Rolling Stock Technology

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Locomotive

Three body styles of diesel locomotive: cab unit, hood unit and box cab. These locomotives are operated by Pacific National in Australia.

R class steam locomotive number R707 as operated by the Victorian Railways of Australia.

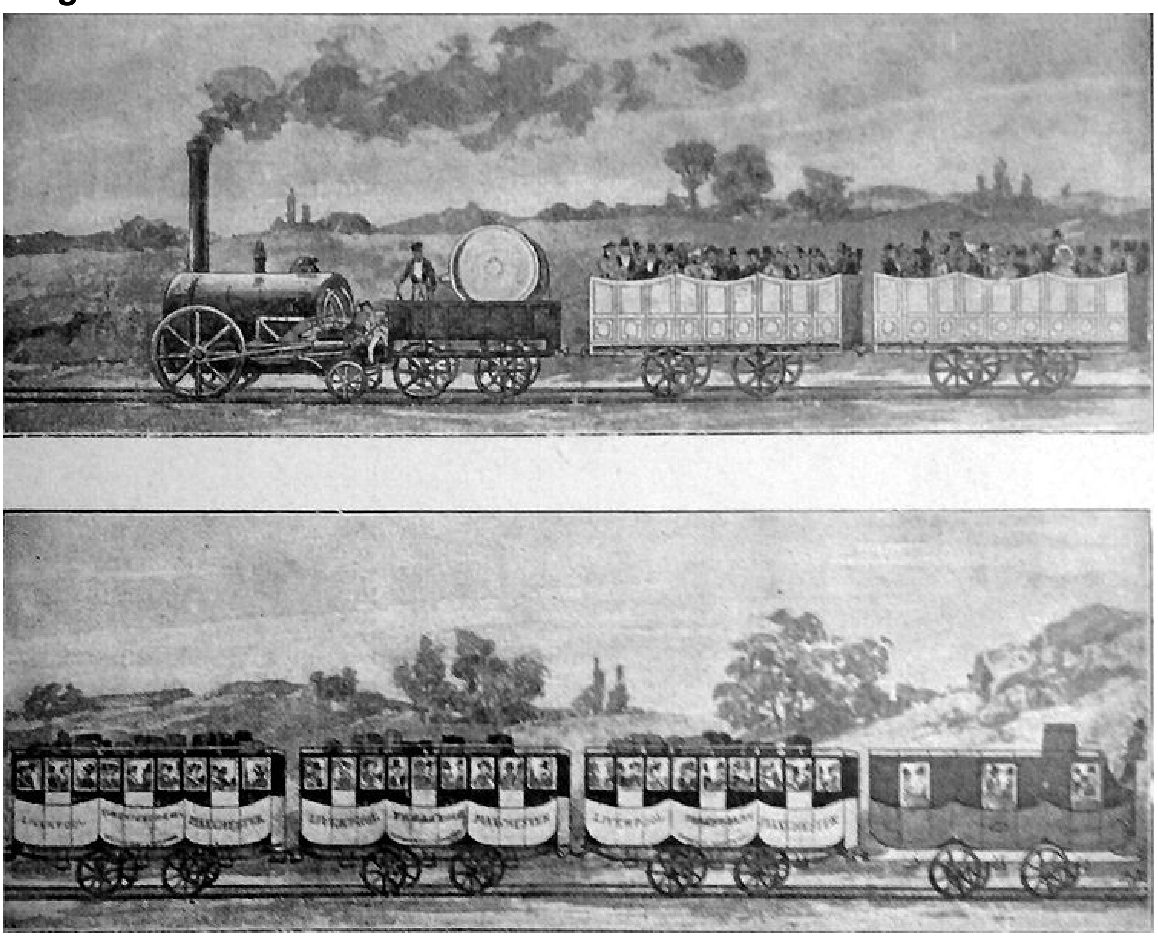
A Green Cargo RC 4 class electric locomotive repainted in its original livery for the Swedish 150-year railway anniversary in 2006.

A **locomotive** is a railway vehicle that provides the motive power for a train. The word originates from the Latin *loco* – "from a place", ablative of *locus*, "place" + Medieval Latin *motivus*, "causing motion", and is a shortened form of the term *locomotive engine*, first used in the early 19th century to distinguish between mobile and stationary steam engines.

A locomotive has no payload capacity of its own, and its sole purpose is to move the train along the tracks. In contrast, some trains have self-propelled payload-carrying vehicles. These are not normally considered locomotives, and may be referred to as multiple units, motor coaches or railcars. The use of these self-propelled vehicles is increasingly common for passenger trains, but rare for freight. Vehicles which provide motive power to haul an unpowered train, but are not generally considered locomotives because they have payload space or are rarely detached from their trains, are known as power cars.

Traditionally, locomotives pull trains from the front. Increasingly common is push-pull operation, where a locomotive pulls the train in one direction and pushes it in the other, and can be controlled from a control cab at the other end of the train.

Origins



First passenger railway, L&MR

The first successful locomotives were built by Cornish inventor Richard Trevithick. In 1804 his unnamed steam locomotive hauled a train along the tramway of the Penydarren ironworks, near Merthyr Tydfil in Wales. Although the locomotive hauled a train of 10 tons of iron and 70 passengers in five wagons over nine miles (14 km), it was too heavy for the cast iron rails used at the time. The locomotive only ran three trips before it was abandoned. Trevithick built a series of locomotives after the Penydarren experiment, including one which ran at a colliery in Tyneside in northern England, where it was seen by the young George Stephenson.

The first commercially successful steam locomotive was Matthew Murray's rack locomotive, *Salamanca*, built for the narrow gauge Middleton Railway in 1812. This was followed in 1813 by the *Puffing Billy* built by Christopher Blackett and William Hedley for the Wylam Colliery Railway, the first successful locomotive running by adhesion only. Puffing Billy is now on display in the Science Museum in London, the oldest locomotive in existence.

In 1814 George Stephenson, inspired by the early locomotives of Trevithick and Hedley persuaded the manager of the Killingworth colliery where he worked to allow him to build a steam-powered machine. He built the *Blücher*, one of the first successful flanged-wheel adhesion locomotives. Stephenson played a pivotal role in the development and widespread adoption of steam locomotives. His designs improved on the work of the pioneers. In 1825 he built the *Locomotion* for the Stockton and Darlington Railway, north east England, which became the first public steam railway. In 1829 he built *The Rocket* which was entered in and won the Rainhill Trials. This success led to Stephenson establishing his company as the pre-eminent builder of steam locomotives used on railways in the United Kingdom, the United States and much of Europe. The first inter city passenger railway, Liverpool and Manchester Railway, opened in 1830, making exclusive use of steam power for both passenger and freight trains.

Locomotives vs. multiple units

Advantages of locomotives

An early design of electric locomotive showing the steeplecab arrangement: North Eastern Railway No.1, England from 1905

There are many reasons why the motive power for trains has been traditionally isolated in a locomotive, rather than in self-propelled vehicles.

Ease
: Should the locomotive fail, it is easy to replace it with another. Failure or maintenance of the motive power unit does not require taking the entire train out of service.

Maximum utilization of power cars
: Idle trains waste costly motive power resources. Separate locomotives enable costly motive power assets to be moved around as needed.

Flexibility
: Large locomotives can be substituted for small locomotives where the grades are steeper and more power is needed. A 'passenger' locomotive can also be used for freight duties if needed, and vice versa.

Obsolescence cycles

Separating the motive power from payload-hauling cars enables one to be replaced without affecting the other. At times locomotives have become obsolete when their cars were not, and vice versa.

Safety

In case of an accident, the locomotive may act as buffer zone for the rest of the train. If an obstacle is encountered on the line, the heavier mass of a locomotive is less likely to be deviated from its normal course. Also it may be safer in the event of fire especially with diesel locomotives.

Noise

A single source of tractive power, which means only motors in one place, means that the train will be quieter than with multiple unit operation, where one or more motors are located under every carriage. The noise problem is particularly present in diesel multiple units.

Advantages of multiple units

There are several advantages of multiple unit (MU) trains compared to locomotives.

Energy efficiency

Multiple units are more energy efficient than locomotive-hauled trains and more nimble, especially on grades, as much more of the train's weight (sometimes all of it) is placed on driven wheels, rather than suffer the dead weight of unpowered coaches.

No need to turn locomotive

Many multiple units have cabs at both ends , the train may be reversed without uncoupling/re-coupling the locomotive, giving quicker turnaround times, reducing crew costs, and enhancing safety. In practice, the development of driving van trailers and cab cars has removed the need for locomotives to run-around, giving easy bi-directional working and removing this MU advantage.

Reliability

As multiple unit trains have multiple engines, the failure of one engine does not prevent the train from continuing its journey. A locomotive drawn passenger train typically only has one power unit, meaning the failure of this causes the train to be disabled. However, some locomotive hauled passenger trains may utilize more than one locomotive, as do many locomotive hauled freight trains, and so are able to continue at reduced speed after the failure of one locomotive.

Safety

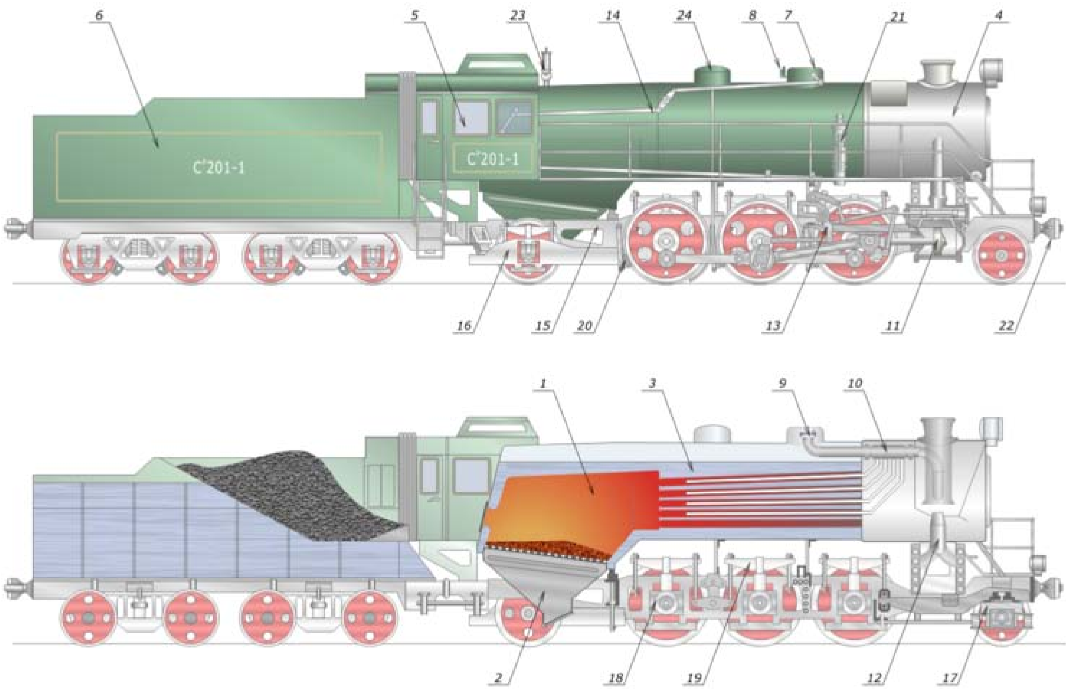
Multiple units normally have completely independent braking systems on all cars, meaning the failure of the brakes on one car does not prevent the brakes throughout the train from operating safely.

Locomotive classifications

Motive power

Locomotives may generate their power from fuel (wood, coal, petroleum or natural gas), or they may take power from an outside source of electricity. It is common to classify locomotives by their source of energy. The common ones include:

Steam



The main components of a steam locomotive

A steam locomotive at the Gare du Nord, Paris, 1930

Locomotive 030-219 of Renfe in Miranda de Ebro, Spain

In the 19th century the first railway locomotives were powered by steam, usually generated by burning coal. Because steam locomotives included one or more steam engines, they are sometimes referred to as "steam engines". The steam locomotive remained by far the most common type of locomotive until after World War II.

The first steam locomotive was built by Richard Trevithick; it first ran on 21 February 1804, although it was some years before steam locomotive design became economically practical.. The first commercial use of a steam locomotive was *The Salamanca* on the narrow gauge Middleton Railway in Leeds in 1812. The locomotive *Fairy Queen*, built in 1855 runs between Delhi and Alwar in India and is the oldest steam locomotive in regular (albeit tourist-only) service in the world, and the oldest steam locomotive operating on a mainline.

The all-time speed record for steam trains is held by an LNER Class A4 4-6-2 Pacific locomotive of the LNER in the United Kingdom, number 4468 *Mallard*, which pulling six carriages (plus a dynamometer car) reached 126 mph (203 km/h) on a slight downhill gradient down Stoke Bank on 3 July 1938. Aerodynamic passenger locomotives in Germany attained speeds very close to this and due to the difficulties of adequately balancing and lubricating the running gear, this is generally thought to be close to the practicable limit for a direct-coupled steam locomotive.

Before the middle of the 20th century, electric and diesel-electric locomotives began replacing steam locomotives. Steam locomotives are less efficient than their more modern diesel and electric counterparts and require much greater manpower to operate and service. British Rail figures showed the cost of crewing and fuelling a steam locomotive was some two and a half times that of diesel power, and the daily mileage achievable was far lower. As labour costs rose, particularly after the second world war, non-steam technologies became much more cost-efficient. By the end of the 1960s-1970s, most western countries had completely replaced steam locomotives in passenger service. Freight locomotives generally were replaced later. Other designs, such as locomotives powered by gas turbines, have been experimented with, but have seen little use, mainly due to high fuel costs.

By the end of the 20th century, almost the only steam power still in regular use in North America and Western European countries was on heritage railways largely aimed at tourists and/or railroad hobbyists, known as 'railfans' or 'railway enthusiasts', although some narrow gauge lines in Germany which form part of the public transport system, running to all-year-round timetables retain steam for all or part of their motive power. Steam locomotives remained in commercial use in parts of Mexico into the late 1970s. Steam locomotives were in regular use until 2004 in the People's Republic of China, where coal is a much more abundant resource than petroleum for diesel fuel. India switched over from steam-powered trains to electric and diesel-powered trains in the 1980s, except heritage trains. In some mountainous and high altitude rail lines, steam engines remain in use because they are less affected by reduced air pressure than diesel engines. Steam locomotives remained in routine passenger use in South Africa until the late 1990s, but are now reserved to tourist trains. In Zimbabwe steam locomotives are still used on shunting duties around Bulawayo and on some regular freight services.

As of 2006 DLM AG (Switzerland) continues to manufacture new steam locomotives.

Gasoline

Gasoline locomotives have been produced since the early 1900s.

Diesel

The EMD F40PH uses a Diesel-electric transmission designed by Electro-Motive Diesel.

Experimental diesel-powered locomotives were first built just after World War I. In the 1940s, they began to displace steam power on American railroads. Following the end of World War II, diesel power began to appear on railroads in many countries. In many countries the significantly better economics of diesel operation triggered a dash to diesel power, a process known as Dieselization. By the late 1960s, few major railroads in North America, Europe and Oceania continued to operate steam locomotives, although significant numbers still existed outside these areas.

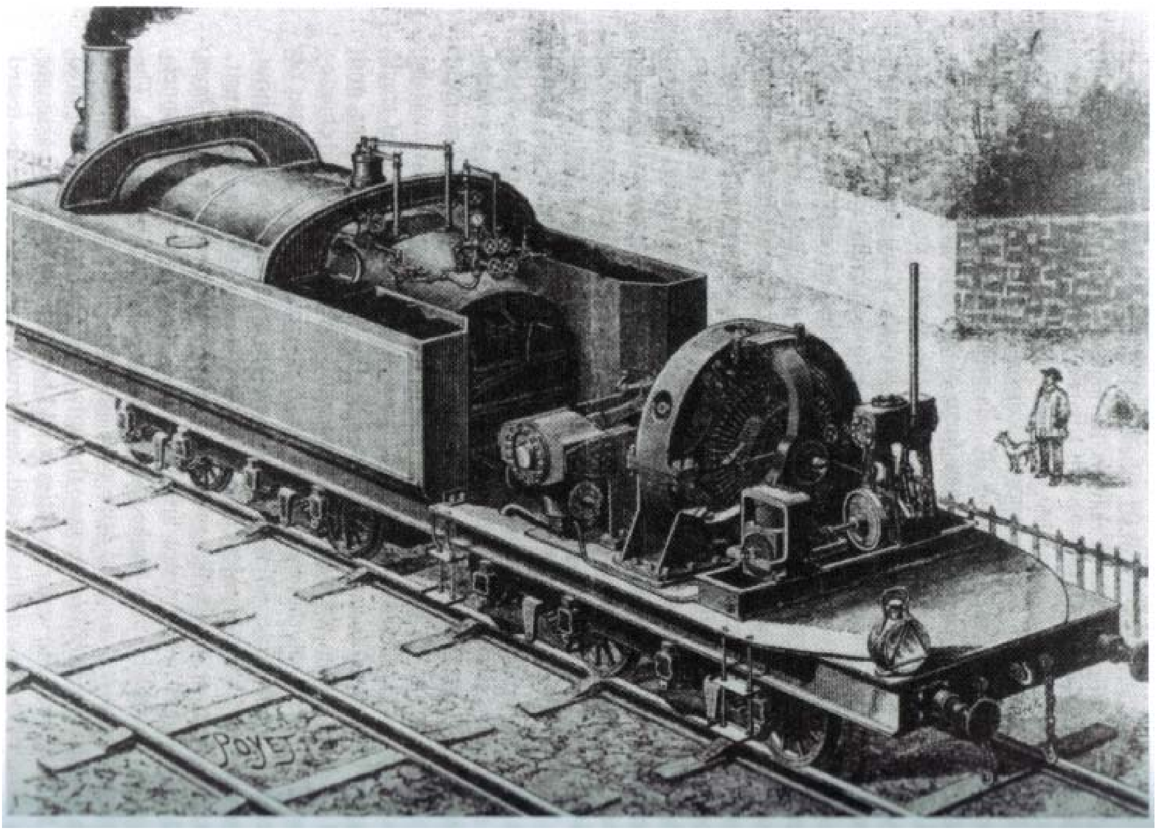
As is the case with any vehicle powered by an internal combustion engine, diesel locomotives require some type of power transmission system to couple the output of the prime mover to the driving wheels. In the early days of diesel railroad propulsion development, electric, hydraulic and mechanical power transmission systems were all employed with varying degrees of success. Of the three, electric transmission has proved to be most popular, and although diesel-hydraulic locomotives have certain advantages and are continuously used in some European countries, most modern Diesel-powered locomotives are diesel-electric.

