Track Gauges in Railway Systems Engineering

Dontae Spain

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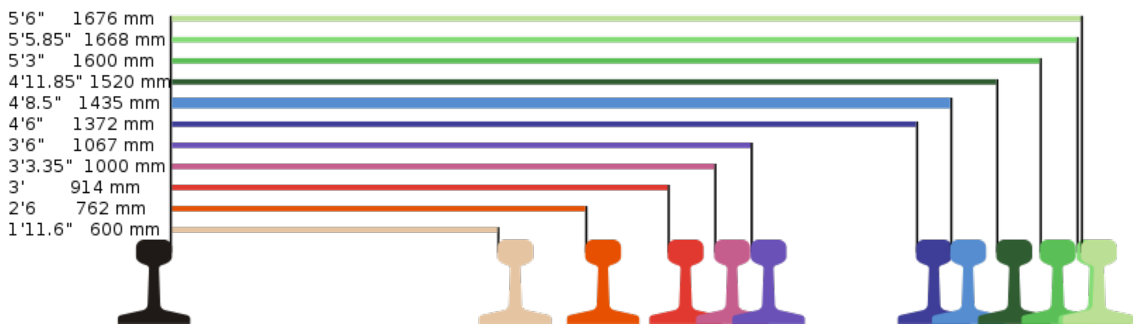
Track Gauge



Track gauge or **rail gauge** is the distance between the inner sides of the heads of the two load bearing rails that make up a single railway line. Sixty percent of the world's railways use a standard gauge of 1,435 mm (4 ft 8 $\frac{1}{2}$ in). Wider gauges are called broad gauge; smaller gauges, narrow gauge. Break-of-gauge refers to the meeting of different gauges. Some stretches of track are dual gauge, with three or four rails, allowing trains of different gauges to share them. Gauge conversion can resolve break-of-gauge problems. An exception of a railway with no gauge is monorail where there is only one supporting rail. Some electrified railways use non load bearing third rail and occasionally a '4th' rail. These additional rails are positioned between or outside the 'running rails' to feed and return electrical current, they do not define the rail gauge.

Gauge tolerances specify how much the actual gauge may vary from the nominal gauge. For example, the U.S. FRA specifies that the actual gauge of track that is rated for a maximum of 60 mph (96.6 km/h) must be between 4 ft 8 in (1,422 mm) and 4 ft 9 $\frac{1}{2}$ in (1,460 mm).

A **track gauge** is also the name of the measuring device used to test whether rails are within the correct gauge.

Overview

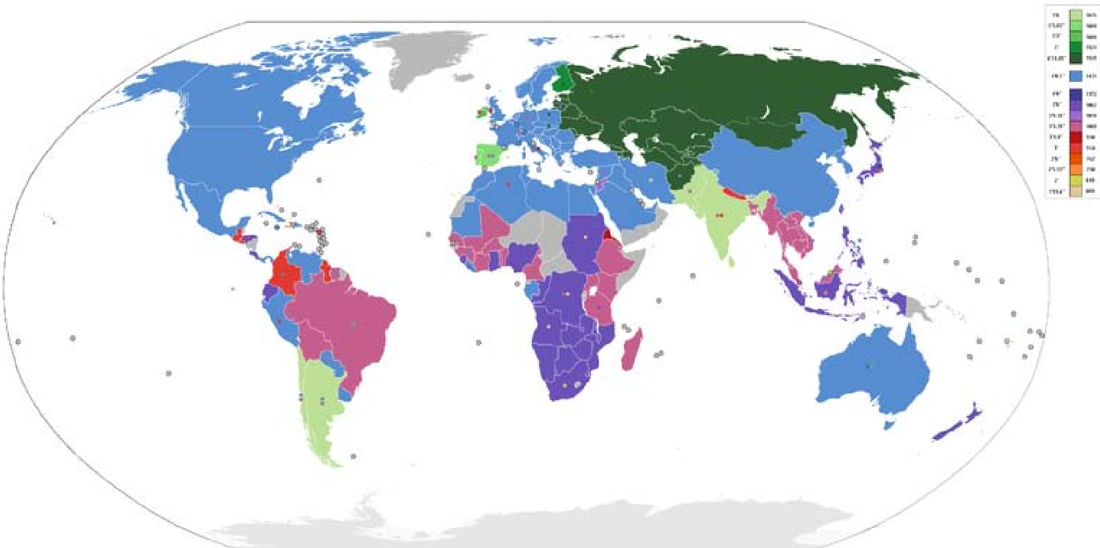
New railways, especially recent high speed rail (AVE and Shinkansen), are usually built to standard gauge. Advantages are:

- It facilitates inter-running with neighbouring railways
- Locomotives and rolling stock can be ordered from manufacturers' standard designs and do not need to be custom built, though some adaptation to local conditions may be necessary, for example, regarding loading gauge.

Generally speaking, of the gauges between 1,000 mm (3 ft 3 ⅜ in) and 1,700 mm (5 ft 6.93 in), standard gauge works well enough. The supposed advantages of broader or narrower gauges in this range are not enough to overcome the disadvantages of any break of gauge in a railway system.

Dominant gauges

ft′ in″	**mm**
5′ 6″	1676
5′ 5⅔″	1668
5′ 3″	1600
5′	1524
4′ 11⅞″	1520
4′ 8½″	**1435**
4′ 6″	1372
3′ 6″	1067
3′ 5⅓″	1050
3′ 3⅜″	1000
3′ 1⅜″	950
3′	914
2′ 6″	762
2′ 5½″	750
2′	610
1′ 11⅝″	600



The dominant rail gauge in each country shown

Gauge	Name	Installation, km	Usage
1,676 mm (5 ft 6 in)	Indian gauge	77,000	India (42,000 km; increasing with Project Unigauge), Pakistan, Argentina (24,000 km), Chile *(approx. 6.55% of the world's railways)*
1,668 mm (5 ft $5\frac{2}{3}$ in)	Iberian gauge	15,394	Portugal, Spain. In Spain as of the Iberian gauge 21 km are of three-rail dual Iberian and standard gauges, more to come in the future
1,600 mm (5 ft 3 in)	Irish gauge	9,800	Ireland, and in Australia mainly Victoria and some South Australia Victorian gauge (4,017 km), Brazil (4,057 km)
1,524 mm (5 ft)	Russian gauge	5,865	Finland
1,520 mm (4 ft $11\frac{5}{6}$ in)	Russian gauge	220,000	CIS states (including Russia), Estonia, Latvia, Lithuania, Mongolia *(approx. 17% of the world's railways)*
1,435 mm (4 ft $8\frac{1}{2}$ in)	Standard gauge	720,000	Europe, Argentina, United States, Canada, China, Korea, Australia, Middle East, North Africa, Mexico, Cuba, Panama, Venezuela, Peru, Uruguay and Philippines. Also high-speed lines in Japan and Spain. *(approx. 60% of the world's railways)*

1,067 mm (3 ft 6 in)	Cape gauge	112,000	Southern and Central Africa, Indonesia, Japan, Taiwan, Philippines, New Zealand, Queensland Australia Queensland Rail *(approx. 9% of the world's railways)*
1,000 mm (3 ft 3 ⅜ in)	Metre gauge	95,000	SE Asia, India (17,000 km, decreasing with Project Unigauge), Argentina (11,000 km), Brazil (23,489 km), Bolivia, northern Chile, Switzerland(RhB, MOB, BOB, MGB), Kenya, Uganda *(approx. 7% of the world's railways)*

Note: Russian gauge can be 1524 mm or 1520 mm.

History

Historically, the choice of gauge was partly arbitrary and partly a response to local conditions. Narrow-gauge railways are cheaper to build and can negotiate sharper curves but broad-gauge railways give greater stability and permit higher speeds. Standard gauge is a compromise between the narrow and broad gauges.

Sometimes railway companies chose their own gauge, such as the Great Western Railway choosing 2,140 mm (7 ft 0 ¼ in).

Other times, statutes required railways to use a particular gauge, such as the Thomasville, Tallahassee and Gulf Railroad having to use standard gauge.

Early origins of the standard gauge

There is an urban legend that Julius Caesar specified a legal width for chariots at the width of standard gauge, causing road ruts at that width, so all later wagons had to have the same width or else risk having one set of wheels suddenly fall into one deep rut but not the other.

In fact, the origins of the standard gauge considerably pre-date the Roman Empire, and may even pre-date the invention of the wheel. The width of prehistoric vehicles was determined by a number of interacting factors which gave rise to a fairly standard vehicle width of a little under 2 m (6.6 ft). These factors have changed little over the millennia, and are still reflected in today's motor vehicles. Road rutting was common in early roads, even with stone pavements. The initial impetus for the ruts probably came from the grooves made by sleds and slide cars dragged over the surfaces of ancient trackways. Since early carts had no steering and no brakes, negotiating hills and curves was dangerous, and cutting ruts into the stone helped them negotiate the hazardous parts of the roads.

Neolithic wheeled carts found in Europe had gauges varying from 130 to 175 cm (4 ft 3 in to 5 ft 9 in). By the Bronze age, wheel gauges appeared to have stabilized between 140 to 145 cm (4 ft 7 in to 4 ft 9 in) which was attributed to a tradition in ancient technology which was perpetuated throughout European history. The ancient Assyrians, Babylonians, Persians and Greeks constructed roads with artificial wheelruts cut in rock spaced the wheelspan of an ordinary carriage. Such ancient stone rutways connected major cities with sacred sites, such as Athens to Eleusis, Sparta to Ayklia, or Elis to Olympia. The gauge of these stone grooves was 138 to 144 cm (4 ft 6 in to 4 ft 9 in). The largest number of preserved stone trackways, over 150, are found on Malta.

Some of these ancient stone rutways were very ambitious. Around 600 BC the citizens of ancient Corinth constructed the Diolkos, which some consider the world's first railway, a granite road with grooved tracks along which large wooden flatbed cars carrying ships and their cargo were pulled by slaves or draft animals. The space between the grooved tracks in the granite was a consistent 1.5 m (4 ft 11 in).

The Roman Empire actually made less use of stone trackways than the prior Greek civilization because the Roman roads were much better than those of previous civilizations. However, there is evidence that the Romans used a more or less consistent wheel gauge adopted from the Greeks throughout Europe, and brought it to England with the Roman conquest of Britain in AD 43. After the Roman departure from Britain, this more-or-less standard gauge continued in use, so the wheel gauge of animal drawn vehicles in 19th century Britain was 1.4 to 1.5 m (4 ft 7 in to 4 ft 10 in). In 1814 George Stephenson copied the gauge of British coal wagons in his area (about 1.42 m (4 ft 8 in)) for his new locomotive, and for technical reasons widened it slightly to achieve the modern railway standard gauge of 1.435 m (4 ft 8.5 in).

Standard gauge

What became the standard gauge of 4 ft 8 ½ in (1,435 mm) was chosen for the first main-line railway, the Liverpool and Manchester Railway (L&MR), by the British engineer George Stephenson; the de facto standard for the colliery railways where Stephenson had worked was 4 ft 8 in (1,422 mm). Whatever the origin of the gauge, it seemed to be a satisfactory choice: not too narrow and not too wide.

Isambard Kingdom Brunel, engineer of the Great Western Railway, chose the broader gauge of 7 ft 0 ¼ in (2,140 mm) because it offered greater stability and capacity at high speed. Brunel's first locomotives were exactly 7 foot gauge and had no slack, hence the extra quarter inch. The Eastern Counties Railway chose 5 ft (1,524 mm) gauge, but soon realised that lack of compatibility was a mistake and changed to Stephenson's gauge. The conflict between Brunel and Stephenson is often referred to as the Gauge War. Several non-interconnecting lines in Scotland were 5 ft 6 in (1,676 mm) but were changed to standard gauge for compatibility reasons.

In 1845 a United Kingdom of Great Britain and Ireland Royal Commission recommended adoption of 4 ft 8 ½ in (1,435 mm) as standard gauge in Great Britain, 5 ft 3 in (1,600 mm) in Ireland. The following year the Parliament of the United Kingdom passed the Gauge Act, which required that new railways use the standard gauge. Except for the Great Western Railway's broad gauge, few main-line railways in Great Britain used a different gauge. The last Great Western line was converted to standard gauge in 1892.

Broad gauge

Broad gauge refers to any gauge wider than standard gauge or 1,435 mm (4 ft 8 ½ in). Russian, Indian, Irish, and Iberian gauges are all broad gauges. Broad gauge railways are also common for cranes in docks for short distances. Broad gauge is used to provide better stability or to prevent the easy transfer of rolling stock from railroads of other countries for political or military reasons. Compare with narrow gauge.

Russian gauge

Russian gauge is 1,520 mm (4 ft 11 ⅚ in) and is the second most widely used gauge in the world.

Engineer Pavel Melnikov hired George Washington Whistler, a prominent American railroad engineer (and father of the artist James McNeill Whistler), to be a consultant on the building of Russia's first major railroad, the Moscow–Saint Petersburg Railway line. The selection of 1,500 mm (4 ft 11 1⁄16 in) gauge was recommended by German and Austrian engineers but not adopted: it was not the same as the 1,524 mm (5 ft) gauge in common use in the southern United States at the time. Russian gauge was defined as 1,524 mm (5 ft) on September 12, 1842 and standardised to the present 1,520 mm (4 ft 11 ⅚ in) in the late 1960s.

The interconnected and compatible system covers Russia and most of the former Soviet Union, including the Baltic states, Ukraine, Belarus, the Caucasian and Central Asian republics and Mongolia.

Curiosities

Finland, which was a Grand Duchy under Russia in the 19th century, uses 1,524 mm (5 ft) gauge. Upon gaining independence in 1917 much thought was given to converting to standard gauge, but nothing came of it. Most of Finland's rail-freight trade is still with Russia, and this trade continues because the Russian 1,520 mm (4 ft 11 ⅚ in) gauge is close enough to allow through-running.

This 1,067 mm (3 ft 6 in) Japanese D51 steam locomotive stands outside the Yuzhno-Sakhalinsk Railway Station on Sakhalin Island, Russia.

The unconnected system on Sakhalin Island, in the far east of Russia, has retained the previous Japanese 1,067 mm (3 ft 6 in) gauge, as built. In 2004 a project was presented to convert this system to Russian gauge, in conjunction with a bridge/tunnel connection to the mainland.

Iberian gauge

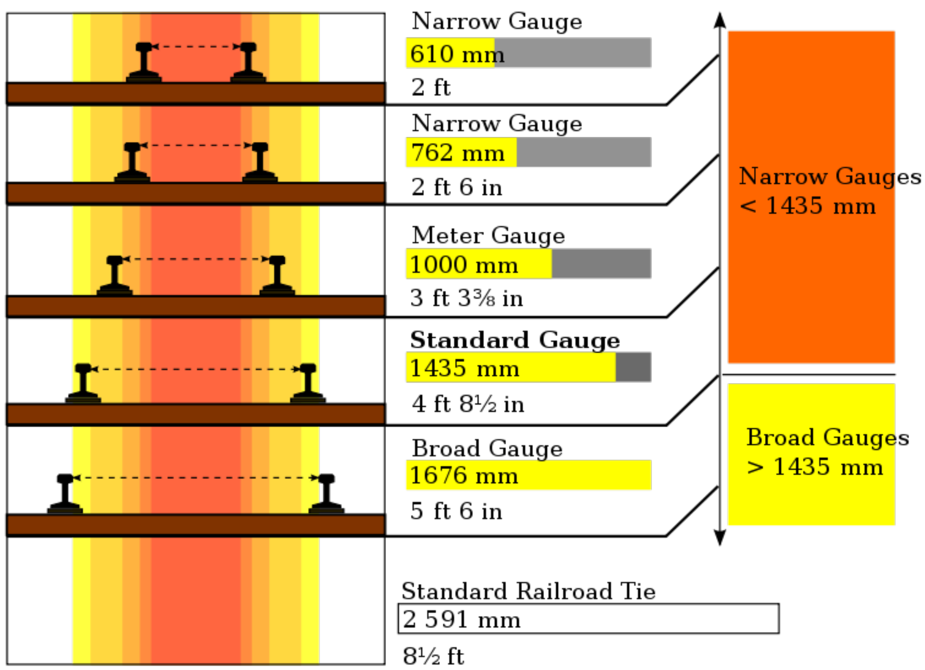
The main railway networks of Spain and Portugal were constructed to gauges of six Castilian feet (1,672 mm/5 ft 5 ⅚ in) and five Portuguese feet (1,664 mm/5 ft 5 ½ in). The two gauges were sufficiently close to allow inter-operation of trains, and in recent years they have both been adjusted to a common "Iberian gauge" (*ancho ibérico* or *trocha ibérica* in Spanish, *bitola ibérica* in Portuguese) of 1,668 mm/5 ft 5 ⅔ in. Although it has been said that the main reason for the adoption of this non-standard gauge was to obstruct any French invasion attempts, it was a technical decision to allow for the running of larger, more powerful locomotives in a mountainous country.

