Report on Metrorail and Monorail

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A metro or metropolitan railway system is an electric passenger railway in an urban area with a high capacity and frequency, and grade separation from other traffic. Rapid transit systems are typically located either in underground tunnels or on elevated rails above street level. Outside urban centers, rapid transit lines may run on grade separated ground level tracks.

Service on rapid transit systems is provided on designated lines between stations using electric multiple units on rail tracks, although some systems use guided rubber tyres, magnetic levitation, or monorail. They are typically integrated with other public transport and often operated by the same public transport authorities. Rapid transit is faster and has a higher capacity than trams or light rail (but does not exclude a fully grade separated LRT), but is not as fast or as far-reaching as commuter rail. It is unchallenged in its ability to transport large amounts of people quickly over short distances with little land use. Variations of rapid transit include people movers, small-scale light metro and the commuter rail hybrid S-Bahn.

The first rapid transit system was the London Underground, which opened in 1863. The technology quickly spread to other cities in Europe, and then to the United States where a number of elevated systems were built. At first these systems used steam locomotives, with the term later coming to entirely mean electric systems. More recently the largest growth has been in Asia and with driverless systems. More than 160 cities have rapid transit systems, totaling more than 8,000 km (5,000 mi) of track and 7,000 stations. Twenty-five cities have new systems under construction.
The biggest rapid transit system in the world by length of routes (including non-revenue track) and by number of stations is the New York City Subway; by length of passenger lines, the largest are the Shanghai Metro and London Underground. The busiest metro systems in the world by daily and annual ridership are the Tokyo subway, the Seoul Metropolitan Subway, and the Moscow Metro.

The Delhi Metro Rail Corporation which builds and operates the Delhi Metro has been certified by the United Nations as the first metro rail and rail-based system in the world to get “carbon credits for reducing greenhouse gas emissions” and helping in reducing pollution levels in the city by 630,000 tons (630 Gg) every year.

**Terminology**

*Metro* is the most common term for underground rapid transit systems. Rapid transit systems may be named after the medium through which their busier inner-city sections travel: use of tunnels inspires names such as *subway*, *underground*, *Untergrundbahn (U-Bahn)* in German, or *Tunnelbana (T-bana)* in Swedish; use of viaducts inspires names such as *elevated (el or L)*, *skytrain*, *overhead* or *overground*. One of these terms may apply to an entire system, even if a large part of the network (for example, in outer suburbs) runs on ground level.

In British English a *subway* is a pedestrian underpass, so the expressions *underground* and *tube* may be preferred. In Scotland, Glasgow's underground rapid transit system is called the Glasgow Subway.

**History**

Rapid transit evolved from steam railways during the late 19th century. In 1890 the City & South London Railway in London was the first electric rapid transit railway. The electric railway eventually was merged into London Underground. The technology swiftly spread to other cities in Europe, as in Budapest, Hungary in 1896, and then to the United States. A number of elevated systems were built, starting with the 1893 100% designed electric Liverpool Overhead Railway, which also had a small underground section complete with station. By 1940, there were 19 systems, and by 1984, there were 66. This included smaller cities like Oslo and Marseille which opened extensive systems in the 1960s. More recently the growth of new systems has been concentrated in Southeast Asia and Latin America.
Western Europe and North America have instead seen a revival of the tram, with light rail systems supplementing full scale urban railways, and less focus on building rapid transit. At the same time, technological improvements have allowed new driverless lines and systems. Hybrid solutions have also evolved, such as tram-train and premetro, which have some of the features of rapid transit systems.

Lines

A Delhi Metro train on the red line.

Each rapid transit system consists of one or more lines. Each line is serviced by at least one specific route with trains stopping at all or some of the line's stations. Most systems operate several routes, and distinguish them by colors, names, numbering, or a combination thereof. Some lines may share track with each other for a portion of their route, or operate solely on their own right-of-way. Often a line running through the city center forks into two or more branches in the suburbs, allowing a higher service frequency in the center. This arrangement is used by many systems, such as the Copenhagen Metro and New York City Subway. Alternatively there might be a single central terminal (often shared with the central railway station), or multiple interchange stations between lines in the city centre, for instance in the Prague Metro. The London Underground and Paris Métro are densely built systems with a matrix of crisscrossing lines throughout the cities. The Chicago 'L' has most of its lines converging on The Loop, the main business, financial, and cultural section.