Diesel locomotives require considerably less maintenance than steam, with a corresponding reduction in the number of personnel needed to keep the fleet in service.

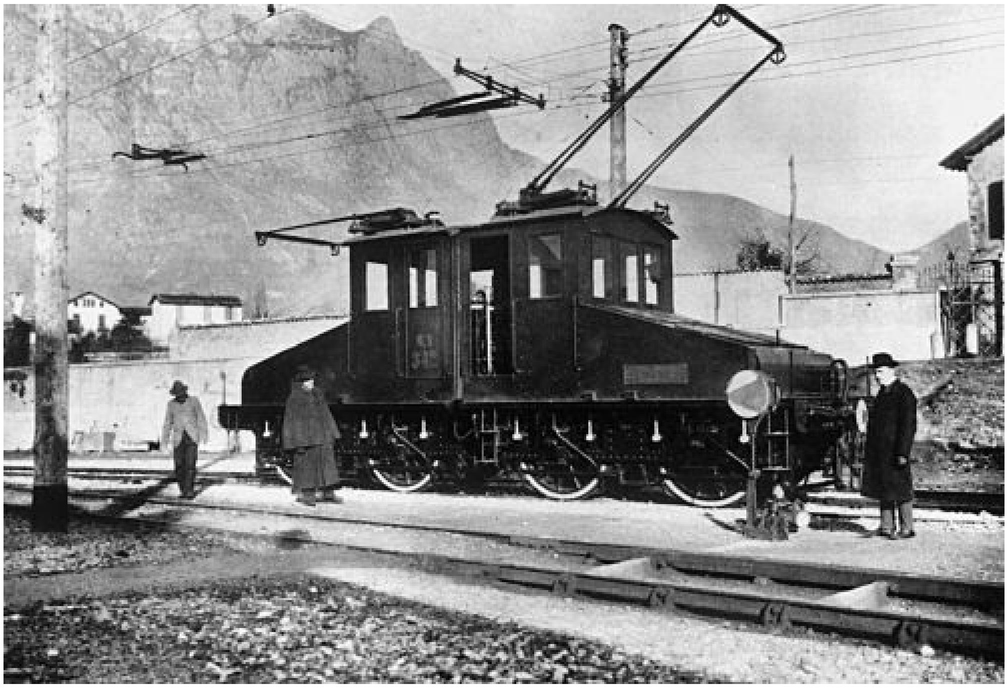
The best steam locomotives spent an average of three to five days per month in the shop for routine maintenance and running repairs. Heavy overhauls were frequent, often involving removal of the boiler from the frame for major repairs. In contrast, a typical diesel locomotive requires no more than eight to ten hours of maintenance per month. and may run for many years between heavy overhauls.

Diesel units are not as polluting as steam power; modern units produce low levels of exhaust emissions. Diesel-electric locomotives are often fitted with "dynamic brakes" that use the traction motors as electrical generators during braking to assist in controlling the speed of a train on a descending grade. This technology is similar to regenerative braking used in hybrid cars, the key difference being that dynamic braking does not store the generated power, instead routing it to resistors where it is converted into waste heat.

Electric



The "Fusée Electrique" of 1893, cab removed. Compounded pistons drove a Gramme-style dynamo powering electric motors on all axles. The small engine, right, was the exciter for the dynamo windings.



AC locomotive in Valtellina (1898-1902). Power supply: 3-phase 15 Hz AC, 3000V, (AC motor 70km/h). It was designed by Kálmán Kandó in Ganz Company, Hungary.

In 1893 in Paris Charles Brown assisted Jean Heilmann in evaluating AC and DC transmission systems for "Fusée Electrique", a steam locomotive with electric transmission, and using this knowledge he designed a three-phase AC electric locomotive for Oerlikon, Zurich. Brown (by then in partnership with Walter Boveri) put these into service on the first electrified main line, the Burgdorf—Thun line, Switzerland, in 1899. Each thirty-tonne locomotive had two 150 hp (110 kW) motors.

In 1894, a Hungarian engineer Kálmán Kandó developed high-voltage three phase alternating current motors and generators for electric locomotives. His work on railway electrification was done at the Ganz electric works in Budapest. The first installation was on the Valtellina line, Italy, in 1902. Kandó was the first who recognised that an electric train system can only be successful if it can use the electricity from public networks. After realising that, he also provided the means to build such a rail network by inventing a rotary phase converter suitable for locomotive usage.

The electric locomotive is supplied externally with electric power, either through an overhead pickup or through a third rail. While the capital cost of electrifying track is high, electric trains and locomotives are capable of higher performance and lower operational costs than steam or diesel power. Electric locomotives, because they tend to be less technically complex than diesel-electric locomotives, are both easier and cheaper to maintain and have extremely long working lives, usually 40 to 50 years – there are many examples of electric locomotives operating for more than half a century with minimal overhaul, and it is not unusual for electric locomotives to be operating close to their centenary. The Finnish State Railroad is planning to phase out the Soviet-manufactured VR Class Sr1 engines, operative since 1973, in 2024, at which time they will have been over fifty years in line service.

A French TGV holds the world speed record for the fastest wheeled train, having reached 574.8 km/h (357.2 mph) on 3 April 2007.

Some electric locomotives can also operate off battery power to enable short journeys or shunting on non-electrified lines or yards. Battery-powered locomotives are used in mines and other underground locations where diesel fumes or smoke would endanger crews, and where external electricity supplies cannot be used due to the danger of sparks igniting flammable gas. Battery locomotives are also used on many underground railways for maintenance operations, as they are required when operating in areas where the electricity supply has been temporarily disconnected.

Hybrids

The main reason why hybrid locomotives have been invented is because this eliminates the need for a mechanical transmission. Otherwise, a gearbox would be needed which is large, complicated and inefficient. A hybrid locomotive allows the internal combustion engine to run at a constant speed, turning an electrical generator which in turn powers an electrical engine.

Several types of internal combustion engine (ICE)-electric hybrids exist, including gasoline-electric, diesel-electric, and Gas turbine-electric

In addition, there are also fuel-cell-electric locomotives, forming a category on their own.

Besides hybrid locomotives which use only a fuelled power source (i.e. internal combustion engine, and a electrical engine , there are also hybrids that use a fuelled power source, battery and electrical engine. Here, the battery acts as a temporary energy store, allowing e.g. the implementation of regenerative braking and switching off the hydrocarbon engine when idling or stationary (as used in automobiles such as the Toyota Prius). Steam-diesel hybrid locomotives have been tried in Britain, Russia and Italy but with only limited success.

Gas turbine-electric

UP 68, one of Union Pacific's 4,500 hp 'veranda' turbines. From the Don Ross Collection

A gas turbine-electric locomotive, or GTEL, is a locomotive that uses a gas turbine to drive an electrical generator or alternator. The electric current thus produced is used to power traction motors. This type of locomotive was first experimented with in 1920 but reached its peak in the 1950s to 1960s. The turbine (similar to a turboshaft engine) drives an output shaft, which drives the alternator via a system of gears.

A turbine offers some advantages over a piston engine. The number of moving parts is much smaller, and the power to weight ratio is much higher. A turbine of a given power output is also physically smaller than an equally powerful piston engine, allowing a locomotive to be very powerful without being inordinately large. However, a turbine's power output and efficiency both drop dramatically with rotational speed, unlike a piston engine, which has a comparatively flat power curve.

Gas turbine locomotives are very powerful, but also tend to be very loud. Union Pacific Railroad operated the largest fleet of gas turbine-electric locomotives in the world, and was the only railroad to use them for hauling freight in regular service. Most other GTELs have been built for small passenger trains, and only a few have seen any real success in that role.

After the 1973 oil crisis and the subsequent rise in fuel costs, gas turbine locomotives became uneconomical to operate, and many were taken out of service. This type of locomotive is now rare.

Fuel cell-electric

In 2002 the first 3.6 tonne, 17 kW hydrogen (fuel cell)-powered mining locomotive was demonstrated in Val-d'Or, Quebec. In 2007 the educational mini-hydrail in Kaohsiung, Taiwan went into service. The Railpower GG20B finally is another example of a fuel cel-electric locomotive.

Slug or Drone

A slug or drone locomotive is a non-powered unit attached to a diesel-electric locomotive to provide additional traction and braking capability. The slug has traction motors but no engine, power being supplied by the attached locomotive (known as a 'mother'). At slow speeds, a diesel-electric prime mover can potentially produce more power than can be usefully used by its own traction motors; a slug increases the number of traction motors available to use the power more effectively.

Slugs are mainly used in rail yards for switching duties, in which case they are normally built without a cab. Other slugs, designed for use on service trains, may be fitted with a cab, which can control the whole consist, and may also provide additional fuel storage for the mother locomotive. In recent years, conventional locomotives have been used in place of slugs on service trains, remotely controlled from the lead locomotive configuration.

CP Rail used a prototype drone locomotive system called LOCOTROL which evolved into today's systems.

Use

A brass makers plaque from an Andrew Barclay locomotive of 1925.

The three main categories of locomotives are often subdivided in their usage in rail transport operations. There are passenger locomotives, freight locomotives and switcher (or shunting) locomotives. These categories determine the locomotive's combination of physical size, starting tractive effort and maximum permitted speed. Freight locomotives are normally designed to deliver high starting tractive effort—needed to start trains that may weigh as much as 15,000 tons—and deliver sustained high power, at the sacrifice of maximum speed. Passenger locomotives develop less starting tractive effort but are able to operate at the high speeds demanded by passenger schedules. Mixed traffic locomotives (US English: general purpose or road switcher locomotives) are built to provide elements of both requirements. They do not develop as much starting tractive effort as a freight unit but are able to haul heavier trains than a passenger engine.

Most steam locomotives are reciprocating units, in which the pistons are coupled to the drivers (driving wheels) by means of connecting rods. Therefore, the combination of starting tractive effort and maximum speed is greatly influenced by the diameter of the drivers. Steam locomotives intended for freight service generally have relatively small diameter drivers, whereas passenger models have large diameter drivers (as large as 84 inches in some cases).

With diesel-electric and electric locomotives, the gear ratio between the traction motors and axles is what adapts the unit to freight or passenger service, although a passenger unit may include other features, such as head end power (also referred to as hotel power or electric train supply) or a steam generator.

Some locomotives are designed specifically to work mountain railways, and feature extensive additional braking mechanisms and sometimes rack and pinion. Steam locomotives built for steep rack and pinion railways frequently have the boiler tilted relative to the wheels, so that the boiler remains roughly level on steep grades.

Operational role

Sometimes a locomotive will work in a specific role, such as:

- **Train engine** is the technical name for the locomotive which is attached to the front of a railway train for the purpose of hauling that train. Exceptionally, where operating facilities exist for push-pull operation, the train engine may be attached to the rear of the train;
- Pilot engine – a locomotive attached in front of the train engine, to enable Double-heading;
- Banking engine – a locomotive temporarily assisting a train from the rear, due to a difficult start or a sharp incline gradient;
- Light engine – a locomotive which is operating without a train behind it, usually because it needs to be relocated for operational reasons.
- Station pilot – a locomotive used for shunting passenger trains at a railway station.

Wheel arrangement

Wheel arrangement is one type of classification. Common methods include the AAR wheel arrangement, UIC classification, and Whyte notation systems.

Remote control locomotives

In the second half of the twentieth century remote control locomotives started to enter service in switching operations, being remotely controlled by an operator outside of the locomotive cab.

Locomotives in numismatics

Locomotives have been a subject for collectors' coins and medals. One of the most famous and recent ones is the 25 euro 150 Years Semmering Alpine Railway commemorative coin. The obverse shows two locomotives: a historical and a modern one. This represents the technical development in locomotive construction between the years 1854 and 2004. The upper half depicts the “Taurus”, a high performance locomotive. Below is shown the first functional Alpine locomotive, the Engerth; constructed by Wilhelm Freiherr von Engerth.

Locomotives

Steam locomotive B-5112 in Ambarawa Railway Museum, Indonesia

WDM-3A diesel passenger and freight locomotive of Indian Railways at Shantiniketan, India

Spanish modern electric locomotive with talgo cars; AVE Class 102 type train

EMD GP50 diesel-electric freight locomotive of the Burlington Northern Railroad

Swiss Electric Locomotive at Brig, Switzerland, note the Alps at top right corner

Chapter 2

Bilevel Rail Car

Double-deck rail car operated by GO Transit, Ontario, Canada

Bombardier double-deck rail cars in Germany, used extensively on suburban trains (here: S-Bahn Rostock)

The **bilevel car** (North American English) or **double-decker train** (British English) is a type of rail car that has two levels of passenger accommodations, as opposed to one, increasing passenger capacity (in example cases of up to 57% per car).

The use of double-decker carriages, where feasible, can resolve capacity problems on a rail line via rolling stock improvements - rather than via the other options of longer trains (which require longer stations), more trains per hour (which the signalling / safety requirements may not allow) or adding extra tracks besides the existing line (which is very expensive).

Bilevel trains have also been argued as improving the (ecologic) sustainability of rail transport, due to their higher efficiency, and some have even gone so far as to laud them as having saved some American transcontinental lines which would otherwise have been shut down for lack of (financial) efficiency.

However, the great height of the cars can limit their use, especially in countries with low loading gauges. Some countries like the United Kingdom are therefore intentionally constructing future lines (or upgrading existing lines) to higher gauge standards to enable double-decker trains. An other disadvantage that has sometimes been cited are issues that may be created at train stations when much larger numbers of passengers try to board or disembark at the same time.

Typical design

The double-deck design usually includes lowerering the bottom floor to below the top level of the wheels, closer to the rails, and then adding an upper floor above. Such as design will fit under more bridges, tunnels and power wires (structure gauge). For cost and safety, this design also minimizes car height (loading gauge) and lowers the centre of gravity.

Depending on train station platform heights, three designs can be used for entry - high platforms require use of a "split level" car design, where the doors are located on a middle level, with access into the upper or lower level branching off - with stairs or ramps going both up and down (sometimes this configuration includes a section of seating at the middle level in the entry section, with double levels only in part of the lengths of the car). For low train station platforms, a "two floor" design with level entry onto the lower floor is used. Occasionally a third, very tall "two floors over-wheel" design is used. This is a traditional single floor car "with a second story" design with, when using low platform, requires steps up to a traditional floor height and then internal stairs up to the upper floor.

Platform height and floor height issues

There are four important height measurements above the railhead: platform height, traditional floor height, downstairs floor height and upstairs floor height. Platform height determines the level entry height for wheeled objects, such as luggage, strollers, wheelchairs and bicycles. Platform height is ideally standardized across all stations the train serves. Traditional rail car floor height matters for end doors connecting to existing single floor rail cars. Downstairs or lowest floor height is primarily determined by the thickness of the beams connecting the span between the wheels and bogies (trucks) of a rail car. The upstairs floor or highest floor height is above the lowest floor and must fit under bridges and tunnels. Level entry floor height must match the platform height. Hopefully either the traditional or downstairs floor height already matches the platform height. Despite the name "bilevel" or "double-decker", for maximum compatibility the rail car will have up to four different floor heights. Using outside steps to avoid having a level entry from the platform is troublesome.

Common High Platform Design

Most high platform trains have level entry over the bogie with stairs inside the car for the upstairs and downstairs double-decker floors. These cars are designed for high platform rail line, such as all the existing stations with a standardized high platform and the rolling stock end doors that connect to any traditional single floor car and even roof line aerodynamics. There are three floor heights (upstairs, downstairs, and platform levels) in these "split level" cars. The entry level floor area has to be big enough to hold wheel chairs, children push-carts, and even wheeled luggage. This high platform "split level" double-decker design is the preferred design in urban and commuter applications, and can be designed to matched to any rail platform height. Car roof lines lengthwise are sloped at each end (not flat) for aerodynamic connection to single level cars and the space is unused. Bombardier commuter cars are 15 ft 11 in (4,850 mm) high.

Common Low Platform Design

Most low platform double-decker trains have level entry onto the lower level of the car, allowing wheelchair access. There are two floor heights (upstairs and downstairs) in these "bilevel" cars. There is a staircase between floors inside the car. Connecting doors between cars are at the (higher) upper floor height and not at the traditional height. These low platform cars use low platform stations across the Western US, because the traditional single floor trains all had exterior entry steps to maximize flexibility (emergency and temporary stops) and minimize infrastructure costs. There are no examples of two floor platforms, so there are no platform doors on the upper floor. Car roof lines lengthwise are flat for connecting doors to the upstairs of bi-level cars. Connecting directly to a single level car causes drag and connecting door problems. A Bombardier Amtrak Superliner car is 16 feet 2 inches (4,930 mm) tall.

