mexico City, has recently overtaken MTA-New York City Transit Authority in ridership. STC carries 1,436 million passengers annually, 29% of the continent's total. MTA-NYCT carries 1,326 million passengers annually, 27% of the continent's total, 50% of the U.S.'s total. Adding all New York City area rail operators makes the New York area the continent's largest user of rail transit with 1,585 million passengers annually, 32% of the continent's total, 59% of the U.S.'s total. Together the rail transit systems in the New York area and in Mexico City account for 61% of all unlinked rail passenger trips in North America. Ridership data is summarized in Exhibit 1-15 and Exhibit 1-16.

Heavy rail carries 81% of all rail transit passengers in North America.

Exhibit 1-15
North American Rail Ridership by Mode (1995)

Mode	Annual Unlinked Trips	%
Rail Rapid Transit	4,137,000,000	80.8%
Light Rail	474,000,000	9.3%
Commuter Rail	334,000,000	6.5%
Automated Guideway	175,000,000	3.4%
TOTAL	5,120,000,000	100.0%

Exhibit 1-16
Transit Ridership Summary (millions) (1995)

Country	All Transit	Rail Transit	% by rail
USA	8,643	2,671	31%
Canada	2,001	770	38%
Mexico	NA	1,503	NA

NA: not available

Rail transit plays a vital role in five metropolitan areas carrying over 50% of all work trips and, in three regions, over 70% of all CBD-oriented work trips. Rail transit plays an important but lesser role in another six regions. Other rail transit systems carry a smaller proportion of all regional trips but fill other functions, such as defining corridors and encouraging densification and positive land-use development.

Rail transit modes.

The four major rail modes consist of: Automated Guideway Transit (AGT), Commuter Rail (CR), Light Rail Transit (LRT) and Heavy Rail Transit (HR), also called Rail Rapid Transit. Exhibit 1-17 gives a condensed look at some of the key North American statistics for each mode. Exhibit 1-18, Exhibit 1-19, and Exhibit 1-20 provide usage statistics for rail transit modes in the United States. Note that long average trip lengths on commuter rail systems give this mode a much higher share of total rail passenger-kilometers (miles) than its share of trips would suggest.

Exhibit 1-17
Comparison of Key North American Rail Mode Statistics (1995)(R15)

Type	Routes	Average Line Length (km)	Total Length (km)	Average Station Spacing (km)	Average Line Speed (km/h)
AGT	3	6.3	19.0	0.70	24.3
CR	77	73.7	5672.1	5.71	52.7
LRT	51	13.9	708.5	0.83	22.1
HR	76	25.3	1868.6	1.47	36.2

Type	Routes	Average Line Length (mi)	Total Length (mi)	Average Station Spacing (mi)	Average Line Speed (mph)
AGT	3	3.9	11.8	0.43	15.1
CR	77	45.8	3524.5	3.55	32.7
LRT	51	8.6	440.2	0.52	13.7
HR	76	15.7	1161.1	0.91	22.5

AGT: automated guideway transit, CR: commuter rail, LRT: light rail transit, HR: heavy rail

Exhibit 1-18
U.S. Rail Transit Annual Unlinked Passenger Trips by Mode (1996)(R7)

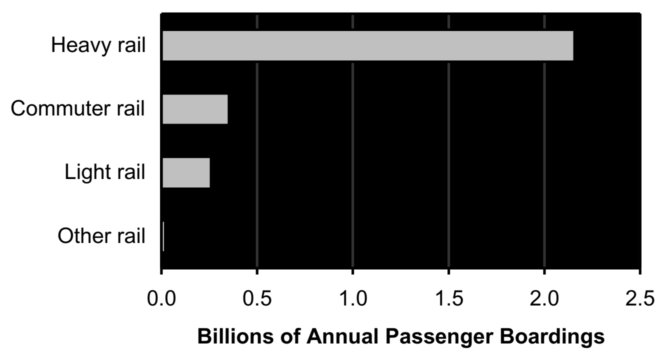


Exhibit 1-19
U.S. "Other Rail" Annual Unlinked Passenger Trips by Mode (1996) (R7)

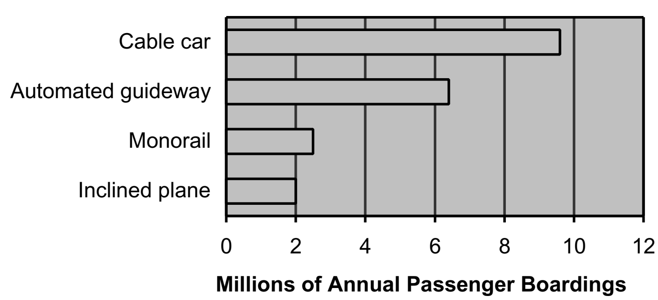
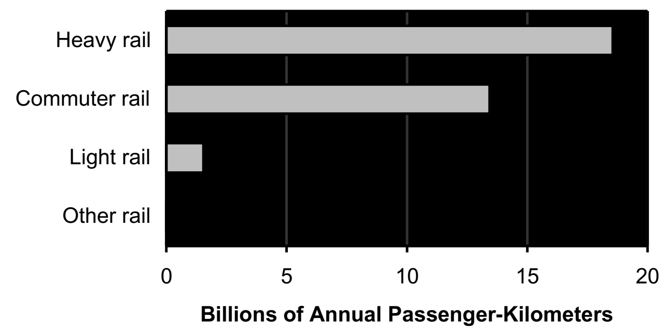
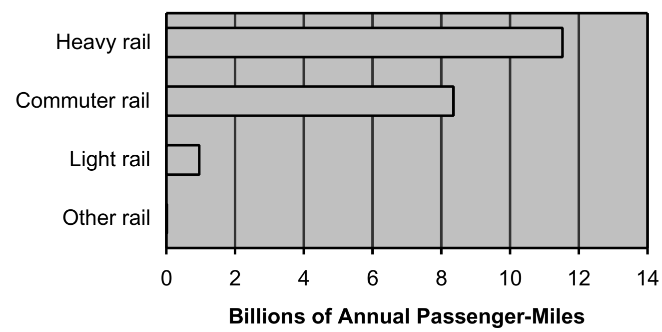


Exhibit 1-20
U.S. Rail Transit Annual Passenger Kilometers (Miles) by Mode (1996)[R7]





Rail Right-of-Way Types

While the rail mode employed on a rail transit line has some bearing on capacity, the type of right-of-way (ROW) used by the line is of vital importance. The three major types of rights-of-way are described below. Similar divisions can be applied to bus systems.

Exclusive right-of-way: The right-of-way is reserved for the exclusive use of transit vehicles. There is no interaction with other vehicle types. Intersections with other modes are grade-separated to avoid the potential for conflict. Exclusive rights-of-way provide maximum capacity and the fastest and most reliable service, although at higher capital costs than other right-of-way types. Automated guideway transit systems must by definition operate on this type of right-of-way as their automated operation precludes any mixing with other modes. This right-of-way type is also most common for heavy rail systems, many commuter rail systems, and at least portions of many light rail systems.

Segregated right-of-way: Segregated rights-of-way provide many of the same benefits of exclusive rights-of-way but permit other modes to cross the right-of-way at defined locations such as grade crossings. Segregated rights-of-way are most commonly employed with commuter rail and light rail transit systems. The use of this right-of-way type for heavy rail transit systems has largely been eliminated.

Shared right-of-way: A shared right-of-way permits other traffic to mix with rail transit vehicles, as is the case with most streetcar and bus lines. While this right-of-way type is the least capital intensive, it does not provide the benefits in capacity, operating speed, and reliability that are provided by the other right-of-way types.

Light Rail Transit

Light rail transit described.

Light rail transit, often known simply as LRT, began as a development of the streetcar to allow higher speeds and increased capacity. Light rail transit is characterized by its versatility of operation, as it can operate separated from other traffic below grade, at-grade, on an elevated structure, or together with motor vehicles on the surface (Exhibit 1-21). Service can be operated with single cars or multiple-car trains. Electric traction power is obtained from an overhead wire, thus eliminating the restrictions imposed by having a live third-rail at ground level. This flexibility helps to keep construction costs low and explains the popularity this mode has experienced since 1978 when the first of 14 new North American light rail transit systems was opened in Edmonton. These newer light rail transit systems have adopted a much higher level of segregation from other traffic than earlier systems enjoyed. A recent trend is the introduction of diesel light rail cars by European manufacturers. Although not yet in regular service in North America, trials of such cars have generated considerable interest in some areas, given the ease with which diesel light rail service can be established on existing rail lines.

Exhibit 1-21
Light Rail Examples

Segregated ROW (Calgary)

Transit Mall (Baltimore)

Median (Los Angeles)

Contraflow (Denver)

Streetcar (San Francisco)

Tunnel (Portland, OR)

Light rail transit passenger loading methods.

LRT passenger loading can be accomplished at street level with steps on the cars, or at car floor level with high-level platforms. The lines in Calgary, Edmonton, Los Angeles, and St. Louis operate entirely with high-platform access. The San Francisco Municipal Railway uses moveable steps on its cars to allow cars to use both high-platform stations and simple street stops. Pittsburgh takes a different approach and has two sets of doors on its light rail vehicles, one for high platforms and the other for low-level loading. Most other systems use low-loading with steps. A variety of loading methods may be employed to accommodate passengers in wheelchairs and scooters where car floors and platforms are not at the same level. A more detailed discussion of how access required by the Americans with Disabilities Act is provided can be found in Part 3. Low-floor cars, already popular in Europe, are now operating in Portland, Oregon and Boston. Such vehicles provide floor-level loading without the need for steps or high platforms. Wheelchair access also benefits since lifts are not required with low-floor cars; other users, such as the elderly and persons with strollers or bicycles also benefit.

As of 1998, there are 23 light rail transit systems in operation in the U.S. and Canada, listed in Exhibit 1-22, with four additional systems in Mexico (Guadalajara, Monterrey, and two systems in Mexico City). As the FTA includes the lines that are primarily operated for heritage and tourist purposes, such as those in Memphis and Seattle, in its light rail reporting category, these lines are included in the total shown in Exhibit 1-22. Similarly, streetcar operations, such as those in New Orleans, San Francisco, and Toronto are included in the total.

Information on specific light rail routes may be found in Appendix A (Part 1).

