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This Is Light Rail Transit

Photo courtesy of Dallas Area Rapid Transit Authority

Inset: America’s newest Light Rail Transit system serves downtown Jersey City across the Hudson River from Lower Manhattan.

Photo courtesy of Jack W. Boorse

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What Is Light Rail Transit?

An aerial LRT structure in Baltimore.

Photo courtesy of Parsons Brinckerhoff

As its surname indicates, Light Rail Transit (LRT) is a transit mode. Its middle name reflects that fact that it runs on rails. Why is it called “light”? That depends on who and where you ask.

In Britain the term “light railway” is applied to any rail mode that is scaled down from the common size of mainline railroads. In previous years, even some of the lines that operated short freight trains pulled by diminutive steam locomotives were classified as light railways. It was not until the 1970s that the term “light rail transit” came into use in the United States. There was no formal definition of LRT at that time, but it was generally understood to mean an urban rail transit form that was leaner and less costly than other rail modes.

A formal definition was adopted in 1989 and placed in

LRT surface trackage in San Jose.

Photo by Wm. H. Watts

An underground LRT station in Portland.

Photo courtesy of Tri-Met

the Transportation Research Board's Urban Public Transportation Glossary: *"A metropolitan electric railway system characterized by its ability to operate single cars or short trains along exclusive rights-of-way at ground level, on aerial structures, in subways, or occasionally, in streets and to board and discharge passengers at track or car floor level."*

LRT is designed to accommodate a variety of environments, including streets, freeway medians, railroad rights-of-way (operating or abandoned), pedestrian malls, underground or aerial structures, and even the beds of drained canals. It is this characteristic that most clearly distinguishes it from other rail modes. Because of this design flexibility, LRT generally is less costly to build and operate than other fixed-guideway modes.

The purpose of this informational booklet is to provide an understanding of this increasingly popular transit mode, with particular emphasis on its application in North American metropolitan areas, and to address the background of LRT's characteristics and capabilities.

The Origin of Light Rail Transit

In North America LRT emerged as an identified transit mode in the 1970s, but long before it existed in name it existed in fact. Its roots extend back more than a hundred years.

OMNIBUS MODE

Transit service in the larger cities of the United States and Canada began in the 19th century with the advent of the omnibus. The omnibus was an enclosed, wooden-wheeled wagon pulled by horses; it traveled on streets that were unpaved or that had, at best, a rough surface made of stones or timber. For those travelers who could not afford their own horse and buggy, the omnibus was the only alternative to walking.

HORSECARS

As the 19th century progressed, new technologies started to emerge. Metal rails were installed in the streets to provide a smooth riding surface for carriages that rolled on flanged metal wheels. These rails offered a much gentler ride for passengers and significantly reduced the effort required of the horses to move the cars. Moreover, the fixed guideway provided by the rails made it feasible to use mechanical power—in place of the horses—from a remote location.

CABLE CARS

Some of the larger cities started to develop cable car lines. The cars that served these lines were propelled by a “grip” instead of being pulled by a horse. The grip was a device placed beneath the car that protruded through a slot between the rails and into a chamber below the street surface. The chamber contained a moving cable that, when clamped by the grip, would move the car forward. It was a functional method of propulsion, but it was cumbersome. Before these cable car systems became widespread, the more advanced technology of electric traction emerged.

ELECTRIC TRACTION

Streetcars

Developed in the 1880s, electric traction technology allowed electricity—used to power onboard electric motors—to be conducted to the streetcars by means of an overhead wire. The electric streetcar proved to be so superior to its predecessors, both the horsecar and the cable car, that electric railways were constructed rapidly throughout the continent in all the large cities and even many moderate-sized ones. As the electric rail lines grew, development of cable railways faltered while the omnibus mode moved swiftly toward extinction. The seeds of LRT had been planted.

Once the concept of electrically powered railways had been discovered, it was applied in a variety of ways. Some main line railroads electrified portions of their trackage to gain the benefits of clean and powerful electric traction. This versatile power source also made it feasible to extend local railway lines beyond urban boundaries into new and future suburbs and, in some cases, cross county to other urban areas. The resulting high-speed, interurban lines offered service that was generally cheaper and more frequent than the service

A scene in downtown Newark during the streetcar era.

Photo by Albert L. Creamer, courtesy of National Railway Historical Society, North Jersey chapter.

offered by parallel railroads with the same destinations.