Since the beginning of the 1990s new high-speed passenger lines in Spain have been built to standard gauge of 1,435 mm (4 ft 8 ½ in), to allow these lines to eventually link to the European high-speed network. Although the 21 km from Tardienta to Huesca (part of a branch from the Madrid to Barcelona high-speed line) has been reconstructed as dual Iberian and standard gauges, so are now being adapted lines between Barcelona and Figueres that will be put into service at the end of 2010. In general the interface between the two gauges in Spain is dealt with by gauge-changing installations, which can adjust the gauge of appropriately designed wheelsets on the move.

There are plans to convert the whole broad gauge network to standard gauge, but so far the only visible indication is the use of dual-gauge concrete sleepers with two positions of bolt holes on renewed stretches of broad-gauge track.

Indian gauge

Bangladesh, India, Pakistan and Sri Lanka inherited a diversity of rail gauges, of which 1,676 mm (5 ft 6 in) was first and predominant. Indian Railways has adopted Project Unigauge, which seeks to systematically convert most of its narrower gauge railways to 1,676 mm.



Comparison of standard gauge with various gauges common in India.

Irish gauge

The gauge of main-line railways in Ireland is 5 ft 3 in (1,600 mm), found also in the Australian states of Victoria, southern New South Wales (as part of the Victorian rail network) and South Australia (where it was introduced by the Irish railway engineer F. W. Sheilds), and Brazil.

The first three railways all had different gauges: the Dublin and Kingstown Railway, 4 ft 8 in (1,422 mm); the Ulster Railway, 6 ft 2 in (1,880 mm); and the Dublin and

Drogheda Railway, 5 ft 2 in (1,575 mm). The Board of Trade, recognising the chaos that would ensue, investigated the matter, and in 1843 recommended the use of 5 ft 3 in (1,600 mm).

This was given legal status by the Railway Regulation (Gauge) Act of 1846 which specified 4 feet 8½ inches (1,435 mm) for Great Britain and 5 feet 3 inches (1,600 mm) for Ireland.

Australian gauge

Despite early attempts at coordination, Australia has three different rail gauges in one country.

The then three mainland colonies adopted 1,435 mm (4 ft 8 ½ in) in 1848, with some states passing legislation to that effect.

Then there was a change to 1,600 mm (5 ft 3 in) at the instigation of New South Wales, which was agreed to by those then three states.

Then New South Wales reverted to standard gauge while Victoria and South Australia stayed with broad gauge, having ordered rolling stock to that gauge.

Queensland was built with 1,067 mm (3 ft 6 in) to save costs. Narrow gauge worked well enough for light traffic to persuade Tasmania, Western Australia and parts of South Australia to follow suit.

Dual and standard gauge lines have been introduced to the main interstate routes. Pilbara iron ore railways have always been standard gauge.

Italian gauge

Italy defined its gauges from the centres of each rail, rather than the inside edges of the rails, giving some unusual measurements (for example, 950 mm instead of 1000 mm). According to the law of 28 July 1879, the only legal gauges in Italy were 1500, 1000 and 750 mm measured to the middle of the rail, corresponding to 1445, 950, and 700 mm inside the rail.

A disadvantage of measuring from the centre of the rail is that the width of the rail varies, affecting the gauge. It is easier and more reliable to measure from the inner edges of the rails.

Narrow gauge

In many areas narrow gauge railways have been built. As the gauge of a railway is reduced the costs of construction can also be reduced since narrow gauges allow a smaller radius curves allowing obstacles to be avoided rather than having to be built over or through (valleys and hills); the reduced cost is particularly noticeable in mountainous regions. For example, many narrow gauge railways were built in Wales and the Rocky Mountains of North America. The disadvantage of tight turns and steep gradients is a reduced line speed and smaller trains leading to higher operating costs. Many narrow gauge railways have been abandoned or converted to standard gauge. Industrial railways are often constructed using narrow gauge. Sugar cane and banana plantations are often served by narrow gauges such as 2 ft (610 mm), as there is little through-traffic to other systems.

The most widely used narrow gauges are

- 1,067 mm (3 ft 6 in) Cape gauge (e.g. Southern and Central Africa, Indonesia, Japan, Taiwan, Philippines, parts of Australia, New Zealand)
- 1,000 mm (3 ft 3 ⅜ in) metre gauge (e.g. SE Asia, 17,000 km (11,000 mi) in India, but gauge conversion with Project Unigauge, East Africa, South America)

There are also minimum gauge railways.

Break of gauge

When a railway line of one gauge meets a line of another gauge there is a **break of gauge**. A break of gauge adds cost and inconvenience to traffic that passes from one system to another.

An example of this is on the Transmongolian Railway, where Russia and Mongolia use broad gauge while China uses standard gauge. At the border, each carriage has to be lifted in turn to have its bogies changed. The whole operation, combined with passport and customs control, can take several hours.

Other examples include crossings into or out of the former Soviet Union: Ukraine/Slovakia border on the Bratislava-L'viv train, and from the Romania/Moldova border on the Chisinau-Bucharest train.

This can be avoided however by implementing a system similar to that used in Australia, where some lines between states using different gauges were converted to dual gauge with three rails, one set of two forming a standard gauge line, with the third rail either inside or outside the standard set forming rails at either narrow or broad gauge. As a result, trains built to either gauge can use the line.

Dual gauge

Dual gauge allows trains of different gauges to share the same track. This can save considerable expense compared to using separate tracks for each gauge, but introduces complexities in track maintenance and signalling, as well as requiring speed restrictions for some trains. If the difference between the two gauges is large enough, for example between 1,435 mm (4 ft 8 ½ in) and 3 ft 6 in (1,067 mm), three-rail dual-gauge is possible, but if the difference is not large enough, for example between 3 ft 6 in (1,067 mm) and 1,000 mm (3 ft 3 ⅜ in), four-rail dual-gauge is used. Dual-gauge rail lines are used in the railway networks of Switzerland, Australia, Argentina, Brazil, North Korea, Spain, Tunisia and Vietnam.

Variable gauge axles

Variable gauge axles (VGA), developed by the Talgo company and Construcciones y Auxiliar de Ferrocarriles (CAF) of Spain, amongst others, enable trains to change gauge with only a few minutes spent in the gauge conversion process. The same system is also used between China and Central Asia, and Poland and Ukraine (SUW 2000 and INTERGAUGE variable axles system). China and Poland are standard gauge, while Central Asia and Russia are 1520 mm gauge.

Designed for Conversion

Equipment can be designed for easy conversion, such as the Garratt locomotives on the Kenya and Uganda Railway designed for conversion from 1,000 mm (3 ft 3 ⅜ in) to 1,067 mm (3 ft 6 in). Several classes of steam locomotives of the Victorian Railways were designed for easy conversion from 1,600 mm (5 ft 3 in) to 1,435 mm (4 ft 8 ½ in). Only one, R766, a preserved historic locomotive, has actually been converted.

Future

Further standardisation of rail gauges seems likely, as individual countries seek to build inter-operable national networks, and international organisations seek to build macro-regional and continental networks. National projects include the Australian and Indian efforts mentioned above to create a uniform gauge in their national networks. The European Union has set out to develop inter-operable freight and passenger rail networks across the EU area, and is seeking to standardise track gauge, signalling and electrical power systems. EU funds have been dedicated to convert key railway lines in the Baltic states of Lithuania, Latvia, and Estonia from 1520 mm gauge to standard gauge, and to assist Spain and Portugal in the construction of high-speed rail lines to connect Iberian cities to one another and to the French high-speed lines. The EU has developed plans for improved freight rail links between Spain, Portugal, and the rest of Europe.

High speed

Except in Russia and neighbouring states, all high-speed rail systems use standard gauge, even in countries like Japan, Taiwan, Spain and Portugal where most of the existing rail lines use a different gauge. Once standard gauge high-speed networks exist, they may provide the impetus for gauge conversion of existing passenger lines to allow for interoperability. All high speed lines have adopted 25 kV 50 Hz AC overhead line as the standard electrification system except in Germany, Sweden, Norway and Switzerland (15 kV AC and 3000 V DC), the first high speed lines in Italy (3000 V DC), the Tōkaidō, Sanyō and Kyūshū Shinkansen lines in Japan (25 kV 60 Hz) and the United States, which uses 25 kV 60 Hz in new construction and has older 12 kV segments.

Mining

Heavy duty mining railways which have little interconnection with other lines, such as in the Pilbara region of Western Australia, also tend to choose standard gauge to allow them to use off-the-shelf equipment, especially heavy-duty rolling stock.

New lines

The United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP) is planning a Trans-Asian Railway that will link Europe and the Pacific, with a Northern Corridor from Europe to the Korean Peninsula, a Southern Corridor from Europe to Southeast Asia, and a North-South corridor from Northern Europe to the Persian Gulf. All the proposed corridors would encounter one or more breaks of gauge as they cross Asia. Current plans have mechanized facilities at the breaks of gauge to move shipping containers from train to train rather than widespread gauge conversion.

- Rail lines for iron ore to Oakajee port in Western Australia are proposed to form a combined dual gauge network.
- Rail lines for iron ore to Kribi in Cameroon are likely to be 1435 mm with a likely connection to the same port from the 1000 mm gauge Cameroon system.

Kenya-Uganda-Sudan proposal

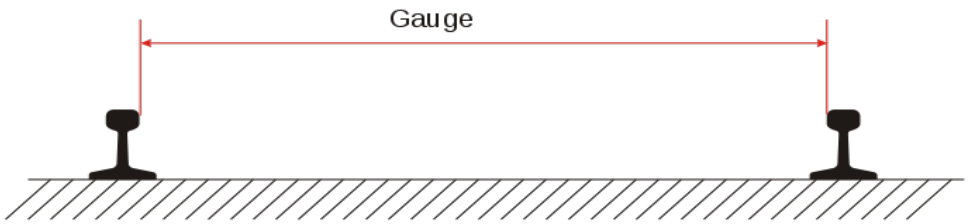
A proposal was aired in October 2004 to build a high-speed electrified line to connect Kenya with southern Sudan. Kenya and Uganda use 1,000 mm (3 ft $3\frac{3}{8}$ in) gauge, while Sudan uses 3 ft 6 in (1,067 mm) gauge. Standard gauge was proposed for the project.

Latin America

- 2008 proposed VCE link between Venezuela, Colombia and Ecuador
- 2008 - VBA - Venezuela via Brazil to Argentina - standard gauge
- 2008 A proposed metre gauge line across Southern Paraguay to link the Argentine rail at Resistencia to the Brazilian line at Cascavel; both those lines are metre gauge, and the new line would allow uninterrupted "bioceanic" running from one coast to the other, from the Atlantic port of Paranagua in Brazil to that of Antofagasta in Chile on the Pacific.

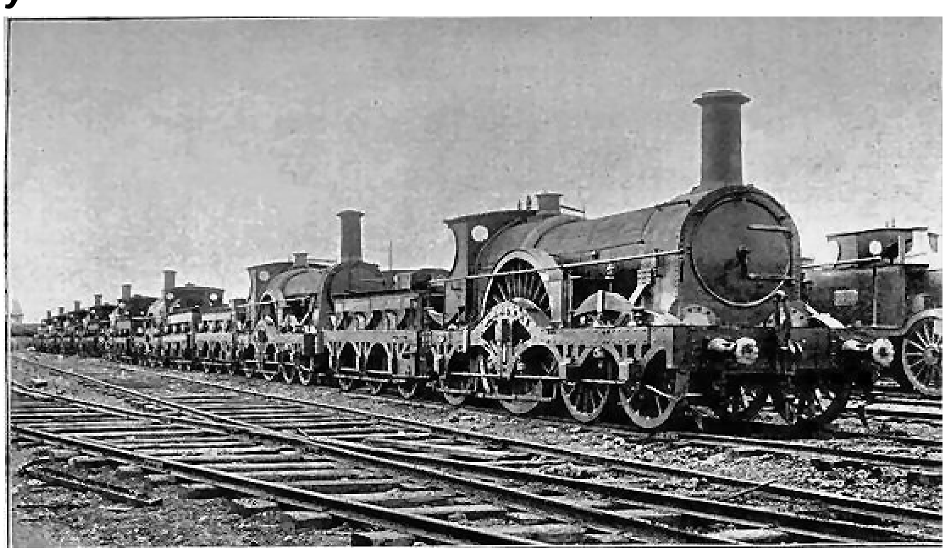
Chapter- 2

Broad Gauge



Broad-gauge railways use a rail gauge (distance between the rails) greater than the standard gauge of 1,435 mm (4 ft 8 ½ in).

History



Great Western Railway broad-gauge steam locomotives awaiting scrapping in 1892 after the conversion of the tracks to standard gauge.

Original broad gauge "bridge rail" used as safety barriers at Neyland - original West Wales terminus of GWR

In Britain the Great Western Railway, designed by Isambard Kingdom Brunel, pioneered broad gauge from 1838 with a gauge of 7 ft 0 $^1⁄_4$ in (2,140 mm), and retained this gauge until 1892. A number of harbours also used railways of this gauge for construction and maintenance. These included Portland Harbour and Holyhead Breakwater, which used a locomotive for working sidings. As it was not connected to the national network, this broad-gauge operation continued until the locomotive wore out in 1913.

It became apparent that standardization on a single gauge throughout a rail transport system was advantageous. Rolling stock did not need to match the gauge exactly; a difference of a few millimeters could be coped with, so that interoperability on systems with gauges only slightly different was possible.

While the parliament of the United Kingdom of Great Britain and Ireland was initially prepared to authorise lines built to the broad gauge of 7 ft 0 $^1⁄_4$ in (2,140 mm), it was eventually rejected by the Gauge Commission in favour of all railways in the British Isles being built to standard gauge of 1,435 mm (4 ft 8 $^1⁄_2$ in), this being the gauge with the highest route-mileage. Ireland, using the same criteria, was allocated a different standard gauge, Irish gauge. Broad-gauge lines in Britain were gradually converted to dual gauge or standard gauge from 1864, and finally the last of Brunel's broad gauge was converted over a single weekend in 1892.

Many countries have broad-gauge railways. Ireland and some parts of Australia and Brazil have a gauge of 5 ft 3 in (1,600 mm), but Luas, the Dublin light rail system, is built to standard gauge. Russia and the other former Soviet Republics use a 1,520 mm (4 ft 11 5⁄6 in) (originally 5 ft (1,524 mm)) gauge while Finland continues to use the 5 ft (1,524 mm) gauge inherited from Imperial Russia (the two standards are close enough to allow full interoperability between Finland and Russia).

In 1839 the Netherlands started its railway system with two broad-gauge railways. The chosen gauge was 1,945 mm (6 ft 4 23⁄40 in) after a visit of engineers to England and a large consignment of Brunel's lighter bridge rail removed from his "Bath Road" was imported for the construction. This was applied between 1839 and 1866 by the Hollandsche IJzeren Spoorweg-Maatschappij (HSM) for its Amsterdam-The Hague-Rotterdam line and between 1842 and 1855, firstly by the Dutch state, but soon by the Nederlandsche Rhijnspoorweg-Maatschappij, for its Amsterdam-Utrecht-Arnhem line. But the neighboring countries Prussia and Belgium already used standard gauge, so the two companies had to regauge their first lines. In 1855, NRS regauged its line and shortly afterwards connected to the Prussian railways. The HSM followed in 1866. There are replicas of one broad-gauge 2-2-2 locomotive (*De Arend*) and three carriages in the Dutch Railway Museum in Utrecht. These replicas were built for the 100th anniversary of the Dutch Railways in 1938–39.

The Baltic states have received funding from the European Union to build new lines with standard gauge. Portugal and the Spanish *Renfe* system use a gauge of 1,668 mm (5 ft 5 2⁄3 in) called "Ancho Ibérico" in Spanish or "Bitola Ibérica" in Portuguese; there are plans to convert to standard gauge. In India, Pakistan and Bangladesh, a gauge of 5 ft 6 in (1,676 mm) is widespread. This is also used by the Bay Area Rapid Transit (BART) system of the San Francisco Bay Area. In Toronto, Canada the gauge for TTC subways and streetcars was chosen in 1861, years after the establishment of 'standard gauge' in Britain, but well before 'standard gauge' in the US and Canada. Toronto uses a unique gauge of 4 ft 10 7⁄8 in (1,495 mm), an "overgauge" originally stated to 'allow horse-drawn wagons to use the rails', but with the practical effect of precluding the use of standard-gauge equipment in the street. In 1861, the province was supplying subsidies only to broad 'provincial gauge' railways.

Irish broad gauge tracks

The value of interoperability was initially not obvious to the industry. The standardization movement was gradual; over time the value of a proprietary gauge diminished, being replaced by the idea of charging money for equipment used on other railroad lines.