Exhibit 1-22
U.S. and Canadian Light Rail Transit Systems (1998)[R1,R7,R15]

Location	Operator	Directional Route km (mi)	Average Weekday Boardings	Vehicles Operated in Max. Service
Baltimore	Mass Transit Administration	70.2 (43.6)	31,200	30
Boston	Massachusetts Bay Transp. Auth.	90.0 (55.9)	248,000	141
Buffalo	Niagara Frontier Transportation Auth.	20.0 (12.4)	20,400	23
Calgary	Calgary Transit	57.6 (35.8)	146,000	72*
Cleveland	Greater Cleveland RTA	49.6 (30.8)	14,000	26
Dallas	Dallas Area Rapid Transit	64.4 (40.0)	38,300	26
Denver	Denver Regional Transp. District	17.1 (10.6)	15,700	14
Edmonton	Edmonton Transit	22.4 (13.9)	35,000*	24*
Galveston,TX**	Island Transit	7.9 (4.9)	300	4
Los Angeles	Los Angeles County MTA.	132.6 (82.4)	70,700	48
Memphis**	Memphis Area Transit Authority	6.9 (4.3)	2,600	8
New Orleans	Regional Transit Authority	25.8 (16.0)	17,700	22
Newark	New Jersey Transit Corporation	13.4 (8.3)	16,900*	16
Philadelphia	Southeastern Pa. Transportation Auth.	111.6 (69.3)	74,400	107
Pittsburgh	Port Authority of Allegheny County	61.3 (38.1)	24,900	44
Portland, OR	Tri-Met	106.3 (66.0)	60,900	54
Sacramento	Regional Transit District	58.3 (36.2)	28,400	32
St. Louis	Bi-State Development Agency	54.7 (34.0)	43,600	26
San Diego	San Diego Trolley, Inc.	92.2 (57.3)	77,300	63
San Francisco	S.F. Municipal Railway (Muni)	84.8 (52.7)	123,700	99
San Jose	Santa Clara Valley Transp. Authority	62.8 (39.0)	22,300	31
Seattle**	King County Metro	6.0 (3.7)	800	3
Toronto	Toronto Transit Commission	219.5 (136.4)	228,100	222*

*1995 data.
**The Galveston, Memphis, and Seattle streetcar lines are classified as light rail by the FTA and so are included in this list. None of these cities operates light rail in the modern sense, although a 37-km (23-mi) LRT line is being planned for Seattle.

Light rail passenger volumes.

The operating experience for typical light-rail transit and streetcar lines in the United States and Canada is given in Exhibit 1-23. This table gives typical peak-hour peak-direction passenger volumes, service frequencies, and train lengths for principal U.S. and Canadian light rail transit lines.

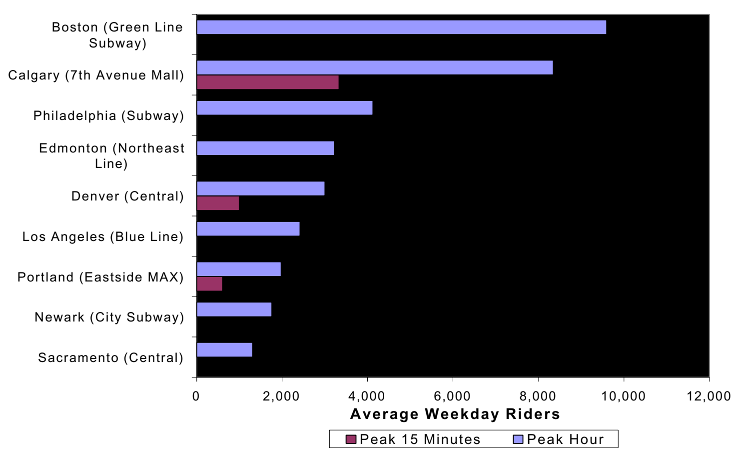
Exhibit 1-23
Observed U.S. and Canadian LRT Passenger Volumes:
Peak Hour at the Peak Point for Selected Lines (1993-96 Data)(R20)

City	Location (may be trunk with several routes)	Trains/h	Cars/h	Avg. Headway (s)	Pass/Peak Hour Direction	Pass/m of Car Length
Calgary	South Line	11	33	320	4,950	6.8
Denver	Central	12	24	300	3,000	4.7
Edmonton	Northeast LRT	12	36	300	3,220	4.0
Los Angeles	Blue Line	9	18	400	2,420	5.4
Boston	Green Line Subway*	45	90	80	9,600	5.3
Newark	City Subway	30	30	120	1,760	4.6
Philadelphia	Norristown	8	8	450	480	3.3
Philadelphia	Subway-Surface*	60	60	60	4,130	5.0
Sacramento	Sacramento LRT	4	12	900	1,310	4.9
Toronto	Queen at Broadway*	51	51	70	4,300	6.1
Portland	Eastside MAX	9	16	400	1,980	5.1

*Trunks with multiple-berth stations.
NOTE: In a single hour a route may have different lengths of trains and/or trains with cars of different lengths or seating configurations. Data represent the average car. In calculating the passengers per meter of car length, the car length is reduced by 9% to allow for space lost to driver cabs, stairwells, and other equipment. Data not available for the heavily used Muni Metro subway in San Francisco.

Exhibit 1-24 provides an indication of the maximum peak passenger volumes carried on a number of light rail systems for which data are available. The exhibit illustrates the peak passenger volumes carried over the busiest segment of the LRT system; in many cases, this represents passengers being carried on more than one route.

Exhibit 1-24
Peak Hour and Peak 15-Minute Directional Flows for Selected U.S. and Canadian Light Rail Transit Trunks (1995)(R15)



NOTE: Data not available for the heavily used Muni Metro subway in San Francisco.

Some streetcar and light rail lines carried substantially higher passenger flows in the peak years of 1946-1960. Post-World War II streetcars operated at as close as 30-second headways both on-street (Pittsburgh) and in tunnels (Philadelphia). Peak-hour passenger flows approximated 9,000 persons per hour. San Francisco's Market Street surface routes carried 4,900 peak-hour one-way passengers per hour before they were placed underground. Now, the observed number of peak-hour passengers at the maximum load point usually reflects demand rather than capacity. Peak 15- to 20-minute volumes expressed as hourly flow rates are about 15 percent higher.

Heavy Rail Transit

Introduction and characteristics.

Heavy rail transit (Exhibit 1-25) is by far the predominant urban rail travel mode in North America, in terms of system size and utilization. Exhibit 1-18 and Exhibit 1-20 illustrate the lead heavy rail transit in the U.S. has over the other rail modes in both annual passenger trips and annual passenger kilometers (miles). Heavy rail transit is characterized by fully grade-separated rights-of-way, high level platforms and high-speed, electric multiple-unit cars.

Exhibit 1-25
Heavy Rail Examples

New York

Atlanta

Miami

Vancouver, BC

The expeditious handling of passengers is enabled through the use of long trains of up to 11 cars running a frequent service. Loading and unloading of passengers at stations is rapid due to level access and multiple double-stream doors.

Power is generally collected from a third rail but can also be received from overhead wires as in Cleveland, the Skokie Swift in Chicago, and a portion of one line in Boston. Third-rail power collection, frequent service, and high operating speeds generally necessitate the use of grade-separated pedestrian and vehicular crossings. A small number of grade crossings are an exceptional feature of the Chicago system.

U.S. and Canadian heavy rail systems generally fall into two groups according to their time of initial construction. Pre-war systems are often characterized by high passenger densities and closely spaced stations, although the postwar systems in Toronto and Montréal also fall into this category. The newer United States systems tend to place a higher value on passenger comfort and operating speed, as expressed by less crowded trains and a more distant spacing of stations, especially in suburban areas. Newer systems also tend to provide extensive suburban park-and-ride facilities.

Status of heavy rail systems.

BART in the San Francisco Bay area is a prime example of the latter category with its fast trains and provision of upholstered seats. BART station spacing outside downtown San Francisco and Oakland is great enough to allow the high overall speed required to compete with the automobile. Vancouver's SkyTrain can be included in the heavy rail category rather than the light rail or automated guideway categories since it most closely resembles heavy rail transit system in operating practices and right-of-way characteristics.

The high costs of constructing fully grade-separated rights-of-way (subway or elevated) for heavy rail transit have limited expansion in recent decades. Exhibit 1-26 identifies the 17 existing heavy rail transit systems in the U.S. and Canada; Mexico City's Sistema de Transporte Colectiva has the greatest ridership in North America.

Exhibit 1-26
U.S. and Canadian Heavy Rail Transit Systems (1998)[R1,R7,R15]

Information on specific heavy rail routes may be found in Appendix A.

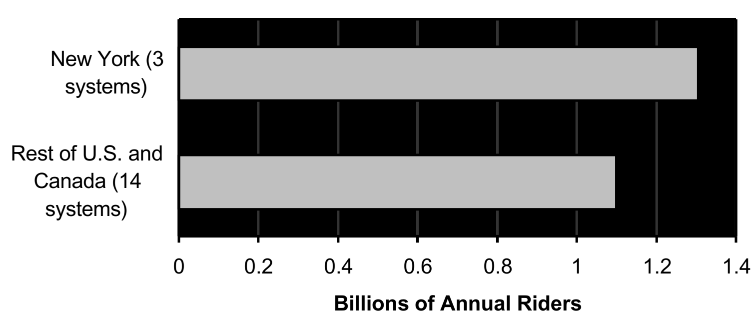
Location	Operator	Directional Route km (mi)	Average Weekday Boardings	Vehicles Operated in Max. Service
Atlanta	Metro. Atlanta Rapid Transit Auth.	148.4 (92.2)	248,700	165*
Baltimore	Mass Transit Administration	47.3 (29.4)	46,400	54
Boston	Massachusetts Bay Transp. Auth.	122.0 (75.8)	405,400	332
Camden, NJ	Port Authority Transit Corporation	50.7 (31.5)	38,300	96
Chicago	Chicago Transit Authority	334.4 (207.8)	447,500	865
Cleveland	Greater Cleveland RTA	61.5 (38.2)	18,900	35
Los Angeles	Los Angeles County MTA	9.7 (6.0)	34,400	16
Miami	Metro-Dade Transit Agency	67.9 (42.2)	44,800	80
Montréal	Société de transport de la Communauté urbaine de Montréal	122.3 (76.0)	700,000*	555*
New York	MTA-New York City Transit	793.2 (492.9)	5,602,500	4,852
New York	MTA-Staten Island Railway	46.0 (28.6)	17,600	36
Newark	Port Authority Trans-Hudson Corp.	46.0 (28.6)	235,500	282
Philadelphia	Southeastern Pa. Transp. Authority	122.5 (76.1)	315,300	277
San Francisco	Bay Area Rapid Transit	299.3 (186.0)	280,300	453*
Toronto	Toronto Transit Commission	128.2 (79.7)	780,800	510*
Vancouver	BC Transit	56.0 (34.8)	132,300	114*
Washington	Washington Metro. Area Transit Auth.	286.8 (178.2)	732,300	586

*1995 data.