The capacity of a line is obtained by multiplying together the car capacity, train length and service frequency. Heavy rapid transit trains might have six to twelve cars, while lighter systems may use only four or fewer cars. Cars have a capacity of 100 to 150, varying with the seated to standing ratio—more standing gives higher capacity. Bilevel cars, used mostly on German S-Bahn type systems, have more space, allowing the higher seated capacity needed on longer journeys. The minimum time interval between trains is shorter for rapid transit than for mainline railways owing to the use of block signaling: the minimum headway might be 90
seconds, which might be limited to 120 seconds to allow for recovery from delays. Typical capacity lines allow 1200 people per train, giving 36,000 people per hour. The highest attained capacity is 80,000 people per hour by the MTR Corporation in Hong Kong.

**Network types**

Circle-system (e.g. Glasgow)  
Seoul, Shanghai, Madrid

Circle-radial-system (e.g. Moscow, Tokyo, São Paulo, Munich, Kuala Lumpur)

Secant-system (e.g. Minsk, Kiev, Prague, São Paulo, Munich, Kuala Lumpur)

Intermeshed-system (e.g. London, Paris New York, Berlin, Osaka)

X-system (e.g. Oslo, San Francisco, Brussels, Rio de Janeiro, Porto, Amsterdam)

Diameter line (e.g. Helsinki, Lima Warsaw, Yekaterinburg, Algiers)
**Infrastructure**

Most rapid transit trains are electric multiple units with lengths from three to beyond ten cars. Power is commonly delivered by a third rail or by overhead wires. The whole London Underground network uses fourth rail and others use the linear motor for propulsion. Most run on conventional steel railway tracks, although some use rubber tires such as the Montreal Metro and Mexico City Metro, and some lines in Paris Métro. Rubber tires allow steeper gradients and a softer ride, but have higher maintenance costs and are less energy efficient. They also lose friction when weather conditions are wet or icy, preventing above ground use of the Montréal Metro but not rubber-tired systems in other cities. Crew sizes have decreased throughout history with some modern systems now running completely unstaffed trains. Other trains continue to have drivers, even if their only role in normal operation is to open and close the doors of the trains at stations.
Monorail

A monorail is a rail-based transportation system based on a single rail, which acts as its sole support and its guideway. The term is also used variously to describe the beam of the system, or the vehicles traveling on such a beam or track. The term originates from joining the words mono (one) and rail (rail), from as early as 1897, possibly from German engineer Eugen Langen who called an elevated railway system with wagons suspended the Eugen Langen One-railed Suspension Tramway (Einschienige Hängebahn System Eugen Langen). The transportation system is often referred to as a railway. Colloquially, the term "monorail" is often used erroneously to describe any form of elevated rail or peoplemover. In fact, the term refers to the style of track, not its elevation.

History

![Gyroscopically balanced monorail (1907) by Brennan and Scherl](image)

Early years

The first monorail was made in Russia in 1820 by Ivan Elmanov. Attempts at creating monorail alternatives to conventional railways have been made since the early part of the 19th century. The earliest patent was taken out by Henry Palmer in the UK in 1821, and the design was employed at Deptford Dockyard in South-East London, and a short line for moving stone from a quarry near Cheshunt, Hertfordshire to the River Lea. The Cheshunt line is notable as it was the world's first monorail to carry passengers, as well as the first railway line to be opened in Hertfordshire.
Around 1879 a "one-rail" system was proposed independently by Haddon and by Stringfellow, which used an inverted "\" rail. The system was intended for military use, but was also seen to have civilian use as a "cheap railway."