Uncommon Very Tall Design

There are several very tall bilevel cars (e.g. Colorado Rail has 19 feet 9.5 inches (6.033 m) or 6033 mm). They typically are described as a traditional rail car with a second story. Most of these cars serve low platforms so they have exterior steps up to the traditional "over-wheel" floor height (e.g. US 51 in (1,300 mm). End doors connect at the traditional height of existing rolling stock. Some cars have upstairs end doors as well. Upstairs and downstairs connect by interior stairs. These cars can fit the most able people, but lack level entry. Some cars are self-propelled Multiple Units so using traditional floor heights appears fixed. In towed cars it is possible to lower the downstairs floor between the wheels/bogies so that level entry is possible with more than 500 mm of added headroom and interior steps from that floor to the traditional floor.

Alternatives

The alternatives to double-decker cars are usually explored first, before going double-decker.

- **Add cars to existing trains**: this works until platform and siding capacity has been used. Until that occurs, lengthening trains is preferable to changing the loading gauge and structure gauge of the rail line. Longer cars (without changing structure gauge) does not add much, because cars are often required to be narrower to negotiate curves. In countries with larger structure gauges for freight traffic (such as the United States) this is often less of a concern.

- **More trains**: increase the frequency of trains scheduled. This added flexibility compared to the same capacity via bilevel cars is generally very popular with passengers. However, it may cause congestion on the rail line, eventually preventing more capacity from being added in this way.

- **Changing seating**: fitting more (smaller) seats into the same space and/or decreasing the pitch (distance between seats) or removing seats completely on existing vehicles.

- **Track amplification**: building additional rail lines and platforms is expensive and often requires land acquisition and service disruptions.

If freight service has increased the structure gauge, and the rail line needs to minimize "per car" maintenance and staffing costs, double-deckers can pay for themselves more quickly than buying single-floor cars of equal capacity. Wheelchair accessibility laws encourage level entry solutions frequently provided by double-decker rail cars. Profitability is encouraging double-decker rail car adaptation before many alternatives.

Operators

Interior of a Cityrail Tangara carriage in Sydney

Australia

In 1964, Tulloch Limited built the first double-decker trailer cars for use in Sydney. They ran with single deck electric motor cars. The first prototype double deck motor car was built by Comeng in 1969 and production versions entered service in 1972. These were the first fully double deck Electric Multiple Unit passenger trains in the world. All CityRail electric commuter trains in Sydney are now double deck. They all have two doors per side per carriage, with a vestibule at each end at platform height. Well-known examples of these trains are the Tangara and Millennium trains. The Sydney double deck commuter trains are 14 ft 4.5 in (4,382 mm) high.

The Public Transport Corporation in Melbourne ordered a prototype Double Deck Development and Demonstration train in 1991. It suffered frequent breakdowns and spent long periods out of use. It was finally withdrawn in 2002 and scrapped in 2006.

Canada

Several regional commuter rail operators used bi-level cars in their fleet. GO Transit's passenger fleet are all Bombardier Transportation Bi-level cars. Others include:

- West Coast Express
- Agence métropolitaine de transport

Tour operator Rocky Mountaineer also uses bi-level cars.

Ontario Northland's Polar Bear Express operates a domed car that has two levels, but it is not technically a bi-level car.

AMT also operated Canadian Vickers bi-level cars and currently ordering Bombardier Transportation Multi-level cars.

Finland

Double-decker Inter City train in Finland

In Finland, VR began operating double-decker sleeping cars on 1 February 2006. The two-bed cabins on the upper deck have toilets and showers while cabins on the lower deck use shared ones. VR also operates double-decker InterCity trains with at seat power supplies for laptops.

France

French suburban double-deck train.

The Chemin de Fer de l'État in France ran voitures à 2 étages double-deck suburban coaches from 1933. Its successor, the SNCF, has been running VB2N double-decker coaches since 1975; VB2N were introduced from 1975 as a replacement of the État cars.

Since the late 1980s, SNCF has been running double-deck RER trains. SNCF runs double-deck TGV cars on heavily used high-speed services. Many suburban, regional and high-speed services are operated by double-deck DMUs, EMU, coaches and TGV. The French loading gauge dictates that the double-deck cars have a maximum height of 4200 mm or 13'-9.35".

Hong Kong

MTR and formerly KCRC operates double-decker carriages with the KTT train sets. These cars were manufactured in Japan by Kinki Sharyo T1 (T1C), T2 (T2A, T2B).

Japan

Kintetsu 30000 series Vista Car introduced in 1978

In Japan, double-decker trains are used either to show better scenery, or to increase seat capacity.

For scenery viewing

The first Japanese double-decker train appeared in 1904. It was Type 5 train of Osaka City Tram, once operated by Osaka Municipal Transportation Bureau. The tram car, however, soon took away its second floor, due to the complaints by residents along the line, concerning their privacies.

The first double-decker heavy rail train, the Kintetsu 10000 series, appeared in 1958. The series, nicknamed "Vista Car", became popular trains used for limited express services. Its successors are still used by Kintetsu. The idea of Vista Car is said to come from Vista Dome Car in United States. The first double-decker high-speed rail in the world was JNR 100 Series Shinkansen used from 1986. The train was purely introduced to improve its luxury. The upper floor of the train was used for Green car accommodation and a dining car.

Other double-decker sightseeing trains include the JR Shikoku 5000 series, JR Hokkaidō KiHa 183 series, Keihan 8000 series, JR Central 371 series, and Odakyū 20000 series RSE.

A similar kind of trains are largely single-decker trains with vehicle cockpit domes on the "second floor", to allow the better front view. This kind of trains include Panorama Cars by Meitetsu, Romancecars by Odakyū, and *Mount Fuji Limited Express* by Fujikyū.

For increased capacity

E4 series Shinkansen

The first Japanese double-decker trains built to increase its capacity were 211 series and 113 series, both by JR East, 1989. These trains were *Green Cars* (Japanese for first class cars), needing more seats than standing spaces. JR East also introduced an experimental 415 series double-decker car with normal class seats on the Jōban Line in 1991, and the 215 series EMUs for *Home Liner* services in 1992. JR East continues to use double-deckers, including E217 series for Sōbu Line (Rapid) and Yokosuka Line, E231 series for Tōkaidō Main Line, Utsunomiya Line (Tōhoku Main Line), Takasaki Line, and Shōnan-Shinjuku Line, and E531 series for the Jōban Line.

In Japan, however, double-decker commuter trains are relatively fewer than those used in Europe or North America. This is because Japanese commuter trains can be much more crowded than Western counterparts. Therefore, they generally need more standing spaces than seats. Also, Japanese train cars are 20 m long or less, and it is technologically difficult or inefficient to have more than 2 doors on each side of double-deckers that size. Japanese crowded trains, however, generally need 4, 5, or 6 doors on each side to make smooth boarding and alighting.

JR East also introduced E1 Series and E4 Series for its Shinkansen Lines. Unlike 100 Series in the past, these trains, nicknamed "Max", all consist of double-decker cars, and are purely made to increase their capacities. In that sense, these trains are similar to TGV Duplex in France. There are also some double-decker sleeping cars made to increase their beds or compartments, like CityNightLine trains in Europe. This includes JR West 285 series EMUs for *Sunrise Izumo/Sunrise Seto* and JR East E26 series cars for *Cassiopeia* services.

Sweden

X40 arriving in Eskilstuna.

SJ AB operates 43 double-decker EMUs built by Alstom and designated class X40. The EMU comes in a two-coach version and a three-coach version. The trains are mainly used in regional trains in the areas around lake Mälaren and in the trains between Gävle and Linköping. It has a maximum speed of 200 km/h (125 mph) and are equipped with wireless internet.

Between 1966 and 1990 SJ used DMUs of class Y3 with double-decker end cars and normal cars in between. Due to the to distinct humps on the endcars it was nicknamed "the camel".

Switzerland

IC 2000 between Zürich and Luzern with the control car leading the train

Double-decker commuter trains are used by the Zürich S-Bahn. Two types of trains are used, an older type consisting of an electric locomotive with double-decker cars, and Electric Multiple Units (DMU or EMU) where the motors are on board the car. From 2010 onwards, a third type – the Stadler DOSTO – is scheduled to enter service.

The Swiss Federal Railways also operate the IC 2000 double-decker passenger coaches in most of Switzerland.

United Kingdom

In the United Kingdom, and countries with a similarly small loading gauge, the railway system cannot accommodate double-deck trains. A modest attempt at double decking was made in 1948 on the Southern Railway with the two trains of the Bulleid 4DD class. Although innovative, with stepped compartments, where the bottoms of the upper seats are above the heads of the people on the lower level, but the feet of the people above are not, see, the loading gauge severely restricted their use and they were removed from service in 1971. However, the Channel Tunnel Rail Link (High Speed 1) was built to European loading gauge standards and is therefore capable of taking double-decker trains. However, nobody has yet expressed an interest in running double-decker trains along this line.

Double-decker trams were common in British cities prior to the dismantling of the networks between the 1930s and 1960s.

USA

Multi-level New Jersey Transit train with quarter-point and end doors.

Passenger cars are manufactured by Bombardier, Kawasaki, Colorado Railcar, IC2000, and several others, with the former two having produced the majority of the High platform "split level" commuter rail cars in use in the Northeast US.

Colorado Railcar make DMUs and IC2000, of Switzerland, make EMUs, where the Multiple Units are self-propelled cars, much like subway cars. Colorado Railcar cars are very tall (19 ft 9.5 in or 6,033 mm) cars for low platforms with steps entry to a normal (51 in or 1,300 mm) floor and an upstairs. The IC2000 cars are strictly low platform design.

Other designs, including rolling stock made by Colorado Railcar Manufacturing, Budd, Pullman-Standard, Bombardier and others, have the entrance on the lower deck rather than an intermediate level. Amtrak Superliners are double-decker cars of this variety, with the entrance a step or so up from the lowest station platform level, or at the level of slightly higher platforms, and allow passage from car to car at upper-deck level.

The northeastern US can accommodate split level (double deck) cars only if they are no higher than 14.5 ft (4,420 mm) due to loading gauge restrictions (i.e. bridges, tunnels, etc. are too low). Bi-level cars that run on the Long Island Rail Road and on New Jersey

Transit were built by Bombardier Transportation to clear these height restrictions. The designs found on these two railroads are based on a 1930s Pullman Sleeping Car design for the Pennsylvania Railroad called a Duplex Sleeper. This design provided 24 Roomettes on two levels with the lower level depressed between the trucks. This idea was copied in 1947 for the Long Island Rail Road, making use of a standard P-70 that was electrified. Current bi-level cars have the entire center sill lowered to the minimum level between the trucks, providing a depressed floor on that level. The upper level is stacked on top between the trucks. At each end, the a common floor is located at normal height over the trucks. While Long Island Rail Road's cars have only two quarter-point doors on each side for high level platforms, New Jersey Transit's cars have four doors on each side, two quarter-point doors at high level platform height and two in the normal Vestibular position, with stairs to reach low level platforms. Similarly the structure gauge of the Mount Royal Tunnel limits the height to 14'-6" or 4420 mm. The Massachusetts Bay Commuter Rail is the only operator on the Northeast Corridor who operates bi-level cars that exceed the 14.5 ft (4,420 mm) loading gauge restriction. The bi-level cars in use by the MBCR were produced by Kawasaki Rail Car, Inc. and have a similar configuration to those used by the LIRR and NJ Transit, but differ in that they only have vestibular side-loading doors.

The double deck cars operated by Chicago's Metra regional rail service are known as "gallery cars" as there is an open space between the two sides of the upper deck, allowing ticket collectors to check tickets on both levels from the bottom level. Chicago does not have the loading gauge problems that affect most eastern US cities (although ex-Metra cars operate on MARC in Baltimore, Maryland), so all Chicago's commuter rail rolling stock is full size bi-level, and many of Amtrak's Superliner trains to the western USA originate from Chicago.

The first bi-level gallery cars were introduced by the Chicago, Burlington & Quincy railroad in 1950.

Other countries

Dutch bilevel train at station Amsterdam Bijlmer ArenA

In the Netherlands, there are two types of double-deck trains, the DDM and the DD-IRM, also called Regiorunner. The DD-IRM, is an example from the Netherlands, of High platform (split level) double-decker cars. It is one step up from the station platform to the entrance, and from there seven steps upstairs or four steps downstairs.

In Spain several lines of Cercanías (Renfe's commuter rail service) use double-deck trains. Bombardier's double-deck rail cars in Germany are also used extensively on suburban trains by the DB. The same rail cars serve some of the routes on the Israel Railways network, hauled by diesel locomotives and include electric generators housed in the control car.

In Iran, the Tehran-Hashtgerd suburban commuter line is served with electric push-pull hauled trainsets with double-decker carriages manufactured by Wagon Pars in Iran.

In Hong Kong, the Kowloon-Canton Railway Corporation uses double-deck cars, named "Ktt", on its cross-boundary route between Kowloon and Guangzhou. In January to May 1998 the "Ktt" cars were used to serve between the Hung Hom and Lo Wu stations. The "Ktt" cars have lower bottom floor than the ordinary single-deck cars serving on the same pair of tracks.

In China, Changchun Railway Vehicles offers a double deck coach, Type SYZ25B, that is similar to Superliner (railcar).

In India, the Flying Ranee, a passenger Train between Surat and Mumbai Central on the Western Railway Track uses double-deck cars.

Russian Railways plan to start using double-deckers in 2011 manufactured by Transmashholding in cooperation with Alstom.

Gallery cars

A Nippon Sharyo bi-level passenger car operated by Caltrain

Because of the two levels being separate on most cars, there is a physical limitation on the conductor, as it is difficult for him to verify, collect payment and sell tickets to such a large concentration of passengers in one car on each level, owing to the sometimes short distance between stops.

A solution came in the form of the design of the "gallery" car, which features upper levels, which are "mezzanines" or "balconies" running along both sides of the car, with an open area between them. Some gallery cars have up to four separate galleries (one on each side, times two for access from each end).

This enables the conductor(s) walking along on the lower level to easily reach up and punch or validate tickets of the passengers seated on the mezzanine level. Passengers can place their tickets in clips along a lengthwise panel, located slightly above the conductor's head and within easy reach. The conductor can then quickly check tickets and move to the next car.

Another advantage of bilevel gallery cars is the relatively low first step of the vestibule entrance to the car, which is 14⅝ inches (371 mm) above the head of the rail. The advantage of this is that commuter rail operators do not have to spend funds on building high-level platforms; a low-level platform is all that is necessary, at a far lower cost. This can be a major disadvantage as well, as many commuter rail systems prefer high-level platforms as they can decrease loading and unloading times substantially, and greatly improve access to trains for the disabled.

Such cars are used by Metra in and around Chicago, Caltrain, and Montreal's Agence métropolitaine de transport. They provide high capacity (155 to 169 passengers each). Chicago's commuter rail system is currently receiving new versions of these cars and Caltrain, the San Francisco peninsula commuter rail service, has recently overhauled its fleet. Virginia Railway Express (VRE) and MARC Train in Maryland are also owners of gallery cars in the Washington DC Area. Many of the gallery cars these commuter railroads use are ex-Metra cars.

Downsides of gallery cars are the often narrow and difficult access to the seats.

In container transport

Similar to passenger cars, one may also have bilevel cargo cars. In intermodal freight transport, many modern types of container well cars cars are designed to accommodate "double-stacking." Where passengers and freight rail use the same lines, containers may have required increasing the lines' structure gauge. Passengers and freight are usually separated. Containers are 8 feet (2.4 m) wide and 8.5 feet (2.6 m) tall or sometimes 9.5 feet (2.9 m) tall. Therefore double stack freight is 17, 18 or 19 feet (5.8 m) above well car floor height.

Chapter 3

Control Car (Rail)

Modern German InterCity *Steuerwagen* cab car.

A **control car** is a generic term for a non-powered railroad vehicle that can control operation of a train from the end opposite to the position of the locomotive. They can be used with diesel or electric motive power, allowing push-pull operation without the use of an additional locomotive.

Cab cars are control cars similar to regular passenger car, but with a full driver's compartment built into one or both ends. They can be very similar to regular railcars, to the point of including a gangway between cars so that they could be used in the middle of a passenger train like a regular car if necessary. They appeared for the first time in the United States and France in the 1960s.

Trains operating with a locomotive at one end and a control car at the other do not require the locomotive to run around to the opposite end of the train when reversing direction at a terminus. Control cars can carry passengers, baggage, mail or a combination thereof, and may contain an engine-generator set to provide head end power.

In addition to the driver's cab, which has all the controls and gauges necessary for remotely operating the locomotive, control cars usually have a horn, whistle, bell, or plough (as appropriate), and all of the lights that would normally be on a locomotive.

Control method

In Britain, a common method is to control the train through a Time-Division Multiplexed (TDM) connection. In North America and Ireland a standard AAR 27-wire multiple unit cable with jumpers between cars is the preferred method.

North America

Some commuter rail agencies in the United States routinely use cab cars in place of regular passenger coaches on trains. The Chicago and North Western Railway had 42 control cabs built by Pullman-Standard in 1960, which eliminated the need for its trains or locomotives to be turned around. It was an outgrowth of multiple-unit operation that was already common on diesel locomotives of the time.

During the mid-1990s, as push-pull operations became more common in the United States, cab-cars came under criticism for providing less protection to engine crews during grade crossing accidents. This has been addressed by providing additional reinforcing in cab cars. This criticism became stronger after the 2005 Glendale train crash, in which a Metrolink train collided with a Jeep Cherokee at a level crossing. The train was traveling with its cab car in the front, and the train jacknifed.