Of the 17 heavy rail transit systems operating in the U.S. and Canada, the three New York City area systems carry two-thirds of all riders using this mode. Exhibit 1-27 shows the dominance of the New York metro area relative to the rest of the U.S. and Canada. Heavy rail transit's efficiency in moving large volumes of passengers in densely populated areas is evident in this, the largest metropolitan area in the U.S. Heavy rail transit plays a key role in enabling such dense urban areas to exist. In 1995, 51.9% of business day travel into Lower Manhattan was by heavy rail transit. During the 7-10 a.m. time period, this share increased to 62.2%.[R14]

Exhibit 1-27
Concentration of Heavy Rail Transit Ridership (1995)[R7]

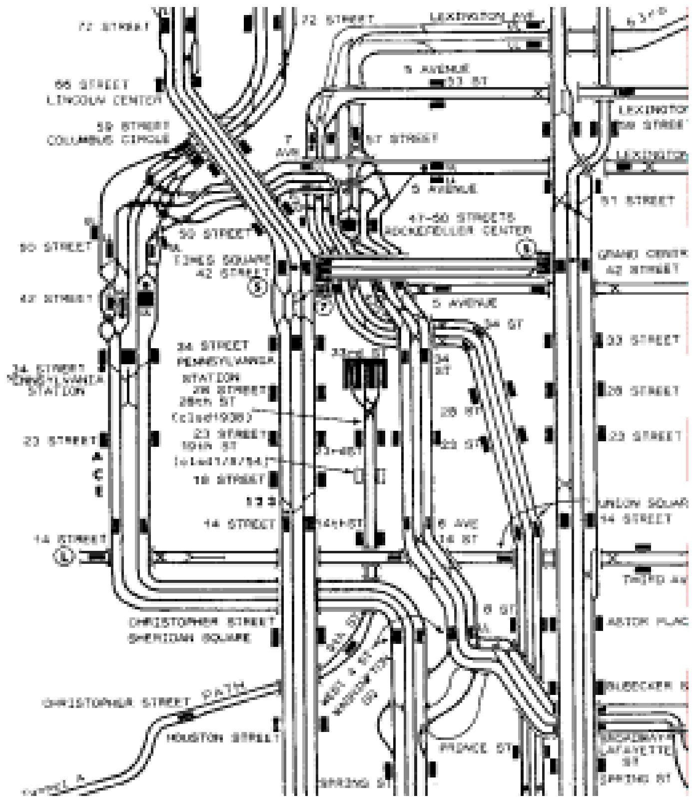
Ridership.



Complexity of the New York subway.

The New York City subway system is one of the largest and most complex in the world. This extensive subway system carries almost twice as many riders as does the local bus system. Most lines are triple or quadruple tracked to allow the operation of express services. A large number of junctions permit trains to be operated on a variety of combinations of line segments to provide an extensive network of service. Exhibit 1-28 shows a diagram of the subway tracks in midtown Manhattan.

Exhibit 1-28
MTA-NYCT Subway Tracks in Midtown Manhattan

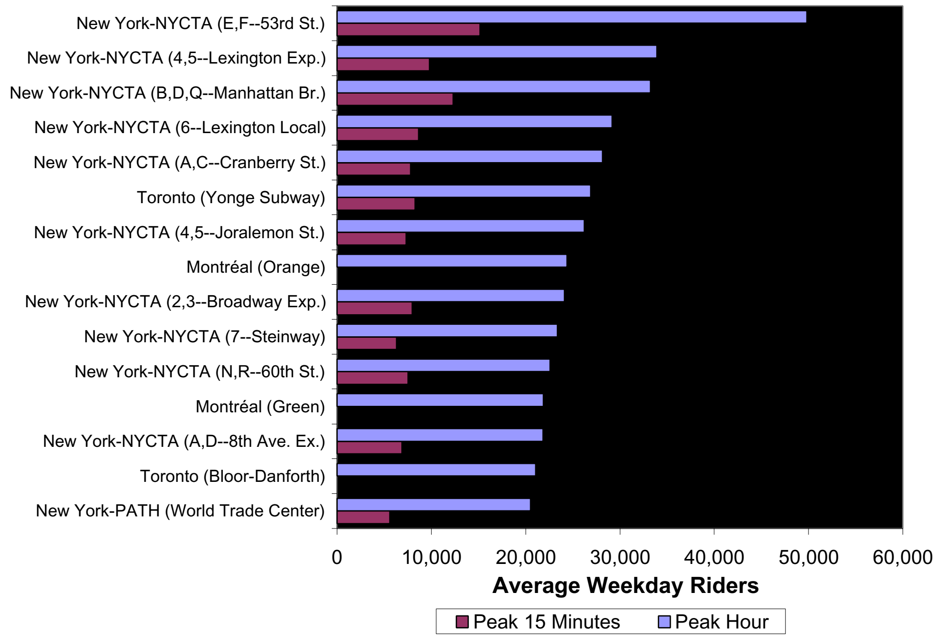


SOURCE: From *New York Railway Map*, courtesy John Yonge, © 1993 Quail Map Company, 31 Lincoln Road, Exeter, England

Exhibit 1-29 illustrates the peak hour and peak 15-minute passenger flow rates for the 15 busiest heavy rail transit trunk lines in the U.S. and Canada. The graph uses trunks rather than routes in order to group those services sharing tracks together. All the trunks listed are double tracked and have at least one station used by all routes.

When four-track lines in New York are taken into consideration the maximum load is a combination of the Lexington Avenue Express and Local at 63,200 passengers per peak hour direction with almost comparable volumes on the combined Queens Boulevard lines at Queens Plaza. In comparison, the busiest two-track heavy rail line in the world is in Hong Kong, with 84,000 passengers per peak hour direction.

Exhibit 1-29
Peak Hour and Peak 15-minute Flows for the Busiest 15
U.S. and Canadian Heavy Rail Transit Trunk Lines (1995)(R15)



NOTE: Data could not be obtained for Philadelphia's SEPTA. However, it is unlikely that either of the SEPTA rapid transit lines would feature in this chart if data were available. Peak 15-minute flow data were not available for all lines for which peak hour data were available.

Commuter Rail

Introduction.

Commuter rail (Exhibit 1-30) is generally a long distance transit mode using trackage that is a part of the general railroad system but which may be used exclusively for passenger movement. Track may be owned by the transit system or access may be by agreement with a freight railroad. Similarly, train operation may be by the transit agency, the track owner, or a third-party contractor.

Exhibit 1-30
Commuter Rail Examples

Toronto San Diego

Service is heavily oriented towards the peak commuting hours, particularly on the smaller systems. All-day service is operated on many of the mainlines of the larger commuter rail systems and the term *regional rail* is more appropriate in these cases.

Commuter rail scheduling.

Commuter rail scheduling is often tailored to the peak travel demand rather than operating a consistent service throughout the peak period. Where track arrangements and signaling permit, operations can be complex with the use of local trains, limited stop express trains and zoned express trains. Zoned express trains are commonly used on busy lines with many stations where express trains serve a group of stations then run non-stop to the major destination station(s).

Commuter Rail Propulsion and Equipment

Diesel and electric power are both used for traction on commuter rail lines. Electric traction is capital intensive but permits faster acceleration while reducing noise and air pollution. It is used mainly on busy routes, particularly where stops are spaced closely together or where long tunnels are encountered. Both power sources can be used for locomotive or multiple-unit operation. All cars in a multiple-unit train can be powered or some can be unpowered "trailer" cars which must be operated in combination with powered cars. Electric multiple-unit cars are used extensively in the New York, Philadelphia, and Chicago regions with the entire SEPTA regional rail system in Philadelphia being electrified. Dallas is currently the only city operating diesel multiple-unit cars in commuter rail service.

Locomotive-hauled commuter trains are standard for diesel operation and are becoming more common on electrified lines as a way to avoid the high costs of multiple-unit cars. New Jersey Transit and SEPTA have both purchased electric locomotives as an economical alternative to buying multiple-unit cars. Other systems value the flexibility of multiple-unit cars in varying train length. The STCUM commuter rail system in Montréal has replaced a mixed fleet with a standard new electric multiple-unit design.

Commuter rail train length can be tailored to demand with cars added and removed as ridership dictates. This is particularly easy with multiple-unit equipment and can result in trains of anywhere from two to twelve cars in length. Where train length is constant all day, unneeded cars can be closed to passengers to reduce staffing needs and the risk of equipment damage.

Passenger comfort and car design.

Commuter rail is unique among the transit modes in that a high priority is placed on passenger comfort as journeys are often long and the main source of competition is the automobile. All lines operate with a goal of a seat for every passenger except for the busy inner portions of routes where many lines funnel together and a frequent service is provided. Such is the case for the 20-minute journey on the Long Island Rail Road between Jamaica and Penn Stations. Service between these points is very frequent (trains on this four-track corridor operate as close as one minute apart in the peak hours) as trains from multiple branches converge at Jamaica to continue to Manhattan.

Commuter rail cars are generally designed with the maximum number of seats possible, although this tradition is changing somewhat where persons in wheelchairs and bicycles are accommodated. A number of common approaches are taken to achieve maximum seating over the car length. The simplest is the use of "2+3" seating where five seats are placed in each row as opposed to the usual four. This can be done quite easily in wide railroad-type cars and brings the number of seats per car to around 120. It is not especially popular with passengers. "2+3" seating is used by many operators including the Long Island Rail Road and the MBTA in Boston, but it places a constraint on aisle width that may make the provision of wheelchair access difficult.

The other main approach to increasing car capacity is to add additional seating levels to the car, subject to any height restrictions, such as tunnels and underpasses, on the rail lines. The gallery type car is one example and adds an upper seating level to the car with an open well to the lower level. The well serves to permit ticket collection and inspection from the lower level but does limit the upper level to single seats on each side. Gallery cars can typically seat 150-160 passengers and are used most extensively by Chicago's

Metra commuter rail system. A more recent development is the bi-level car[2] which has upper and lower levels over the center of the car with an intermediate level at each end of the vehicle. Toronto's GO Transit popularized this design with relatively spacious seating for 160. It is now also being used by Metrolink in Los Angeles, the Coaster in San Diego, Tri-Rail in Florida, and the West Coast Express in Vancouver. This style of car has become common on many European commuter rail (suburban) services.