The use of a non-standard gauge precludes interoperability of rolling stock on railway networks. On the GWR the 7 ft 0 $^1/_4$ in (2,140 mm) gauge was supposed to allow high speed, but the company had difficulty with locomotive design in the early years, losing much of the advantage, and rapid advances in permanent way and suspension technology allowed standard-gauge speeds to approach broad-gauge speeds within a decade or two. On the 5 ft 3 in (1,600 mm) and 5 ft 6 in (1,676 mm) gauges, the extra width allowed bigger inside cylinders and greater power, a problem solvable by using outside cylinders and higher steam pressure on standard gauge. In the event, the most powerful engines on standard gauge in North America and Scandinavia far exceeded the power of any broad-gauge locomotive.

Canadian gauge

The first railway in British North America, the Champlain and St. Lawrence Railroad, was built in 1835-36 to **5 ft 6 in (1,676 mm)** gauge, setting the standard for Britain's colonies for several decades. Today, this is commonly known as Indian gauge, but in 1851 the 5 ft 6 in (1,676 mm) broad gauge was officially adopted as the standard gauge for the Province of Canada, becoming known as the *Provincial gauge*, and government subsidies were unavailable for railways that chose other gauges. However, this caused problems in interchanging freight cars with northern United States railroads, most of which were built to standard gauge or a gauge similar to it. In the 1870s, mainly between 1872 and 1874, Canadian broad-gauge lines were changed to standard gauge to facilitate interchange and the exchange of rolling stock with American railroads. Today, all Canadian freight railways are standard-gauge, with only the Toronto Transit Commission operating streetcars and subway vehicles on its own unique overgauge of 4 ft 10 ⅞ in (1,495 mm).

Indian and Pakistani gauge

The British Raj in India adopted **5 ft 6 in (1,676 mm)** gauge, although some standard-gauge railways were built in the initial period. The standard-gauge railways were soon converted to broad gauge. Reputedly, broad gauge was thought necessary to keep trains stable in the face of strong monsoon winds. Attempts to economise on the cost of construction led to the adoption of 1,000 mm (3 ft 3 ⅜ in) gauge and then 2 ft 6 in (762 mm) and 2 ft (610 mm) narrow gauges for many secondary and feeder lines, particularly in mountainous terrain.

However, broad gauge remained the most prevalent gauge across the Indian Subcontinent, reaching right across from Iran into Pakistan to Burma and Kashmir to Sri Lanka. After independence, the Indian Railways adopted 5 ft 6 in (1,676 mm) as the standard Indian gauge, and began Project Unigauge to convert metre-gauge and narrow-gauge lines to this gauge. Some of the newer specialized rail projects in India, such as the Konkan Railway and the Delhi Metro, use Indian gauge. There was a move to use standard gauge for the Delhi Metro, but the decision was made to use Indian gauge to maintain compatibility with the rest of the rail network. The decision was later changed and several new lines, including the Airport Express Line, use standard gauge. The new Bangalore Metro, Mumbai Metro, and Hyderabad Metro systems, all in planning or under construction as of 2009, will be on standard gauge.

Because of the broad gauge, trains in India can carry standard shipping containers double-stacked on standard flatcars, which is more economical than single containers, but standard-gauge railways in North American and elsewhere must use special double-stack cars to lower the center of gravity and reduce the loading gauge. Indian Railways is able to carry containers double-stacked on standard flatcars at 100 km/h (62 mph). Triple-stacked operation with lower, 6.5-foot (1,981 mm) containers, is planned. Flatcars, in addition to being much less expensive than well cars, can carry more containers in a given length of train.

Iberian gauge

As finally established, the Iberian gauge of **1,668 mm (5 ft 5 ⅔ in)** is a compromise between the similar, but slightly different, gauges first adopted as respective national standards in Spain and Portugal in the mid-19th century. The main railway networks of Spain were initially constructed to a 1,672 mm (5 ft 5 ⅚ in) gauge of six Castilian feet. Those of Portugal were initially built in standard gauge, but by 1864 were all converted to a 1,664 mm (5 ft 5 ½ in) gauge of five Portuguese feet – close enough to allow interoperability in practice. The new high-speed network in Spain and Portugal uses standard gauge. The dual-gauge high-speed train RENFE Class 130 can change gauge at low speed without stopping.

Irish gauge

As part of the railway gauge standardisation considered by the United Kingdom Parliamentary Gauge Commission, Ireland was allocated its own gauge, **Irish gauge**, again based on the gauge with the highest route-mileage. The Irish gauge of **1,600 mm (5 ft 3 in)** is used in Ireland and parts of Australia and Brazil.

Russian gauge

Russian gauge or CIS gauge **1,520 mm (4 ft 11 ⅚ in)** is the second most widely used gauge in the world, and spans the whole of the former Soviet Union/CIS bloc including the Baltic states and Mongolia. Finland uses 1524 mm. The difference is clearly lower than the tolerance margin, so through running is feasible. Care must however be taken when servicing international trains because the wear profile of the wheels differs from that of trains that run on domestic tracks only.

The original standard of 1,524 mm (5 ft) was approved on September 12, 1842 with re-standardisation to 1520 mm taking place during the 1960s.

United States

Originally, various gauges were used in the United States and Canada. Some railways, primarily in the northeast, used standard gauge; others used gauges ranging from 4 ft (1,219 mm) to 6 ft (1,829 mm). Problems began as soon as lines began to meet and, in much of the north-eastern United States, standard gauge was adopted. Most Southern states used 5 ft (1,524 mm) gauge. Following the American Civil War, trade between the South and North grew and the break of gauge became a major economic nuisance. Competitive pressures had forced all the Canadian railways to convert to standard gauge by 1880, and Illinois Central converted its south line to New Orleans to standard gauge in 1881, putting pressure on the southern railways.

In the early days of rail transport in the US, railroads tended to be built out of coastal cities into the hinterland, and systems did not connect. Each builder was free to choose its own gauge, although the availability of British-built locomotives encouraged some railroads to be built to standard gauge. As a general rule, southern railroads were built to one or another broad gauge, mostly 5 ft (1,524 mm), while northern railroads that were not standard-gauge tended to be narrow-gauge. Most of the original track in Ohio was built in 4 ft 10 in (1,473 mm) Ohio gauge, and special *compromise cars* were able to run on both this track and standard-gauge track. When American railroads' track extended to the point that they began to interconnect, it became clear that a single nationwide gauge was desirable.

In 1886, the southern railroads agreed to coordinate changing gauge on all their tracks. After considerable debate and planning, most of the southern rail network was converted from 5 ft (1,524 mm) gauge to 4 ft 9 in (1,448 mm) gauge, then the standard of the Pennsylvania Railroad, over two remarkable days beginning on Monday, May 31, 1886. Over a period of 36 hours, tens of thousands of workers pulled the spikes from the west rail of all the broad gauge lines in the South, moved them 3 in (76 mm) east and spiked them back in place. The new gauge was close enough that standard-gauge equipment could run on it without difficulty. By June 1886, all major railroads in North America were using approximately the same gauge. The final conversion to true standard gauge took place gradually as track was maintained.

In modern uses, certain isolated occurrences of non-standard gauges can still be found, such as the Pennsylvania Trolley Gauge. The Bay Area Rapid Transit (BART) system in the San Francisco Bay Area chose 5 ft 6 in (1,676 mm) gauge. The San Francisco cable cars use a narrow gauge of 3 ft 6 in (1,067 mm).

Pennsylvania Trolley Gauge

Used on the former (defunct) Pittsburgh Railways and the defunct West Penn Railways (5 ft 2 ½ in/1,588 mm) and still used on the current Pittsburgh Light Rail, on some SEPTA lines such as the Philadelphia streetcar lines and the Philadelphia Market-Frankford subway line (5 ft 2 ¼ in/1,581 mm & 5 ft 2 ½ in/1,588 mm) as well as in New Orleans (5 ft 2 ½ in/1,588 mm).

Broader gauges

Some applications require broader gauges, including:

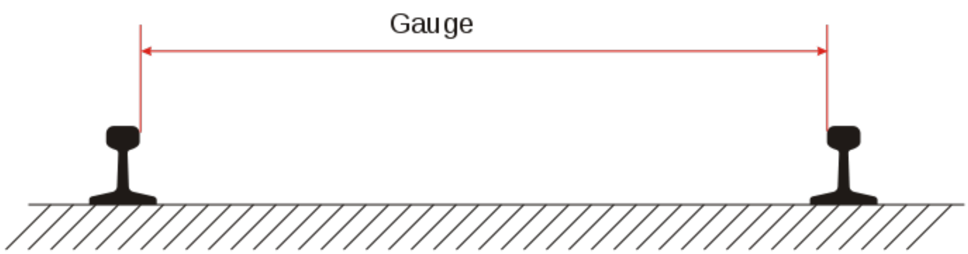
- Large telescopes and telescope arrays.
- Rocket launchers - The European Space Agency, Russian Federal Space Agency, and NASA use double-track railroad to move rockets and supporting equipment at launch sites. (The US Apollo program and Space shuttles use caterpillar tracks on a river stone roadbed because other solutions could not support the loads required).
- Dockside cranes for unloading cargo from ships and for constructing ships
    - The Kockums Crane, now in Ulsan, South Korea, has 175 m gauge.
- Ship railways
- Railway guns

These applications might use double track of the country's usual gauge to provide the necessary stability and axle load. These applications may also use much heavier than normal rails, the heaviest rails for actual trains being about 70 kg/m (141 lb/yd).

Chapter- 3

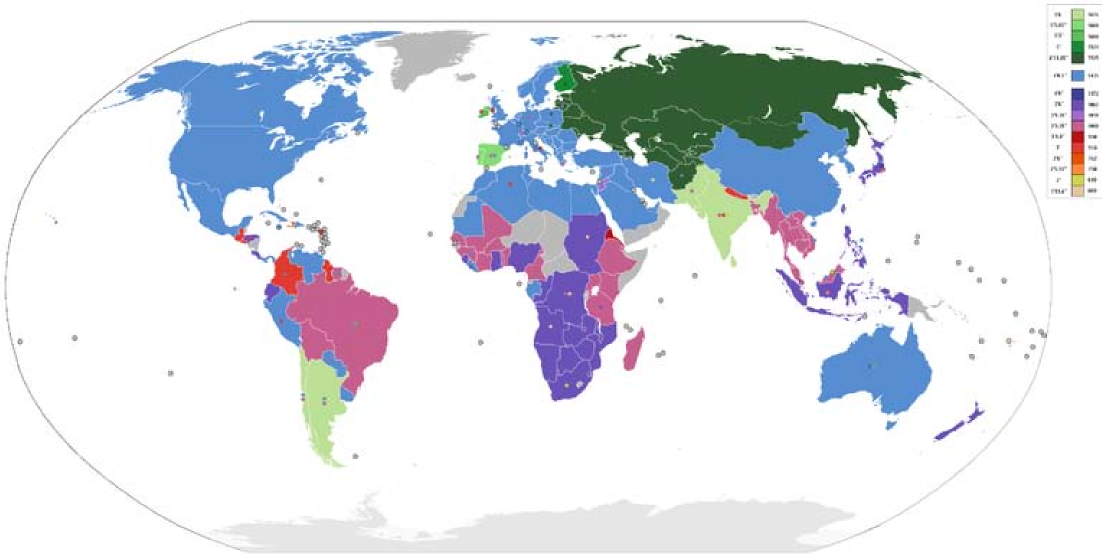
Standard Gauge and Minimum Gauge Railway

Standard gauge



The **standard gauge** (also named the **Stephenson gauge** after George Stephenson, or **Normal gauge**) is a widely-used rail gauge. Approximately 60% of the world's existing railway lines are built to this gauge. The distance between the inside edges of the rails of standard gauge track is 1,435 mm (4 ft 8 ½ in).

History



The dominant rail gauge in each country shown

As railways developed and expanded one of the key issues to be decided was that of the rail gauge (the distance, or width, between the inner sides of the rails) that should be used. The eventual result was the adoption throughout a large part of the world of a "standard gauge" of 1,435 mm (4 ft 8 ½ in) allowing inter-connectivity and the inter-operability of trains.

In England some early lines in colliery (coal mining) areas in the northeast of the country were built to a gauge of 1,422 mm (4 ft 8 in); and in Scotland some early lines were 1,372 mm (4 ft 6 in) (Scotch gauge). By 1846, in both countries, these lines were widened to standard gauge. Parts of the United States rail system, mainly in the northeast, adopted the same gauge because some early trains were purchased from Britain. However, until well into the second half of the 19th century Britain and the USA had several different track gauges. The American gauges converged over time as the advantages of equipment interchange became more and more apparent; notably, the South's 1,524 mm (5 ft) broad gauge system was converted to be compatible with standard gauge over two days, beginning May 31, 1886.

Origins

ft in	mm
5' 6"	1676
5' 5.85"	1668
5' 3"	1600
5'	1524
4' 11.85"	1520
4' 8.5"	**1435**

4' 6"	1372
3' 6"	1067
3' 5.35"	1050
3' 3.37"	1000
3' 4.1"	950
3'	914
2' 6"	762
2' 5.55"	750
2'	610
1' 11.6"	600

A popular legend traces the origin of the 1,435 mm (4 ft 8 ½ in) gauge even further back than the coalfields of northern England, pointing to the evidence of rutted roads marked by chariot wheels dating from the Roman Empire. Snopes categorized this legend as false but commented that "...it is perhaps more fairly labeled as 'True, but for trivial and unremarkable reasons.'" The historical tendency to place the wheels of horse-drawn vehicles approximately 1500mm (5 ft) apart probably derives from the width needed to fit a carthorse in between the shafts. In addition, while road-traveling vehicles are typically measured from the outermost portions of the wheel rims (and there is some evidence that the first railroads were measured in this way as well), it became apparent that for vehicles travelling on rails, it was better to have the wheel flanges located **inside** the rails, and thus the distance measured on the inside of the wheels (and, by extension, the inside faces of the rail heads) was the important one.

There was no standard gauge for horse railways, but there were rough groupings: in the north of England none were less than 4 ft (1,219 mm). Wylam colliery's system, built before 1763, was 5 ft (1,524 mm); as was John Blenkinsop's Middleton Railway, the old 4 ft (1,219 mm) plateway was relaid to 5 ft (1,524 mm) so that Blenkinsop's engine could be used. Others were 4 ft 4 in (1,321 mm) Beamish or 4 ft 7 ½ in (1,410 mm) (Bigges Main and Kenton and Coxlodge).

The English railway pioneer George Stephenson spent much of his early engineering career working for the coal mines of County Durham. He favoured 4 ft 8 in (1,422 mm) for wagonways in Northumberland and Durham and used it on his Killingworth line. The Hetton and Springwell wagonways also used the gauge.

Stephenson's Stockton and Darlington railway (S&DR) was built primarily to transport coal from several mines near Shildon to the port at Stockton-on-Tees. The S&DR's initial track gauge of 4 ft 8 in (1,422 mm) was set to accommodate the existing gauge of hundreds of horse-drawn chaldron wagons that were already in use on the wagonways in the mines. It was built and used at this gauge for fifteen years before being changed to 4 ft 8 ½ in (1,435 mm) gauge.

The beginnings of the 1435 mm gauge

George Stephenson used the 4 ft 8 ½ in (1,435 mm) gauge (with an extra 0.5 in/13 mm of free movement to reduce binding on curves) for the Liverpool and Manchester Railway, authorised in 1826 and opened 30 September 1830. The success of this project led to George Stephenson and his son Robert being employed to engineer several other larger railway projects. However, the Chester and Birkenhead Railway, authorised on 12 July 1837, was 4 ft 9 in (1,448 mm); the Eastern Counties Railway, authorised on 4 July 1836, was 5 ft (1,524 mm); London and Blackwall Railway, authorised on 28 July 1836, was 5 ft (1,524 mm); the London and Brighton Railway, authorised on 15 July 1837, was 4 ft 9 in (1,448 mm); the Manchester and Birmingham Railway, authorised on 30 June 1837, was 4 ft 9 in (1,448 mm); the Manchester and Leeds Railway, authorised on 4 July 1836, was 4 ft 9 in (1,448 mm) and the Northern and Eastern Railway, authorised on 4 July 1836, was 1524 mm (5 ft 0 in). The 4 ft 9 in (1,448 mm) railways were intended to take 4 ft 8 ½ in (1,435 mm) gauge *vehicles* and allow a running tolerance.

The influence of the Stephensons appears to be the main reason that the 4 ft 8 ½ in (1,435 mm) gauge became the standard, and its usage became more widespread than any other gauge..