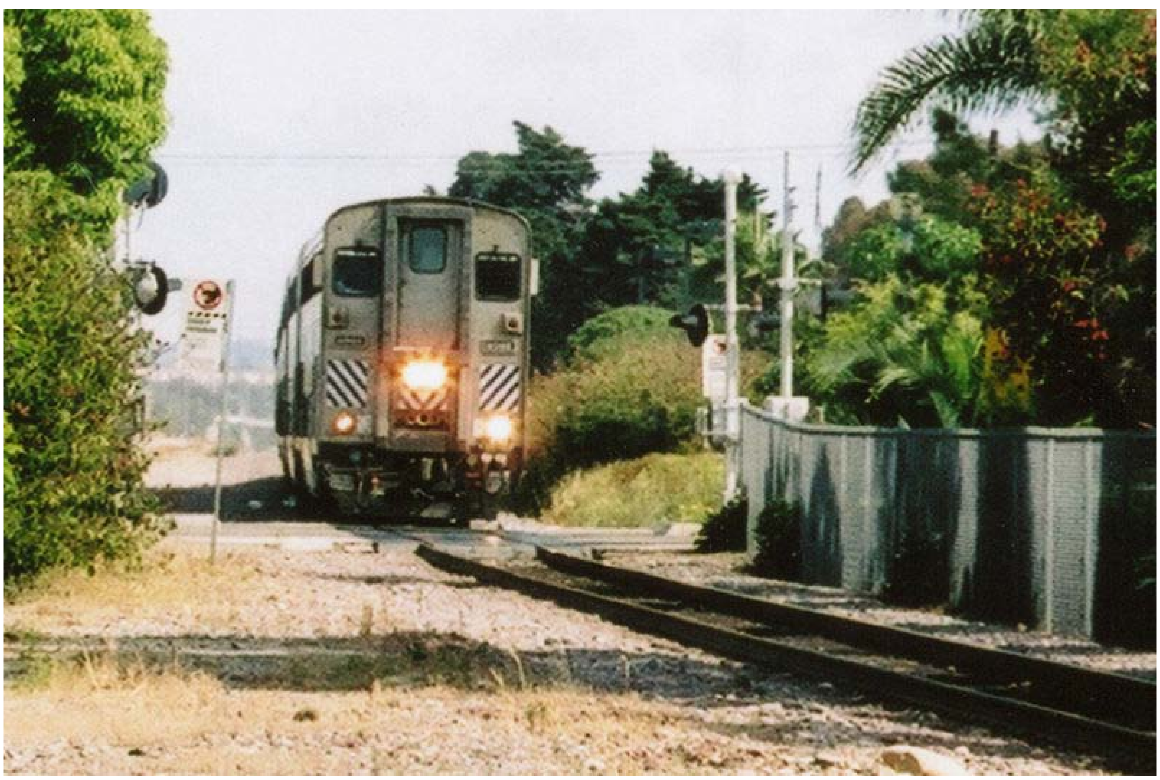
Amtrak non-powered control unit (NPCU) No. 90218 in Galesburg, Michigan.

Converted locomotives

From the 1970s until 1999, the Long Island Rail Road used a number of older locomotives converted to "power packs". The original prime movers were replaced with 600 horsepower (450 kW) engines/generators solely for supplying Head End Power or HEP with the engineer's controls left intact. Locomotives converted included Alco FA-1s, FA-2s, EMD F7s and one F9. Ontario's GO Transit had a similar program for EMD FP7s.

Amtrak developed their Non-powered Control Units (NPCUs) by removing the prime mover, main alternator, and traction motors from surplus F40 locomotives. The control cab was left in place, as were equipment allowing horn, bell & headlight operation. A floor and roll-up side-doors were then installed to allow for baggage service leading to the nickname "cab-baggage cars" or "cabbages."

Northstar Line cab car (BiLevel Coach) in Elk River, Minnesota



Pacific Surfliner cab car in Carlsbad, California

NJ Transit Comet V Cab Car in Bay Head, New Jersey

Europe

In Britain, this type of car is called a *driving trailer* and mostly this term is also used on the Continent. There are many examples of this type of vehicle in operation in Europe.

Austria

Austrian NPZ EMU Steuerwagen of the Montafonerbahn in Schruns

The Steuerwagen of the Austrian CityShuttle in Lower Austria

Belgium

SNCB make extensive use of push-pull working. Trains are powered by class 27 or class 13 electric locomotives and are operated in one direction from a driving carriage.

Germany

The German term for control cars is *Steuerwagen*.

The first German attempts to use control cars and remote control-equipped steam locomotives were before the Second World War by the Deutsche Reichsbahn (DRG). The driver's control instructions were transmitted from the control car to the locomotive by a Chadburn-type machine telegraph (similar to engine order telegraphs on ships). The order had to be immediately acknowledged and implemented by the automatic firebox controllers. This indirect control was judged as impractical and unsafe because, although the driver controlled the brake directly, the danger existed that in an emergency the locomotive would continue supplying "push" power for some time and possibly derail the train.

Attempts to use electric locomotives (beginning with a converted E 04 class model) were more promising, as the engine driver could control the locomotive directly. World War II interrupted the test program, despite good successes. Only after the war would control car operation be slowly accepted, when locomotives and suitably equipped cars became available.

The length of train consists in push-pull operations was originally limited to 10 cars for reasons of guidance dynamics. A speed limit of 120 km/h was also imposed, rising to 140 km/h in 1980. This was not an operational hindrance, as push-pull trains were generally initially used in six-car commuter trains.

Only since the mid 1990s have long-distance trains, which can have up to 14 cars and travel at speeds of 200 km/h, been operated with control cars. A special circumstance is the ICE 2, which may operate with the control car in the lead at up to 250 km/h on the recently built high-speed lines.

ICE2 Steuerwagen at Cologne-Bonn Airport

Different livery on a double-decker German Steuerwagen

German InterRegio livery in Heidelberg

Modern German version in an older livery

Frontal view of the German model

A German commuter train clearly showing the locomotive driving from the rear

Ireland

Iarnród Eireann operates three classes of push-pull trainsets, each with its own Control Car:

- Mk 3 with driving cab containing replica locomotive control stand, luggage compartment, under-slung Cummins engine / generator set for train heating and passenger seating.
    - Numbered 6101 - 6105, converted from Mk 3 intercity cars for suburban push-pull service.
- De Dietrich (Enterprise service) with driving cab containing EMD control stand, luggage compartment and passenger seating. On this set, train heating is supplied from the locomotive Head End Power System.
    - Numbered 9001 - 9004
- CAF (Mk IV) with driving cab containing replica locomotive control stand, luggage compartment and twin engine / generator sets for train heating. No passenger seating is provided.
    - Numbered 4001 - 4008

All the Control Cars have full-sized driving cabs with EMD locomotive type power and brake controls. Locomotive control is by means of an AAR system, modified by Iarnród Éireann (IE) to include control of train doors and operate with IE 201 Class locomotives.

An Enterprise DVT at Dublin Connolly

CAF Control Car (GC), 2006

Italy

In Italy the first push-pull trains began to run after World War II.

At the time there were no systems to actually remote command the rear locomotive, so an engineer had to take place in it and command traction, following instructions (via an apposite intercom) given by the other driver, who remained in the front car, commanding brakes and sighting signals. This lasted until the adoption of the 78-wire cable in the 1970s, which enabled full remote commanding from control cars.

Today push-pull trains are very common, and different kinds of control cars are employed:

- **UIC Z1** control cars.
- **MDVC** type control cars, with aerodynamic or communicating cabin.
- **Piano ribassato** type control cars, with flat, refurbished E464-like or communicating cabin.
- **Doppio Piano** two floors control cars.
- **UIC-X** type control cars.
- **Vivalto** type control car.

These types allow full remote control of any Italian locomotive supplied with standard 78-wire cable, except for UIC Z1, which are used on IC services and are only able to command class E.402 locomotives, and MDVC diesel specific version, usable only with class D.445 diesel locomotives.
The same driving commands are used for both rheostatic and electronic locomotives, but their meanings change.

Vivalto type control cars, at this time, can only remote command Class E.464 and Class E.632 locomotives, because of software issues, tough are able to command other locomotive types. Vivalto cars can also use TCN remote control cable.

Driving cars can be recognized because of the "**np**" in their identification number and usually also have a dedicated compartment for bicycle and luggage transportation.

There also are specific EMU/DMU non-motorized units control cars, which (in Trenitalia) are classified as Le / Ln XXX; no significant difference between them and motorized units, except the lack of traction motors.

Trenitalia refurbished Piano Ribassato driving carriage with E.464-like cabin.

Two floors driving carriage in Udine station in 1997.

Trenitalia UIC-Z1

The Netherlands

NS use their driving carriages in two different strategies.

For short distance trains they use a "virtual EMU" concept. Train sets are formed of a driving carriage, two or three intermediate carriages and either a class 1700 electric locomotive or an EMU motor vehicle. These train sets are diagrammed as if they were all EMUs resulting in formations with two locomotives, often at intermediate positions in the train.

For longer distance workings, including the Benelux services to Brussels the more normal mode of operation is used.

Switzerland

Swiss driving trailers operate in many different configurations. There are several models currently in service on S-Bahn networks as well as regional, InterRegio, and InterCity services. These are operated by the federal railway system (SBB) as well as various private railroads throughout the country (including narrow gauge lines) and into France, Germany, and Italy.

Driving trailers are classified after the UIC-lettering system, adding a "t," giving *Bt* (second class), *BDt* (second class + baggage), *ABt* (first + second class), or *Dt* (baggage).

For Intercity trains there are the Bt IC that work together with EW IV and the double-deck version for the IC 2000 trainsets, working with Re 460.

The Zürich S-Bahn trainsets with Re 450 work in fix consists of Re 450 - B - AB - Bt but intermediate cars and driving trailers are numbered as coaching stock.

"NPZ" Regional and S-Bahn trains with RBDe 560 usually have a matching Bt driving trailer. Replacement by an older BDt EW I/II is technically possible. Older driving trailers, mostly BDt EW I/II and a few remaining Dt of SBB can be used with Re 420 and RBe 540 and some motive power of private railways. In theory also Re 430 and Re 620 can be controlled but these classes only work freight trains today.

The BLS operates four groups of driving trailers:

- ABt NPZ to go with RBDe 565 and RBDe 566 II (ex RM)
- ABt of a modified type EW I for RBDe 566 I (ex RM)
- Bt EW III, BDt EW II (both ex SBB), Bt EW I 901-902 (ex Thurbo/MThB) and leased Dt from SBB can work with Re 420.5 ex SBB and BLS Re 465.
- Bt EW I 950-953, BDt 940-941, car-shuttle BDt 942-945, 946-949 and 939 can work with Re 425, Ae 4/4 and Re 465

Südostbahn had a fleet of ABt for their BDe 4/4 but they will soon be fully replaced by FLIRTs. NPZ ABt exist for the two types of RBDe 566 SOB ownes (566 071-076 ex BT and 566 077-080 ex SOB of the SBB-type). Nine BDt are used for the Voralpen-Express with Re 456, Re 446 or SBB-CFF-FFS Re 420.

The narrow gauge Zentralbahn ABt can control HGe 101 (ex SBB), De 110, BDeh 140 (ex LSE) and the new "SPATZ" ABe 130.

The Rhaetian Railway (RhB) has, besides the ABDt that work with Be 4/4 511-516, a group of driving trailers that can be used with their Ge 4/4 I, II and III locomotives. Three of them are specially fitted for Vereina car shuttle trains.

The Matterhorn-Gotthard-Bahn (MGB) has numerous driving trailers for almost all types of motive power. They work regional trains and car shuttle trains through the Furka Base Tunnel.

The Swiss Bt IC model in Zürich

Double-decker Swiss IC 2000 Steuerwagen

S-Bahn Zürich double decker

Swiss NPZ Steuerwagen in Biel

SBB BDt Steuerwagen near Wil

Swiss MThB Bt EW I Steuerwagen in Konstanz

The BLS Bt EW III (former Swiss Express)

An ABt Steuerwagen ex Furka-Oberalp for Deh 51-55 and 91-96 in Andermatt

Bt ex BVZ for Deh 4/4 21-24 at Stalden in the Valais

United Kingdom

Control cars have been in use in the United Kingdom for many decades, with the Great Western Railway often using 'autocoaches' on branch line services. These allowed a train driver to remotely control the regulator and reverser of a suitably equipped locomotive. The fireman remained on the locomotive to operate the boiler and locomotive whistle. Locomotives were commonly sandwiched between a pair of autocoaches, allowing a maximum of four to be used.

- **Driving Brake Standard Open**

A Driving Brake Standard Open or **DBSO** is a specially converted passenger car. These have not been used on mainline passenger trains since 2006, but some have been refurbished for use on Network Rail test trains.

DBSO 9710 at Norwich

DBSO in different livery

- **Driving Van Trailer**

A Driving Van Trailer or **DVT** is a more modern type of control car, purpose-built to include space for baggage and a guard's office. The DVT was developed from the DBSO and originally designed to be used with British Rail Mark 3 and Mk 4 coaches. DVTs are in service with East Coast (Mk 4), Virgin Trains (Mk 3), National Express East Anglia (Mk 3) and Wrexham & Shropshire (Mk 3).

New Zealand

In Auckland, Veolia (New Zealand) operates 14 DC class locomotives (owned by KiwiRail) in push-pull mode with 12 sets (2 more on order) of 2-4 (generally 3) SA cars and an SD driving car with driving cab and remote controls (ex British Rail Mark 2 carriages rebuilt for suburban service), owned by ARTA.

Chapter 4

Railroad Car

American Wooden passenger car

British Mark 3 rail coach; an all-steel car from the 1970s

Inside a modern day car from Finland

A **railroad car** (US) or **railway vehicle** (UK and international), also known as a **bogie** in Indian English, is a vehicle on a rail transport system (railroad or railway) that is used for the carrying of cargo or passengers. Cars can be coupled together into a train and hauled by one or more locomotives. Passenger cars can be self-propelled in which case they can be single railcars or multiple units.

Most cars carry a "revenue" load, although "non-revenue" cars exist for the railroad's own use, such as for maintenance-of-way purposes. Such uses can generally be divided into the carriage of passengers and of freight. "Revenue" cars are basically of two types: **passenger cars**, or **coaches**, and **freight cars** or **wagons/trucks**.

Passenger cars

Passenger cars, or coaches, vary in their internal fittings:

In standard gauge cars, seating is usually between three and five seats across the width of the car, with an aisle in between (resulting in 2+1, 2+2 or 3+2 seats) or at the side. Tables may be present between seats facing one another. Alternatively, seats facing the same direction may have access to a fold-down ledge on the back of the seat in front.

- If the aisle is located between seats, seat rows may face the same direction, or be grouped, with twin rows facing each other. Sometimes, for example on a commuter train, seats may face the aisle.
- If the aisle is at the side, the car is usually divided in small compartments. These usually contain 6 seats, although sometimes in second class they contain 8, and sometimes in first class they contain 4.
- In vehicles intended for commuter services seats are sometimes placed with their backs to the carriage side. This gives a wide accessway and standing room which accommodates standing passengers at peak times and improves loading and unloading speeds.

Passenger cars can take the electricity supply for heating and lighting equipment from two main sources - either directly from a head end power generator on the locomotive via bus cables; or by an axle powered generator which continuously charges batteries whenever the train is in motion.

Modern cars usually have either air-conditioning or windows that can be opened (sometimes, for safety, not so far that one can hang out), or sometimes both. Various types of onboard train toilet facilities may also be provided.

Other types of passenger car exist, especially for long journeys, such as the dining car, parlor car, disco car, and in rare cases theater and movie theater car. In some cases another type of car is temporarily converted to one of these for an event.

Observation cars were built for the rear of many famous trains to allow the passengers to view the scenery. These proved popular, leading to the development of dome cars multiple units of which could be placed mid-train, and featured a glass-enclosed upper level extending above the normal roof to provide passengers with a better view.

Sleeping cars outfitted with (generally) small bedrooms allow passengers to sleep through their night-time trips, while couchette cars provide more basic sleeping accommodation. Long-distance trains often require baggage cars for the passengers' luggage. In European practice it used to be common for day coaches to be formed of compartments seating 6 or 8 passengers, with access from a side corridor. In the UK, Corridor coaches fell into disfavor in the 1960s and 1970s partially because open coaches are considered more secure by women traveling alone.

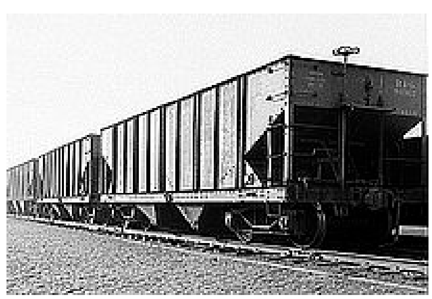
Another distinction is between single- and double deck train cars. An example of a double decker is the Amtrak superliner.

A "trainset" (or "set") is a semi-permanently arranged formation of cars, rather than one created 'ad hoc' out of whatever cars are available. These are only broken up and reshuffled 'on shed' (in the maintenance depot). Trains are then built of one or more of these 'sets' coupled together as needed for the capacity of that train.

Often, but not always, passenger cars in a train are linked together with enclosed, flexible gangway connections that can be walked through by passengers and crew members. Some designs incorporate semi-permanent connections between cars and may have a full-width connection, making in essence one longer, flexible 'car'. In North America, passenger equipment also employ tightlock couplings to keep a train reasonably intact in the event of a derailment or other accident.