Commuter rail platform height.

Passenger access to commuter rail trains can be from platform or ground level, with the former commonly used on busy lines or at major stations to speed passenger movements. Standard railway type "traps" in the stepwells allow cars to use both types of platform but require the train crew to raise and lower the trap door above the steps. The electric multiple unit cars used by the Northern Indiana Commuter Transportation District on the South Shore line out of Chicago employ an extra set of doors at the center of the cars that are used exclusively at high platform stations while the car end doors are fitted with traps in the conventional manner for use at high and low platform stations. This arrangement is also used on the new electric multiple-unit cars used on Montréal's Mount Royal tunnel line.

Commuter rail status.

Commuter rail services operate in 15 North American metropolitan regions, including the recently opened Coaster service between San Diego and Oceanside, California; and new lines in Dallas, Texas and Vancouver, British Columbia. There has been rapid growth in this mode as a result of the availability of government funding and the relatively low capital costs of the mode. This is offset by higher operating costs per passenger trip — particularly for lower-volume commuter rail services.

Exhibit 1-31
U.S. and Canadian Commuter Rail Systems (1998)[R1,R7,R15]

Location	Operator	Directional Route km (mi)	Average Weekday Boardings	Vehicles Operated in Max. Service
Baltimore	Mass Transit Administration	600.9 (373.4)	19,400	109
Boston	Massachusetts Bay Transp. Auth.	924.2 (574.3)	118,900	308
Chicago	Metropolitan Rail (Metra)	1,511.8 (939.4)	277,600	927
Chicago	Northern Indiana Commuter T.D.	243.0 (151.0)	12,100	53
Dallas	Dallas Area Rapid Transit	32.2 (20.0)	1,900	NA
Los Angeles	Southern Calif. Regional Rail Auth.	1,171.0 (727.6)	26,300	113
Miami	Tri-Rail	213.7 (132.8)	8,300	25
Montréal	Agence Métropolitaine de Transp.	188.0 (116.8)	NA	NA
New Haven,CT	Connecticut DOT	162.9 (101.2)	1,100	12
New Jersey	New Jersey Transit	1,919.6 (1,192.8)	191,300	706
New York	MTA-Long Island Rail Road	1,027.1 (638.2)	343,300	981
New York	MTA-Metro North Railroad	861.6 (535.4)	233,000	725
Philadelphia	Pennsylvania DOT	231.7 (144.0)	700	9
Philadelphia	Southeastern Pa. Transp. Authority	712.6 (442.8)	93,200	279
San Diego	North County T.D. (Coaster)	132.2 (82.2)	3,900	20
San Francisco	Peninsula Corridor JPB (CalTrain)	247.1 (153.6)	26,900	82
San Jose	Altamont Commuter Express JPA	276.9 (172.0)	NA	NA
Toronto	GO Transit	426.1 (264.8)	103,800	259*
Vancouver	West Coast Express	134.3 (83.5)	7,100	NA
Washington	Virginia Railway Express	281.6 (175.0)	6,900	46

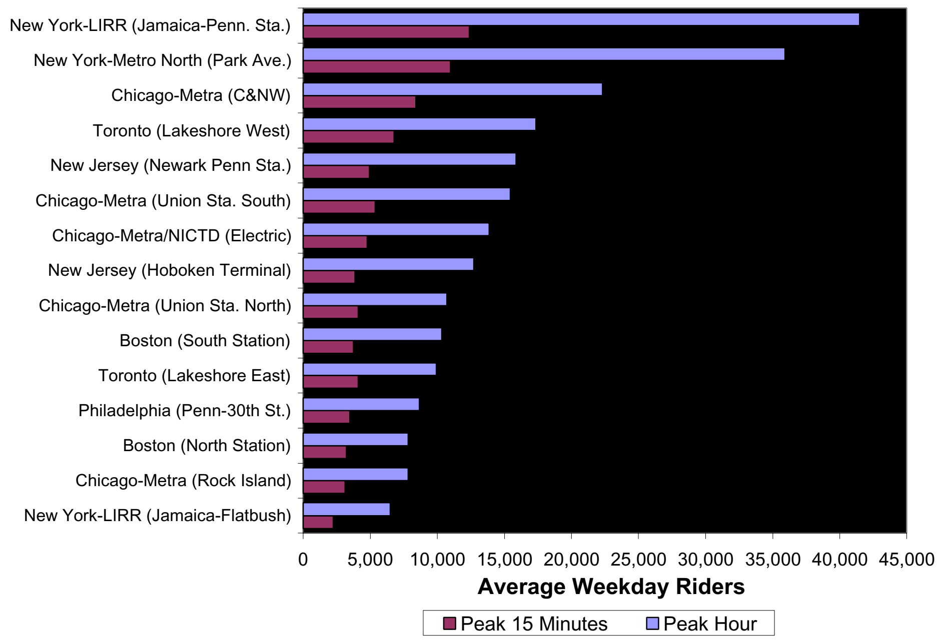
*1995 data.
NA: not available

2 Less commonly known as tri-level cars as there are technically three floor levels.

Extensions and expansions are planned on other systems to enlarge the service area and provide additional parking for patrons. With many commuter rail lines serving low-density suburban areas, the provision of adequate customer parking is a key to maximizing ridership. To meet this need, "cornfield" stations are built to allow parking capacity to be expanded at low cost in relatively undeveloped areas.

Commuter rail ridership is highly concentrated— the New York and Chicago metropolitan systems are the four busiest on the continent, as shown in Exhibit 1-31. GO Transit in Toronto, one of the first of the new generation of commuter rail systems, ranks fifth. Boston's MBTA has had ridership double over the last decade thanks to extensive new service and capital investment. Exhibit 1-32 illustrates the peak hour and peak 15-minute flows handled on the busier commuter rail lines in North America.

Exhibit 1-32
Peak Hour and Peak 15-minute Flows for the Busiest 15 U.S. and Canadian Commuter Rail Trunk Lines (1995)(R15)



Automated Guideway Transit

Introduction to AGT.

Automated guideway transit (Exhibit 1-33) is the newest of the rail transit modes and has played a relatively minor role in North American transit. As the name indicates, the operation of these systems is completely automated (vehicles without drivers), with personnel limited to a supervisory role. Inherent in the definition of this mode is the need for guideways to be fully separated from other traffic. Cars are generally small and service is frequent— the name "people mover" is often applied to these systems which can take on the role of horizontal elevators.

AGT status.

Over 40 automated guideway transit systems are operated in the U.S. today. There are no such systems in Canada. These systems operate in four types of environments:

- airports,
- institutions (universities, shopping malls, government buildings),
- leisure and amusement parks (e.g., Disneyland), and
- public transit systems.

Most of these systems are operated by airports or by private entities, especially as amusement park circulation systems.

Exhibit 1-33
Automated Guideway Transit Examples

Newark Airport　　Miami

AGT transit services.

There are four public transit AGT systems operating in the United States. Of these, three operate in regular transit service in the downtown areas of Detroit, Jacksonville, and Miami. The Detroit People Mover line has remained unchanged from opening in 1987 while the Miami MetroMover added two extensions in 1994. Jacksonville opened the first 1.1-km (0.7-mi) section of its Automated Skyway Express in 1989, with new extensions opening from 1997-1999 to serve both sides of the St. Johns River.

A relatively large institutional system is the automated guideway transit system at the West Virginia University campus in Morgantown, WV. This 5-km (3-mile) line features off-line stations which enable close headways, down to 15 seconds, and permit cars to bypass intermediate stations. The cars are small, accommodating only 21 passengers, and are operated singly. On-demand service is possible at off-peak hours.

The SkyTrain in Vancouver, British Columbia, and the Scarborough RT in Toronto, while sharing the same basic technology that is used on the Detroit People Mover, have more in common with heavy rail systems than AGT lines in their service characteristics, ridership patterns, and operating practices and so are included in the heavy rail listings. Exhibit 1-34 lists ridership and other statistics for North American AGT systems used for public transit.

Exhibit 1-34
North American AGT Systems Used For Public Transit (1998)(R1,R7,R15)

Location	Operator	Directional Route km (mi)	Average Weekday Boardings	Vehicles Operated in Max. Service
Detroit	Detroit Transportation Corporation	4.7 (2.9)	9,700*	8
Jacksonville	Jacksonville Transportation Authority	8.0 (5.0)	1,000	10
Miami	Miami-Dade Transit Agency	6.3 (3.9)	12,900	16
Tampa	Hartline	1.4 (0.9)	400	1

*1995 data.

Daily ridership data for other North American AGT systems are shown in Exhibit 1-35. Caution should be exercised with many of these figures as the non-transit systems are not required to provide the reporting accuracy mandated by the FTA. Ridership on many systems is also likely affected by seasonal patterns and less pronounced peaking than occurs on transit systems. Regardless of these qualifications, the total daily ridership on the 38 non-transit systems amounts to over 660,000, compared to about 24,000 on the transit AGT lines.

Exhibit 1-35
Daily Ridership for North American Non-Transit AGT Systems (1995)

Category	Location	Avg. Daily Ridership
Airport	Atlanta, GA	109,000
Airport	Chicago-O'Hare, IL	12,000
Airport	Cincinnati, OH	30,000
Airport	Dallas-Fort Worth, TX	50,000
Airport	Denver, CO	50,000
Airport	Houston, TX	8,500
Airport	Las Vegas, NV	15,000
Airport	Miami, FL	15,000
Airport	Orlando, FL	49,000
Airport	Pittsburgh, PA	50,000
Airport	Seattle-Tacoma, WA	43,000
Airport	Tampa, FL	71,000
Airport	Tampa-parking, FL	8,000
Institutional	Duke Univ. Hospital, NC	2,000
Institutional	J. Paul Getty Ctr., Los Angeles, CA	NA
Institutional	Los Colinas, Dallas, TX	NA
Institutional	Pearlridge Mall, HI	4,000
Institutional	Senate Subway, DC	10,000
Institutional	University of West Va., Morgantown	16,000
Leisure	Bronx Zoo, NY	2,000
Leisure	Busch Garden, VA	6,000
Leisure	CalExpo, CA	4,000
Leisure	Carowinds, NC	7,000
Leisure	Circus-Circus, Las Vegas, NV	11,000
Leisure	Circus-Circus, Reno, NV	6,000
Leisure	Circus-Water Park, Las Vegas, NV	2,000
Leisure	Disneyland, CA	15,000
Leisure	Disneyworld, FL	20,000
Leisure	Hersheypark, PA	8,000
Leisure	Kings Dominion, VA	5,000
Leisure	Kings Island, OH	7,000
Leisure	Lux-Excal, Las Vegas, NV	10,000
Leisure	Magic Mountain, CA	8,000
Leisure	Memphis/Mudd Is., TN	2,000
Leisure	Miami Zoo, FL	1,200
Leisure	Minnesota Zoo, MN	1,000
Leisure	Mirage, Treasure Is., Las Vegas, NV	8,000
Leisure	Toronto Zoo, ON	2,000
All	Total	667,700

SOURCE: Transit Pulse, P.O. Box 249, Fields Corner Station, Boston, MA 02122

Other Rail

Cable Car

Cable cars are now only found in San Francisco, but were once used briefly throughout the United States.