Early designs centred on use of a double-flanged single metal rail alternative to the double rail of conventional railways. Wheels on this rail would both guide and support the monorail car. A surviving suspended version is the Wuppertal monorail. Into the 1900s, Gyro monorails, with cars gyroscopically balanced on top of a single rail, were tested, but never developed beyond the prototype stage. The Ewing System, used in the Patiala State Monorail Trainways in Punjab, India, relies on a hybrid model with a load-bearing single rail and an external wheel for balance. One of the first systems put into practical use was that of French engineer Charles Lartigue, who built a monorail line between Ballybunion and Listowel in Ireland, which was opened in 1888 and closed in 1924 (due to damage from Ireland's Civil War). The Lartigue system uses a load-bearing single rail and two lower, external rails for balance, the three carried on triangular supports.

Possibly the first monorail locomotive was a 0-3-0 steam locomotive.

1900s-1950s

A highspeed monorail using the Lartigue system was proposed in 1901 between Liverpool and Manchester.

In 1910, the Brennan monorail was considered for use to a coal mine in Alaska.

The first half of the 20th century saw many further proposed designs, that either never left the drawing board or remained as short lived prototypes. One of the first monorail systems planned in the United States was in New York City in the early 1930s. But the monorail was scrubbed instead for an elevated train system.

1950s-1980s

In the later half of the 20th century, monorail designs had settled on using larger beam or girder based track, with vehicles supported by one set of wheels and guided by another. On of the first testing of this type of system was by the German's of a 40% scale of the actual passenger carrying system was designed for speed of 200 mph on straight stretches and
90 mph on curves in the early. There were designs featuring vehicles supported, suspended or cantilevered from the beams. In the 1950s the ALWEG straddle design emerged, followed by an updated suspended type, the SAFEGE system. Versions of ALWEG's technology are currently used by both of the two largest monorail manufacturers Hitachi Monorail and Bombardier.

In 1956, the first monorail to operate in the US, begun test operations in Houston, Texas. Later during this period, major monorails were installed at Disneyland in California, Walt Disney World in Florida, Seattle, Japan, and many other locations. Monorail systems were also heavily promoted as futuristic technology with exhibition installations and amusement park purchases, as seen by the number of legacy systems in use today. However, monorails gained little foothold compared to conventional transport systems.

Niche private enterprise uses for monorails emerged, with the emergence of air travel and shopping malls, with many shuttle type systems being built.

**Perceptions of monorail as public transport**

*The Las Vegas Monorail pulling into the Las Vegas Convention Center Station*

From 1950 to 1980 the monorail concept may have suffered, as with all public transport systems, from competition with the automobile. Monorails in particular may have suffered from the reluctance of public transit authorities to invest in the perceived high cost of un-proven monorails when faced with cheaper mature alternatives. There were also many competing monorail technologies, splitting their case further.

This high cost perception was challenged most-notably in 1963, when the ALWEG consortium proposed to finance the construction of a major monorail system in Los Angeles, in return for the right of operation. This was turned down by the city authorities in favour of
no system at all, and the later subway system has faced criticism as it has yet to reach the scale of the proposed monorail.

Several monorails initially conceived as transport systems survive today on revenues generated from tourism usage, benefitting from the unique views offered from the largely elevated monorail installations.

**Recent history**

![Monorail in the Europa-Park in Rust, Germany](image)

From the 1980s onwards, with the rise of traffic congestion and urbanization, monorails have experienced a resurgence in interest for mass transit usage, notable from the early use by Japan and now Malaysia. Tokyo Monorail, the world's busiest monorail line, averages 127,000 passengers per day and has served over 1.5 billion passengers since 1964. Monorails have also seen continuing use in niche shuttle markets, as well as amusement parks.

Modern mass transit monorail systems have settled on developments of the ALWEG beam and tyre approach, with only two suspended types in large use. Monorail configurations have also been adopted by maglev trains. The Chongqing Rail Transit in China has adopted a unique form of an ALWEG-based design such that the design of its monorail rolling stock is much wider than most other monorails so as to have capacities comparable to that of heavy rail systems. This is because the city of Chongqing is criss-crossed by numerous hills, mountains and rivers, therefore tunnelling underground is not feasible except in some cases (Line 1 and future Line 6) due to the extreme depth involved.