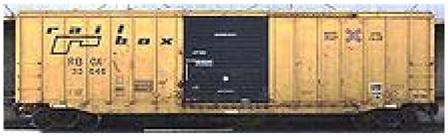
Many multiple unit trains consist of cars which are semi-permanently coupled into sets; these sets may be joined together to form larger trains, but generally passengers can only move around between cars within a set. This "closed" nature allows the separate sets to be easily split to go separate ways. Some multiple-unit trainsets are designed so that corridor connections can be easily opened between coupled sets; this generally requires driving cabs either set off to the side or (as in the Dutch *Koploper*) above the passenger compartment. These cabs or driving trailers are also useful for quickly reversing the train.

Freight cars



American style Hopper Car.

Tank Car.



U.S. type Boxcar.

Articulated Well Cars with containers

A Spine car with a 20 ft tanktainer and an open-top 20 ft container with canvas cover

Freight cars (UK: "wagons" or "trucks") exist in a wide variety of types, adapted to the ideal carriage of a whole host of different things. Originally there were very few types of cars; the boxcar (UK: "van"), a closed box with side doors, was among the first.

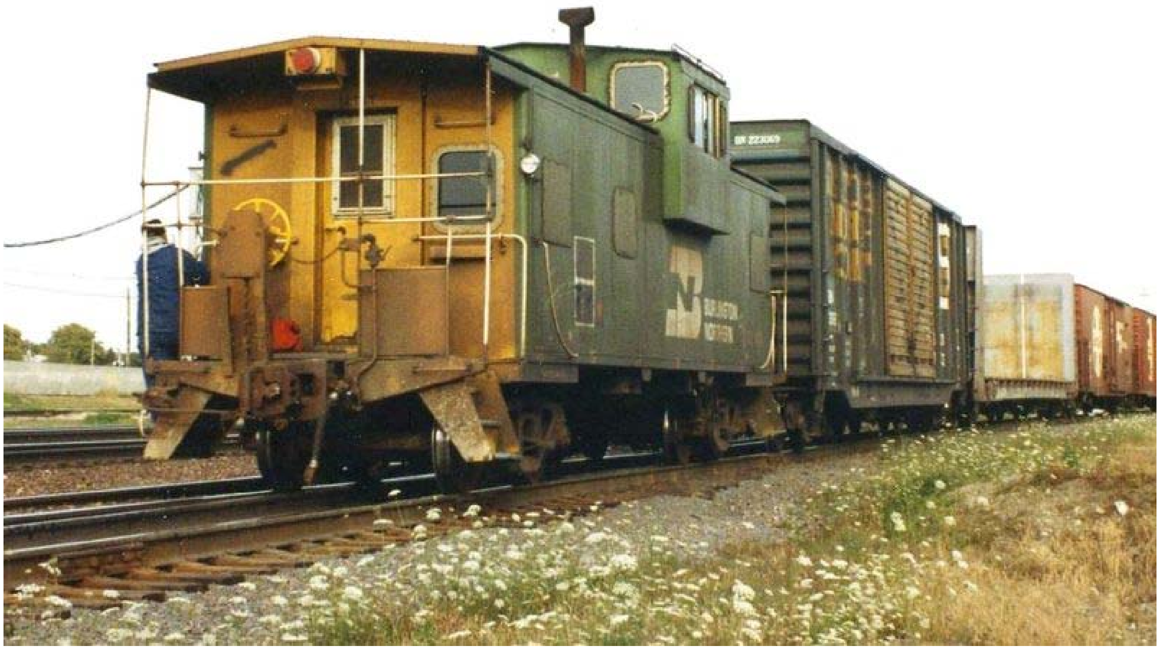
- Aircraft Parts Car
- Autorack - (also called *auto carriers*) are specialized multi-level cars designed for transportation of unladen automobiles.
- Boxcar (US), covered wagon (UIC) or van (UIC) - box shape with roof and side or end doors.

- CargoSprinter - a self propelled container flatcar.
- Centerbeam cars
- Coil car - a specialized type of rolling stock designed for the transport of coils of sheet metal, particularly steel. They are considered a subtype of the gondola car, though they bear little resemblance to a typical gondola.
- Conflat (UK) - A flat truck for carrying containers.
- Covered wagon (UIC), van (UIC) or boxcar (US) - fully enclosed wagon for moisture-susceptible goods.
- Covered hopper - similar to open top hoppers but with a cover for weather and temperature-sensitive loads.
- Double-Stack Car (or *well car*) - specialized cars designed for carrying shipping containers. These have a "well" with a very low bottom floor to allow double stacking.
- Flatcar (or *flat*) - for larger loads that don't load easily into a boxcar. Specialized types such as the depressed-center flatcar (aka "well car") exist for oversize items or the Schnabel car for even larger and heavier loads. With the advent of containerized freight, special types of flatcars were built to carry standard shipping containers and semi-trailers.
- Gondola (US) - railroad car with an open top but enclosed sides and ends, for bulk commodities and other goods that might slide off.
- Hicube boxcars
- Hoppers - similar to gondolas but with bottom dump doors for easy unloading of things like coal, ore, grain, cement, ballast and the like. Short hoppers for carrying iron ore are called ore jennys in the US.
- Lorry - An open wagon (UIC) or gondola (US) with a tipping trough, often found in mines.
- Lowmac (UK) - A low-floor wagon for carrying machinery.
- Modalohr Road Trailer Carriers.
- Open wagon (UIC) - railway wagon with an open top but enclosed sides and ends, for bulk commodities and other goods that might slide off.
- Refrigerator car (or *reefer*) - a refrigerated subtype of boxcar.
- Roll-block - a train designed to carry another railway train.
- Rolling highway - a train designed to carry trucks and/or semi-trailers
- Side Dump Cars - used to transport roadbed materials such as, ballast, riprap, and large stone, and are able to unload anywhere along the track.
- Schnabel car - specialized freight car for heavy or oversized loads.
- Slate wagon - specialized freight cars used to transport slate.
- Spine car, a center sill and side sill only car with lateral arms to support intermodal containers. No deck.
- Stock Car - for the transport of livestock.
- Tank car (US), tank wagon (UIC) (or *tanker*) - for the transportation of liquids or gases.
- Tippler (UK), Gondola (US) (or Lorry) - An open wagon with no doors or roof which are unloaded by being inverted on a Wagon Tippler (UK) or Rotary car dumper (US). They are, used for minerals, such as coal, limestone and iron ore as well as other bulk cargo.

- Transporter wagon - a wagon designed to carry other railway equipment.
- "Whale Belly" car, a tank car with a "belly".

The vast majority of freight cars fit into the above categories.

Non-revenue cars



Typical American extended vision caboose.

- Cabooses (or *guard's vans* or *brakevans*) which attach to the rear of freight trains to order to watch the train and assist in shoving moves.
- Clearance car, special car to check for obstructions.
- Handcars, which are powered by their passengers.
- Maintenance of way (MOW) cars, for the maintenance of track and equipment.
    - Tower cars used to maintain overhead lines
    - Track tester
- Rail car mover — some of which resemble HiRail trucks.
- Railroad cranes
- Road-rail vehicle
- Scale test car
- Office car which contains a mobile office for a train company.
- Crew car aka Outfit Car or a Camp Car, a bunk car or modular home mounted on a flatcar to house railroad employees.

Military cars

Armored train Hurban located in Zvolen, Slovakia

Soviet RT-23 Molodets ICBM launch train, in the St Petersburg museum

Military armoured trains use several types of specialized cars:

- artillery — fielding mixture of guns and machine guns
- infantry — fielding machine guns, designed to carry infantry units
- machine gun — dedicated to machine guns
- anti-air — equipped with anti-air guns
- command — similar to infantry wagons, but designed to be a train command center
- anti-tank — equipped with anti-tank guns, usually in a tank gun turret

- platform — unarmoured, with purposes ranging from transport of ammunition or vehicles, through track repair or derailing protection to railroad ploughs for railroad destruction.
- troop sleepers
- DODX is the reporting mark for the United States Department of Defense Military Traffic Management Command. (Index of dodx.)

Mobile missile systems

During the Cold War, the Soviet Union fielded a number of trains that served as mobile missile silos. These trains carried the missile and everything necessary to launch, and were kept moving around the railway network to make them difficult to find and destroy in a first-strike attack. A similar rail-borne system was proposed in the United States of America for the LGM-30 Minuteman in the 1960s, and the LGM-118 Peacekeeper in the 1980s, but neither were deployed. The Strategic Air Command's 1st Combat Evaluation RBS "Express" did deploy from Barksdale Air Force Base with radar bomb scoring units mounted on military railroad cars with supporting equipment, to score simulated thermonuclear bombing of cities in the continental United States.

Chapter 5

Bogie Exchange

Bogie exchange is a system for operating railway wagons on two or more gauges to overcome difference in the rail gauge. To perform a bogie exchange, a car is converted from one gauge to another by removing the chassis containing the wheels and axles of the car, and installing a new chassis with differently spaced wheels. It is generally limited to wagons and carriages, though engines can be exchanged if more time is available.

Bogies exchange operation in Ussuriisk (near Vladivostok) at the Chinese–Russian border

Bogie change station at Chop, Ukraine station, Ukraine which connects to Hungary and Slovakia

Wagons and carriages

Bogie wagons can have their gauge changed by lifting them off one set of bogies and putting them back down again on another set of bogies. The pin that centres the bogies and the hoses and fittings for the brakes must be compatible. There needs to be a generous supply of bogies of each gauge to accommodate the ebb and flow of traffic.

The bogies and wagons also need to have standardized hooks, etc, where they may be efficiently lifted.

Four-wheel wagons are not suitable for gauge change.

Engines

Steam

Steam engines can be designed for more than one gauge, by having, for example, reversible wheel hubs that suit two alternative gauges. This was done in the 1930s and beyond in Victoria for possible gauge conversion, though no engines were ever converted in this manner other than one heritage engine (R766). Some 1,000 mm (3 ft 3 ⅜ in) Garratt locomotives of East Africa were designed for easy conversion to 3 ft 6 in (1,067 mm) Cape gauge, though again none ever were.

In the southern United States, some steam locomotives built by Baldwin were designed for easy conversion from 1,524 mm (5 ft) to 1,435 mm (4 ft 8 ½ in).

Diesel

Diesel locomotives have bogies like wagons and carriages, only with more cables for the traction motors and take a little longer to convert. In Australia, some classes of diesel locomotives are regularly gauge-converted to suit traffic requirements on the 1,435 mm (4 ft 8 ½ in), 1,600 mm (5 ft 3 in) and 1,067 mm (3 ft 6 in) networks.

Since the 1,067 mm (3 ft 6 in) networks are not all connected to each other, being separated by deserts or lines of other gauges, the are bogie-exchanged or piggybacked on road or rail vehicles when transferred between these networks.

Raising or lowering

Raise

The simplest way to carry out bogie exchange is the lift the wagons off the bogies and replace them back on new bogies. This may require the wagons in a train to be uncoupled, and continuous brakes disconnected. As the bogies are swung out of the way, they sway, which wastes time settling them down.

Lower

A cleverer way of carrying out bogie exchange is to lower the bogies onto a trolley in a pit, after which the trolleys are rolled out of the way and others return. This keeps the train couplings and continuous brakes connected. In addition, the bogies never need leave a solid surface, so that they can be wheeled in and out more quickly. This method was used at Dry Creek railway station, Adelaide.

International

Australia

Between 1961 and 1995, Australia had five bogie exchange centres, which opened and closed as gauge conversion work proceeded. The gauges served were 1,435 mm (4 ft 8 ½ in) and 1,600 mm (5 ft 3 in), though the 1,067 mm (3 ft 6 in) Queensland did acquire 100 bogie-exchange compatible QLX wagons just in case. All the wagons involved had wagon codes ending in "X", such as VLX.

The centres were:

- Dynon, Melbourne, Victoria
- Wodonga near Albury on state border.
- Port Pirie, South Australia
- Peterborough, South Australia
- Dry Creek, Adelaide, South Australia - the youngest and most modern.

The busiest facility was that at Dynon, in a typical year (1981–82) 24,110 wagons were bogie exchanged, an average of 66 per day. This was done by one shift of 18 men, compared with the 100 men required if the same amount of freight was transferred wagon to wagon.

Belarus

- Brest, Belarus – between 1,520 mm (4 ft 11 5⁄6 in) and 1,435 mm (4 ft 8 1⁄2 in) at the border to Poland

Bolivia

Bogie exchange used between 762 mm (2 ft 6 in) and 1,000 mm (3 ft 3 3⁄8 in) gauge on the Ferrocarril de Antofagasta a Bolivia Railway.

Canada

- Between 1,435 mm (4 ft 8 1⁄2 in) Standard gauge and the 3 ft 6 in (1,067 mm) gauge of the former Newfoundland Railway (Terra Transport) at Port aux Basques

China

A bogie exchange station exists at the Chinese border to Mongolia. Both the Moscow-Beijing passenger train (Trans-Siberian) and freight trains get their bogies exchanged. Mongolia has Russian gauge 1,520 mm (4 ft 11 5⁄6 in), China has 1,435 mm (4 ft 8 1⁄2 in).

Finland

A bogie exchange station exists in the Port of Turku with a short stretch of 1,435 mm (4 ft 8 1⁄2 in) gauge railway. Freight cars get their bogies exchanged. SeaRail train ferries go from Germany and Sweden. They carry no passenger trains, and passengers must walk by foot to Turku Harbour railway station opposite the ferry terminals. Finland has 1,524 mm (5 ft) broad gauge.

Iran

- Jolfa - c1950, between 1,435 mm (4 ft 8 1⁄2 in) and 1,520 mm (4 ft 11 5⁄6 in) (Russian gauge)

- Sarakhs - c1990, between 1,435 mm (4 ft 8½ in) and 1,520 mm (4 ft 11⅚ in) (Russian gauge)
- Zahedan - proposed 2008, between 1,435 mm (4 ft 8½ in) and 1,676 mm (5 ft 6 in) (Indian gauge)

Kazakhstan

- Druzhba, KZ - Alashankou, CN between 1,520 mm (4 ft 11⅚ in) and 1,435 mm (4 ft 8½ in).

North Korea

- Tumangan, North Korea – between 1,435 mm (4 ft 8½ in) and 1,520 mm (4 ft 11⅚ in) (Russian gauge) at the border to Russia.

The bogies of the direct sleeping car Moscow - Pyongyang, which runs twice monthly, are exchanged here.

Peru

- Between 1,435 mm (4 ft 8½ in) Standard gauge and 3 ft (914 mm) on the Ferrocarril Central Andino, including locomotives

Romania

- Between 1,435 mm (4 ft 8½ in) and 1,520 mm (4 ft 11⅚ in) at Vadul Siret between Romania and Ukraine
- Between 1,435 mm (4 ft 8½ in) and 1,520 mm (4 ft 11⅚ in) at Ungheni, Iași between Romania and Moldova

Russia

- Zabaikalsk (450 km from Chita) with China
- Grodekovo (116 km from Ussuriisk and 224 km from Vladivostok) with China
- Khasan - North Korea (315 km from Vladivostok).
- Kholmsk, Sakhalin Island. The bogie exchange is necessary to enable Russian mainland cars to run on the Sakhalin railways, which use the Japanese gauge of 1,067 mm (3 ft 6 in).

Spain

- At Irun, between 1,435 mm (4 ft 8½ in) and 1,668 mm (5 ft 5⅔ in) (Iberian gauge)
- At Portbou, between 1,435 mm (4 ft 8½ in) and 1,668 mm (5 ft 5⅔ in)

Tunisia

- Between 1,435 mm (4 ft $8\frac{1}{2}$ in) Standard gauge and 1,000 mm (3 ft $3\frac{3}{8}$ in) (meter gauge), including locomotives

Ukraine

- Chop, Ukraine – between 1,520 mm (4 ft $11\frac{5}{6}$ in) (Russian gauge) and 1,435 mm (4 ft $8\frac{1}{2}$ in) at the border to Hungary and Slovakia
- Jagodin, Ukraine – between 1,520 mm (4 ft $11\frac{5}{6}$ in) (Russian gauge) and 1,435 mm (4 ft $8\frac{1}{2}$ in) at the border to Poland

Transfer time

Bogie exchange conversion times were:

- Dynon, Australia - one wagon every 7.3 minutes.
- Zabaykalsk - one a rail car takes 5–6 hours.
- Erenhot - one a rail car takes 5–6 hours.

Variable Gauge Axles

Variable Gauge Axles also called Automatic Track Gauge Changeover System is a newer and faster development than bogie exchange. While Bogie Exchange is "obvious" and brute force, VGA / ATGCS is "subtle, hidden" and elegant. The SUW 2000 ATGCS requires a change over track about 20 m long, with a shed if there is snow compared to a small marshalling yard required by bogie exchange.

Chapter 6

Passenger Car (Rail)

Amtrak Superliner double-deck lounge car

WORLD TECHNOLOGIES

Italian passenger car.

A **passenger car** (known as a **coach** or **carriage** in the UK, and also known as a **bogie** in India) is a piece of railway rolling stock that is designed to carry passengers. The term *passenger car* can also be associated with a sleeping car, baggage, dining and railway post office cars.

History

19th century: First passenger cars and early development

Restored passenger cars on display at the Mid-Continent Railway Museum in North Freedom, USA.

Up until about the end of the 19th century, most passenger cars were constructed of wood. The first passenger trains did not travel very far, but they were able to haul many more passengers for a longer distance than any wagons pulled by horses.