Elevated Systems

In the largest cities, where major streets became congested, railways were installed on structures above the streets. New York and Chicago started to build their elevated systems—also called “L” systems—as early as the 1870s. For the most part, these systems used trains of railroad-type cars pulled by small steam locomotives, although in a few cases, by cable. These elevated lines were ideal candidates for electric traction and were quickly converted.

Subways

This new power delivery method also opened other opportunities for urban transport. As the 20th century dawned, Boston, New York, and Philadelphia began to place railway tracks and stations in enclosed subways beneath the streets—a concept that would have been unthinkable with animal or steam power.

Trolleys

The major application of electric traction, however, was on the urban street railways that had supplanted the omnibus mode. The horsecar was redesigned with electric motors beneath the floor, and a device on the roof that trolled the overhead wire and collected energy to power the motors. Early on the trolling device came to be known as the trolley, a term that eventually identified the cars, the wires, and the entire mode. In all the large cities, including the three that were developing subways, the electric trolley became the dominant transit mode and would remain so for decades.

During the second quarter of the 20th century, the internal combustion engine and the pneumatic tire were refined, and paved streets and highways were being constructed throughout the metropolitan areas with public funds. These improvements inspired a return of the omnibus and family buggy, each with much improved motive power and running gear. The electric trolley slowly forfeited to the automobile not only its dominance of the roadways but also much of its patronage. Concurrently, the bus not only became practical, but being a lower capacity conveyance it was more appropriate on the weaker lines where riding had dwindled considerably.

In the decade before World War II and in the two immediately after, it became a matter of survival of the fittest for the trolley mode. Ridership decreased as automobile use increased and many of the interurban lines were rendered unprofitable—all but a few succumbed. The majority of streetcar lines in urban areas were either converted to bus operation or simply abandoned.

The trolley lines that were least vulnerable to the erosion were those that had substantial sections of trackage that were on separate rights-of-way, free of the increasingly congested street traffic. During the early decades of the 20th century, Boston, Newark, and Philadelphia built trolley subways in their core areas. Pittsburgh and San Francisco constructed lengthy trolley tunnels under steep hills at the edge of their downtown districts to connect street trackage there with growing residential areas on the other side of the hills. In Cleveland and New Orleans the lines that survived were those which had long stretches of trackage in separate surface rights-of-way.

By the beginning of the last quarter of the 20th century only those seven cities in the United States and Toronto, Canada, had surviving trolley lines.

It was at this time that the North American public transportation community reawakened to the potential of LRT. The depletion halted and the trend reversed. New systems were initiated at an average rate of nearly one per year (Table 1). Just before the close of the 20th century two new systems—one focused on Salt Lake City and the other on Jersey City—began passenger service and brought the total number of operating systems to 23.

TABLE 1 Dates of New LRT System Openings Since 1975

City	*Date*
Edmonton	April 1978
Calgary	May 1981
San Diego	July 1981
Buffalo	October 1984
Portland	September 1986
Sacramento	March 1987
San Jose	December 1987
Los Angeles	July 1990
Baltimore	April 1992
St. Louis	July 1993
Denver	October 1994
Dallas	June 1996
Salt Lake City	December 1999
Jersey City	April 2000

LRT Today

North American LRT, as we know it today, represents a blend of design and operating practices and parallels the development of the mode in Europe, Asia, and Australia. Today's systems can be categorized into two types:

- "First Generation" systems have evolved from earlier trolley and tramway lines that remained in operation throughout their transformation.
- "Second Generation" systems were designed afresh (occasionally utilizing portions of abandoned trolley or railroad lines, or both).

In the United States and Canada there are seven First Generation systems. They operate in the metropolitan areas of Boston, Cleveland, New Orleans, Newark, Philadelphia, San Francisco, and Toronto. All of the other systems (16 at present and growing) are of the Second Generation type.

Some LRT operating agencies like to give special names to their light rail lines. For example, Portland's system is called ***MAX***, which stands for **M**etropolitan **A**rea e**X**press, and Salt Lake City's is named ***TRAX*** (**TRA**nsit e**X**press). In San Diego the light rail line is simply designated ***Trolley***, but in San Francisco riders travel on the ***Muni Metro***. St. Louis refers to their system as ***Metro Link***, and Calgary passengers jump on the ***C-Train***.

Regardless of type or name, all LRT systems have the following basic elements:

The Church Street Line of San Francisco's First Generation system.