The Royal Commission

In 1845, in the United Kingdom of Great Britain and Ireland, a Royal Commission reported in favour of a standard gauge. In Great Britain, Stephenson's gauge was chosen as the *standard gauge* on the grounds that lines built to this gauge were eight times longer than that of the rival 2,140 mm (7 ft 0 ¼ in) gauge, adopted principally by the Great Western Railway. The subsequent Gauge Act ruled that new passenger-carrying railways in Great Britain should be built to a standard gauge of 1,435 mm (4 ft 8 ½ in); and those in Ireland to a standard gauge of 1,600 mm (5 ft 3 in). It allowed the broad gauge companies in Great Britain to continue repairing their tracks and expanding their networks within the **Limits of Deviation** and the exceptions defined in the Act. After an intervening period of mixed-gauge operation (tracks were laid with three running-rails), the Great Western Railway finally converted its entire network to standard gauge in 1892.

Pioneer lines

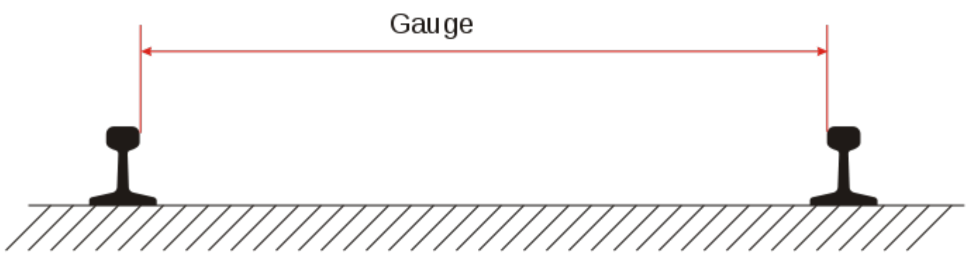
John Whitton, the longest serving engineer of the New South Wales Railways, was always being pressured to cut costs on new construction, by using horses or by using a narrower gauge. He resisted as much as possible so as to avoid any wasteful breaks-of-gauge, but did eventually introduce so-called pioneer lines for more remote and lightly trafficked areas to reduce costs. These lines eliminated extravagances like fencing, used half-round sleepers, light rails and replaced metal ballast with earth or ash. Only light locomotives were allowed. Speeds and axleloads and train loads were thus limited.

Only if traffic increased would these lines be upgraded to normal standards of construction. Indeed as the country was developed, many lines including those not of the pioneer type have seen their rail weights increase to allow heavier axleload, heavier engines and heavier and faster trains, all of which can be done progressively and incrementally without any need to change the gauge.

Road Vehicles

Several states in the United States had laws requiring that road vehicles have a consistent gauge. This would allow the vehicles to follow ruts in the road all the better. These gauges were roughly similar to the railway Standard Gauge.

Minimum gauge railway



Minimum gauge railways have a gauge of less than 2 ft (610 mm) or 600 mm (1 ft 11 ⅝ in), most commonly 1 ft 3 in (381 mm), 400 mm (1 ft 3 ¾ in), 1 ft 6 in (457 mm) or 500 mm (1 ft 7 ¾ in). The notion of minimum gauge railways was originally developed by estate railways and by the French company of Decauville for industrial railways.

The major distinction between a *miniature railway* (USA: 'grand scale railroad') and a *minimum gauge railway* is that miniature lines use models of full-sized prototypes. There are miniature railways that run on gauges as wide as 2 ft (610 mm), for example the Wicksteed Park Railway. There are also minimum gauge railways running on extremely narrow track as small as 10 ¼ in (260 mm) gauge, for example the Rudyard Lake Steam Railway. Generally minimum gauge railways have a working function as estate railways, or industrial railways, or providers of public transport links; although most also have a distinct function in relation to tourism as well, and depend upon tourism for the revenue to support their working function.

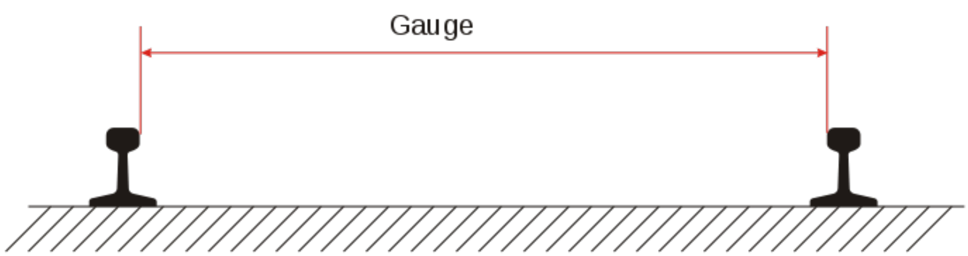
A general aspect about minimum gauge railways is that the loading gauge is maximized, which is to say the dimension of the equipment is made as large as possible to the track gauge, while still providing enough stability to keep it from tipping over.

List of Minimum Gauge Railways

- Anacortes Railway,
  457 mm (1 ft 6 in)
- Anse (Chemin de fer Touristique d'),
  381 mm (1 ft 3 in)
- Artouste (Petit train d'),
  500 mm (1 ft 7 ¾ in)
- Assiniboine Valley Railway,
  7 ½ in (190.5 mm)
- Bicton Woodland Railway,
  457 mm (1 ft 6 in)
- Bure Valley Railway,
  381 mm (1 ft 3 in)
- Cleethorpes Coast Light Railway,
  381 mm (1 ft 3 in)
- Coronado Railroad,
  1 ft 8 in (508 mm)
- Dresdner Parkeisenbahn
  381 mm (1 ft 3 in)
- Duffield Bank Railway,
  381 mm (1 ft 3 in)
- Eaton Hall Railway,
  381 mm (1 ft 3 in)
- Fairbourne Railway
  1895-1916: 2 ft (610 mm)
  1916-1986: 1 ft 3 in (381 mm)
  1986–Present: 12 ¼ in (311 mm)
- Far Tottering and Oyster Creek Branch Railway
- Hesston Steam Museum
  356 mm (1 ft 2 in)
- Isle of Mull Railway,
  260 mm (10 ¼ in)
- Kirklees Light Railway,
  381 mm (1 ft 3 in)
- Lappa Valley Steam Railway,
  381 mm (1 ft 3 in)
- Meadows and Lake Kathleen Railroad,
  457 mm (1 ft 6 in)
- Ohsabanan Sweden,
  600 mm (1 ft 11 ⅝ in)
- Perrygrove Railway,
  381 mm (1 ft 3 in)
- Ravenglass and Eskdale Railway,
  381 mm (1 ft 3 in)
- Riverside and Great Northern Railway,
  381 mm (1 ft 3 in)
- Rhyl Miniature Railway,
  381 mm (1 ft 3 in)
- Romney, Hythe & Dymchurch Railway,
  381 mm (1 ft 3 in)
- Rudyard Lake Steam Railway,
  260 mm (10 ¼ in)
- Ruislip Lido Railway,
  305 mm (12 in)
- Sand Hutton Light Railway,
  457 mm (1 ft 6 in)
- Scarborough North Bay Railway,
  508 mm (1 ft 8 in)
- Sons of Gwalia Firewood Tramway,
  1 ft 8 in (508 mm)
- Southern Fuegian Railway,
  500 mm (1 ft 7 ¾ in)
- Steeple Grange Light Railway,
  1 ft 6 in (457 mm)
- Tarn Light Railway, ,
  500 mm (1 ft 7 ¾ in)
- Royal Arsenal 18 inch Railway,
  457 mm (1 ft 6 in)

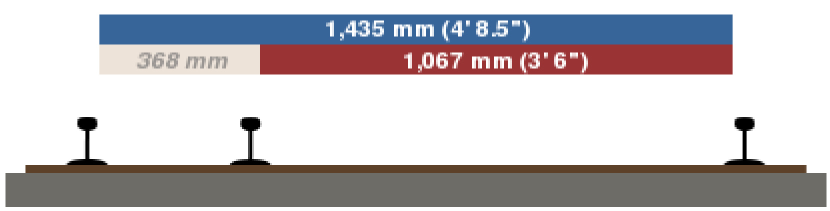
Chapter- 4

Narrow Gauge Railway



A **narrow gauge railway** (or **narrow gauge railroad**) is a railway that has a track gauge narrower than the 1,435 mm (4 ft 8 ½ in) of standard gauge railways. Most existing narrow gauge railways have gauges of between 2 ft (610 mm) and 3 ft 6 in (1,067 mm).

Overview



Comparison of standard gauge (blue) and Cape gauge (red) width.

A train at Bad Bubendorf station on the 750 mm (2 ft 5 ½ in) gauge Waldenburgerbahn between Liestal and Waldenburg in Switzerland.

Typical industrial 2 ft (610 mm) gauge tracks seen here at the Leighton Buzzard Narrow Gauge Railway

Since narrow gauge railways are usually built with smaller radius curves and smaller structure gauges, they can be substantially cheaper to build, equip, and operate than standard gauge or broad gauge railways, particularly in mountainous or difficult terrain. The lower costs of narrow gauge railways mean they are often built to serve industries and communities where the traffic potential would not justify the cost of building a standard or broad gauge line.

Narrow gauge railways also have specialized use in mines and other environments where a very small structure gauge makes a very small loading gauge necessary.

On the other hand, standard gauge or broad gauge railways generally have a greater haulage capacity and allow greater speeds than narrow gauge systems.

Historically, many narrow gauge railways were built as part of specific industrial enterprises and were primarily industrial railways rather than general carriers. Some common uses for these industrial narrow gauge railways were mining, logging, construction, tunnelling, quarrying, and the conveying of agricultural products. Extensive narrow gauge networks were constructed in many parts of the world for these purposes. For example, mountain logging operations in the 1800s often used narrow gauge railways to transport logs from mill sites to market. Trench railways on the western front in World War I were a short-lived military application. Significant sugarcane railways still operate in Cuba, Fiji, Java, the Philippines and in Queensland in Australia. Narrow gauge railway equipment remains in common use for the construction of tunnels.

Narrow gauge railways also have more general applications. The national railway systems of countries such as Indonesia, Japan and New Zealand are primarily or solely narrow gauge. Non-industrial narrow gauge mountain railways are or were common in the Rocky Mountains of the United States and the Pacific Cordillera of Canada, in Mexico, Switzerland, the former Yugoslavia, Greece, India, and Costa Rica. Another country with a notable national railway built to narrow gauge is South Africa where the "Cape gauge" of 3 ft 6 in (1,067 mm) is the most common gauge. In India, the narrow gauge system is slowly being converted to broad gauge, although some of India's most famous railways, the Darjeeling Himalayan Railway and Kalka-Shimla Railway are both narrow gauge. All 1,000 mm (3 ft 3 $^3⁄_8$ in) (metre gauge) railways are being converted to 5 ft 6 in (1,676 mm) (broad gauge) under the Unigauge project.

History of narrow gauge railways

The earliest recorded railway is shown in the De re metallica of 1556, which shows a mine in Bohemia with a railway of approximately 2 ft (610 mm) gauge. During the 16th century railways were mainly restricted to hand-pushed narrow gauge lines in mines throughout Europe. During the 17th century mine railways were extended to provide transportation above ground. These lines were industrial, connecting mines with nearby transportation points, usually canals or other waterways. These railways were usually built to the same narrow gauge as the mine railways from which they developed.

Extensive narrow gauge railway systems served the front-line trenches of both sides in World War I. After the end of the war the surplus equipment from these created a small boom in narrow gauge railway building in Europe.

Advantages of narrow gauge

Narrow gauge railways usually cost less to build because they are usually lighter in construction, using smaller cars and locomotives (smaller loading gauge) as well as smaller bridges, smaller tunnels (smaller structure gauge) and tighter curves. Narrow gauge is thus often used in mountainous terrain, where the savings in civil engineering work can be substantial. It is also used in sparsely populated areas where the potential demand is too low for broader gauge railways to be economically viable. This is the case in some of Australia and most of Southern Africa, where extremely poor soils have led to population densities too low for standard gauge to be viable.

There are many narrow gauge street tramways, particularly in Europe where 1,000 mm (3 ft 3 ⅜ in) gauge tramways are common.

For temporary railways that will be removed after short term use, such as for construction, the logging industry, the mining industry or large scale construction projects, especially in confined spaces, such as the Channel Tunnel a narrow gauge railway is substantially cheaper and easier to install and remove. The use of such railways has almost vanished due to the capabilities of modern trucks. A double track narrow gauge construction railway may fit inside the profile of a single track normal gauge line, which is useful.

In many countries narrow gauge railways were built as "feeder" or "branch" lines to feed traffic to more important standard gauge lines, due to their lower construction costs. The choice was often not between a narrow gauge railway and a standard gauge one, but between a narrow gauge railway and none at all.

Disadvantages of narrow gauge

Narrow gauge railways cannot interchange rolling stock such as freight and passenger cars freely with the standard gauge or broad gauge railways they link with, unless they exchange bogies. Thus it is expensive and inconvenient for the railway company to transfer passengers and freight between the two railway systems: the transfers require time consuming manual labour or substantial capital expenditure. Some bulk commodities, such as coal, ore and gravel, can be mechanically transshipped, but this still incurs time penalties and the equipment required for the transfer is often complex to maintain.

One solution to the problem of transshipment is bogie exchange between cars. Another solution to this problem is the roll-block system. Although successfully deployed in some countries such as Germany and Austria, this technique came too late for the majority of narrow gauge lines. Transfer of containers is also an option.

Transfers between systems are less of a problem if there is a large system of lines on the same narrow gauge, for example in northern Spain, and there is no problem in those countries in which a narrow gauge is standard, e.g. the Cape gauge in Japan, New Zealand, South Africa, and Tasmania, and the metre gauge in Malaysia and Thailand.

The problem of interchangeability is more serious in North America because a continent-wide system of freight car interchange developed. All the standard gauge railways in North America use the same standard couplings and air brakes, so freight cars can be freely interchanged between railways from Northern Canada to Southern Mexico.

Railways which need more freight cars in peak periods can hire them from other railways, at rates set by common agreement. Peak demand, particularly for grain shipment, occurs in different parts of North America at different times, so the freight cars are moved to wherever they are needed. Motive power can also be interchanged, so Mexican locomotives sometimes pull Canadian freight cars and vice versa.

Narrow gauge railways (as well as railways with a broader gauge than the regional standard) could not participate in this system, so they had to own enough rolling stock to meet peak demand, which might be much more than needed by equivalent standard gauge railways, and the surplus equipment generated no cash flow during periods of low demand.

All North American broad gauge railways were converted to standard gauge by 1910. Increased costs and lower revenues eventually resulted in nearly all North American narrow gauge railways either converting to standard gauge or going bankrupt. In many cases, larger railways subsidized the conversion of connecting short-line railways to standard gauge.

Another problem for narrow gauge railways was that they lacked the physical space to grow: their cheap construction meant they were engineered only for their initial traffic demands. While a standard or broad gauge railway could more easily be upgraded to handle heavier, faster traffic, many narrow gauge railways were impractical to improve. Speeds and loads hauled could not increase, so traffic density was significantly limited.

Narrow gauge railways can be built to handle increased speed and loading, but at the price of removing most of the narrow gauge's cost advantage over standard or broad gauge.

Successful narrow gauge railways

The heavy duty 3 ft 6 in (1,067 mm) narrow gauge railways in Australia (e.g. Queensland), South Africa and New Zealand show that if the track is built to a heavy-duty standard, performance almost as good as a standard gauge line is possible. 200-car trains operate on the Sishen-Saldanha railway in South Africa, and high-speed tilt-trains in Queensland. Another example of a heavy-duty narrow gauge line is EFVM in Brazil. 1,000 mm (3 ft 3 $^{3}/_{8}$ in) gauge, it has over-100-pound rail and a loading gauge almost as large as US non-excess-height lines. It sees 4,000 hp (3,000 kW) locomotives and 200+ car trains. In South Africa and New Zealand, the loading gauge is similar to the restricted British loading gauge, and in New Zealand some British Rail Mark 2 carriages have been rebuilt with new bogies for use by Tranz Scenic (Wellington-Palmerston North service), Tranz Metro (Wellington-Masterton service) and Veolia (Auckland suburban services).

An economical alternative to a narrow gauge line is a standard or even a broad gauge line built to light railway standards with short radii (tight curves) and steep grades. The trains operate at lower speeds and with lower capacities. However the gauge allows through-routing of rolling stock, and simplifies later upgrading.

Fastest narrow gauge trains

The reduced stability of narrow gauge means that its trains cannot run at the same high speeds as on broader gauges, unless the tracks are aligned with greater precision. In Japan and in Queensland, Australia, recent permanent way improvements have allowed trains on 1,067 mm (3 ft 6 in) gauge tracks to run at 160 km/h (99 mph) and faster. Queensland Rail's tilt train is currently the fastest train in Australia and the fastest 1,067 mm (3 ft 6 in) gauge train in the world, setting a record at 210 km/h. A special 2 ft (610 mm) gauge railcar was built for the Otavi Mining and Railway Company with a design speed of 137 km/h.