As railways were first constructed in England, so too were the first passenger cars. One of the early coach designs was the "Stanhope". It featured a roof and small holes in the floor for drainage when it rained, and had separate compartments for different classes of travel. The only problem with this design is that the passengers were expected to stand for their entire trip. The first passenger cars in the United States resembled stagecoaches. They were short, often less than 10 ft (3 m) long and had two axles.

British railways had a little bit of a head start on American railroads, with the first "bed-carriage" (an early sleeping car) being built there as early as 1838 for use on the London and Birmingham Railway and the Grand Junction Railway. Britain's early sleepers, when made up for sleeping, extended the foot of the bed into a boot section at the end of the carriage. The cars were still too short to allow more than two or three beds to be positioned end to end.

Britain's Royal Mail commissioned and built the first Travelling Post Office cars in the late 1840s as well. These cars resembled coaches in their short wheelbase and exterior design, but were equipped with nets on the sides of the cars to catch mail bags while the train was in motion. American RPOs, first appearing in the 1860s, also featured equipment to catch mail bags at speed, but the American design more closely resembled a large hook that would catch the mailbag in its crook. When not in use, the hook would swivel down against the side of the car to prevent it from catching obstacles.

As locomotive technology progressed in the mid-19th century, trains grew in length and weight. Passenger cars, particularly in America, grew along with them, first getting longer with the addition of a second truck (one at each end), and wider as their suspensions improved. Cars built for European use featured side door compartments, while American car design favored what was called a "coach", a single long cabin with rows of seats, with doors located at the ends of the car. Early American sleeping cars were not compartmented, but by the end of the 19th century they were. The compartments in the later sleepers were accessed from a side hall running the length of the cars, similar to the design of European cars well into the 20th century.

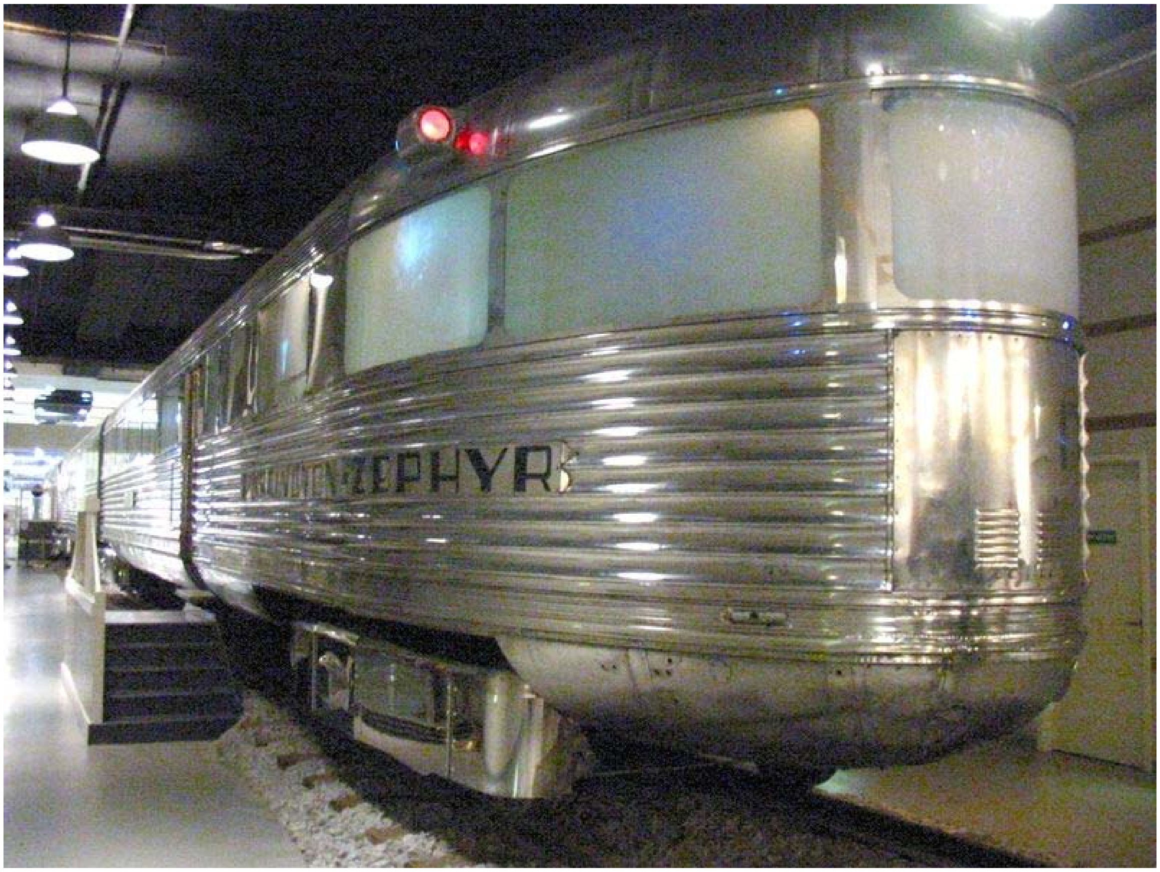
Many American passenger trains, particularly the long distance ones, included a car at the end of the train called an observation car. Until about the 1930s, these had an open-air platform at the rear, the "observation platform". These evolved into the closed end car, usually with a rounded end which was still called an "observation car". The interiors of observation cars varied. Many had special chairs and tables.

The end platforms of all passenger cars changed around the turn of the 20th century. Older cars had open platforms between cars. Passengers would enter and leave a car through a door at the end of the car which led to a narrow platform. Steps on either side of the platform were used for getting on or off the train, and one might hop from one car platform to another. Later cars had enclosed platforms called vestibules which together with gangway connections allowed passengers not only to enter and exit the train protected from the elements, but also to move more easily between cars with the same protection.

Dining cars first appeared in the late 1870s and into the 1880s. Until this time, the common practice was to stop for meals at restaurants along the way (which led to the rise of Fred Harvey's chain of Harvey House restaurants in America). At first, the dining car was simply a place to serve meals that were picked up en route, but they soon evolved to include galleys in which the meals were prepared. The introduction of vestibuled cars, which for the first time allowed easy movement from car to car, aided the adoption of dining cars, lounge cars, and other specialized cars.

1900-1950: Lighter materials, new car types

By the 1920s, passenger cars on the larger standard gauge railroads were normally between 60 ft (18.3 m) and 70 ft (21.3 m) long. The cars of this time were still quite ornate, many of them being built by experienced coach makers and skilled carpenters.



The observation car on CB&Q's *Pioneer Zephyr*. The carbody was made of stainless steel in 1934; it is seen here at Chicago's Museum of Science and Industry in 2003.

With the 1930s came the widespread use of stainless steel for carbodies. The typical passenger car was now much lighter than its "heavyweight" wood cousins of old. The new "lightweight" and streamlined cars carried passengers in speed and comfort to an extent that had not been experienced to date. Aluminum and Cor-Ten steel were also used in lightweight car construction, but stainless steel was the preferred material for carbodies. It isn't the lightest of materials, nor is it the least expensive, but stainless steel cars could be, and often were, left unpainted except for the car's reporting marks that were required by law.

By the end of the 1930s, railroads and carbuilders were debuting carbody and interior styles that could only be dreamed of before. In 1937, the Pullman Company delivered the first cars equipped with roomettes – that is, the car's interior was sectioned off into compartments, much like the coaches that were still in widespread use across Europe.

Pullman's roomettes, however, were designed with the single traveler in mind. The roomette featured a large picture window, a privacy door, a single fold-away bed, a sink and small toilet. The roomette's floor space was barely larger than the space taken up by the bed, but it allowed the traveler to ride in luxury compared to the multilevel semiprivate berths of old.

Now that passenger cars were lighter, they were able to carry heavier loads, but the size of the average passenger that rode in them didn't increase to match the cars' new capacities. The average passenger car couldn't get any wider or longer due to side clearances along the railroad lines, but they generally could get taller because they were still shorter than many freight cars and locomotives. So the railroads soon began building and buying dome and bilevel cars to carry more passengers.

1950-present: High-technology advancements

Amtrak Cascades operates with tilting Talgo permanently coupled trainsets

Starting in the 1950s, the passenger travel market declined in North America, though there was growth in commuter rail. Private intercity passenger service in the U.S. mostly ended with the creation of Amtrak in 1971. Amtrak took over equipment and stations from most the railroads in the U.S. with intercity service.

The higher clearances in North America enabled a major advancement in passenger car design, bi-level (double-decker) commuter coaches that could hold more passengers. These cars started to become common in the United States in the 1960s, and were adopted by Amtrak for the Superliner design as well as by many other railroads and manufacturers. By the year 2000 double-deckers rivaled single level cars in use around the world.

While intercity passenger rail travel declined in America, ridership continued to increase in other parts of the world. With the increase came an increased use of newer technology on existing and new equipment. The Spanish company Talgo began experimenting in the 1940s with technology that would enable the axles to steer into a curve, allowing the train to move around the curve at a higher speed. The steering axles evolved into mechanisms that would also tilt the passenger car as it entered a curve to counter the centrifugal force experienced by the train, further increasing speeds on existing track. Today, Talgo trains are used in many places in Europe and they have also found a home in North America on some short and medium distance routes such as Eugene, Oregon, to Vancouver, British Columbia.

Another type of tilting train that is seeing widespread use across Europe is the Pendolino. These trains, built by Fiat Ferroviaria (now owned by Alstom), are in regular service in Italy, Portugal, Slovenia, Finland, Czech Republic and now the United Kingdom. Using tilting trains, railroads are able to run passenger trains over the same tracks at higher speeds than would otherwise be possible.

Amtrak continued to push the development of U.S.-designed passenger equipment even when the market demand didn't support it, ordering a number of new passenger locomotive and car types in the 1980s and 1990s. However, by the year 2000 Amtrak went to European manufacturers for the Amtrak Cascades (Talgo) and Acela Express trains, their premier services. These trains use new designs and are made to operate as coherent "trainsets".

High-speed trains are made up of cars from a single manufacturer and usually of a uniform design (although the dining car on the ICE has a dome). In the 1960s and 1970s countries around the world started to develop trains capable of traveling in the 150-200 mph range, to rival air travel. One of the first was France's TGV which entered service in 1981. By the year 2000, Western Europe's major cities (London, Paris, Brussels, Amsterdam, Geneva, Berlin, Rome, etc.) were connected by high-speed rail service.

Often tilting and high-speed cars are left in "trainsets" throughout their service. For example, articulated cars cannot be uncoupled without special equipment because the individual cars share trucks. This gives modern trains a smooth, coherent appearance because all the cars and often the engines share a similar design and paint scheme.

Heavyweight vs. lightweight

Baltimore and Ohio Railroad #3505, a modernized heavyweight coach, photographed in June, 1960. The marker lamps mounted on each side are required on the last car of any consist.

A heavyweight car is one that is physically heavier than a lightweight car due to its construction. While early cars used wood construction, Pullman switched to heavyweight riveted steel construction in 1910, more or less at the same time as other rail car manufacturers. Heavyweights are said to offer a more luxurious ride due to their added mass (from the plate steel construction and concrete floor) and, usually, six-wheeled trucks (bogies). The stepped roof line of early heavyweights usually consisted of a center sill section (the clerestory) that ran the length of the car and extended above the roof sides by as much as a foot. This section of the roof usually had windows or shutters that could be opened for ventilation while the train was in motion. However, railroad crews and passengers quickly discovered that when these windows were opened on a passenger train pulled by one or more steam locomotives, smoke and soot from the locomotives tended to drift in through the windows, especially when the train went through a tunnel.

In the early 20th century, air conditioning was added to heavyweight cars for the first time. An air conditioned heavyweight car could be spotted easily since the area where the roof vent windows existed was now covered, either partially or in full, by the AC duct. As lightweight cars were introduced, many heavyweight cars were repurposed into maintenance of way service by the railroads that owned them.

Lightweight passenger cars required developments in steel processing that weren't available until the 1920s and 1930s. By building passenger cars out of steel instead of wood, the manufacturers were able to build lighter weight cars with smooth or fluted sides and smooth roof lines.

Steel cars were ushered in at the beginning of the streamline era of the 1930s (although not all lightweight cars were streamlined) and steel has continued in use ever since then. With the use of steel for the car sides, railroads were able to offer more innovative passenger car types. It wasn't until after the first lightweight cars were introduced that railroads began building and using dome cars because the sides of heavyweight cars weren't strong enough to support the weight of the dome and its passengers. Lightweight cars also enabled the railroads to operate longer passenger trains; the reduced car weight meant that more passengers could be carried in a greater number of cars with the same locomotives. The cost savings in hauling capacity coupled with the increased car type options led to the quick replacement of heavyweight cars with lightweight cars.

Car types

Traditionally the passenger car can be split into a number of distinct types.

Second class of Eurostar Italia

The most basic division is between cars which do carry passengers and "head end" equipment. The latter are run as part of passenger trains, but do not themselves carry passengers. Traditionally they were put between the locomotive and the passenger-carrying cars in the consist, hence the name.

Some specialized types are variants of or combine elements of the most basic types.

Also the basic design of passenger cars is evolving, with articulated units that have shared trucks, with double-decker designs, and with the "low floor" design where the loading area is very close to the ground and slung between the trucks.

Passenger-carrying types

Coach

The coach is the most basic type of passenger car, also sometimes referred to as 'chair cars'.

An interior view of a Finnish bilevel coach. The seating arrangement of the 'open' type

An 'Open' type [3+3] Chair Car in Kerala, India

Two main variants exist: 'Open', with a centre corridor; the car's interior is often filled with row upon row of seats like that in a passenger airliner, other arrangements of the 'open' type are also found, including seats around tables, seats facing windows (often found on mass transit trains since there is increase standing room for rush hours), as well as variations of all three. Seating arrangement is typically [2+2]. The seating arrangements and density, as well as the absence or presence of other facilities depends on the intended use - from mass transit systems to long distance luxury trains.

The interior of a compartment car, viewed from the connecting side corridor

The other variant is the 'closed' or 'Compartment car', in which a side corridor connects individual compartments along the body of the train, each with two rows of seats facing each other.

In both arrangements carry-on baggage is stowed on a shelf above the passenger seating area. The opening into the cars is usually located at both ends of the carriage, often into a small hallway - which in railway parlance is termed a vestibule.

In India normal carriages often have double height seating, with benches (berths), so that people can sit above one another (not unlike a bunk bed), in other countries true double decker carriages are becoming more common.

The seats in most coaches until the middle of the 20th century, were usually bench seats; the backs of these seats could be adjusted, often with one hand, to face in either direction so the car would not have to be turned for a return trip. The conductor would simply walk down the aisle in the car, reversing the seat backs to prepare for the return trip. This arrangement is still used in some modern trains.

Dining car

A dining car (or diner) is used to serve meals to the passengers. Its interior is split with a portion of the interior partitioned off for a galley, which is off-limits to passengers. A narrow hallway is left between the galley and one side wall of the car for passengers to use. The remainder of the interior is laid out with tables and chairs to look like a long, narrow restaurant dining room. There is special personnel to perform waitstaff and kitchen duties.

Lounge

Amtrak Superliner lounge car (is also a low-floor, double-decker car)

Lounge cars carry a bar and public seating. They usually have benches or large swivelling chairs along the sides of the car. Some lounge cars include small pianos and are staffed by contracted musicians to entertain the passengers.

These cars are often pulled in addition to the dining car, and on very long trains in addition to one or more snack or cafe cars.

Lounge cars are an important part of the appeal of passenger trains when compared to aircraft, buses and cars; there is more space to move around, socialize, eat and drink, and a good view.

Observation

A heavyweight observation car.

The observation car almost always operated as the last car in a passenger train. Its interior could include features of a coach, lounge, diner, or sleeper. The main spotting feature was at the tail end of the car - the walls of the car usually were curved together to form a large U shape, and larger windows were installed all around the end of the car. Before these cars were built with steel walls, the observation end of heavyweight cars resembled a roofed porch area; larger windows were installed at the observation end on these cars as well. At this end of the car, there was almost always a lounge where passengers could enjoy the view as they watch the track rapidly recede into the distance.

Sleeping car

Often called "sleepers" or "Pullman cars" (after the main American operator), these cars provide sleeping arrangements for passengers travelling at night. Early models were divided into sections, where coach seating converted at night into semi-private berths. More modern interiors are normally partitioned into separate bedroom compartments for passengers. The beds are designed in such a way that they either roll or fold out of the way or convert into seats for daytime use. Compartments vary in size; some are only large enough for a bed, while others resemble efficiency apartments including bathrooms.

Head-end equipment

Baggage car

A baggage car

Although passengers generally were not allowed access to the baggage car, they were included in a great number of passenger trains as regular equipment. The baggage car is a car that was normally placed between the train's motive power and the remainder of the passenger train. The car's interior is normally wide open and is used to carry passengers' checked baggage. Baggage cars were also sometimes commissioned by freight companies to haul less-than-carload (LCL) shipments along passenger routes (Railway Express Agency was one such freight company). Some baggage cars included restroom facilities for the train crew, so many baggage cars had doors to access them just like any other passenger car. Baggage cars could be designed to look like the rest of a passenger train's cars, or they could be repurposed box cars equipped with high-speed trucks and passenger train steam and air connections.

Express car

Express cars carried high value freight in passenger consists. These cars resembled baggage cars, though in some cases specially equipped box cars or refrigerator cars were used.