Cable cars (Exhibit 1-36) are operated only in San Francisco, where the first line opened in 1873. Although now associated with San Francisco's steep hills, more than two dozen other U.S. cities, including relatively flat cities such as Chicago and New York, briefly employed this transit mode as a faster, more economical alternative to the horse-drawn streetcar. Most cable lines were converted to electric streetcar lines in the 1890s due to lower operating costs and greater reliability, but lines in San Francisco, Seattle, and Tacoma that were too steep for streetcars continued well into the 20th century.(R10)

Three cable car routes remain in San Francisco as a National Historic Landmark and carry 9.6 million riders a year. The cars are pulled along by endless underground cables that move at a constant speed of 15 km/h (9 mph). A grip on the car allows the cable to be picked up through a slot between the tracks and released as required for passenger stops, curves, avoiding other cables that cross the line, and so on. Cable car systems are not very efficient, as 55-75% of the energy used is lost to friction.

Exhibit 1-36
Cable Car (San Francisco)

Inclined Plane

Many inclined planes are also known as funicular railways.

Inclined planes, often referred to as funicular railways, with grades as steep as 70% or more have played a role in many transit systems, moving not just people but cars, trucks, and streetcars up steep hillsides (Exhibit 1-37). In the past, inclined planes were also used to transport railroad cars and canal boats. An example of a remaining vehicle-carrying incline plane that is part of a transit system is in Johnstown, Pennsylvania. Nearby in Pittsburgh, the transit agency owns the two remaining inclined planes from a total of more than 15 that once graced the hilly locale.

Inclined plane status.

The number of remaining inclined planes in North America is small, but they are used extensively in other parts of the world to carry people up and down hillsides in both urban and rural environments. Switzerland alone has over 50 funiculars, including urban funiculars in Zürich and Lausanne. Many other cities worldwide have funiculars, including Budapest, Haifa, Heidelberg, Hong Kong, Paris, and Prague. Many of these systems are less than 30 years old or have been completely rebuilt in recent years. In addition, inclined planes are still being built for access to industrial plants, particularly dams and hydroelectric power plants, and occasionally, ski resorts. New ones, primarily in Europe, also provide subway or metro station access. New designs rarely handle vehicles and make use of hauling equipment and controls derived from elevators.

The person capacity of older inclined planes is modest, but modern designs can carry large numbers of people.

Capacity is a function of length, number of intermediate stations (if any), number of cars (one or two), and speed. Person capacity is usually modest— on the order of a few hundred passengers per hour. However high-speed, large-capacity inclined planes are in use and a new facility, designed for metro station access in Istanbul, Turkey has a planned capacity of 10,000 passengers per peak hour direction.

Most typical design involves two cars counterbalancing each other, using either a single railway-type track with a passing siding in the middle, or double tracks. Single-track inclined planes have just one car and often do not use railway track— see, for example, the Ketchikan inclined plane in Exhibit 1-37. When passing sidings are used, the cars are equipped with steel wheels with double flanges on one set of outer wheels per car, forcing the car to always take one side of the passing siding without need for switch movement. Earlier designs used a second emergency cable, but this is now replaced by automatic brakes, derived from elevator technology, that grasp the running rails when any excess speed is detected. Passenger compartments can either be level, with one end supported by a truss, or they can be sloped, with passenger seating areas arranged in tiers.

Various combinations of track and car styles are illustrated in Exhibit 1-37. Ridership and other data for known U.S. and Canadian inclined planes are given in Exhibit 1-38.

Exhibit 1-37
Inclined Plane Examples

Single Track (Ketchikan, AK)

Single Track, Passing Siding (Switzerland)

Single Track, Intermediate Station (Prague)

Double Track (Johnstown, PA)

Exhibit 1-38
U.S. and Canadian Inclined Planes (1998)(R1,R7)

Location	Operator	Average Weekday Boardings	Track Type	Maximum Grade (%)
PUBLIC TRANSIT				
Chattanooga, TN	Chattanooga Area RTA	1,100	ST/DT	73
Johnstown, PA	Cambria County Transit Authority	400	DT	72
Pittsburgh, PA	Soc. Pres. Duquesne Hts. Incline	1,200	DT	50
Pittsburgh, PA	Port Authority (Monongahela Incline)	2,400	DT	58
OTHER INCLINED PLANES				
Altoona, PA	Horseshoe Curve Nat'l. Hist. Ldmk.	NA	SP	37
Cañon City, CO	Royal Gorge Incline Railway	NA	NA	NA
Capitola, CA	Shadowbrook Restaurant	NA	ST	57
Diablo, WA	Seattle City Light	NA	TR	56
Dubuque, IA	Fenelon Place Elevator	NA	DP	64
Industry, CA	Industry Hills Resort	NA	SP	NA
Ketchikan, AK	Cape Fox Lodge	NA	ST	NA
Los Angeles, CA	Angels Flight Railway Foundation	NA	DP	33
Montréal, QC	Funiculaire de la Tour de Montréal	NA	ST	100
Niagara Falls, ON	Niagara Parks Commission	NA	DT	73
Québec, QC	Funiculaire du Vieux-Québec	NA	DT	100

Additional sources: Funimag by Michael Azéma, private operator data.
NA: not available, ST: single track, SP: single track with passing siding, DT: double track, DP: double track with passing siding, TR: two pairs of tracks, with transverse car. A 100% grade is a 45° slope.

Monorail

Although often thought of as being relatively modern technology, monorails have existed for nearly 100 years. Vehicles either straddle or are suspended from a single rail. Driverless monorails fall into the category of automated guideway transit, but those used as parts of public transit systems often have drivers and thus form their own category. Exhibit 1-39 illustrates two different kinds of monorails, while Exhibit 1-40 presents ridership and other data for the two U.S. monorails that are part of public transportation systems.

When operated by a driver, monorails are not AGT, but their own category.

Exhibit 1-39
Monorail Examples

Straddle (Seattle) | Suspended (Wuppertal, Germany)

Exhibit 1-40
U.S. Public Transit Monorails (1996)[R1,R7]

Location	Operator	Directional Route km (mi)	Average Weekday Boardings	Vehicles Operated in Max. Service
Las Vegas	RTC of Clark County	2.4 (1.5)	NA	NA
Seattle	City of Seattle	2.9 (1.8)	8,700	8

NA: not available

Aerial Tramway

Aerial tramways (Exhibit 1-41) suspend the car from one aerial cable and pull the car by a separate cable attached to the vehicle suspension system. Aerial tramways are typically associated with ski resorts, but are also used to carry passengers across obstacles such as rivers or narrow canyons, and as aerial rides over zoos and amusement parks. The lone aerial tramway in the United States used for public transit is in New York City, running from Manhattan to Roosevelt Island. The calculation of the vehicle capacity of aerial tramways is beyond the scope of this manual (depending greatly on the technology chosen). However, once the vehicle capacity has been determined for a particular application, the person capacity procedures presented in this manual are applicable.

Exhibit 1-41
Aerial Tramway and Public Elevator Examples

Aerial Tramway (New York)

Public Elevator (Oregon City, OR)

Public Elevators

Public elevators (Exhibit 1-41) are occasionally used to provide for pedestrian movement up and down steep hillsides where insufficient pedestrian volumes exist to justify other modes. These elevators allow pedestrians to bypass stairs or long, out-of-direction routes to the top or bottom of the hill.

FERRY SERVICES

Ferry services are important parts of the transit systems of a number of coastal communities in North America.

While not covered further in this manual, ferry services (Exhibit 1-42) play a role in the transit systems of a number of North American cities, and provide vehicle, bicycle, and pedestrian access across waterways where transportation connections are desirable, but conditions do not justify a bridge. The Alaska Marine Highway System provides the sole means of access (other than by air) to a number of communities in southeastern and southwestern Alaska, including the state capital, Juneau.

Some automobile ferries also carry public transit buses.

The Washington State Ferry system carries public transit buses in addition to private cars, bicycles, and walk-on passengers. The New York City, Alaska Marine Highway, and British Columbia (BC Ferries) systems are other major systems that carry private motor vehicles as well as passengers. The SeaBus ferry in Vancouver operates high-speed boats between North Vancouver and downtown Vancouver and connects to the SkyTrain, commuter rail, and bus systems. Several ferry routes on San Francisco Bay that had not operated since the opening of the Bay Bridge in the 1930s were reinstated following the 1989 earthquake that closed the Bay Bridge for a month. Two of these once-temporary routes are still in service. Major ferry systems in the U.S. and Canada that are part of public transportation systems are shown in Exhibit 1-43.

Exhibit 1-42
Ferry Service Examples

New York

Rural ferry (Wheatland, OR)

San Francisco

Seattle

Exhibit 1-43
U.S. and Canadian Public Transit Ferry Systems (1998)(R1,R7)

Location	Operator	Directional Route km (mi)	Average Weekday Boardings	Ferries Operated in Max. Service
Boston	Massachusetts Bay Transp. Auth.	35.4 (22.0)	4,000	7
Bremerton, WA	Kitsap Transit	5.6 (3.5)	1,000	3
Halifax, NS	Metro Transit	NA	4,800*	3
Hartford, CT	Connecticut DOT	1.4 (0.9)	600*	2
New Orleans	Crescent City	4.8 (3.0)	9,700*	5
New York	New York City DOT	16.7 (10.4)	58,200*	4
New York	Port Authority of NY & NJ	5.5 (3.4)	9,500	4
Norfolk, VA	Tidewater Transit Dist. Commission	1.6 (1.0)	2,000	2
Portland, ME	Casco Bay Island Transit District	32.2 (20.0)	2,300*	4
San Francisco	Alameda-Oakland Ferry Service	44.4 (27.6)	1,400*	3
San Francisco	Golden Gate Bridge District	62.3 (38.7)	4,900	4
San Francisco	Vallejo Transit	128.1 (79.6)	600*	1
San Juan, PR	Puerto Rico Ports Authority	16.1 (10.0)	2,900*	4
Seattle	Washington State DOT	395.6 (245.8)	36,700*	24*
Tacoma, WA	Pierce County Ferry Operations	17.9 (11.1)	400*	1
Vancouver, BC	BC Transit	NA	16,600	2

*1996 data.