Compare these speeds with standard gauge or broad gauge trains which can run at up to 320 km/h (199 mph). The contrast is most evident in Japan, home of the Shinkansen, a network of standard gauge lines built solely for high speed rail in a country where 1,067 mm (3 ft 6 in) narrow gauge is the predominant standard.

Curve radius is also important for high speeds. Narrow gauge lines tend to have sharper curve for cheapness sake, and this tends to limit speeds.

Gauges used

There are many narrow gauges in use or formerly used between 1 ft 3 in (381 mm) gauge and 4 ft 8 ½ in (1,435 mm) gauge. They fall into three broad categories:

Medium gauge railways

Railways built on gauges between slightly under a metre and 4 ft 8 ½ in (1,435 mm) are sometimes referred to as "medium-gauge" railways.

In those parts of the world where the railways were built to British standards, this meant most commonly a gauge of 3 ft 6 in (1,067 mm) or the "Cape gauge", while those built to American standards were normally 3 ft (914 mm). Railways built to European metric standards were most commonly of 1,000 mm (3 ft 3 ⅜ in) or "metre gauge" and 900 mm (2 ft 11 ½ in) gauge.

These larger narrow gauges are capable of hauling most traffic with little difficulty and are thus suitable for large-scale "common carrier" applications, although their ultimate speed and load limits are lower than for standard gauge. In many countries, gauges in this range are the local standard.

Two foot gauge railways

A 2 ft (610 mm) gauge train on the Leighton Buzzard Light Railway in England.

The next natural "grouping" of narrow gauge railways covers the range from just above 600 mm (1 ft 11 5⁄8 in) to just below 3 ft (914 mm), although the majority are between 2 ft (610 mm) and 760 mm (2 ft 5 7⁄8 in). These lightweight lines can be built at a substantial cost saving over medium or standard gauge railways, but are generally restricted in their carrying capacity. The majority of these were built in mountainous areas and most were to carry mineral traffic from mines to ports or standard gauge raiways.

Many were industrial lines rather than common carriers, though there were exceptions such as the extensive 760 mm (2 ft 5 7⁄8 in) lines built in the former Austro-Hungarian Empire, the "Maine two footer" lines in New England, the Chicago Tunnel Company's 60-mile (97 km) network under the Chicago Loop, the Otavi Mining and Railway Company of South Africa, the Chemins de Fer du Calvados of Normandy, and the Darjeeling Himalayan Railway. Trench railways of World War I produced the greatest concentration of two foot gauge railways observed to date. The most common metric gauges in this group are 760 mm (2 ft 5 7⁄8 in) and 750 mm (2 ft 5 1⁄2 in).The longest

750 mm rail is the Old Patagonian Express or "La Trochita" with 402 km of track operates from Jacobacci to Esquel.

Australia has many networks of 2-foot (0.61 m) railways (affectionately called "tramways") to serve the sugar industry. Trackage totals over 4000 km over the coastal areas of Queensland, carrying more than 30 million tonnes of sugar cane a year from farms to mills. Motive power is small to mid size diesel locomotives of varied configurations.

Minimum gauge railways

Gauges below 600 mm (1 ft 11 $\frac{5}{8}$ in) were rare, but did exist. In Britain, Sir Arthur Heywood developed 1 ft 3 in (381 mm) gauge estate railways, while in France Decauville produced a range of industrial railways running on 400 mm (1 ft 3 $\frac{3}{4}$ in) and 500 mm (1 ft 7 $\frac{3}{4}$ in) tracks, most commonly in such restricted environments such as underground mine railways. A number of 1 ft 6 in (457 mm) gauge railways were built in Britain to serve ammunition depots and other military facilities, particularly during the First World War.

Narrow gauge railways less than 1 ft 10 $\frac{3}{4}$ in (578 mm) gauge are known as minimum gauge railways.

Narrow gauge worldwide

Europe

Austria

Train of the Mariazellerbahn in Lower Austria

The first railway in Austria was the narrow gauge line from Gmunden in the Salzkammergut to Budweis, now in the Czech Republic, this was 1,106 mm (3 ft 7 $\frac{1}{2}$ in) gauge. Some two dozen lines were built in 760 mm (2 ft 5 $\frac{7}{8}$ in) gauge, a few in 1,000 mm (3 ft 3 $\frac{3}{8}$ in) gauge. The first was the Steyrtalbahn. Others were built by provincial governments, some lines are still in common carrier use and a number of others are preservation projects. The tramway network in Innsbruck is also metre gauge; in Linz the rather unusual gauge of 900 mm (2 ft 11 $\frac{1}{2}$ in) is in use.

Bulgaria

Train of the Septemvri-Dobrinishte line in Bulgaria

From the 19th into the early 20th there were many 600 mm (1 ft 11 $\frac{5}{8}$ in) and 760 mm (2 ft 5 $\frac{7}{8}$ in) gauge railways in existence Bulgaria, some were dismantled and others were converted to Standard gauge.

The picturesque Septemvri-Dobrinishte narrow gauge line is 125 km long and features many tunnels, bridges, spiral loops and last but not least the highest railway station in the Balkans, namely Avramovo Station situated at 1267 m altitude. The line is still used for regional services by no less than 5 pairs of diesel-hauled trains per day as of the 2011 Timetable. There are a couple of preserved steam locomotives, but as of 2010 only

609.76 is operational and occasionally hauls tourist trains along the line. There are plans for restoration of the other preserved engines, but when would this happen is still unclear.

Other examples in Bulgaria include the 600 mm (1 ft 11 $^5/_8$ in) Children's Railways in Plovdiv and Kurdzhali and the industrial railway of the Burgas salt pans.

The greater part of the extensive Sofia tramway network is 1,009 mm (3 ft 3 $^{11}/_{32}$ in) metre gauge.

Belarus

Belarus has one operating 750 mm (2 ft 5 $^1/_2$ in) gauge Children's railway, located in Minsk. Locos - TU2.

Some industrial narrow gauge railways can still be found in Belarus particularly associated with the peat extraction industry.

Belgium

The coastal tramway in Belgium

The *Vicinal* or *Buurtspoorwegen* were a system of narrow gauge local railways or tramways covering the whole country and having a greater routage than the mainline railway system. They were 1,000 mm (3 ft 3 ⅜ in) gauge and the system included electrified city lines as well as rural lines using steam locomotives and railcars; half of the system was electrified. Many lines carried freight. Only the coastal line and two routes near Charleroi are still in commercial use, four museums hold significant collections of former SNCV/NMBS rolling stock, one of which is the ASVi museum in Thuin. The tramway networks in Antwerp and Ghent are also metre gauge.

The Stoomcentrum Maldegem has a 600 mm (1 ft 11 ⅝ in) gauge line laid on the former standard gauge trackbed to Donk.

Croatia

In Istria peninsula, narrow gauge railway line called Parenzana, a.k.a. Trieste - Buje - Parenzo, from Trieste Italy - trough Capodistria - Koper Slovenia - to Parenzo - Poreč Croatia (dismantled) in formerly Italian territory . Samoborček was narrow gauge (760 mm) railway operating from 1901 until 1979, linking Zagreb and Samobor with extension to Bregana.

Czech Republic

Several lines were built in the nineteenth century. The most notable lines are Obrataň-Jindřichův Hradec-Nová Bystřice and Třemešná ve Slezsku-Osoblaha, that are still in operation.

Denmark

A few narrow gauge lines were built in Denmark. One was the Faxe Jernbane, 6,5 km long with a gauge of 791mm, now closed. Other narrow gauge railways, which had 1,000 mm (3 ft 3 ⅜ in) gauge, were Skagensbanen, Horsens-Tørring, Horsens-Bryrup and Kolding-Egtved. Of these has Skagensbanen traffic today, now with normal gauge. The three others are closed, so no narrow gauge lines exist anymore, except for a heritage railway. Most lines in Denmark were built with normal gauge from the beginning, since the country was fairly densely populated in the 19th century, creating better economy for railways. Most notably, narrow gauge railways in Denmark were built and used by De Danske Sukkerfabrikker (Danish Sugar Corporation)to transport juice from sugar beets from purpose built "juice stations" to the main sugar factories in towns such as Nakskov, Nykøbing F and Assens. All narrow gauge sugar lines are now closed as of the 1960s. However, a few engines survived with Bloustrød-banen, as well as one engine surviving as a display item in Assens park until the mid 90's. This engine is reportedly under the care of a private owner.

Estonia

Four museums lines and some industrial peat railways remain in Estonia. The Lavassaare railway museum houses a large collection of steam and diesel locomotives with a 2 km long 750 mm (2 ft 5 ½ in) gauge railway. There is a museum with a 750 mm (2 ft 5 ½ in) gauge, 500 m long line in Avinurme which houses one locomotive and a collection of wagons. An underground museum with a short electric line is located in Kiviõli in the Northeast-Estonian industrial area. A former military railway line with a 750 mm (2 ft 5 ½ in) gauge is located on Naissaar Island in the northern Estonia.

Finland

Lovisa-Wesijärvi Railway (LWR) 2-8-0 steam locomotive number 6 (built in 1909) in running order on Jokioinen Museum Railway, Finland.

The vast majority of Finnish narrow gauge railways were owned and operated by private companies. There are only a few instances where narrow gauge railways were in direct connection with each other, and those interchanges did not last for long. The railways never formed a regional rail traffic network, but were only focused on maintaining connections between the national broad gauge railway network and the off-line industries. One of the longest common carriers was the Lovisa-Wesijärvi railway (1900–1960) that operated a 80 km (50 mi) line between Lahti and Loviisa. Other notable ones were the Hyvinkää–Karkkila railway that operated a 46 km (29 mi) line, and the Jokioinen railway that operated a 23 km (14.3 mi) line until 1974, being the last common carrier narrow gauge railway.

Other lines were notably shorter. The common gauges were 600 mm (1 ft 11 $^5/_8$ in) and 750 mm (2 ft 5 $^1/_2$ in), with a few railways built with 785 mm (2 ft 6 $^9/_{10}$ in) and 1,000 mm (3 ft 3 $^3/_8$ in) gauges.

Narrow gauge tourist and heritage lines of 600 mm (1 ft 11 $^5/_8$ in) and 750 mm (2 ft 5 $^1/_2$ in) gauge still operate.

France

The French National Railways used to run a considerable number of 1,000 mm (3 ft 3 $^3/_8$ in) lines, a few of which still operate mostly in tourist areas, such as the St Gervais-Vallorcine (Alps) and the "Train jaune" (yellow train) in the Pyrenees. The original French scheme was that every sous-prefecture should be rail connected. Extensive near 600 mm (1 ft 11 $^5/_8$ in) gauge lines were also built for the sugar-beet industry in the north often using ex-military equipment after the First World War. Decauville was a famous French manufacturer of industrial narrow gauge railway equipment and equipped one of the most extensive regional 600 mm (1 ft 11 $^5/_8$ in) narrow gauge railway, the Chemins de Fer du Calvados. Corsica has a narrow gauge network of two lines following the coast line, that are connected by one line crossing the island through highly mountaineous terrain. The petit train d'Artouste, a tourist line in the Pyrenees, uses 500 mm (1 ft 7 $^3/_4$ in) gauge.

Germany

600 mm (1 ft 11 $^5/_8$ in) Berlin narrow gauge railway / Berliner Parkeisenbahn

A number of narrow gauge lines survive, largely as a consequence of German reunification, in the former East Germany where some of them form part of the public transport system as active commercial carriers. Most extensive of those still employing steam traction is the Harz mountain group of metre gauge lines, the Harzer Schmalspurbahnen. Other notable lines are the Zittau-Oybin-Jonsdorf line in Saxony, the Mollibahn and the Rügensche Kleinbahn on the Isle of Rügen on the Baltic coast and the Radebeul-Radeburg line, Weisseritztalbahn in the suburbs of Dresden. Although most rely on the tourist trade, in some areas they provide significant employment as steam traction is particularly labour intensive.

In the Western part of Germany, *Selfkantbahn* (close to Heinsberg near Aachen) and *Brohltalbahn* (Linz/Rhine) are the best known ones, offering services in summer weekends.

Greece

A bridge on the Pelion Railway, Greece

1,000 mm (3 ft 3 ³⁄₈ in) ALCo locomotive of Hellenic State Railways at Corinth Old Railway Station

The Peloponnese narrow gauge network length is about 914 km. Of this, metre gauge is used for 892 km. This is the network that connects major cities in the Peloponnese. The remaining 22 km form the Diakofton-Kalavryta Rack Railway, which uses 750 mm (2 ft 5 $^1\!/_2$ in) gauge. The Peloponnese network has suffered various setbacks, ranging from the abandonment of entire lines (such as the Pyrgos Katakolon Railway) to inefficient management on part of the public Greek railway operator, OSE, which resulted in poor quality of services and rolling stock. Currently major restoration works are underway, which have resulted in parts of the line having been closed. Additionally, the reactivation of certain lines that were closed down during the latter half of the 20th century is planned, mainly the Pyrgos-Katakolon line and in parts of western Greece (around Agrinion and Messologgi).

Another small railway which uses narrow gauge 600 mm (1 ft 11 $^5\!/_8$ in) is the Mt. Pelion railway, originally from Volos to Milies. Currently parts of the line are operational during the summer, mainly for excursions.

There was also a metre gauge network in Thessaly. This has now been replaced with single track standard gauge lines from Volos to Larissa and Palaiofarsalos to Kalampaka. However, the old narrow gauge tracks remain in place between Velestino and Palaiofarsalos via Aerino, so that occasional special excursion trains use them.

A metric line network existed in Attica, operated by Attica Railways and later by SPAP. The line ran from the center of Athens to Kifissia with a branch from Heraklion to Lavrion, serving the suburbs and towns of the region as well as Dionysos marble quarries and Lavrion mines. The line to Kifissia closed in 1938 and was reopened as standard gauge in the 1950s, operated by ISAP. The line to Lavrion closed in 1957 due to political pressures from the road transport lobby. Sections of the Lavrion line still survive and there are plans to reopen the southern part (Koropi-Lavrion) as an electrified standard gauge suburban line.

Development of open lignite mines for electricity production led to the construction of industrial railway networks in Ptolemais, Western Macedonia (900 mm/2 ft 11 $^1\!/_2$ in industrial gauge, electrified) and Aliveri, Evoia Island (1,000 mm/3 ft 3 $^3\!/_8$ in). These networks are no longer active, as the lignite mines they served are exhausted.

The 750 mm (2 ft 5 $^1\!/_2$ in) railway in Diakofto-Kalavryta and the 600 mm (1 ft 11 $^5\!/_8$ in) in Volos-Milies (the current operational line is Lechonia-Milies, since the Volos-Lechonia section was abandoned) are heritage railways. The metre gauge network of Peloponnese, however, is a busy passenger line, although there are no longer freight trains. A major project has started to construct new 1,435 mm (4 ft 8 $^1\!/_2$ in) lines in the busiest parts of Peloponnese and to rebuild the century-old tracks in the remainder. The branch lines from Asprohoma to Messini and from Pyrgos to Katakolo were re-opened for passenger services in September and April 2007 respectively and the Corinth to Argos, Nafplio and Tripoli line was reopened in August 2009.

Széchenyi Museum Railway in Nagycenk

Mátra Railway in Gyöngyös

The former Kingdom boasted a narrow gauge network thousands of kilometres in length, most of it using 760 mm (2 ft 5 7⁄8 in) or 600 mm (1 ft 11 5⁄8 in) gauge, constructed between 1870 and 1920. Landlords, mines, agricultural and forest estates established their own branch lines which, as they united into regional networks, increasingly played a role in regional passenger traffic. Following the Treaty of Trianon some railways were cut by the new border, many remained on the territory of Romania, Czechoslovakia and Yugoslavia. Due to a lack of intact roads, following World War II in many places narrow-gauge railway was the only reasonable way to get around. In 1968 the Communist government started to implement a policy to dismantle the narrow-gauge network in favour of road traffic. Freight haulage on the few remaining lines continued to decline until 1990 from when a patchwork of railways was gradually taken over by associations and forest managements for tourist purposes. State Railways operated narrow-gauge railways at Nyíregyháza and Kecskemét that played a role in regional transport until December 2009. Children aged 10 to 14 provide services at the Budapest *Children's Railway*.

Ireland

Guinness brewery locomotive

Several 3 ft (914 mm) narrow gauge systems once existed in Ireland. In County Donegal an extensive network existed, with two companies operating from Derry – the Londonderry & Lough Swilly Railway (L&LSR) and the County Donegal Railways (CDRJC). Well known was the West Clare Railway – in County Clare, which saw diesel locomotion before closure. The Cavan & Leitrim Railway (C&LR) operated in what is now the border area of County Cavan and County Leitrim. Some smaller narrow gauge routes also existed in County Antrim and also County Cork – notably the Cork Blackrock & Passage Railway.

Apart from small heritage venues, the Irish narrow gauge today only survives in the bogs of the Midlands as part of Bord na Móna's extensive industrial network for transporting harvested peat to distribution centres or power plants.