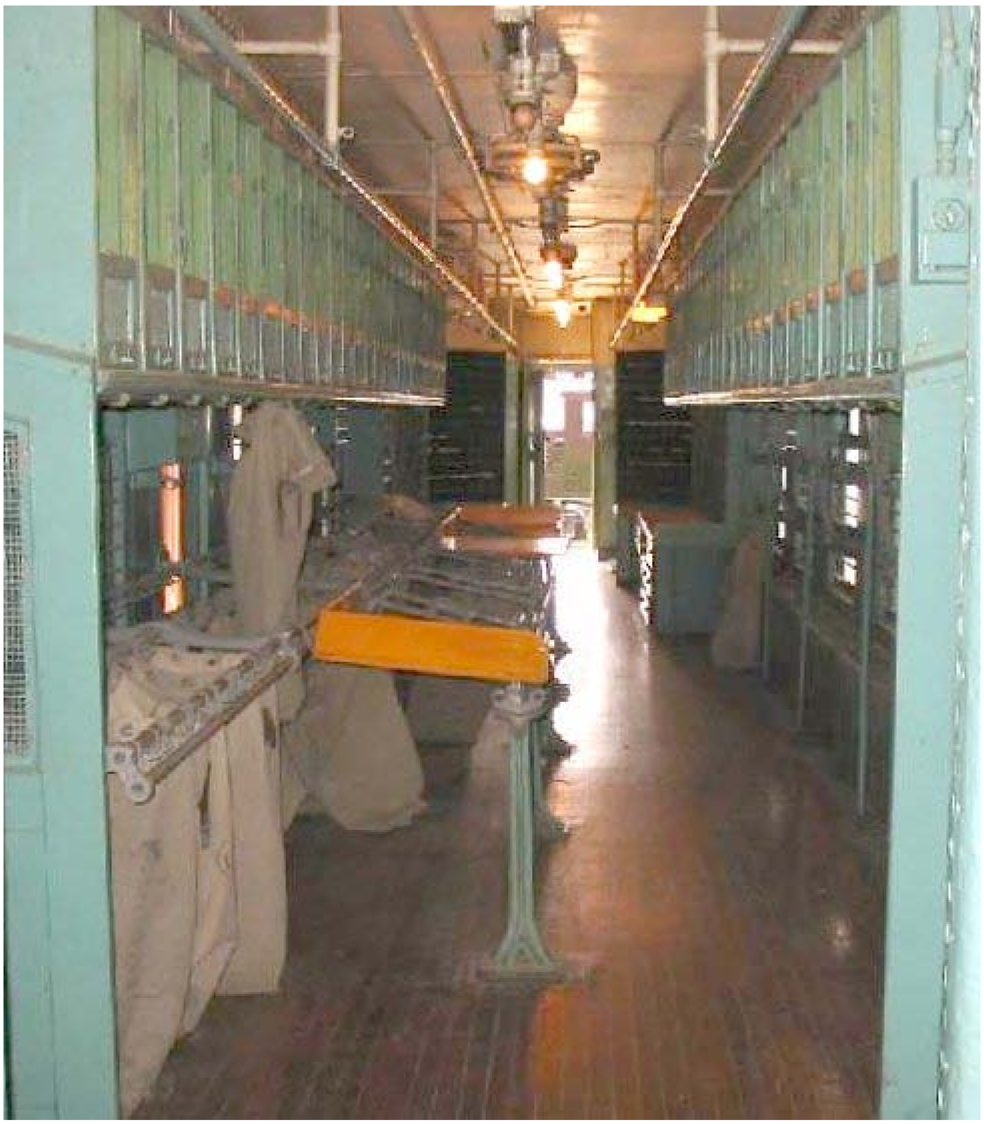
Horse car

Specialized stock cars were used to transport horses and other high value livestock as part of passenger consists. Similar equipment is used in circus trains to transport their animals.

Prisoner car

In some countries, convicts are transported from court to prison or from prison to another by railway. In such transportation a specific type of coach, prisoner car, is used. It contains several cell compartments with minimal interior and commodities, and a separate guard compartment. Usually the windows are of nontransparent opaque glass to prevent prisoners from seeing outside and determine where they are, and windows usually also have bars to prevent escapes. Unlike other passenger cars, prisoner cars do not have doors at the ends of the wagon.

Railway post office



The interior of an RPO on display at the National Railroad Museum in Green Bay, Wisconsin.

Like baggage cars, railway post office (RPO) cars or travelling post offices (TPOs) were not accessible to paying passengers. These cars' interiors were designed with sorting facilities that were often seen and used in conventional post offices around the world. The RPO is where mail was sorted while the train was en route. Because these cars carried mail, which often included valuables or quantities of cash and checks, the RPO staff (who were employed by the postal service and not the railroad) were the only train crews allowed to carry guns. The RPO cars were normally placed in a passenger train between the train's motive power and baggage cars, further inhibiting their access by passengers.

Specialized types

Combine

A coach-baggage combine

A combine is a car that combines features of a head-end and a regular passenger car. The most common combination is that of a coach and a baggage car, but the combination of coach and post office car was also common. Combines were used most frequently on branch lines and short line railroads where there wasn't necessarily enough traffic to economically justify single-purpose cars. As lightweight cars began to appear on railroads, passenger cars more frequently combined features of two or more car types on one car, and the classic heavyweight combine fell out of use.

Control car (Cab)

A double-decker driving trailer in Germany.

A control car (also known as a 'Driving Trailer' in Europe and the UK) is a passenger car which lets the train be run in reverse with the locomotive at the back. It is common on commuter trains in the US and Europe. This can be important for serving small towns without extensive switching facilities, dead-end lines, and having a fast turn around when changing directions in commuter service.

Dome car

A dome car can include features of a lounge car, dining car and an observation. A portion of the car, usually in the center of the car, is split between two levels, with stairs leading both up and down from the train's regular passenger car floor level. The lower level of the dome usually consisted of a small lounge area, while the upper portion was usually coach or lounge seating within a "bubble" of glass on the car's roof. Passengers in the upper portion of the dome were able to see in all directions from a vantage point above the train's roofline. On some dome cars, the lower portion was built as a galley, where car attendants used dumbwaiters to transfer items between the galley and a dining area in the dome portion of the car.

Some dome cars were built with the dome extending the entire length of the car, while others had only a small observation bubble. There were also combination dome-observation cars built which were meant to be the last car on the train, with both rear observation and the dome up top.

Double-decker or Bilevel

A Bombardier BiLevel Coach

As passenger car construction improved to the point where dome cars were introduced, some passenger car manufacturers began building double decker passenger train cars for use in areas that are more heavily populated or to carry more passengers over a long distance while using fewer cars (such as Amtrak's Superliner cars). Cars used on long-distance passenger trains could combine features of any of the basic car types, while cars used in local commuter service are often strictly coach types on both levels.

Double decker coaches were tried in the UK (SR Class 4DD) but the experiment was unsuccessful because the restricted British loading gauge resulted in cramped conditions.

Private car

A heavyweight Pullman "business car."

Many cars built by Pullman and other companies were either originally built or later converted for use as business and private cars which served as the "private jet" of the early-to-mid-20th century. They were used by railroad officials and dignitaries as business cars, and wealthy individuals for travel and entertainment. There are various configurations, but the cars generally have an observation platform and include a full kitchen, dining room, state rooms, secretary's room, an observation room, and often servant's quarters. A number of these private cars have survived the decades and some are used for tour rides, leasing for private events, etc. A small number of private cars (along with other types of passenger cars), have been upgraded to meet current Amtrak regulations, and may be chartered by their owners for private travel attached to Amtrak trains.

The only current example in Britain is the British Royal Train.

Drovers' car

C&NW coach #10808, in drovers' service. Chadron, Nebraska, July 14, 1956.

Drovers' cars were used on long distance livestock trains in the western United States. The purpose of a drovers' car was to accommodate the livestock's handlers on the journey between the ranch and processing plant. They were usually shorter, older cars, and equipped with stove heaters, as no trainline steam heating was provided.

Troop sleeper

A "troop sleeper" was a railroad passenger car which had been constructed to serve as something of a mobile barracks (essentially, a sleeping car) for transporting troops over distances sufficient to require overnight accommodations. This method allowed part of the trip to be made overnight, reducing the amount of transit time required and increasing travel efficiency. **Troop kitchens**, rolling galleys, also joined the consists in order to provide meal service en route (the troops took their meals in their seats or bunks). **Troop hospital** cars, also based on the troop sleeper carbody, transported wounded servicemen and typically travelled in solid strings on special trains averaging fifteen cars each.

Hospital car

A variety of hospital trains operate around the world, employing specialist carriages equipped as hospital wards, treatment rooms, and full-scale operating theatres.

Car technology

Passenger cars are as almost as old as railroading itself, and their development paralleled that of freight cars. Early two axle cars gave way to conventional two truck construction with the floor of the car riding above the wheels; link and pin couplers gave way to automatic types.

Several construction details characterized passenger equipment. Passenger trains were expected to run at higher speeds than freight service, and therefore passenger trucks evolved to allow superior ride and better tracking at those speeds. Over time, in most cases provision was made for passengers and train staff to move from car to car; therefore platforms and later vestibules were used to bridge the gap.

In later years a number of changes to this basic form were introduced to allow for improvements in speed, comfort, and expense.

Articulated

Two TGVs (coupled) with articulated trainsets

Articulated passenger cars are becoming increasingly common in Europe and the US. This means that the passenger cars share trucks and that the passageways between them are more or less permanently attached. The cars are kept in "trainsets" and not split up during normal operations.

Articulated cars have a number of advantages. They save on the total number of wheels and trucks, reducing costs and maintenance expenses. Further, movement between cars is safer and easier than with traditional designs. Finally, it is possible to implement tilting schemes such as the Talgo design which allow the train to lean into curves. The chief disadvantage is that failure of a single car disables the entire set, since individual cars cannot be readily switched in and out of the consist.

Low-floor

Siemens Light rail vehicle (articulated, low-floor) in Portland, Oregon

In some countries (such as the US), platform level may be below the level of the floor of passenger cars, resulting in a significant step up from platform level - leading to slower boarding times, which are important for high-capacity systems. Low-floor cars have their main passenger and loading floor directly on level with the loading platform, instead of having a step up to the passenger compartment as was traditional until around the 1970s. This is achieved by having a low-slung chassis with the "low floor" resting *between* the trucks, rather than resting completely on top with a simpler straight chassis design. This improved design is seen in many passenger cars today, especially double decker cars. The low floor enables easy access for bicycles, strollers, suitcases, wheelchairs and those with disabilities, which is otherwise not always convenient or even possible with the traditional passenger car design.

Self-propelled passenger equipment

These vehicles usually carry motive power in each individual unit. Trams, Light Rail Vehicles and subways have been widely constructed in urban areas throughout the world since the late 19th century. By the year 1900, electric-powered passenger cars were ubiquitous in the developed world, but they fell into decline after World War II, especially in the U.S. By the year 2000 they had regained popularity and modern lines were being rebuilt where they had been torn up only 40 years earlier to make way for automobiles.

On lighter-trafficked rural railways, powered diesel cars (such as the Budd Rail Diesel Car) continue to be popular. In Germany the new Talent design shows that the diesel-powered passenger car is still a viable part of rail service. In the UK, locomotive-hauled passenger trains have largely been replaced by diesel multiple units, such as the Bombardier Voyager family, even on express services.

Tilting

These cars are able to tilt to counter the effects of inertia when turning, making the ride more comfortable for the passengers. Amtrak has adopted Talgo trainsets for its Amtrak Cascades service in the Pacific Northwest. Other manufacturers have also implemented tilting designs. The British Rail Class 390 is a tilting train operating in the UK.

Passenger car manufacturers

While some railroads, like the Milwaukee Road, preferred to build their own passenger cars, several railcar manufacturers built the majority of passenger cars in revenue service. Most of these companies produced both passenger and freight equipment for the railroads. This is by no means a comprehensive list of all passenger car builders. Quite a large number of firms built passenger cars over the years, but the majority of cars in the 20th century were built by these companies.

American Car and Foundry

American Car and Foundry was formed in 1899 through the merger of 13 smaller railroad car manufacturing companies (in much the same way as the American Locomotive Company was formed from the merger of 8 smaller locomotive manufacturers two years later in 1901). ACF built the first all-steel passenger car in the world for Interborough Rapid Transit in 1904, and then built the first steel cars used on the London Underground in the following year. The company continued to manufacture passenger equipment until 1959. ACF still manufactures freight cars today.

Bombardier

BOMBARDIER I11 passenger cars of SNCB

Bombardier is the largest manufacturer of passenger cars in the world. This company started in Canada and has become multi-national, making everything from passenger cars to commuter aircraft in factories around the world.

Budd Company

The Budd Company got its start in the early 1930s when Edward G. Budd developed a way to build carbodies out of stainless steel. In 1932 he completed his first railcar, dubbed the *Green Goose*. It used rubber tires and a stainless steel body, and was powered by the engine out of Budd's own Chrysler Imperial automobile. Budd sold a few of these early powered cars to the Reading Railroad, Pennsylvania Railroad and the Texas and Pacific Railway. The next year, Ralph Budd, only a very distant relation, but president of the Chicago, Burlington and Quincy Railroad at the time, came to Budd to build the *Pioneer Zephyr*.

Budd was soon called on by another railroad president before the end of the decade. Samuel T. Bledsoe asked Budd to build the new lightweight cars for the Santa Fe's new *Super Chief* passenger train.

Budd continued building lightweight powered and unpowered cars through the 20th century for nearly every major railroad in North America.

Pullman

The most famous of all the car manufacturers was Pullman, which began as the *Pullman Palace Car Company* founded by George Pullman in 1867. The Pullman Palace Car Company manufactured railroad cars in the mid-to-late 19th century through the early decades of the 20th century during the boom of railroads in the United States.

Pullman developed the sleeping car which carried his name into the 1980s.

In 1900, the Pullman Palace Car Company was reorganized as *The Pullman Co.*.

In 1924, *Pullman Car & Manufacturing Co.* was organized from the previous Pullman manufacturing department to consolidate the car building interests of The Pullman Co.

In 1934, Pullman Car & Manufacturing merged with Standard Steel Car Co. to form the *Pullman-Standard Car Manufacturing Company*, which remained in the car manufacturing business until 1982. Pullman manufactured its last cars for Amtrak in 1981. The last car built and delivered at the end of July 1981 was named *George Mortimer Pullman* in honor of the ompany's founder.

Siemens AG

The Siemens was founded in 1847 in Berlin, Germany building Conglomerates, Electric and Industry products, Healthcare Radioative systems, rolling stock,etc. The Siemens "Viaggio" passenger car models are to all purposes in the European railways: Viaggio Twin: double-deck coaches used on CityNightLine and ÖBB CityShuttle regional trains; Viaggio Classic: Original Siemens passenger cars, similar to Eurofima UIC cars, used in Germany, Greece, Czech Republic and Austria; Viaggio Light: new low-floor regional passenger coaches now used in Israel and Viaggio Comfort: New luxury articulated coaches used on ÖBB's railjet and Siemens Coach 2000 prototype lounge car.

St. Louis Car Company

Founded in April 1887, in its namesake city, St. Louis Car Company manufactured railroad cars for streetcar lines (urban passenger railways) and steam railroads. The company made brief forays into building automobiles and aircraft, but they are best known as the manufacturers of Birney and PCC streetcars which have seen worldwide use. St. Louis Car Company closed in 1973.

Lighting, heating, air-conditioning

The earliest form of train lighting was provided by Colza oil lamps. The next stage was gas lighting, using compressed gas stored in cylinders under the coaches. Finally, electric lighting was introduced.

Early railway coaches had no heating but passengers could hire foot-warmers. These worked on the same principle a modern sodium acetate heating pads. Later, steam heating was introduced, using a steam supply from the steam locomotive. Steam heating continued into the diesel locomotive era, with steam supplied by a steam generator. Now, electric heating is almost universal and air-conditioning is often provided as well. In the case of diesel multiple units, the coaches may be heated by waste heat from the engines, as in an automobile.

Chapter 7

Train

A **train** is a connected series of vehicles for rail transport that move along a track (permanent way) to transport cargo or passengers from one place to another. The track usually consists of two rails, but might also be a monorail or maglev guideway.

Propulsion for the train is provided by a separate locomotive, or from individual motors in self-propelled multiple units. Most modern trains are powered by diesel locomotives or by electricity supplied by overhead wires or additional rails, although historically (from the early 19th century to the mid-20th century) the steam locomotive was the dominant form of locomotive power. Other sources of power (such as horses, rope or wire, gravity, pneumatics, and gas turbines) are possible.

The word 'train' comes from the Old French *trahiner*, itself from the Latin *trahere* 'pull, draw'.