**Types and technical aspects**
Modern monorails depend on a large solid beam as the vehicles' running surface. There are a number of competing designs divided into two broad classes, \textit{straddle-beam} and \textit{suspended} monorails.

The most common type of monorail in use today is the \textit{straddle-beam monorail}, in which the train straddles a reinforced concrete beam in the range of two to three feet (~0.6-0.9 m) wide. A rubber-tired carriage contacts the beam on the top and both sides for traction and to stabilize the vehicle. The straddle-beam style was popularized by the German company ALWEG.

The French company SAFEGE offers a monorail system in which the train cars are suspended beneath the wheel carriage. In this design the carriage wheels ride inside the single beam. The Chiba Urban Monorail is presently the world's largest suspended monorail network.

There is also a historical type of \textit{suspension monorail} developed by German inventors Nicolaus Otto and Eugen Langen in the 1880s. It was built in the twin cities of Barmen and Elberfeld in Wupper Valley, Germany, opened in 1901, and is still in operation.

**Power**

Almost all modern monorails are powered by electric motors fed by dual third rails, contact wires or electrified channels attached to or enclosed in their guidance beams. However, diesel-powered monorail systems also exist. Historically, some systems, such as the Lartigue Monorail, used steam locomotives.
**Magnetic levitation**

![Transrapid maglev on monorail track](image)

Magnetic levitation train (maglev) systems by the German Transrapid were built as straddle-type monorails, as they are highly stable and allow rapid deceleration from great speed. When in full-speed operation maglev trains hover over the track and are thus not in physical contact with it. The maglev is the fastest train of any type, the experimental JR-Maglev having recorded a speed of 581 km/h (361 mph). The commercial Shanghai Maglev Train has run at 501 km/h (311 mph). However, the guideway system is so wide that it can be argued it is not legitimate to call it a monorail. There are also slower maglev monorails intended for urban transport, such as Japan's Linimo (2003).

**Switching**

![Switches at storage facility of Osaka Monorail.](image)

Some early monorail systems (notably the suspended monorail of Wuppertal (Germany), dating from 1901 and still in operation) have a design that makes it difficult to switch from one line to another. Some other monorail systems avoid switching as much as possible, by operating in a continuous loop or between two fixed stations, as in Seattle, Washington.

Current operating monorails are capable of more efficient switching than in the past. In the case of suspended monorails, switching may be accomplished by moving flanges inside the beamway to shift trains to one line or another.
Straddle-beam monorails require that the beam structure itself be moved to accomplish switching, which originally was an almost prohibitively ponderous procedure. Now, however, the most common way of achieving this is to place a moving apparatus on top of a sturdy platform capable of bearing the weight of vehicles, beams and its own mechanism. Multiple-segmented beams move into place on rollers to smoothly align one beam with another to send the train in its desired direction, with the design originally developed by ALWEG capable of completing a switch in 12 seconds. Some of these beam turnouts are quite elaborate, capable of switching between several beams or even simulating a railroad double-crossover.

In cases where it must be possible to move a monorail train from one beam to any of a number of other beams, as in storage or repair shops, a traveling beam not unlike a railroad transfer table may be employed. A single beam, at least long enough to carry a single monorail vehicle, is aligned at an entry beam to be mounted by the monorail cars. The entire beam then rolls with the vehicle to align with the desired storage beam.

Grades

Rubber-tired monorails are typically designed to cope with 6% grade. However, rubber-tired conventional light rail or metro lines can cope with similar or even greater grades - for
example, the Lausanne Metro has grades of up to 12% and the Montreal Metro up to 6.5%, while VAL systems can handle 7% grades.

**Gauge**

One can quibble if the monorail has a gauge, i.e. the distance between the rails. However if the dimensions two monorails vary, type, height and width of beam, type and position of power conductors, etc., then you will have a break of gauge, which implies a gauge.