Italy

Tourist line Macomer-Bosa, in Sardinia

Railcar on the Rittnerbahn/Ferrovia del Renon

Narrow gauge railways in Italy are (or were) mainly built with 950 mm (3 ft $1\frac{3}{8}$ in) gauge, with some 1,000 mm (3 ft $3\frac{3}{8}$ in) gauge lines and with a few other gauges.

In Istria, narrow gauge railway line called Parenzana was built from Trieste - Capodistria now Koper Slovenia - to Parenzo now Poreč Croatia (dismantled). The Trieste-Opicina is a 1,000 mm (3 ft $3\frac{3}{8}$ in) tramway with a funicular.

In Sardinia, a network of narrow gauge lines (950 mm/3 ft $1\frac{3}{8}$ in) was built, to complement the standard-gauge main network which covered the main cities and ports. The lines were:

- Siliqua-San Giovanni Suergiu-Calasetta (dismantled)
- Iglesias-Monteponi-San Giovanni Suergiu (dismantled)
- Monteponi-Portovesme (dismantled)
- Cagliari-Mandas-Isili-Sorgono
- Mandas-Gairo-Arbatax (tourist service only)
- Gairo-Jerzu (dismantled)
- Isili-Villamar-Villacidro (dismantled)
- Villamar-Ales (dismantled)
- Macomer-Bosa (dismantled between Bosa Marina and Bosa) (tourist service only)
- Macomer-Tirso-Nuoro
- Tirso-Ozieri (dismantled)
- Sassari-Alghero, Sassari-Sorso
- Sassari-Tempio Pausania-Luras-Palau (tourist service only)
- Luras-Monti (dismantled).

Of the lines which are still present, only

- Cagliari-Mandas-Isili
- Sassari-Alghero
- Sassari-Sorso
- Sassari-Nulvi
- Macomer-Nuoro

still carry regular passenger services, operated by Ferrovie della Sardegna *(Railways of Sardinia)*. The others only operate a scenic tourist service known as Trenino verde (small green train)

In Sicily, the Ferrovia Circumetnea (950 mm/3 ft $1\frac{3}{8}$ in gauge) runs around the Mount Etna. Other 950 mm (3 ft $1\frac{3}{8}$ in) narrow gauge lines of Ferrovie dello Stato operated, but are now closed. The last of which was the Castelvetrano-Porto Empedocle, closed in 1985.

In Trento only the 1,000 mm (3 ft $3\frac{3}{8}$ in) narrow gauge lines from Trento to Malè and Marilleva are still operating by Trentino Trasporti. Recently the line has been renovated and extended to Fucine.

In Bolzano-Bozen (Alto Adige/South Tyrol) there are two 1,000 mm (3 ft $3\frac{3}{8}$ in) gauge lines: the Rittnerbahn, or Ferrovia del Renon, a very nice rural tramway and the Laas-Lasa feight private railway to marble cave, that use a funicular too. There are two tourist mines using 600 mm (1 ft $11\frac{5}{8}$ in) gauge trains.

Between Naples and Sorrento, around the base of Mt. Vesuvius, the Circumvesuviana railway operates frequent services on 950 mm (3 ft $1\frac{3}{8}$ in) tracks.

In the Puglia and Basilicata regions there are some 950 mm (3 ft $1\frac{3}{8}$ in) lines connecting Bari, Potenza, Matera and Avigliano. These are owned by Ferrovie Apulo Lucane.

In Calabria there are the Catanzaro Lido-Catanzaro-Cosenza 950 mm (3 ft $1\frac{3}{8}$ in) line, with a branch to Camigliatello Silano, and two lines from Gioia Tauro. All are owned by Ferrovie della Calabria.

The Genova-Casella is a 1,000 mm (3 ft $3\frac{3}{8}$ in) line.

Isle of Man

Both main railways in the Isle of Man are of 3 ft (914 mm) gauge. The Isle of Man Steam Railway to the southwest is operated largely as a tourist attraction but the Manx Electric Railway to the northeast is a commercially operated railway system though its operation is closer to that of a tramway than a railway. The Snaefell Mountain Railway, climbs the island's main peak and has a gauge of 3 ft 6 in (1,067 mm); it is the sole operating Fell Incline Railway System in the world.

Latvia

There are one public, one museum and some industrial peat railways.

A public 750 mm (2 ft $5\frac{1}{2}$ in) narrow gauge railway of around 30 km long joins the towns of Gulbene and Aluksne (two trains per day).

There is a museum railway in Ventspils. The gauge is 600 mm (1 ft $11\frac{5}{8}$ in) and the length is a 2 km circle. The locomotives are former "Brigadelok" steam locomotives. From 1918 until the early 1960s they ran a regular service from Ventspils along the coast to Mazirbe and further down to Talsi and Stende.

The peat companies mainly use 750 mm (2 ft $5\frac{1}{2}$ in), but there also exist 700 mm (2 ft $3\frac{9}{16}$ in) and 600 mm (1 ft $11\frac{5}{8}$ in) gauge railways.

Lithuania

158.8 km of 750 mm (2 ft $5\frac{1}{2}$ in) narrow gauge lines remain, although only 68.4 km of them (serving five stations) are regularly used, employing 12 locomotives. They are included in the Registry of Immovable Cultural Heritage Sites of Lithuania. There also still exist many peat factories, which have private narrow gauge railways for transportation peat from field to factory.

Norway

Thamshavn line Locomotive 3, relocated to the NTNU campus in Trondheim, Norway

In Norway, a number of main lines were in the 19th century built with narrow gauge, 3 ft 6 in (1,067 mm), to save cost in a sparsely populated mountainous country. This included Norway's first own long-distance line, Rørosbanen, connecting Oslo and Trondheim, 1877. Some secondary railways also had this gauge. These railways have been rebuilt to standard gauge or closed down. Some private railways had 750 mm (2 ft 5 ½ in) and one had 1,000 mm (3 ft 3 ⅜ in). A few railways partly still are operated as museum railways, specifically Thamshavnbanen, Urskog-Hølandsbanen and Setesdalsbanen. The tramway in Trondheim, Gråkallbanen is also narrow gauge.

Poland

Kolejka Parkowa Maltanka - 600 mm (1 ft 11 ⅝ in) gauge in Poznań

There are hundreds of kilometres of 600 mm (1 ft 11 ⅝ in), 750 mm (2 ft 5 ½ in), 785 mm (2 ft 6 $^{9}/_{10}$ in), and 1,000 mm (3 ft 3 ⅜ in) narrow gauge lines in Poland. The metre gauge lines are mostly found in the northwest part of the country in Pomerania, while 785 mm (2 ft 6 $^{9}/_{10}$ in) lines are found only in the Upper Silesia region. 750 mm (2 ft 5 ½ in) is the most commonly used narrow gauge; it is used, for example, in the Rogów Narrow Gauge Railway (Rogowska Kolej Wąskotorowa). Some narrow gauge lines in Poland still operate as common carriers (for example the lines operated by SKPL, the Association of Local Railway Haulage) , while others survive as tourist attractions. One of the finest of the latter is the 600 mm (1 ft 11 ⅝ in) narrow gauge railway (*Żnińska Kolej Powiatowa*) running from Żnin via Wenecja (Polish *Venice*) and famous Biskupin to Gąsawa in the Pałuki region. Railway traditions of Pałuki date back to July 1894 when the first two lines were opened.

In the past, there have also been 760 mm (2 ft 5 ⅞ in), 800 mm (2 ft 7 ½ in) and 900 mm (2 ft 11 ½ in) lines. A 900 mm (2 ft 11 ½ in) recreational line 4.2 km long still operates in the Amusement-Recreation Park in Chorzów, Upper Silesia. A similar 600 mm (1 ft 11 ⅝ in) line, Kolejka Parkowa Maltanka, operates in Poznań. Some of Poland's narrow gauge railways are maintained by volunteers; one organization dedicated to preserving narrow gauge railways is the FPKW, the Polish Narrow Gauge Railways Foundation.

Portugal

Rail Station of Sernada do Vouga

Railcar of Linha do Tâmega sits in Amarante station in 2002.

Portugal had hundreds of km of 1,000 mm (3 ft 3 $^3\!/_8$ in) gauge railways, including: Linha do Porto à Póvoa e Famalicão - Closed. Some of the old trackbed is now used by the Oporto's Metropolitan railcars. Linha de Guimarães - Closed between Guimarães and Fafe, converted into a bike way. The rest is now broad gauge. Linha do Tâmega. Linha do Corgo. Linha do Tua. Linha do Sabor. Linha do Vouga (closed in Sernada do Vouga - Viseu, working in Aveiro - Sernada do Vouga - Albergaria-a-Velha - Oliveira de Azeméis - Espinho). Linha do Dão.

Four passenger services are known to still be in operation.

The Tamega Line runs between Livração and Amarante in the District of Oporto and runs near the River Tâmega.

The Corgo line runs from Regua, on the Douro River to Vila Real. The line previously ran to Chaves and the track is still in situ in 2008. There is a small Railway Museum at Chaves.

The Tua Line runs north from Tua to Bragança and previously ran to Mirandela. This line is the least used and may close soon but was still operating in spring 2008. The line was closed temporarily on 10 April 2008 after a landslide which cause the derailment of a light inspection vehicle near Santa Luzia station, and it's unknown when the line will reopen.

Finally a line still runs from Oporto to Lisbon main line at Espinho to Sernada do Vouga and back to the same main line at Aveiro, Linha do Vouga. This line has a museum at Macinhata do Vouga whilst the main workshops are at Sernada do Vouga. This line may also shut at any time.

Romania

Vasar Valley Mocăniță *Mariuța*

Romanian narrow-gauge tracks usually use a 760 mm (2 ft $5\frac{7}{8}$ in) gauge, though there were also some 700 mm (2 ft $3\frac{9}{16}$ in) gauge locomotives manufactured at Reşita. Several old narrow-gauge railways in Romania are being renovated for tourist purposes: the one in the Vaser Valley (Maramureş County) is now well known, the line from Abrud to Campeni is sporadically operating and other renovation projects have made tentative steps and may commence regular operations in the near future, such as the Sibiu-Agnita railway, which has been declared as a historical monument and is now starting to be restored by volunteers. More information can be found under "mocăniță", the term by which such railways are often called in Romanian.

Russia

In Russia, while older imperial Russian narrow gauge was 3 ft 6 in (1,067 mm), current narrow gauge is most often 750 mm (2 ft 5 $^1\!/_2$ in) or 1,000 mm (3 ft 3 $^3\!/_8$ in).
3 ft 6 in (1,067 mm) gauge is remained only in the southern part of Sakhalin Island (to be converted to 1,520 mm (4 ft 11 $^5\!/_6$ in)), where railways were built by the Japanese. A complete list of Russian and other ex-Soviet Narrow Gauge railways.

Serbia

The Šargan Eight in Mokra Gora, Zlatibor (Serbia)

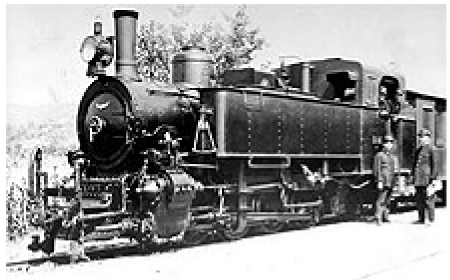
The narrow gauge railway line in Mokra Gora on the northern slopes of mountain Zlatibor in Serbia climbs a 300 metre ascent using an unusual loop in the form of the figure 8 – the popular "Šargan Eight".

Slovakia

Čierny Hron Railway at the station in Čierny Balog

Bratislava municipal transport system uses 1,000 mm (3 ft 3 $^3⁄_8$ in) gauge for trams, while Košice transport system uses standard gauge 1,435 mm (4 ft 8 $^1⁄_2$ in). Railways, however use standard gauge 1,435 mm (4 ft 8 $^1⁄_2$ in) making Bratislava tram and railways networks incompatible with each other. There is a discussion regarding transforming Bratislava's tram gauge to standard gauge to allow trams to use the railways tracks to increase transportation capabilities of Bratislava's public transportation system. The most notable tourist lines in operation are the 760 mm (2 ft 5 $^7⁄_8$ in) gauge Čiernohronská železnica and Oravsko-kysucká lesná železnica - Vychylovka. Another notable narrow gauge tracks include: the Štrbské Pleso - Štrba rack railway and the Tatra Electric Railway (both 1,000 mm (3 ft 3 $^3⁄_8$ in) gauge) in the Tatra mountains and the 760 mm (2 ft 5 $^7⁄_8$ in) gauge railway from Trenčianska Teplá to Trenčianske Teplice.

Slovenia



A steam locomotive of the Parenzana

The narrow-gauge railway line was built in the valley of Dravinja, connecting Poljčane - Slovenske Konjice - Zreče (dismantled 1962).

In formerly Italian Istria, a narrow gauge railway line called Parenzana, a.k.a. Trieste - Buje - Parenzo, connected Trieste (Italy) - Capodistria Koper, Isola d'Istria Izola (Slovenia) - Parenzo Poreč (Croatia) (dismantled).

Spain

Electric unit 3500, operated by FEVE, arriving to the Muros de Nalón station, on the way to Oviedo

EuskoTran (BasqueTram) in Bilbao

In Spain there is an extensive system of 1,000 mm (3 ft 3 $^3/_8$ in) gauge railways, in the north of the country, operated by FEVE (Ferrocarriles Españoles de Vía Estrecha, Spanish narrow gauge railways) and EuskoTren (Eusko Trenbideak, Basque Railways). At the centre of this system is a metre gauge line which runs for 650 km (404 mi) along the entire length of Spain's north coast. FEVE and EuskoTren form the longest narrow gauge network in Europe. Also near Madrid, on the mountain range of Guadarrama runs a mountain train through a short but extremely sinuous track, operated by Renfe. Separate metre gauge railways are operated by the FGC (Ferrocarrils de la Generalitat de Catalunya, Catalan regional government railways) from Barcelona to Manresa and Igualada, the FGV (Ferrocarrils de la Generalitat Valenciana, Valencian regional government railways) around the city of Valencia, as well as along the Costa Blanca from Alicante to Denia, and the SFM (Serveis Ferroviaris de Mallorca) on the island of Majorca. Also on the island of Majorca, the FS (Ferrocarril de Sóller) operates a 3 ft (914 mm) gauge electrified railway and connecting tramway. Also the Euskotran in Bilbao, which is *not* a "light rail", is unusual in new tramway and light rail systems opened in the last twenty-five years in having adopted metre gauge. EuskoTran is part of EuskoTren, the Basque regional government rail company. This company also owns several bus lines. Metro Bilbao started in 1995 on EuskoTren track and has a metre gauge.

Sweden

The Roslagsbanan railway, Stockholm

Sweden once had some fairly extensive narrow gauge networks, but most narrow gauge railways are now closed. Some were converted to standard gauge (the latest one the line between Berga and Kalmar in the 1970s) and some remain as heritage railways. The most common narrow gauge, 891 mm (2 ft 11 $^{1}/_{10}$ in) (3 Swedish feet), existed only in Sweden. A smaller 3 ft 6 in (1,067 mm) gauge network existed, and 600 mm (1 ft 11 $^{5}/_{8}$ in) gauge was used mostly by smaller, industrial railways.

The only commercial narrow gauge railway left is the Roslagsbanan suburban railway in north-eastern Stockholm (891 mm/2 ft 11 $^{1}/_{10}$ in gauge). A branch line, the *Långängsbanan*, was built and run for some years as an isolated standard gauge tramway in anticipation of a planned conversion of the main line to raise its capacity, but those plans came to naught and the branch was rebuilt to narrow gauge; it is now closed.

The longest other remaining narrow gauge railway is the 891 mm (2 ft 11 $^{1}/_{10}$ in) line between Åseda, Hultsfred and Västervik. 70 km between Hultsfred and Västervik as well as the shorter sections between Virserum-Hjortöström and Åseda-Hultanäs are served by tourist trains in the summer, including 4 km of dual gauge track.

Between Bor and Os, Värnamo in Småland, there is a 600 mm (1 ft $11\frac{5}{8}$ in) gauge that today is in use as a tourist railway with steam trains.

Sweden also had the unique 1,093 mm (3 ft 7 in) gauge Köping-Uttersberg-Riddarhyttan Railway. Still other but lesser used gauges in the country were 802 mm (2 ft $7\frac{3}{5}$ in), 1,188 mm (3 ft $10\frac{4}{5}$ in) and 1,217 mm (3 ft $11\frac{9}{10}$ in).

Switzerland

A train at Bad Bubendorf station on the 750 mm (2 ft $5\frac{1}{2}$ in) gauge Waldenburgerbahn between Liestal and Waldenburg in Switzerland .