Photo by Wm. H. Watts

- Infrastructure—composed of the trackways, stations, and storage yards, including any associated structures, such as tunnels and bridges.
- Rolling Stock—comprising one or more fleet of railcars that carry the passengers along the trackways. Generally, these cars are designed so that they can be assembled into short trains. They are sometimes referred to as vehicles, although most statutory definitions of that term, including the one contained in the *Uniform Vehicle Code*, specifically exclude railcars.
- Fixed Equipment—consisting of an operations and maintenance center, the electric power supply, signals, and communications facilities.

Each of these elements is discussed on following pages.

Infrastructure

TRACKWAYS

LRT trackways can be constructed in a variety of configurations. As with other electric railway modes, they can be placed on the surface of the ground, below the surface in an open cut or in a subway, or above the surface on an embankment or aerial structure.

A surface LRT trackway may be physically separated from vehicle and pedestrian traffic by means of bridges or underpasses. It may also cross roadways and walkways at grade, in which case the conflicting movements are temporally separated by appropriate control devices, usually automatic crossing gates or traffic signals.

Surface LRT trackage may also be constructed along a street right-of-way, commonly in segregated lanes but occasionally within vehicle lanes used by general traffic.

Sub-surface trackways are generally positioned below streets and follow the street pattern, but they can also follow an independent alignment and pass under structures, parks, bodies of water, or other railways. Aerial trackways may also follow street patterns, but are more likely to trace a different alignment, crossing above streets, rivers, and other rail lines.

In northern climates provisions for snow and ice removal must be included in system designs and operating plans.

A crossing controlled by automatic gates on Philadelphia's LRT system.

Photo courtesy of Jack W. Boorse

A surface station in San Jose.

Photo by Wm. H. Watts

STATIONS

Stations range from simple platforms at ground level where passengers can safely board and alight from trains, to elaborate structures above or below ground, which may be accessed via stairways, escalators, and elevators.

Underground stations, even where they are far below the surface, can be served safely because electric railcars emit no harmful fumes into the air.

STORAGE YARDS

The storage yards do not need to be elaborate. Unlike buses, electric LRT cars have no engines that are temperature sensitive. They will start reliably in any ambient temperature experienced by North American cities. There is no necessity to house them in enclosed buildings, although in extreme climates simple roofing over the storage tracks is sometimes installed. Also, the cars require no fueling stations, thereby eliminating the possibility of fuel spills.

Rolling Stock

The versatility of LRT as a mode is in no small measure attributable to the capabilities of the railcars that have been developed to serve the lines. Sometimes referred to as light rail vehicles (LRVs), trolleys, or trains, LRT cars can be tailored to the needs of specific operating environments.

Where the tracks are constructed along, above, or below a public street network, the presence of adjacent buildings or other structures may necessitate track alignments that include sharp turns and steep grades. A curve radius of 25 meters (82 feet) is the customary minimum for new LRT lines, and longer radii are preferable where conditions permit. However, it is possible to design cars to negotiate curves with a radius as short as 11 meters (36 feet).

While a maximum gradient of 5 percent is considered a desirable design criterion, there has been a need on some new systems to include track segments with gradients as steep as 7 and 8 percent. The cars operating on those systems negotiate these gradients without difficulty. LRT cars could be designed to climb a slope of 12 percent and indeed some predecessor streetcar lines had such gradients. However, 10 percent is now considered the limit from the perspective of passenger comfort. Exotic technologies with rubber tires or linear induction propulsion are not needed to conquer precipitous track profiles.

The use of external electric power not only provides the cars with the muscle needed to climb steep trackage, it also gives them the ability to serve enclosed passenger stations that may be located inside buildings or, more commonly, underground where an onboard combustion engine could cause a health risk. The electric power also provides the ability to maintain air conditioning or heat in the car during layovers without wasting fuel.

Today's LRT cars come in a variety of shapes and sizes. Of those currently operating in the United States, body widths vary

A Buffalo LRT car with a one-piece body more than 20 meters in length.

Photo courtesy of Parsons Brinckerhoff

from 2.6 to 2.9 meters (8.5 to 9.5 feet). The lengths of the one-piece cars range from 15 meters (50 feet) to 20.4 meters (67 feet). When the length of the body exceeds that range it is split into two or three sections.

Those sections are hinged to each other so that the car is able to negotiate short-radius curves. These are called articulated cars and their lengths vary from 21 to 29 meters (70 to 95 feet).

Most North American LRT systems use articulated cars. Boston, San Francisco, and Toronto operate mixed fleets that include some shorter cars with traditional one-piece bodies. One-piece bodies only comprise the fleets in Buffalo, Fort Worth, New Orleans, and Philadelphia.