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2. TRANSIT CAPACITY AND QUALITY OF SERVICE CONCEPTS

INTRODUCTION

Capacity basics.

Transit capacity is different than highway capacity: it deals with the movement of *both* people and vehicles; depends on the size of the transit vehicles and how often they operate; and reflects the interaction between passenger traffic concentrations and vehicle flow. It depends on the operating policy of the transit agency, which normally specifies service frequencies and allowable passenger loadings. Accordingly the traditional concepts applied to highway capacity must be adapted and broadened.

Quality of service measures contrasted with other transit performance measures.

While transit capacity issues are mainly concentrated in larger cities, transit quality of service— the overall measured or perceived performance of transit service from the passenger's point of view— is important to all communities. Transit quality of service measures reflect two important aspects of transit service: (1) the degree to which transit service is *available* to given locations, and (2) the comfort and convenience, or *quality,* of the service provided to passengers. Quality of service measures differ from both traditional highway service quality measures, which are more vehicle-oriented than person-oriented, and from the numerous utilization and economic performance measures routinely collected by the transit industry, which tend to reflect the transit operator's point-of-view.

CAPACITY

Person Capacity

Maximum number of people past a point.

At the simplest level, transit capacity is determined by the product of transit vehicle capacity and the maximum frequency with which transit vehicles can pass a given location. The person capacity or passenger-carrying capability for any given transit route can be defined as "the maximum number *of people* that can be carried past a given location during a given time period under specified operating conditions without unreasonable delay, hazard, or restriction, and with reasonable certainty." More specifically, person capacity depends on the mix of vehicles in the traffic stream, including the number and occupancy of each type of vehicle that can reasonably be expected to pass a point on a transit route. It is a function of vehicle size, type, occupancy, and headway. The number of transit vehicles along a route reflects the degree of scheduled service.

Transit Line Capacity

The passenger capacity of a transit line is the product of the number of vehicles per hour (usually past the busiest stop) and the number of passengers that each vehicle can carry. Four basic factors determine the maximum passenger capacity:

1. the maximum number of vehicles per transit unit (bus, car, train);
2. the passenger capacity of the individual transit vehicles;
3. the minimum possible headway or time spacing between individual vehicles or trains; and,
4. the number of lanes or passenger loading positions available.

The factors which influence transit capacity are given in Exhibit 1-44. Some of these factors affect the number of passengers per unit, while others affect the number of units that can pass a given location within a specified time period.

Exhibit 1-44
Factors That Influence Transit Capacity(R5)

1.	*Vehicle Characteristics* • Allowable number of vehicles per transit unit (i.e., single unit bus, or several units-cars per train) • Vehicle dimensions • Seating configuration and capacity • Number, location, width of doors • Number and height of steps • Maximum speed • Acceleration and deceleration rates • Type of door actuation control
2.	*Right-of-Way Characteristics* • Cross-section design (i.e., number of lanes or tracks) • Degree of separation from other traffic • Intersection design (at- grade or grade-separated, type of traffic controls) • Horizontal and vertical alignment
3.	*Stop Characteristics* • Spacing (frequency) and duration • Design (on-line or off-line) • Platform height (high level or low level loading) • Number and length of loading positions • Method of fare collection (prepayment, pay when entering vehicle; pay when leaving vehicle) • Type of fare (single-coin, penny, exact) • Common or separate areas for passenger boarding and alighting • Passenger accessibility to stops
4.	*Operating Characteristics* • Intercity versus suburban operations at terminals • Layover and schedule adjustment practices • Time losses to obtain clock headways or provide driver relief • Regularity of arrivals at a given stop
5.	*Passenger Traffic Characteristics* • Passenger concentrations and distribution at major stops • Peaking of ridership (i.e., peak-hour factor)
6.	*Street Traffic Characteristics* • Volume and nature of other traffic (in shared right-of-way) • Cross traffic at intersections if at-grade
7.	*Method of Headway Control* • Automatic or by driver/trainman • Policy spacing between vehicles

The capacity of a transit line varies along the route. Limitations may occur (a) between stops (i.e., way capacity), (b) at stops or stations (i.e., station capacity), (c) at major intersections with cross traffic, or (d) at terminals (station capacity).

Transit line capacity is generally governed by the critical stops where major passenger boarding or alighting takes place, or where vehicles terminate or turn around. This is similar to estimating arterial street capacity based on critical intersections along a route. Sometimes, however, outlying rail transit terminals limit system capacity due to heavy passenger boardings, and track configurations or operating practices that limit train turnarounds.

In many cases the design capacity of a transit route will not be achieved in actual operation. Frequently this is a result of resource limitations which mean that not enough transit vehicles are available to provide the maximum possible design capacity. In many cases there simply might not be sufficient passenger demand to justify operation at the design capacity. The net result either way is that the service frequency operated is below that which is theoretically possible.

The following considerations are important:

1. The *maximum* rate of passenger flow is usually constrained by such factors as acceptable levels of passenger comfort, the presence of other traffic sharing the same right-of-way, and safety considerations. Therefore, transit operators generally are more concerned with the realistic rates of flow that can be achieved by different modes, rather than with physical capacity in the theoretical sense.
2. Operations at "capacity" tend to strain transit systems, and do not represent desirable operating conditions. Moreover, most North American transit systems operate at capacity for a relatively short period of time, if at all.
3. Capacity relates closely to system performance and service quality in terms of speed, comfort, and service reliability. A single fixed number often can be misleading. The concept of "productive capacity," the product of passenger flow and speed, provides an important index of system efficiency.(R20)
4. Capacities obtained by analytical methods must be cross-checked against actual operating experience for reasonableness.

Loading Diversity

Passenger demand is uneven, spread out over both time and space.

The temporal and spatial distribution of transit passengers often prevents transit capacity from being fully utilized for the duration of the peak period. In the temporal sense, peaks within the peak period occur at major work start and finish times and can result in brief periods of operation at capacity followed by under capacity operation. Short-term fluctuations in ridership demand must be considered to avoid unacceptable passenger queuing or overcrowding. Variations in arrival patterns and dwell times at stops will tend to reduce capacity. Temporal diversity can be accommodated in capacity calculations through the use of a peak hour factor, as will be described later.

Spatial diversity can be manifested in a number of ways, from boarding and alighting locations at the macro scale to the distribution of passengers within the vehicle at the micro scale. A transit line with a relatively uniform distribution of boarding passengers among stops will usually have a higher capacity than one where passenger boarding is concentrated at a single stop. Loading is often uneven between cars in a single train or between buses operating together on a single route.

Economic Constraints

Transit operators' economic realities can constrain capacity to a level below that suggested by passenger demand.

Economic factors often constrain capacity at a level below what is technically feasible and suggested by passenger demand. Typically, this takes the form of a shortage of vehicles to supply service on a given route, resulting in passengers being left behind and crowding conditions which deter would-be riders. A survey of rail transit systems(R15) found that the passing up of waiting passengers was relatively rare except on some subway lines in New York City and Toronto, and occasionally on the SkyTrain in Vancouver. However, in the New York and Toronto cases trains were being operated at close to the minimum headway so the constraint was not so much economic, barring the construction of new subway lines or extending platforms, but technical. In the Vancouver case, passengers would voluntarily wait for a less crowded train, indicating that crowding conditions were at least partially avoidable. Systems in other cities, such as Portland, Oregon, indicated that their available capacity was constrained by a shortage of cars and that this capacity shortfall was discouraging new ridership on the light rail line.

Agency Policies

Transit agency policies can influence capacity levels by dictating policy headways and vehicle loading standards. Policies are often set to ensure that scheduled service operates below capacity in order to provide a higher degree of passenger comfort. This can be manifested in the form of more frequent service or the use of larger vehicles than would be the case with lighter loading standards. Such policies can be the result of safety decisions, such as the banning of standees on buses operating on freeways, or a desire to ensure that the transit system remains attractive to new riders. The latter justification is especially important where transit is unable to provide a large travel time saving to the commuter and so must compete more directly with the automobile in comfort.

QUALITY OF SERVICE

Quality of service reflects the kinds of decisions a potential passenger makes, consciously or not, when deciding to whether to use transit or another mode, usually the private automobile. There are two parts to this decision process: (1) assessing whether transit is even an option for the trip, and if so, (2) comparing the comfort and convenience of transit to competing modes.

Transit Availability

Unlike the automobile mode, which has near-universal access to locations, and (for those who own an automobile) provides the ability to be used for trips at any desired time, transit service is limited to specific areas and specific times. Further, transit service is usually not available to one's door, so a potential transit passenger must find a way to get to a location served by transit. As a result, the availability of transit service is a critical issue in one's decision to use transit.

There are a number of conditions that affect transit availability, all of which need to be met for transit to be an option for a particular trip:

- *Transit must be provided near one's trip origin.* If demand-responsive service is not provided to one's door, a transit stop must be located within walking distance and the pedestrian environment in the area should not discourage walking (e.g., due to lack of sidewalks, steep grades, or wide or busy streets). Alternatively, one may be able to ride a bicycle to a transit stop if bicycle storage facilities are available at the stop or if bicycles can be carried on transit vehicles. One may also be able to drive to a park-and-ride facility if one is provided along the way and space is available in the parking lot.
- *Transit must be provided near one's destination.* The same kinds of factors discussed for the trip origin apply to the trip destination as well, except that bicycles or automobiles left behind at the boarding transit stop will not be available to passengers at their destination.
- *Transit must be provided at or near the times required.* In most cases, service must be available for both halves of a round trip— from one's origin to one's destination, as well as for the return trip. If passengers perceive a risk of missing the final return trip of the day, or if transit is available for only one of the two halves of passengers' round trip, transit is not likely to be an option for those passengers.
- *Passengers must be able to find information on when and where transit service is provided and how to use transit.* If passengers are unable to find out where to go to board transit, where they need to transfer, etc., transit will again not be an option.
- *Sufficient capacity must be provided.* If a transit vehicle must pass up passengers waiting at a stop, transit service was not available to those waiting passengers at that time.