Switzerland boasts extensive networks of 1,000 mm (3 ft $3\frac{3}{8}$ in) metre gauge railways, many of which interchange traffic (most prominent is the Rhaetian Railway). They are concentrated in the more heavily mountainous areas. The Jungfraubahn terminates at the highest station in Europe. Dual gauge (combined metre- and standard gauge trackway) also exists in many areas. Also, nearly all street tramways in Switzerland were and still are also metre gauge.

United Kingdom

A train on the Welsh Highland Railway.

Double Fairlie locomotive *David Lloyd George* on the Ffestiniog Railway.

The United Kingdom once had a large number of narrow gauge railways which were mostly isolated from each other. The first locomotive-hauled railway in the world was the narrow gauge Penydarren Tramway in south Wales. Most of the lines were originally built to haul minerals or agricultural products over short distances, though many also carried passengers. The longest passenger line was the combined Welsh Highland and Ffestiniog railways at 36 miles / 58 kilometres. The Welsh Highland is currently (2010) being re-built and extended, and will be completely re-opened in 2011 giving a total length (together with the Ffestiniog) of about 40 miles (64 km).

Only a few of these lines survive as commercial common carriers. The great majority of the remaining narrow gauge lines operate purely as tourist attractions, and a number of new narrow gauge tourist lines have been built in recent years. The sole passenger-carrying exception is the Glasgow Subway, an underground metro line that operates on a 4 ft (1,219 mm) gauge. The Talyllyn Railway holds the distinction of being the first railway in the world of any gauge to be run entirely by volunteers. In addition a few private industrial narrow gauge railways remain, mainly serving the coal and peat extraction industries.

Amongst the most well-known narrow gauge lines in Britain are the Ffestiniog - one of the earliest railway organisations in the world - the Corris, the Vale of Rheidol, and the

Welshpool & Llanfair in Wales, and the Lynton & Barnstaple and the Romney, Hythe and Dymchurch, in England. Unique amongst British railways is the rack-and-pinion Snowdon Mountain Railway which climbs to just below the summit of Wales' highest peak.

North America

Canada

Although many railways of central and eastern Canada were initially built to a 5 ft 6 in (1,676 mm) (broad gauge), there were several railways, especially on Canada's Atlantic coast, which were built as individual narrow gauge lines.

The first public passenger carrying narrow gauge railways in North America were in Ontario, the Toronto, Grey and Bruce Railway and the Toronto and Nipissing Railway, opening in the summer of 1871. These 3 ft 6 in (1,067 mm) Ontario lines were over 300 miles (483 km) in length, and both were built with the objective of connecting with a future Pacific railway. The New Brunswick Railway and the Lake Champlain and St. Lawrence Junction Railway of Quebec were built to the same gauge. All were acquired and converted to standard gauge in 1881 and eventually became part of the Canadian Pacific Railway.

Construction of the 3 ft 6 in (1,067 mm) Prince Edward Island Railway began in 1871 and was completed by the Canadian government in 1874 as a condition for Prince Edward Island joining the Canadian Confederation. Construction on the 3 ft 6 in (1,067 mm) Newfoundland Railway took place between 1881 and 1898. It became part of the Canadian National Railways (CNR) when Newfoundland became part of Canada in 1949.

The 3 ft (914 mm) White Pass and Yukon Route which was completed in 1900 at the end of the Klondike gold rush is Canada's last remaining narrow gauge carrier. It no longer carries freight, but is the busiest tourist railroad in North America. Its tracks connect to no other railroad but do connect to the cruise ship docks at Skagway, Alaska, which provide it with most of its passengers

Mexico

Various 3 ft (914 mm) narrow gauge lines operated around Mexico City. A famous one operated in Morelos State. There were dozens of private narrow gauge lines built to service the mining district, and some 2 ft (610 mm) common carriers including the Córdoba and Huatusco Railroad, Cazadero and San Pablo Railroad, Hornos Railroad, and Tacubaya Railroad.

The Yucatán Peninsula region of Mexico has a network of narrow gauge lines, established before the region was linked by rail to the rest of Mexico in the 1950s. Only the main line connecting Mérida to central Mexico has been widened to standard gauge.

United States

Shay logging locomotive in California

A steam locomotive of the C&TS RR

Many narrow gauge railways were built in the United States. The most extensive and well known systems were the 3 ft (914 mm) gauge lines through the Rocky Mountain states of Colorado and New Mexico. For a while the majority of the railway mileage in these states was narrow gauge.

In 1882, thirty-two narrow-gauge logging railroads were constructed in Michigan, and by 1889 there were eighty-nine such logging railroads in operation, totaling almost 450 miles (720 km) of track.

In Maine, a network of 2 ft (610 mm) gauge lines served the rural economy between the 1870s and 1940s. Across the US, industrial narrow gauge railways were used, perhaps the best known being the 3 ft (914 mm) gauge logging lines of the western states of Oregon and California. In Pennsylvania, the 3 ft (914 mm) gauge coal-hauling East Broad Top Railroad is the oldest surviving 3-foot (0.91 m) gauge in the United States hauling excursion trains during the summer months.

Today a few lines survive as heritage railways and tourist attractions. USG Corporation operates an industrial 3 ft (914 mm) gauge line at Plaster City, California and narrow gauge railways are still used for some tunneling and mining work. Tweetsie Railroad in western North Carolina still operates today as a family tourist attraction.

Central America

Costa Rica

Costa Rican railways are 3 ft (914 mm) gauge and mostly 3 ft 6 in (1,067 mm) gauge.

El Salvador

El Salvador ran 3 ft (914 mm) gauge steam trains into the 1970s. How much of this survived a civil war, earthquake and hurricane is unknown.

Guatemala

- 3 ft (914 mm) gauge, Ferrovías Guatemala

Haiti

Haiti has had two different gauges on its railways. 130 km of rural line between Port-au-Prince, Saint-Marc, and Verrettes (1905–about 1960s) used 3 ft (914 mm) gauge. Tramlines in Port-au-Prince (1878–1888 and 1896–1932), which was the first known track in Haiti, and a total of 80 km of rural line west to Léogâne and east to Manneville (1896–1950s(?)) used 3 ft (914 mm) gauge. Totalling over 100 km of track, the plantation railways in the north and north-east most likely used 2 ft 6 in (762 mm). There were at least four separate isolated lines. The story of the demise of one Haitian railroad is that it was sold and physically picked up, and shipped to Asia during the Papa Doc period (approx. 1957–1971). Other gauges may have been used on the plantation tracks in the north and north-east of Haiti. The CIA fact book suggests that in the 1990s there were only 40 km of abandoned track left(?). History of Haitian railways.

South America

Metre and 914 mm (3 ft) gauge lines are found in South America. Some of the 1,000 mm (3 ft 3 3⁄8 in)-gauge lines cross international borders, though not as efficiently as they might.

Argentina, Bolivia, Brazil and Chile have 1,000 mm (3 ft 3 3⁄8 in) gauge lines. Colombia and Peru have 914 mm (3 ft) gauge lines.

Argentina

The Rainforest Ecological Train in Argentina

1,000 mm (3 ft $3\frac{3}{8}$ in) railways are found in the northern half of the country. The *Old Patagonian Express* (*La Trochita*) is a 402 km-long 750 mm (2 ft $5\frac{1}{2}$ in) narrow gauge railway in the Andean foothills of Patagonia, now running as two portions of its original length, and only as a tourist attraction. However, all the track is preserved. The Southern Fuegian Railway (*End of the World Train*) on a 500 mm (1 ft $7\frac{3}{4}$ in) track is considered the southernmost operating railway in the world, also solely as a tourist operation. The Rainforest Ecological Train is a 600 mm (1 ft $11\frac{5}{8}$ in) environmentally-friendly train that runs through the forest inside Iguazú National Park in the north of the province of Misiones of Argentina and there is also a coal railway, *Red de Ferrocarril Industrial de Rio Turbio*, that however is no longer in operation. It previously operated between Rio Turbio and Rio Gallegos on 750 mm (2 ft $5\frac{1}{2}$ in) track gauge.

Brazil

Anhumas station of the Campinas-SP

In Brazil, almost all the lines are 1,000 mm (3 ft $3\frac{3}{8}$ in) gauge, with the exception of a few lines in the states of São Paulo, Minas Gerais, Rio de Janeiro and Mato Grosso. Vale (ex-CVRD) also has a line with 1,600 mm (5 ft 3 in) gauge lines once operated in Minas Gerais, centered around the city of São João del-Rey. This network at one time had over 770 km of railway in operation, but only about 13 km remain in operation as a steam powered tourist railway. Other small narrow gauge lines include the Rio de Janeiro streetcar (Bonde de Santa Teresa), with approximately 13 km of 1,100 mm (3 ft $7\frac{7}{16}$ in) gauge, and a very short industrial railway near Bertioga built to 800 mm (2 ft $7\frac{1}{2}$ in) gauge. A number of industrial (a 2 ft (610 mm) gauge Portland Cement line near São Paulo, for example) and agricultural (rubber plantations, sugar plantations, logging) railways also existed in Brazil in a number of narrow gauges, but few of those survive today.

Chile

Metre gauge railways are found in the northern half of the country but are no longer in operation. The Ferrocarril de Antofagasta a Bolivia was originally built to 2 ft 6 in (762 mm) gauge, as were a number of mining and nitrate railways. The Transandean railway was metre gauge but is no longer in operation between Chile and Argentina. However, there is a short section used for industrial (copper) operations in the area between the station at Los Andes and the Río Blanco station.

Colombia

Most of the railways in Colombia are 914 mm (3 ft) gauge.

Ecuador

The railways in Ecuador are 1,067 mm (3 ft 6 in) cape gauge. This is a famous route, the one that zig zags past the chilling canyon of the Devil's Nose. Floods, landslides and government neglect have put this operation in doubt, but they are working to restore the railway. The recently elected president Rafael Correa declared the state of emergency of the national railway. He has secured funding for a master plan to restore it to its previous glory. In the first phase of this plan, the Ecuadorian government will invest over US $283 million to completely repair the country's existing railway system and infrastructure, such as bridges, walls and stations. The government will also purchase new locomotives. A second phase seek the building of new railway lines to connect the country with Brazil and Venezuela. Currently two Baldwin locomotives are ready to work, depending on track and traffic. There are also a number of diesel railbuses and some Alsthom diesel locomotives available.

The railway from Guayaquil to Quito featured in the 1983 BBC television series *Great Little Railways*.

Peru

The Cusco-Machu Picchu railway

The Cuzco-Quillibama line in Peru is 914 mm (3 ft) gauge. The other 914 mm (3 ft) narrow gauge line (Huancayo-Huancavelica) will be converted to standard gauge.

Uruguay

There were four big narrow gauge lines in Uruguay: Puerto del Sauce (now Juan Lacaze)-Terminal: 914 mm (3 ft) , (1901–1959), Piriapolis-Pan de Azucar: 750 mm (2 ft 5 ½ in) (1903–1958), km 393-Arrozal 33: 600 mm (1 ft 11 ⅝ in) and km 110-Cantera Burgueño: 600 mm (1 ft 11 ⅝ in). All were dismantled. There were also several quarry lines of 600 mm (1 ft 11 ⅝ in) gauge, among them the famous INDARE sand line. Around 300 m of that sand line is preserved and also a lot of steam locomotives. One of those is in working order. Also, a new narrow gauge line, of around 1 km, with two diesel locomotives from the former km 110-Cantera Burgueño line, was constructed in a park on the town of Santiago Vazquez, in the West of Montevideo.

Asia

Bangladesh, India, Pakistan and Sri Lanka inherited a diversity of rail gauges, some of which was 1,000 mm (3 ft 3 ⅜ in). Indian Railways has adopted **Project unigauge**, which seeks to systematically convert most of its narrower gauge railways to 5 ft 6 in (1,676 mm).

Southeast Asia

The railways of Southeast Asia, including Vietnam, Cambodia, Laos, Thailand, Myanmar and Malaysia are predominantly 1,000 mm (3 ft 3 ⅜ in) gauge. The proposed ASEAN Railway would be a standard gauge or dual gauge, using both metre and standard gauge regional railway networks, linking Singapore at the southern tip of the Malay Peninsula, through the Association of Southeast Asian Nations region Malaysia, Thailand, Laos and Vietnam to the standard gauge railway network of the People's Republic of China. Indonesia's railways are predominantly 1,067 mm (3 ft 6 in).

China

Some of the railway network of the People's Republic of China is 1,000 mm (3 ft 3 ⅜ in) gauge.

Many narrow gauge railways existed in China. Metre gauge railways were popular in China in several regions before 1949. The 1,000 mm (3 ft 3 ⅜ in) gauge Kunming-Hekou Railway (previously known as Sino-Vietnamese Railway) was built by French colonists between Vietnam and China. In Manchuria, lumber industries built narrow gauge railways into the forests, mostly of 2 ft 6 in (762 mm) gauge.

Hong Kong

Preserved Kowloon-Canton Railway locomotive

In Hong Kong the Kowloon-Canton Railway was partially laid to 2 ft (610 mm) and 3 ft (914 mm) gauge during its construction in 1910 but was very soon converted to standard gauge. The Sha Tau Kok Railway was 2 ft (610 mm) gauge for much of its existence. The famous Hong Kong Tramways are 3 ft 6 in (1,067 mm) gauge, and the territory's metro, the MTR, runs on 1432 mm gauge except for the standard gauge KCR network it operates under a lease.

India

The Darjeeling Himalyan Railway

The Kalka Shimla Railway

India has a substantial network of narrow gauge railways. The majority of these are 1,000 mm (3 ft 3 ⅜ in) gauge or Metre gauge, totalling approximately 10,000 km of track. There are some 2 ft 6 in (762 mm) gauge railways, and a few that use 2 ft (610 mm) gauge; these are known as "narrow gauge" (as opposed to "metre gauge") lines in India.

As of 31 March 2008, of the 63,273 km railway lines in India, 9,442 km were metre gauge lines, and 2,749 km narrow gauge lines; the rest 51,082 km were broad gauge lines.

In 1999 the 2 ft (610 mm) gauge Darjeeling Himalayan Railway was officially designated as a UNESCO World Heritage Site. It runs from Siliguri to Darjeeling in the state of West Bengal.

Indonesia

Indonesia had large numbers of narrow gauge railways supporting industry, mainly sugar cane plantations in Java. In recent years, sugar cane production in Java has been declining and the railways are now largely closed or used for tourism.

Most of the current active railways in Indonesia use the Cape gauge 1,067 mm (3 ft 6 in).

Japan

Modern JR East express train

Modern Japan Railways freight locomotive

Except for the high-speed Shinkansen lines and JR East Ou Main Line and Tazawako Line, all of Japan Railways Group's network is narrow gauge, built at 1,067 mm (3 ft 6 in). Some companies, such as Kintetsu, Keisei Electric Railway, Keihin Electric Express Railway, Hankyu Railway, Toei Asakusa Line, Tokyo Metro's Ginza Line and Marunouchi line, use standard gauge.

Tokyo's Keio Electric Railway network and the Toei Shinjuku metro line, which operate through services, use an exceptional 1,372 mm (4 ft 6 in) gauge. This gauge is also used on the Tokyo and Hakodate tramways.

There are some dual gauge lines which allow Shinkansen trains to travel on narrow gauge branches. Japan adopted 762 mm (2 ft 6 in) as a standard narrow gauge for minor, forestry and industrial lines. However, most of these narrow gauge lines were abandoned and currently only four lines remain in operation.

Malaysia

A KTMB train

Malaysia's oldest railway systems are solely 1,000 mm (3 ft 3 ⅜ in) gauge, a standard that has been adopted since the British colonial government laid down the first railway lines in 1885.

Keretapi Tanah Melayu, the main railway operator in Peninsular Malaysia, uses metre gauge for the main west and east coast intercity lines, as well as railway lines spanning Singapore, from the Johor-Singapore Causeway to the Tanjong Pagar railway station. Existing metre gauge lines are also used for KTM Komuter, the country's commuter rail service, which links Kuala Lumpur with neighbouring suburbs. However, standard gauge is used by the newer light rail operators in Kuala Lumpur city (Putra LRT, Star LRT) as well as the privately operated Express Rail Link to the airport.

In Sabah, the North Borneo Railway ("Keretapi Negeri Sabah") runs a metre gauge line from Kota Kinabalu up to Tenom in the Crocker Ranges, via Beaufort. Steam trains are also used in this route.

Philippines

Except for the Light Rail Transit (LRT) and Metro Rail Transit (MRT) systems in Metro Manila, which have both been constructed to the international standard gauge, the Philippine National Railways ("PNR") uses the "Cape Gauge" of 3 ft 6 in (1,067 mm). The PNR currently operates only one line: from Manila to the southern Luzon city of Legaspi. Until the 1980s a more extensive network existed going as far north as San Fernando in La Union province. There are plans to restore the La Union line and to build new lines connecting Manila to Batangas and the international airport.