Individual cars of either type can be assembled into a short train that is controlled from the front car. A three-car train of articulated cars operated by a single driver can safely transport more than 400 passengers. Where conditions dictate, individual cars or multi-car trains can be and are operated in mixed traffic.

Although, to date, it has only been implemented on a test track, completely automatic operation without an onboard operator would be feasible on track segments that are fully separated from the roadway network.

An articulated car negotiates a sharp turn in San Francisco.

Photo by Wm. H. Watts

State-of-the-art electric LRT cars are neighborhood friendly. Not only are they nearly silent, but modern electronic propulsion and braking control enables them to stop very quickly when necessary. This technology allows them to run at the appropriate speed for the zone in which they operate.

This same equipment gives them the ability to move rapidly where it is safe to do so. The usual maximum speed of LRT cars is about 90 kilometers (56 miles) per hour, but some

LRT cars are part of the neighborhood in suburban Philadelphia.

Photo courtesy of Jack W. Boorse

recently produced cars travel as fast as 105 kilometers (65 miles) per hour. A few of their interurban predecessors ran at speeds as high as 145 kilometers (90 miles) per hour, and there is no technological reason why they could not be designed to operate at 160 kilometers (100 miles) per hour.

Contemporary LRT cars are also passenger friendly. Because they roll on steel rails, they furnish an especially smooth ride. They are not only immune from vertical jolting caused by paving flaws that are unavoidable in a metropolitan setting, but also from the lateral and longitudinal lurching that is common with steerable, rubber-tired vehicles. In many applications they can have a generous body width so that broader and more comfortable seats and aisles can be provided.

Their interiors are temperature controlled for all seasons—in climates as diverse as those of Dallas in the summer and Edmonton in the winter. Externally supplied electric power allows them to maintain the necessary heating and cooling continuously without any loss of performance, even while simultaneously climbing long and steep gradients. Another passenger-pleasing attribute that is inherent to electric traction is

A stationary lift at a station in San Jose.

Photo by Wm. H. Watts

its freedom from engine noise, vibration, and odor.

LRT cars can be especially friendly to passengers with disabilities. Some cars carry lifts like those in new buses to assist the boarding and alighting of mobility-impaired passengers. Others have stationary lifts at the stations.

However, an increasing number of LRT systems are being designed to provide easy access through level boarding. This type of boarding assures that the floor of the car at all or most of the doors matches the height of the station platform. Until recently, in order to achieve level boarding it was necessary to design stations with platforms about one meter above the rails because that was the traditional car floor height. These high platforms exist in two forms. The more common is a full-length version that provides level boarding at every door. The less common form is the mini-high platform (sometimes called a high block), which serves only the front door.

Today many of the new systems (and a few of the more established ones) are acquiring low-floor cars. These cars are designed with floors that are only about 35 centimeters (14 inches) high. This gives them the ability to provide level boarding at a low-platform station.

A high-platform station in Edmonton.

Photo courtesy of Jack W. Boorse

A mini-high platform in Denver.

Photo courtesy of T. R. Hickey

In addition to aiding mobility-impaired passengers, level boarding also eliminates the need for ambulatory passengers to climb steps, thereby expediting the boarding and alighting process and minimizing the station stop time. The result is shorter trip times for everyone.

A low-floor LRT car at a station in Portland.

Photo courtesy of Tri-Met

Fixed Equipment

OPERATIONS AND MAINTENANCE CENTER

The operations and maintenance center is the focal point of an LRT system. It includes a control room from where operations are coordinated, accommodations for train crews preparing for duty, and a maintenance facility where the cars are inspected, cleaned, and repaired. The center can also include administrative and management offices.

ELECTRIC POWER SUPPLY

Two basic elements comprise the electric power supply: a network of traction power substations and a distribution system. The power substations receive high-voltage commercial electrical power and convert it to medium-voltage direct current. The distribution system delivers that converted power from the substations via overhead wires to the individual LRT cars as they travel along the line.

SIGNALS

The movement of the cars or trains is guided by signals. On some systems all of the signals are located alongside the trackway. These trackside signals may include, or be coordinated with, traffic signals along the line. On other systems only certain signals are installed trackside, while others are displayed on a console in front of the train operator.

COMMUNICATIONS FACILITIES

Communications facilities link the operations and maintenance center with the train operators and other personnel. These facilities range from conventional telephone lines to the very newest wireless technologies.

Operating Experience

Since the North American resurgence of LRT a quarter of a century ago, operating experience generally has been favorable, particularly in some metropolitan areas that previously had been without rail transit service.