Types of trains

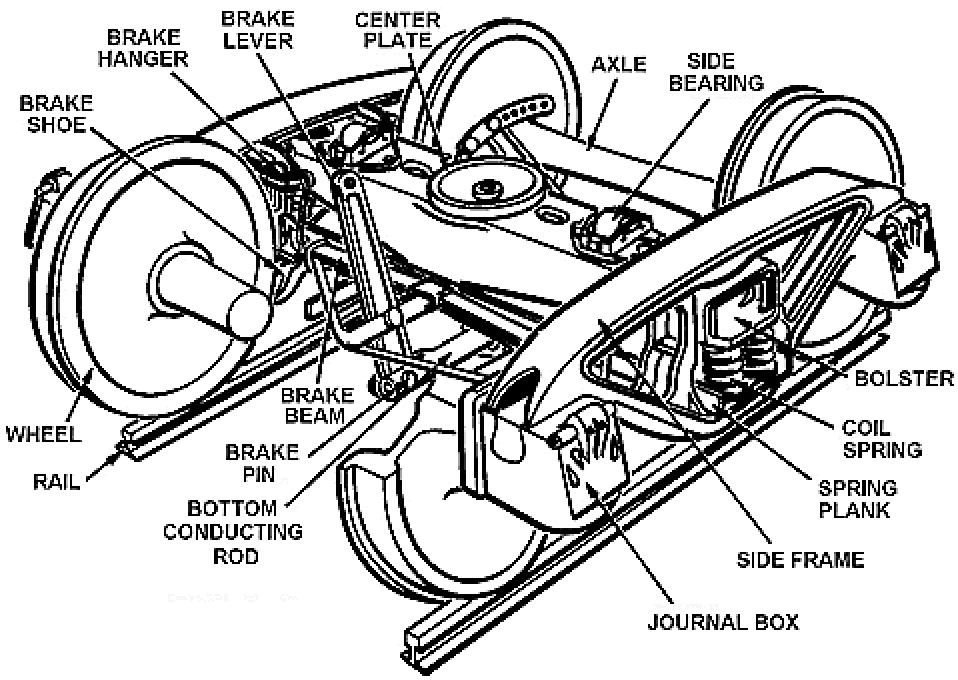
Steam locomotive-hauled passenger train

German ICE high speed passenger train (a form of multiple unit)


Hungarian Máv-Start Intercity

British Rail Class 153 (single-unit) diesel railcar

Newag 14WE of Warsaw Urban Rapid Railway in Pruszków



US-style railroad truck (bogie) with journal bearings

V43, a common Hungarian electric locomotive used in passenger train service.

Kashmir Railway, India is the second highest railway in the world. It has facilitated economic growth in the Kashmir Valley. Seen here is security personnel standing guard as a train passes near Budgam

Interior of a passenger car in a long-distance train in Finland

Japanese Shinkansen 500 Series (High-speed rail)

Russian Velaro high speed passenger train (a form of multiple unit)

Romanian Căile Ferate Române diesel railcar in Bucharest's Gara de Nord station

Mumbai's suburban trains handle 6.3 million commuters daily.

A CityTrain SMU (Suburban Multiple Unit) operating on the suburban rail network in Brisbane, Queensland, Australia

A Transperth B-series train

Interior of a 6-door passenger car in Japan, when the bench seats are folded

A Swiss train

There are various types of train designed for particular purposes. A train can consist of a combination of one or more locomotives and attached railroad cars, or a self-propelled multiple unit (or occasionally a single powered coach, called a railcar). Trains can also be hauled by horses, pulled by a cable, or run downhill by gravity.

Special kinds of trains running on corresponding special 'railways' are atmospheric railways, monorails, high-speed railways, maglev, rubber-tired underground, funicular and cog railways.

A passenger train may consist of one or several locomotives, and one or more coaches. Alternatively, a train may consist entirely of passenger carrying coaches, some or all of which are powered as a "multiple unit". In many parts of the world, particularly Japan and Europe, high-speed rail is utilized extensively for passenger travel.

Freight trains comprise wagons or trucks rather than carriages, though some parcel and mail trains (especially Travelling Post Offices) are outwardly more like passenger trains.

Trains can also be 'mixed', comprising both passenger accommodation and freight vehicles. Such mixed trains are most likely to occur where services are infrequent, and running separate passenger and freight trains is not cost-effective, though the differing needs of passengers and freight usually means this is avoided where possible.

Special trains are also used for track maintenance; in some places, this is called maintenance of way.

In the United Kingdom, a train hauled by two locomotives is said to be "double-headed", and in Canada and the United States it is quite common for a long freight train to be headed by three or more locomotives. A train with a locomotive attached at each end is described as 'top and tailed', this practice typically being used when there are no reversing facilities available. Where a second locomotive is attached temporarily to assist a train up steep banks or grades (or down them by providing braking power) it is referred to as 'banking' in the UK, or 'helper service' in North America. Recently, many loaded trains in the US have been made up with one or more locomotives in the middle or at the rear of the train, operated remotely from the lead cab. This is referred to as "DP" or "Distributed Power."

Terminology

The railway terminology that is used to describe a 'train' varies between countries.

United Kingdom

In the United Kingdom, the interchangeable terms **set** and **unit** are used to refer to a group of permanently or semi-permanently coupled vehicles, such as those of a multiple unit. While when referring to a train made up of a variety of vehicles, or of several sets/units, the term **formation** is used. (Although the UK public and media often forgo 'formation', for simply 'train'.) The word **rake** is also used for a group of coaches or wagons.

In the United Kingdom Section 83(1) of the Railways Act 1993 defines "train" as follows:

> a) two or more items of rolling stock coupled together, at least one of which is a locomotive; or
> b) a locomotive not coupled to any other rolling stock.

United States

In the United States, the term **consist** is used to describe the group of rail vehicles which make up a train. When referring to motive power, **consist** refers to the group of locomotives powering the train. Similarly, the term **trainset** refers to a group of rolling stock that is permanently or semi-permanently coupled together to form a unified set of equipment (the term is most often applied to passenger train configurations).

The Atchison, Topeka and Santa Fe Railway's 1948 operating rules define a train as: "An engine or more than one engine coupled, with or without cars, displaying markers."

Bogies

A **bogie** is a wheeled wagon or trolley. In mechanics terms, a bogie is a chassis or framework carrying wheels, attached to a vehicle. It can be fixed in place, as on a cargo truck, mounted on a swivel, as on a railway carriage or locomotive, or sprung as in the suspension of a caterpillar tracked vehicle.

Motive power

The first trains were rope-hauled, gravity powered or pulled by horses. From the early 19th century almost all were powered by steam locomotives. From the 1910s onwards the steam locomotives began to be replaced by less labour intensive and cleaner (but more complex and expensive) diesel locomotives and electric locomotives, while at about the same time self-propelled multiple unit vehicles of either power system became much more common in passenger service. In most countries dieselisation of locomotives in day-to-day use was completed by the 1970s. A few countries, most notably the People's Republic of China, where coal and labour are cheap, still use a few steam locomotives, but most have been phased out. Historic steam trains still run in many other countries, for the leisure and enthusiast market.

Electric traction offers a lower cost per mile of train operation but at a higher initial cost, which can only be justified on high traffic lines. Since the cost per mile of construction is much higher, electric traction is less viable for long-distance lines with the exception of long-distance high speed lines. Electric trains receive their current via overhead lines or through a third rail electric system.

A recent variation of the electric locomotive is the fuel cell locomotive. Fuel cell locomotives combine the advantage of not needing an electrical system in place, with the advantage of emissionless operation. However, the initial cost of such fuel cell vehicles is still substantial at the moment.

Passenger trains

A passenger train is one which includes passenger-carrying vehicles. It may be a self-powered multiple unit or railcar, or else a combination of one or more locomotives and one or more unpowered trailers known as coaches, cars or carriages. Passenger trains travel between stations or depots, at which passengers may board and disembark. In most cases, passenger trains operate on a fixed schedule and have superior track occupancy rights over freight trains.

Oversight of a passenger train is the responsibility of the conductor. He or she is usually assisted by other crew members, such as service attendants or porters. During the heyday of North American passenger rail travel, long distance trains carried two conductors: the aforementioned train conductor, and a Pullman conductor, the latter being in charge of sleeping car personnel.

Many prestigious passenger train services have been given a specific name, some of which have become famous in literature and fiction. In past years, railroaders often referred to passenger trains as the "varnish", alluding to the bygone days of wooden-bodied coaches with their lustrous exterior finishes and fancy livery. "Blocking the varnish" meant a slow-moving freight train was obstructing a fast passenger train, causing delays.

Some passenger trains, both long distance and short distanced, may use bi-level (double-decker) cars to carry more passengers per train. Car design and the general safety of passenger trains have dramatically evolved over time, making travel by rail remarkably safe.

Long-distance trains

Long-distance trains travel between many cities and/or regions of a country, and sometimes cross several countries. They often have a dining car or restaurant car to allow passengers to have a meal during the course of their journey. Trains travelling overnight may also have sleeping cars.

High-speed rail

One notable and growing long-distance train category is high-speed rail. Generally, high speed rail runs at speeds above 200 km/h (124 mph) and often operates on dedicated track that is surveyed and prepared to accommodate high speeds. Japan's Shinkansen ("bullet-train") commenced operation in 1964, and was the first successful example of a high speed passenger rail system.

The fastest wheeled train running on rails is France's TGV (Train à Grande Vitesse, literally "high speed train"), which achieved a speed of 574.8 km/h (357.2 mph), twice the takeoff speed of a Boeing 727 jetliner, under test conditions in 2007. The highest speed currently attained in scheduled revenue operation is 350 km/h (217 mph) on the Beijing–Tianjin Intercity Rail and Wuhan–Guangzhou High-Speed Railway systems in China. The TGV runs at a maximum revenue speed of 300–320 km/h (186–199 mph), as does Germany's Inter-City Express.

In most cases, high-speed rail travel is time- and cost-competitive with air travel when distances do not exceed 500 to 600 km (311 to 373 mi), as airport check-in and boarding procedures may add as many as two hours to the actual transit time. Also, rail operating costs over these distances may be lower when the amount of fuel consumed by an airliner during takeoff and climbout is considered. As travel distance increases, the latter consideration becomes less of the total cost of operating an airliner and air travel becomes more cost-competitive.

Some high speed rail equipment employs tilting technology to improve stability in curves. Examples of such equipment are the Advanced Passenger Train (APT), the Pendolino, the N700 Series Shinkansen, Amtrak's Acela Express and the Talgo. Tilting is a dynamic form of superelevation, allowing both low- and high-speed traffic to use the same trackage (though not simultaneously, of course), as well as producing a more comfortable ride for passengers.

Maglev

In order to achieve much faster operation over 500 km/h (310 mph), innovative Maglev technology has been researched for years. The Shanghai Maglev Train, opened in 2003, is the fastest commercial train service of any kind, operating at speeds of up to 430 km/h (270 mph). So far, however, Maglev has not been used for inter-city mass transit routes.

Inter-city trains

Passenger trains can be divided into three major groups:

- Intercity trains: connecting cities in the fastest time possible, by passing all intermediate stations
- Fast trains: calling at larger intermediate stations between cities, serving large urban communities
- Regional trains: calling at all intermediate stations between cities, serving all lineside communities

The distinction between the types can be thin or even non-existent. Trains can run as Intercity services between major cities, then revert to a fast or even regional train service to serve communities at the extremity of their journey. This practice allows marginal communities remaining to be served while saving money at the expense of a longer journey time for those wishing to travel to the terminus station.

Regional trains

Regional trains usually connect between towns and cities, rather than purely linking major population hubs like inter-city train, and serve local traffic demand in relatively rural area.

Short-distance trains

Commuter trains

For shorter distances many cities have networks of commuter trains, serving the city and its suburbs. Trains are a very efficient mode of transportation to cope with large traffic demand in a metropolis. Compared with road transport, it carries many people with much smaller land area and little air pollution.

Some carriages may be laid out to have more standing room than seats, or to facilitate the carrying of prams, cycles or wheelchairs. Some countries have double-decked passenger trains for use in conurbations. Double deck high speed and sleeper trains are becoming more common in mainland Europe.

Sometimes extreme congestion of commuter trains becomes a problem. For example, an estimated 3.5 million passengers ride every day on Yamanote Line in Tokyo, Japan, with its 29 stations. For comparison, the New York City Subway carries 4.8 million passengers per day on 24 services serving 468 stations. To cope with large traffic, special cars in which the bench seats fold up to provide standing room only during the morning rush hour (until 10 a.m.) are operated in Tokyo (E231 series train). This train has as many as six sets of doors on each side to shorten the time for passengers to get on and off at station.

Passenger trains usually have emergency brake handles (or a "communication cord") that the public can operate. Misuse is punished by a heavy fine.

Rapid transit

Large cities often have a metro system, also called underground, subway or tube. The trains are electrically powered, usually by third rail, and their railroads are separate from other traffic, usually without level crossings. Usually they run in tunnels in the city center and sometimes on elevated structures in the outer parts of the city. They can accelerate and decelerate faster than heavier, long-distance trains.

The term **rapid transit** is used for public transport such as commuter trains, metro and light rail. However, in New York City, services on the New York City Subway have been referred to as "trains".

Tram

In most countries, such as the United Kingdom, the distinction between a tramway and a railway is precise and defined in law. In the US and Canada such street railways are mostly referred to as trolleys. The key difference between a railroad and a trolley system is the latter running primarily on public streets, whereas trains have a right of way separated from the public. Often the US style interurban and modern light rail are confused with a trolley system, as it too may run on on the street for short or medium long sections. In some languages the word tram also refers to interurban and light rail - style networks, in particular Dutch.

The length of a tram or trolley may be determined by national regulations. Germany has the so-called Bo-Strab standard, restricting the length of a tram to 75 meters, while in the US, vehicle length is normally restricted by local authorities, often allowing only a single type of vehicle to operate on the network.

Light rail

The term light rail is sometimes used for a modern tram system, but it may also mean an intermediate form between a tram and a train, similar to a subway except that it may have level crossings. These are then usually protected with crossing gates. In US terminology these systems are often referred to as interurban, as they connect larger urban areas in the vicinity of a major city to that city. Modern light rail systems often use abandoned heavy rail rights of way (e.g. former railway lines) to revitalize deprived areas and redevelopment sites in and around large agglomerations.

Monorail

Monorail was developed to meet medium-demand traffic in urban transit, but represents a relatively small part of the overall railway field.

Named trains

Railway companies often give a name to a train service as a marketing exercise, to raise the profile of the service and hence attract more passengers (and also to gain kudos for the company). Usually, naming is reserved for the most prestigious trains: the high-speed express trains between major cities, stopping at few intermediate stations. The names of services such as the Orient Express, the Flying Scotsman, the Flèche d'Or and the Royal Scot have passed into popular culture.

A somewhat less common practice is the naming of freight trains, for the same commercial reasons. The "Condor" was an overnight London-Glasgow express goods train, in the 1960s, hauled by pairs of "Metrovick" diesel locomotives. In the mid-1960s, British Rail introduced the "Freightliner" brand, for the new train services carrying containers between dedicated terminals around the rail network. The Rev. W. Awdry also named freight trains, coining the term *The Flying Kipper* for the overnight express fish train that appeared in his stories in The Railway Series books.

Other types

Heritage trains

Heritage trains are operated by volunteers, often railfans, as a tourist attraction. Usually trains are formed from historic vehicles retired from national commercial operation.

Airport trains

Airport trains transport people between terminals within an airport complex.

Mine trains

Mine trains are operated in large mines and carry both workers and goods.

Overland trains

Overland trains are used to carry cargo over rough terrain.

Freight trains

British electric container freight train

American freight service

A freight train (also known as goods train) uses **freight cars** (also known as wagons or trucks) to transport goods or materials (cargo) – essentially any train that is not used for carrying passengers. Much of the world's freight is transported by train, and in the United States the rail system is used more for transporting freight than passengers.

Under the right circumstances, transporting freight by train is highly economic, and also more energy efficient than transporting freight by road. Rail freight is most economic when freight is being carried in bulk and over long distances, but is less suited to short distances and small loads. Bulk aggregate movements of a mere twenty miles (32 km) can be cost effective even allowing for trans-shipment costs. These trans-shipment costs dominate in many cases and many modern practices such as Intermodal container freight are aimed at minimizing these.

The main disadvantage of rail freight is its lack of flexibility. For this reason, rail has lost much of the freight business to road competition. Many governments are now trying to encourage more freight onto trains, because of the benefits that it would bring.

There are many different types of freight trains, which are used to carry many different kinds of freight, with many different types of wagons. One of the most common types on modern railways are container trains, where containers can be lifted on and off the train by cranes and loaded off or onto trucks or ships.

In the U.S. this type of freight train has largely superseded the traditional boxcar (wagon-load) type of freight train, with which the cargo has to be loaded or unloaded manually. In Europe the sliding wall wagon has taken over from the ordinary covered goods wagon.

In some countries "piggy-back" trains or rolling highways are used: In the latter case trucks can drive straight onto the train and drive off again when the end destination is reached. A system like this is used through the Channel Tunnel between England and France, and for the trans-Alpine service between France and Italy (this service uses Modalohr road trailer carriers). "Piggy-back" trains are the fastest growing type of freight trains in the United States, where they are also known as "trailer on flatcar" or TOFC trains. Piggy-back trains require no special modifications to the vehicles being carried. An alternative type of "inter-modal" vehicle, known as a Roadrailer, is designed to be physically attached to the train. The original trailers were fitted with two sets of wheels — one set flanged, for the trailer to run connected to other such trailers as a rail vehicle in a train; and one set tyred, for use as the semi-trailer of a road vehicle. More modern trailers have only road wheels and are designed to be carried on specially adapted bogies (trucks) when moving on rails.

There are also many other types of wagons, such as "low loader" wagons for transporting road vehicles. There are refrigerator cars for transporting foods such as ice cream. There are simple types of open-topped wagons for transporting minerals and bulk material such as coal, and tankers for transporting liquids and gases. Today, however, most coal and aggregates are moved in hopper wagons that can be filled and discharged rapidly, to enable efficient handling of the materials.

Freight trains are sometimes illegally boarded by passengers who do not wish to pay money, or do not have the money to travel by ordinary means. This is referred to as "freighthopping" and is considered by some communities to be a viable form of transport. A common way of boarding the train illegally is by sneaking into a train yard and stowing away in an unattended boxcar; a more dangerous practice is trying to catch a train "on the fly", that is, as it is moving, leading to occasional fatalities. Railroads treat it as trespassing and may prosecute it as such.