If all of these conditions are met, transit is an *option* for a particular trip. Whether or not a passenger will decide to use transit will depend on the *quality* of the service relative to competing modes.

Transit Quality

Unlike transit availability, the kinds of questions weighed by potential passengers when assessing the comfort and convenience of transit service are not necessarily all-or-nothing. Each person assesses the factors that enter into transit quality differently, depending on their own needs and situation. A passenger's decision to use transit rather than a competing mode (when transit is an option) will depend on how well transit service quality compares with that of competing modes.

Some of the more important factors that affect transit quality are the following:

- *Passenger loads* on-board transit vehicles. It is more uncomfortable to stand for long periods of time and the time spent standing cannot be used for more productive or relaxing purposes, such as reading.
- The kinds of *passenger amenities* provided at transit stops.
- The *reliability* of transit service. Are passengers assured of getting to their destinations at the promised time, or must they allow extra time for frequent schedule irregularities?
- *Door-to-door travel times,* relative to other modes.
- The out-of-pocket *cost* of using transit, relative to other modes.
- Passengers' perceptions of *safety and security* at transit stops, on-board vehicles, and walking to and from transit stops.
- Whether *transfers* are required to complete a trip.
- The *appearance and comfort* of transit facilities.

Quality of Service Framework

This manual presents six measures of transit quality of service: three measures of the spatial and temporal availability of transit and three measures of passenger comfort and convenience. Depending on the application, these service measures can be used individually to assess transit quality of service for a transit stop, route segment, or system, or they can be combined into a transit "report card" to provide a broader perspective. As not every factor that affects transit quality of service can be accounted for by these six service measures, it is important for planners and analysts not to lose sight of the broader issues that influence transit quality of service by concentrating solely on calculations of level of service.

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APPENDIX A. RAIL ROUTE CHARACTERISTICS

Exhibit 1-45
1995 Light Rail Route Characteristics and Ridership[R15]

System	Route	Length in km (mi)	Stations	Ridership (Avg. weekday)	Peak Hour		
					Pass.	Trains	Cars
Bi-State	MetroLink	30.6 (19.0)	18	27,055			
CTS	201 (NW-South)	19.5 (12.1)	22	68,000	4,950	11	33
CTS	202 (Northeast)	11.8 (7.3)	18	38,000	3,395	11	33
Denv. RTD	101	8.5 (5.3)	14	15,222	3,000		
ETS	101	13.7 (8.5)	10	35,000	3,219		
GCRTA	67AX (Shaker)		18				
GCRTA	67X (Van Aken)		18				
LACMTA	Blue Line	35.4 (22.0)	22	40,640	2,416	9	18
MBTA	B Boston College	10.3 (6.4)	18	32,979			
MBTA	C Cleveland Circ.	9.3 (5.8)	15	12,727			
MBTA	D Riverside	21.7 (13.5)	24	18,421			
MBTA	E Heath St.	6.0 (3.7)	10	13,451			
MBTA	Mattapan	4.1 (2.5)	8	7,104			
Metrorrey	Metrorrey	17.5 (10.9)	17				
MTA	Light Rail	36.4 (22.6)	24	20,500			
NFTA	Metro Rail	10.3 (6.4)	14	28,129			
NJT	7 City Subway	8.1(5.0)	11	16,871	1,769		
PAT	42L Library	13.0 (8.1)	48	6,649			
PAT	42S South Hills	21.0 (13.0)	35	20,134			
RTA - N.O.	12 St. Charles	10.6 (6.6)					
RTA - N.O.	Riverfront	2.6 (1.6)	10				
SCCTA	Light Rail	33.8 (21.0)	33	20,155			
SDT	East	30.0 (18.6)	22	12,989			
SDT	South	26.4 (16.4)	20	30,722			
SDTEO	1 North-South	15.5 (9.6)	19	65,000			
SDTEO	2 East-West	8.5 (5.3)	11				
SEPTA	10 Overbrook	9.5 (5.9)		14,494	528		
SEPTA	11 Darby	10.8 (6.7)		13,864	463		
SEPTA	13 Darby/ Yeadon	11.2 (7.0)		20,962	1,342		
SEPTA	34 Angora	8.0 (5.0)		15,674	1,009		
SEPTA	36 Eastwick	11.4 (7.1)		14,727	788		
SEPTA	100 Norristown	21.7 (13.5)	22	7,212	477	8	
SEPTA	101 Media	13.7 (8.5)	35	5,082	630	10	10
SEPTA	102 Sharon Hill	8.5 (5.3)	27	3,366	321	6	6
SF Muni	J Church	10.8 (6.7)		15,584			
SF Muni	K Ingleside	12.6 (7.8)		27,828			
SF Muni	L Taraval	12.7 (7.9)		28,451			
SF Muni	M Ocean View	14.6 (9.1)		27,864			
SF Muni	N Judah	11.4 (7.1)		31,148			
SRTD	RT	27.0 (16.8)	29	24,382	1,311		
Tri-Met	Eastside MAX	24.1 (15.0)	30	24,900	1,975	9	16
TTC	501 Queen	16.9 (10.5)		59,138	1,224		
TTC	502 Downtowner	9.7 (6.0)		7,737	413		
TTC	503 Kingston Rd.	9.3 (5.8)		2,561	327		
TTC	504 King	12.8 (8.0)		58,756	1,613		
TTC	505 Dundas	10.8 (6.7)		47,955	792		
TTC	506 Carlton	14.9 (9.3)		59,371	1,127		
TTC	507 Long Branch	7.8 (4.8)		7,003	268		
TTC	511 Bathurst	4.7 (2.9)		23,533	979		
TTC	512 St. Clair	7.0 (4.3)		29,200	1,293		
TTC	604 Harbourfront	1.8 (1.1)	6	9,950	520		

NOTES: Bi-State = St. Louis, MO; CTS = Calgary Transit; ETS = Edmonton Transit; GCRTA = Cleveland, OH; LACMTA = Los Angeles; MBTA = Boston; Metrorrey = Monterrey, Mexico; MTA = Baltimore; NFTA = Buffalo; NJT = Newark, NJ; PAT = Pittsburgh; RTA-N.O. = New Orleans; SCCTA = San Jose, CA; SDT = San Diego; SDTEO = Guadalajara, Mexico; SEPTA = Philadelphia; SF Muni = San Francisco; SRTD = Sacramento; Tri-Met = Portland, Oregon; TTC = Toronto.

Most Toronto streetcar lines serve subway stations at their outer ends and run through downtown, giving them effectively four peak points per line. They also serve many short trips and have high off-peak use. This accounts for the exceptionally low ratio of peak hour to daily ridership.

Between the time the table was compiled and this manual was published, Portland, San Diego, and San Francisco opened new light rail extensions. Therefore, data may not always match Exhibit 1-22.

Exhibit 1-46
1995 Heavy Rail Route Characteristics and Ridership(R15)

System	Route	Length in km (mi)	Stations	Ridership (Avg. weekday)	Peak Hour Pass.	Peak Hour Trains	Peak Hour Cars
BART	Concord/Daly City	58.6 (36.4)	19		7,349	8	80
BART	Fremont/Daly City	62.7 (390)	19		4,571	5	50
BART	Fremont/Rich.	58.4 (36.3)	18		2,004	4	24
BART	Richmond/Daly C.	44.8 (27.8)	19		3,713	4	40
BCT	SkyTrain	28.8 (17.9)	20	110,000	6,932	25	100
CTA	Blue	55.1 (34.2)	43	122,800	9,376		
CTA	Brown	18.2 (11.3)	28	32,750	7,051		
CTA	Green	33.9 (21.1)	33	26,800	2,952		
CTA	Orange	19.9 (12.4)	17	14,800	4,287		
CTA	Purple	26.1 (16.2)	22	10,050	3,479		
CTA	Red	34.9 (21.7)	33	182,350	11,533		
CTA	Yellow	8.1 (5.0)	2	5,300			
GCRTA	66X	30.8 (19.1)	18				
LACMTA	Red	7.1 (4.4)	5	15,550			
MARTA	East/West	25.8 (16.0)	16	71,396	2,986	8	60
MARTA	North/South	35.7 (22.2)	18	117,941	5,093	8	58
MBTA	Blue	9.6 (6.0)	12	54,000	6,389		
MBTA	Orange	18.0 (11.2)	19	127,000	7,379		
MBTA	Red	33.0 (20.5)	22	185,000	9,282		
MDTA	Metrorail	33.1 (20.6)	21	46,300	3,698		
MTA	Metro	22.9 (14.2)	12	43,000			
NYCT	1, 9	23.7 (14.7)	38		16,991	16	160
NYCT	2	41.2 (25.6)	49		14,052	12	120
NYCT	3	29.4 (18.3)	34		10,524	10	90
NYCT	4	33.0 (20.5)	27		18,084	15	150
NYCT	5	40.1 (24.9)	40		15,975	13	130
NYCT	6	24.3 (15.1)	38		29,175	22	220
NYCT	7	15.2 (9.4)	21		23,369	21	231
NYCT	A	54.5 (33.9)	61		22,526	15	136
NYCT	B	33.8 (21.0)	46		10,715	8	80
NYCT	C	36.2 (22.5)	47		6,611	9	72
NYCT	D	41.6 (25.8)	42		12,377	10	80
NYCT	E	24.9 (15.5)	20		22,530	12	120
NYCT	F	43.4 (27.0)	49		28,554	17	136
NYCT	Franklin Shuttle	2.2 (1.4)	5				
NYCT	G	23.3 (14.5)	27		4,300	6	36
NYCT	42nd St. Shuttle	0.7 (0.4)	2		5,860		100
NYCT	H	10.7 (6.7)					
NYCT	J, Z	21.4 (13.3)	30		13,791	13	104
NYCT	L	16.3 (10.1)	24		12,621	13	104
NYCT	M	27.5 (17.1)	37		3,710	8	64
NYCT	N	32.6 (20.3)	44		11,030	11	100
NYCT	Q	26.2 (16.3)	20		12,111	9	72
NYCT	R	34.8 (21.6)	43		12,208	12	96
PATCO	PATCO	22.9 (14.2)	13	41,190	7,720		
PATH	Hoboken - 33rd	5.6 (3.5)	6	38,650	6,138	11	77
PATH	Hoboken - WTC	4.8 (3.0)	4	55,200	8,939	13	91
PATH	Journal Sq. - 33rd	9.2 (5.7)	8	36,600	4,763	9	63
PATH	Newark - WTC	14.3 (8.9)	6	83,800	11,580	15	120
SEPTA	Blue (Mkt - Frank)	19.6 (12.2)	28	193,362			
SEPTA	Orange (Broad)	18.3 (11.4)	24	131,952			
SIR	Staten Island Rly.	23.0 (14.3)	22	19,161			
STC	1	18.8 (11.7)	20	1,037,726	70,700	50	450
STC	2	23.4 (14.5)	24	1,199,173	75,300	53	468
STC	3	23.6 (14.7)	21	940,962	63,000	53	468
STC	5	15.7 (9.8)	13	254,224	20,700	23	207
STC	6	13.9 (8.6)	11	152,369	10,300	12	108
STC	7	18.9 (11.7)	14	241,842	18,300	20	140
STC	9	15.3 (9.5)	12	365,430	27,600	23	207
STC	A	17.0 (10.6)	10	147,374	18,100	20	120
STCUM	1 (Green)	22.1 (13.7)	27	369,766	21,869		
STCUM	2 (Orange)	24.8 (15.4)	28	407,731	24,382		
STCUM	4 (Yellow)	4.3 (2.7)	3	56,943	10,928		
STCUM	5 (Blue)	9.7 (6.0)	12	85,555	6,360		
TTC	601 B-D	27.0 (16.8)	31	362,811	21,050		
TTC	602 Y-U-S	29.9 (18.6)	31	475,530	26,908	24	144
TTC	603 SRT	7.2 (4.5)	6	38,481	3,507		