Adding an LRT component to a transit system does not drain passengers from the bus lines as some observers have claimed. Rather, it encourages more people to use both bus and rail transit. Adding LRT trunk lines and coordinating them with a region's buses to create a multimodal, multidestination transit system results in growth for both modes—even in the low-density, auto-oriented cities of the American West.

Sacramento provides a good example. An examination of the Federal Transit Administration (FTA) National Transit database showed that in 1987—its last year of all-bus operation—regional transit vehicles carried fewer than 14 million passengers. Eleven years later the system accommodated more than 28 million riders. The LRT trunk line attracted over 8 million passengers, while bus ridership grew to nearly 20 million. There were similar results in San Diego, Portland, and St. Louis.

Used appropriately, LRT enhances transit efficiency. By 1998 LRT trunk lines, each 23 or more kilometers in length, had opened and were providing primary rail services in San Diego, Portland, Sacramento, San Jose, St. Louis, and Dallas. Previously, only buses served these six cities. In 1998, these systems operated more than 3,000 buses in route service plus more than 500 small vehicles in demand-responsive service; there were fewer than 300 light rail cars. By providing high-capacity service on major routes, the LRT lines became highly productive, accommodating 22 percent of total system boardings and carrying 30 percent of systemwide passenger miles but consuming only 17 percent of the operating and maintenance costs.

One-person operation of trains (of up to four cars) makes it possible for an LRT line to do the work of many buses. Using LRT results in greater efficiency, even after taking into account the cost of added staff to maintain the tracks, stations, electrification, signals, and other fixed facilities. However, achieving these economies of scale requires a high level of ridership. That is why it makes sense to provide LRT service on a transit system's high-demand primary corridors and to operate buses (or even smaller vehicles in local shuttle and circulator service) where they are the better choice on secondary radial lines and crosstown and feeder routes.

Only the largest, most densely developed cities generate passenger volumes that require fully grade-separated heavy rapid transit systems. Commuter railroads are best suited to longer radial corridors linking cities with their more distant suburbs. LRT is a medium to high-capacity mode that fits well into many metropolitan areas with good productivity.

One way of measuring the productivity of a transit mode is by calculating the number of passenger kilometers produced per transit employee both onboard and for support. A productivity comparison of the measurements for five urban transit modes is shown in Table 2.

TABLE 2 Productivity Comparison of Annual Passenger Kilometers

Mode	*Annual Passenger Kilometers Per Employee*
Commuter (Regional) Railroads	608,200
Rail Rapid Transit (Metros)	413,500
Light Rail Transit (LRT)	301,618
Urban Bus Transit	201,125
Automated Guideway Transit (AGT)	64,360

Another measurement of productivity is the average number of passengers carried by one vehicle. In this category LRT exceeds even that of the nation's rapid transit systems. The productivity per unit (one railcar or bus) for the three major urban transit modes is compared in Table 3.

All transit modes are basically safe. However, LRT excels in safety and has a record clearly superior to that of automobile travel. Of all of the transit modes, LRT is among the safest. Data submitted to FTA document that LRT's safety record even surpasses that of urban bus service by moving people with 47 percent fewer casualties per passenger kilometer. This is to be expected since LRT cars are reliably guided by rails and often are located in reserved lanes or exclusive right-of-ways, as compared with operator-steered vehicles maneuvering in street traffic.

TABLE 3 Productivity Comparison of Average Number of Weekday Passengers

Mode	*Average Weekday Passengers Per Unit*
Light Rail Transit (LRT)	1,134
Rail Rapid Transit (Metros)	982
Urban Bus Transit	362

New residential, retail, and office development around the Hazard Center LRT station in San Diego.

Photo courtesy of San Diego Metropolitan Transportation Development Board

Yet another attribute of LRT, which it shares with other rail modes, is its ability to stimulate growth, leading to healthy economic development in the form of private sector investment and higher real estate values. The presence of a major transit infrastructure is broadly viewed as a promise of permanence. Once a rail line is built, it is likely to remain for a long time.

LRT Tomorrow

What lies ahead for LRT? The beginning of the 21st century will see continuing expansion of the LRT mode in North America. Fifteen of the 23 systems now in operation are actively extending or upgrading their lines. There are currently eight future new systems in various stages of planning or design.

Whether you are a transportation professional, an elected official, a civic leader, or a citizen of a metropolitan area who is interested in the betterment of your community, we invite you to learn as much as you can about this increasingly popular transit mode.

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