Exhibit 1-46 (continued)

System	Route	Length in km (mi)	Stations	Ridership (Avg. weekday)	Peak Hour Pass.	Peak Hour Trains	Peak Hour Cars
WMATA	Blue	37.5 (23.3)	24		4,600		
WMATA	Green, Inner	8.1 (5.0)	9		2,800		
WMATA	Green, Outer	12.8	5		1,200		
WMATA	Orange	42.1 (26.2)	26		10,700		
WMATA	Red	48.9 (30.4)	25		11,700		
WMATA	Yellow	17.1 (10.6)	12		4,700		

NOTES: BART = San Francisco Bay Area; BCT = Vancouver, BC; CTA = Chicago; GCRTA = Cleveland; LACMTA = Los Angeles; MARTA = Atlanta; MBTA = Boston; MDTA = Miami; MTA = Baltimore; NYCT = New York; PATCO = Camden, NJ; PATH = Newark, NJ; SEPTA = Philadelphia; SIR = New York (Staten Island); STC = Mexico City; STCUM = Montréal; TTC = Toronto; WMATA = Washington, DC.

Mexico City provided hourly and 30-minute two-way data, which were adjusted to one-way data at 72% on heavy lines and 80% on lighter lines. The 30-minute rate is 51-59% of hourly for heavy lines and about 70% on lighter lines.

Between the time the table was compiled and this manual was published, BART and Washington Metro opened new extensions. Therefore, data may not always match Exhibit 1-26.

Exhibit 1-47
1995 Commuter Rail Route Characteristics and Ridership(R15)

System	Route	Length in km (mi)	Stations	Ridership (Avg. weekday)	Peak Hour Pass.	Peak Hour Trains	Peak Hour Cars
CalTrain	CalTrain	123.7 (76.9)	34	2,374	2,374	6	23
Coaster	Coaster	66.2 (41.1)	8	1,900	600		
ConnDOT	Shore Line East	52.8 (32.8)	7	1,100			
GO Transit	Bradford	66.8 (41.5)	6	1,559	798	1	7
GO Transit	Georgetown	47.3 (29.4)	8	8,689	3,318	3	24
GO Transit	Lakeshore East	50.9(31.6)	10	29,993	7,537	5	51
GO Transit	Lakeshore West	63.3 (39.3)	12	37,157	10,091	6	62
GO Transit	Milton	50.2 (31.2)	8	13,246	3,996	3	27
GO Transit	Richmond Hill	33.8 (21.0)	5	4,760	1,830	3	18
GO Transit	Stouffville	46.7 (29.0)	8	1,987	1,238	2	12
LIRR	Babylon	59.4 (36.9)	15	68,290	12,980	14	132
LIRR	Far Rockaway	34.6 (21.5)	17	12,890	2,780	5	36
LIRR	Flatbush Terminal	15.0 (9.3)	4		6,490	12	86
LIRR	Hempstead	32.4 (20.1)	15	14,110	3,200	5	36
LIRR	LIC Terminal	14.5 (9.0)	7		120	2	11
LIRR	Long Beach	37.7 (23.4)	11	20,110	5,000	6	56
LIRR	Montauk	172.0 (106.9)	22	7,340	1,340	4	20
LIRR	Oyster Bay	38.5 (23.9)	13	5,040	1,010	2	11
LIRR	Penn Terminal	15.0 (9.3)	6		41,480	38	380
LIRR	Port Jefferson	93.1 (57.9)	22	51,380	10,960	12	109
LIRR	Port Washington	29.6 (18.4)	13	41,390	9,130	8	76
LIRR	Ronkonkoma	151.8 (94.3)	22	39,050	8,700	6	68
LIRR	West Hempstead	21.1 (13.1)	11	3,570	1,340	3	20
MARC	Brunswick	119.1 (74.0)	17	5,539	1,789	3	
MARC	Camden	58.6 (36.4)	12	3,138	793	3	
MARC	Penn	123.3 (76.6)	13	10,492	2,480	4	
MBTA	Attleboro/Stou'ton	76.6 (47.6)	15	21,612	4,962	4	
MBTA	Fairmount	15.3 (9.5)	5	1,452	518	2	
MBTA	Fitchburg	79.7 (49.5)	18	6,648	2,101	3	
MBTA	Framingham	34.5 (21.4)	12	9,228	1,832	2	
MBTA	Franklin	49.6 (30.8)	17	13,068	2,579	3	
MBTA	Haverhill/Reading	53.0 (32.9)	14	6,604	2,096	3	
MBTA	Lowell	41.1 (25.5)	8	7,474	1,840	3	
MBTA	Needham	22.1 (13.7)	12	6,846	1,918	3	
MBTA	Rockport/Ipswich	72.0 (44.7)	16	10,230	2,292	4	
Metra	BN	60.4 (37.5)	27	50,082	12,848	14	101
Metra	C & NW-N	83.1 (51.6)	26	25,549	6,126	8	44
Metra	C & NW-NW	113.5 (70.5)	22	38,587	10,438	8	71
Metra	C & NW-W	57.2 (35.6)	17	28,592	7,739	7	57
Metra	Heritage Corridor	59.9 (37.2)	6	1,317	677	2	6
Metra	Milw. District-N	79.7 (49.5)	19	20,205	5,313	6	40
Metra	Milw. District-W	64.1 (39.8)	23	21,273	5,833	7	44
Metra	Metra Electric	65.4 (40.6)	49	41,024	11,292	20	100
Metra	Rock Island	75.4 (46.9)	25	31,062	7,813	9	62

Exhibit 1-47 (continued)

System	Route	Length in km (mi)	Stations	Ridership (Avg. weekday)	Peak Hour Pass.	Peak Hour Trains	Peak Hour Cars
Metra	South Shore	145.1 (90.2)	20	11,602	2,968	4	28
Metra	Southwest Service	40.6 (25.2)	9	5,862	1,957	2	15
Metro-North	Harlem	124.0 (77.1)	36	59,675	13,377	17	138
Metro-North	Hudson	119.0 (74.0)	29	33,461	8,541	15	88
Metro-North	New Haven	168.0 (104.4)	39	75,656	15,282	20	158
Metro-North	Waterbury Branch	52.0 (32.3)	8	314			
NICTD	South Shore	145.0 (90.1)	21	11,602	2,968	4	28
NJT	Atlantic City	109.3 (67.9)	8	1,504	222	2	
NJT	Boonton Line	77.1 (47.9)	20	5,657	1,920	5	
NJT	Main/Bergen Line	153.1 (95.2)	31	17,103	4,671	10	
NJT	Montclair	20.6 (12.8)	6	1,239	335	2	
NJT	Morris & Essex	96.9 (60.2)	33	25,704	4,752	13	
NJT	N. Jersey Coast	107.4 (66.7)	25	37,346	6,924	7	
NJT	Northeast Corridor	97.9 (60.8)	14	54,076	6,668	8	
NJT	Pascack Valley	49.3 (30.6)	17	6,125	1,895	4	
NJT	Raritan Valley	69.9 (43.4)	19	12,761	2,971	6	
SCRRA	Orange County	140.4 (87.3)	9	2,444	859	2	
SCRRA	Riverside	94.5 (58.7)	5	2,877	797	2	
SCRRA	San Bernardino	90.6 (56.3)	13	4,835	1,277	2	
SCRRA	Santa Clarita	124.3 (77.3)	8	2,632	614	2	
SCRRA	Ventura County	106.6 (66.3)	10	2,873	769	2	
SEPTA	R1	47.7 (29.6)	15	2,461	103	2	
SEPTA	R2	75.7 (47.0)	33	10,142	1,444	3	
SEPTA	R3	77.3 (48.0)	35	12,218	1,835	5	
SEPTA	R5	127.0 (78.9)	54	26,210	3,899	6	
SEPTA	R6	39.8 (24.7)	20	3,067	632	4	
SEPTA	R7	73.7 (45.8)	27	11,524	1,314	4	
SEPTA	R8	38.5 (23.9)	21	7,700	817	3	
STCUM	Deux-Montagnes	27.2 (16.9)	13	10,731	2,499		
STCUM	Dorion-Rigaud	64.4 (40.0)	18	11,781	3,503		
Tri-Rail	Tri-Rail	107.0 (66.5)	15	8,065	601	1	
VRE	Fredricksburg	86.5 (53.8)	11	4,605	1,188	2	
VRE	Manassas	56.0 (34.8)	10	3,295	892	2	

NOTES: CalTrain = San Francisco/San Jose; Coaster = San Diego; Conn DOT = New Haven, CT; GO Transit = Toronto; LIRR = New York (Long Island Rail Road); MARC = Baltimore; MBTA = Boston; Metra = Chicago; Metro-North = New York (Metro North Railroad); NICTD = Chicago; NJT = New Jersey Transit; SCRRA = Los Angeles; SEPTA = Philadelphia; STCUM = Montréal; Tri-Rail = Miami; VRE = Washington, DC.

Between the time the table was compiled and this manual was published, Altamont Commuter Express (San Jose) commenced operations.