There are also a number of industrial narrow gauge steam railways operating in the sugar cane industry. These are concentrated on the islands of Negros and Panay. The Visayas region is the main center for the sugar cane lines; some of the mills, such as La Carlotta Milling in Negros, run charter trains for tourists. Abandoned lines exists on the islands of Cebu, abandoned in the 1950s or 1960s, Mindanao, and Panay, closed in the 1990s. There are plans to restore the Panay Rail line which connects Roxas City with Iloilo.

Taiwan

Taiwan narrow gauge service

Taiwan started to build up railway in the Qing dynasty using 3 ft 6 in (1,067 mm) gauge. The Japanese colonial government, which ruled from 1895 to 1945, continued using 3 ft 6 in (1,067 mm). The system is now under Taiwan Railway Administration. The new Taipei Metro and Kaohsiung MRT use standard gauge. The Taiwan High Speed Rail (THSR), which started operation in January 2007, also uses standard gauge. An isolated 2 ft 6 in (762 mm) gauge line on the east coast was regauged to 3 ft 6 in (1,067 mm) when the line was interconnected.

A 2 ft 6 in (762 mm) narrow gauge Alishan Forest Railway stretches 72 km and connects the city of Chiayi to the mountain resort of Alishan. The line serves mainly as a tourist attraction and offers breathtaking mountain views.

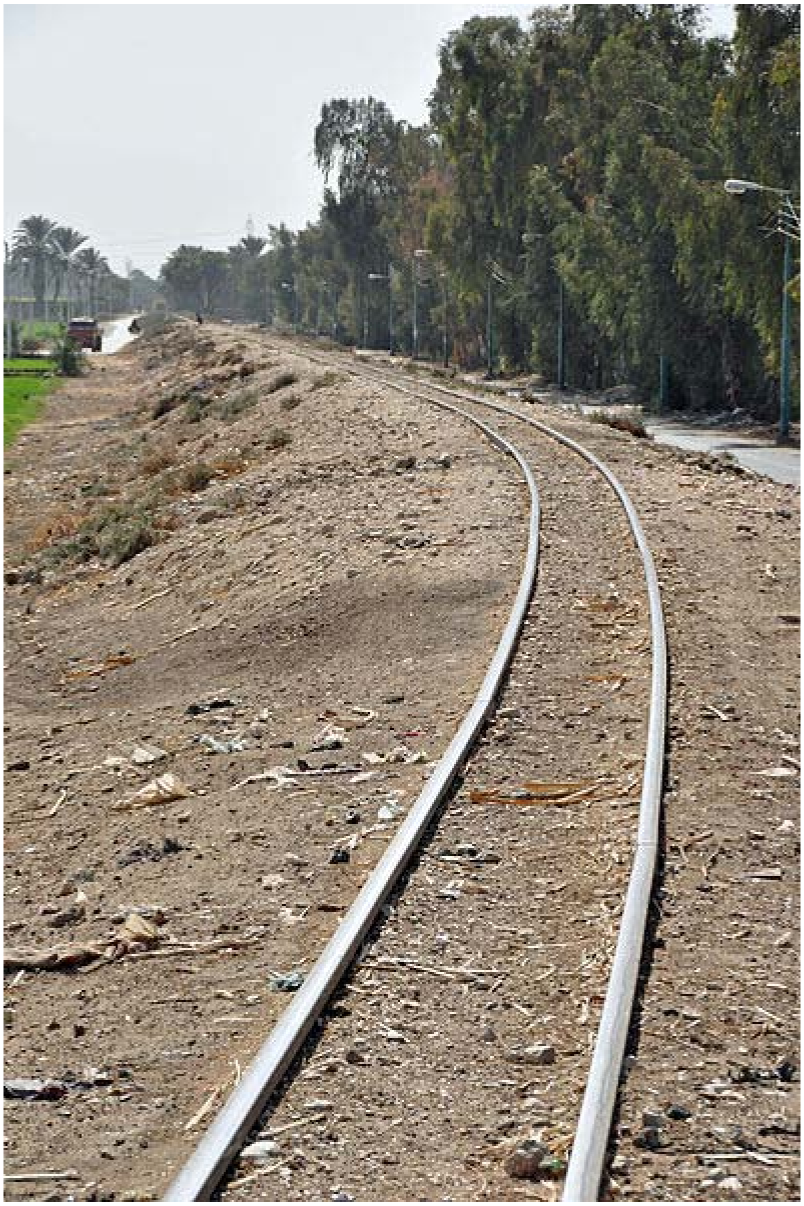
On September 7, 2006, Taiwanese government declared a plan to update to a standard gauge system. Though, it's not the first time that this plan was proposed. In fact, some of the facilities have allowed for standard gauge conversion such as the underground tunnels constructed since the late 1980s. Many experts criticize the proposal as prohibitively expensive especially given that most lines would likely experience modest, if any, benefits of upgrading.

Thailand

SRT Alsthom-built metre gauge locomotive

While the Northern Line was originally build as 1,435 mm (4 ft 8 $\frac{1}{2}$ in) standard gauge, the line was regauged after 1919 and the State Railway of Thailand now operates entirely on 1,000 mm (3 ft 3 $\frac{3}{8}$ in) gauge, including international through services to Malaysia ans Lao. However, standard gauge is used by the Bangkok Skytrain and the Bangkok Metro and the new Bangkok airport link due to be open in August 2009. In 2010, new high speed lines are to be standard gauge again.

Africa



Narrow gauge railway at Qurna (Luxor region, Egypt) used for transporting sugar cane

Narrow gauge railways are common in Africa, where great distances, challenging terrain and low funding have made the narrow gauges attractive. Many nations, particularly in southern Africa, including the extensive South African Railway network (Spoornet), use a 3 ft 6 in (1,067 mm) gauge. Metre gauge is also common, as in the case of the Uganda Railway. There used to be extensive 2 ft (610 mm) and 600 mm (1 ft 11 ⅝ in) gauge networks in countries such as Morocco, Congo, Angola, Namibia and South Africa, but these have mostly been dismantled or converted. Some also survives in Egypt: in the countryside around Luxor, narrow gauge railways are used for the transportation of sugar cane.

Because Africa is divided into many countries, railways built by different governments tend not to link up with each other, each country's lines connecting its outlands with its own port. Incompatible gauges are therefore not obvious. For example, a link from Nigeria to Cameroon would join 3 ft 6 in (1,067 mm) to 1,000 mm (3 ft 3 ⅜ in).

The railways of South Africa and many other African countries, including Angola, Botswana, Congo, Ghana, Mozambique, Namibia, Nigeria, Sudan, Zambia and Zimbabwe, use 1,067 mm (3 ft 6 in) gauge, sometimes referred to as **Cape gauge**. Kenya, Uganda and others use 1,000 mm (3 ft 3 ⅜ in) gauge lines. In Tanzania former East African Railways lines are metre gauge while the TAZARA line is 3 ft 6 in (1,067 mm)

During the period of British colonisation of Africa, Cecil Rhodes advocated the construction of a Cape to Cairo railway, linking all British possessions along the eastern side of Africa between South Africa and Egypt. While most countries through which such a line would run have cape gauge lines, Tanzania and Kenya have metre gauge lines, although the TAZARA line in Tanzania is cape gauge.

Eritrea

Further north, the Eritrean Railway is in the midst of resurrecting its 950 mm (3 ft 1 ⅜ in) narrow gauge railway, a relic of its former Italian colonial days that was abandoned and heavily damaged during Eritrea's war of independence. Neighbouring railways (should they ever connect) are 3 ft 6 in (1,067 mm) in Sudan and 1,000 mm (3 ft 3 ⅜ in) in Ethiopia.

Cameroon

During the First World War when Cameroon was a German possession, a network of 2 ft (610 mm) gauge Feldbahn railways were built. These eventually extended to around 150 km of track serving rubber and palm oil plantations.

The 1,000 mm (3 ft 3 ⅜ in) gauge is now in use.

Morocco

Morocco had from 1912 - 1935 one of the largest 600 mm (1 ft 11 ⅝ in) gauge network in Africa with total length of more than 1700 kilometres. After the treaty of Algeciras where the representatives of Great Powers agreed not to build any standard gauge railway in Morocco until the standard gauge Tangier - Fez Railway being completed, the French had begun to built military 600 mm (1 ft 11 ⅝ in) gauge lines in their part of Morocco French Morocco.

South Africa

A modern commuter service near Cape Town

Class 19D locomotive at Pretoria

Originally standard gauge, the railways of the then Cape Colony changed to narrow gauge 3 ft 6 in (1,067 mm), sometimes known as *Cape gauge*, for cost-cutting reasons. However, with the development of a strong economy, with heavy export coal and iron ore traffic, and electrification of most main lines, South Africa, like Queensland, operates several narrow gauge trains that outdo all standard gauge (except China) and all broad gauge trains. In fact, in 1989 the Sishen-Saldanha line set a world record by carrying the biggest train in history, 7.2 km long containing 660 wagons pulled by 15 locomotives and weighing 71,232 tonnes (70,107 LT; 78,520 ST). However, the proposed Gautrain railway between Johannesburg and Pretoria will operate on standard gauge, and will thus not be capable of using any of the country's existing rail network.

The Avontuur Railway operates between Port Elizabeth and Avontuur in South Africa. It is the longest 610 mm (2 ft) gauge route in the world at a length of 285 km. It is operated by the South African railway company Spoornet. The line is commonly known as the Apple Express.

Oceania

Australia

Sugar train near Mossman in 1995

Puffing Billy train at Lakeside station

Queensland, Tasmania, Western Australia and parts of South Australia adopted 1,067 mm (3 ft 6 in) gauge to cover greater distances at lower costs. Most industrial railways are built to 610 mm (2 ft) gauge. Three different rail gauges are currently in wide use in Australia, and there is little prospect of full standardisation.

Before 1901, each of the six British colonies was responsible for rail transport infrastructure. Queensland, Western Australia, and Tasmania constructed for narrow gauge railways. The other colonies built either standard gauge or broad gauge railways, maintaining only limited narrow gauge rail lines, except for South Australia, which built both narrow and broad gauge. As a result of this legacy, Australian railways are a mix of all three gauges.

In 1865, the Queensland Railways was the first mainline narrow gauge railway in the world . Its tracks would eventually extend to around 9000 km. Queensland Rail operates the QR Tilt Train, with a maximum speed of 165 km/h. This train currently holds the Australian Railway Speed Record of 210.7 km/h. Queensland also has extensive sugar cane tramways of 2 ft (610 mm) gauge.

Following the success of the narrow gauge in Queensland, several narrow gauge lines were built in South East Australia. From the 1920s onwards several of these were converted to broad gauge.

Inspired by the success of the narrow gauge in Queensland, Western Australia adopted the same gauge. Until closure in 1958 Perth had the only narrow gauge tramway network of any considerable extent in mainland Australia.

The Northern Territory adopted narrow gauge when it was still part of South Australia, and a North-South transcontinental line was planned from Adelaide to Darwin in the 1870s. In the event this line was never completed, and due to flood damage and lack of traffic, the narrow gauge line was closed.

Four common carrier lines in Victoria were built to the 2 ft 6 in (762 mm) narrow gauge standard, to serve local farming and forestry communities. Sections of two lines (Belgrave to Gembrook and Thomson to Walhalla) have been restored as tourist railways.

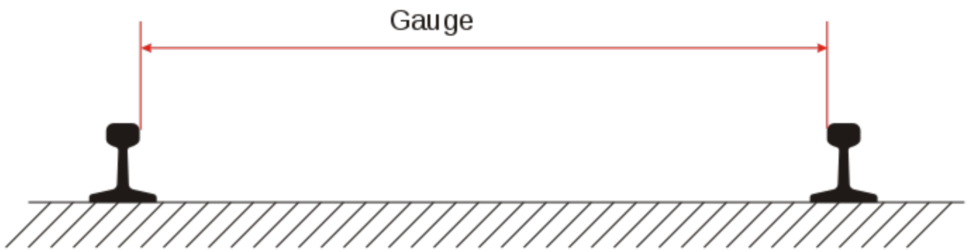
New Zealand

New Zealand adopted narrow gauge 1,067 mm (3 ft 6 in) (cape gauge) due to the need to cross mountainous terrain in the country's interior. This terrain has necessitated a number of complicated engineering feats, notably the Raurimu Spiral. There are 1787 bridges and 150 tunnels in less than 4,000 km of track. Around 500 km of this track is electrified, on the North Island Main Trunk, between Palmerston North and Hamilton.

Much like Australia, there was initially no uniformity in track gauges in New Zealand. This was because the construction of railways was undertaken by the various provinces of New Zealand rather than the central government. The Canterbury Provincial Railways opened New Zealand's first railway in 1863 and used a broad gauge of 1,600 mm (5 ft 3 in) , while Southland built the Bluff and Kingston Branches to 1,435 mm (4 ft 8 ½ in), and short segments of 1,435 mm (4 ft 8 ½ in) railway were also constructed in the Auckland and Northland Regions. Eventually, under the public works schemes of Premier Julius Vogel, the railways of New Zealand were made to adhere to a 1,067 mm (3 ft 6 in) gauge. The first 1,067 mm (3 ft 6 in) gauge railway in New Zealand was the Dunedin and Port Chalmers Railway, which opened on 1 January 1873. Today, the network connects most major New Zealand cities, and is around 4,000 km in length.

Chapter- 5

Break-of-Gauge



With railways, a **break-of-gauge** occurs where a line of one gauge meets a line of a different gauge. Trains and rolling stock cannot run through without some form of conversion between gauges, and freight and passengers must otherwise be transloaded. Either way, a break-of-gauge adds delays, cost, and inconvenience to traffic that must pass from one gauge to another.

Inconvenience

Bogie changing in Ussuriisk (near Vladivostok) at the Chinese–Russian border

One solution to the break-of-gauge problem – the transporter car

Transloading of freight from cars of one gauge to cars of another is very labour and time intensive, and increases the risk of damage to goods. If the capacity of freight cars on each system does not match, additional inefficiencies can arise. Technical solutions to avoid transloading include variable gauge axles, replacing the bogies of cars, and the use of transporter cars that can carry a car of a different gauge.

Talgo and *CAF* have developed dual gauge axles (variable gauge axles) which permit through running between broad gauge and standard gauge. In Japan the *Gauge Change Train* has been built on Talgo patents that can run on standard and narrow (1067 mm) gauge.

In some cases, breaks-of-gauge are avoided by installing dual gauge track, either permanently or as part of a project to replace one gauge with another.

At almost every break-of-gauge, passengers have to change trains, but there are a few passenger trains that can run through a break-of-gauge. For example, the Talgo, and the Moscow-Beijing trains (bogie exchange) although on the latter passengers usually have to leave the train for some time whilst the work is done.

Advantages

An advantage is that invading armies may be severely hampered (as when Germany invaded the USSR in WWII).

Another advantage might be that if the different gauges have different loading gauges, the break of gauge helps keep the larger wagons clear of smaller tunnels.

Passengers

For passengers trains the inconvenience is less, especially if it is at a major train station, where many passengers change trains or end their journey anyway. Therefore some passenger-only railways have been built with other gauges than would otherwise be used in a country, like the high-speed railways in Japan and Spain.

For night trains, which are very common in places like Russia, train change is less desired, especially by night. For these often the bogies are replaced, even if it takes much more time than having the passengers change trains.

Tidal traffic

The inefficiencies of a break of gauge are especially apparent when there is a tide of traffic in one direction, as might happen when fodder from a drought-free region needs to be transhipped to a drought-affected region on the other gauge. Firstly, one might run out of suitable wagons on the other gauge, while loaded wagons unable to be transhipped obstruct the main lines or crossing loops on the first gauge.

Overcoming a break of gauge

Where trains encounter a different gauge, such as at the Spanish-French border or the Russian-Chinese one, the traditional solution has always been transshipment — transferring passengers and freight to cars on the other system. This is obviously far from optimal, and a number of more efficient schemes have been devised. One common one is to build cars to the smaller of the two systems' loading gauges with bogies that are easily removed and replaced, with a bogie exchange at an interchange location on the border. This takes a few minutes per car, but is quicker than transshipment. A more modern and sophisticated method is to have multigauge bogies whose wheels can be moved inward and outward. Normally they are locked in place, but special equipment at the border unlocks the wheels and pushes them inward or outward to the new gauge, relocking the wheels when done. This can be done as the train moves slowly over special equipment.

When transhipping from one gauge to another, chances are that the quantity of rolling stock on each gauge is unbalanced, leading to more idle rolling stock on one gauge than other.

In some cases, breaks of gauge are avoided by installing dual gauge track, either permanently or as part of a changeover process to a single gauge.

Piggyback operation

One method of achieving interoperability between rolling stock of different gauges, is to piggyback stock of one gauge on special transporter wagons or even ordinary flat wagons fitted with rails. This enables rolling stock to reach workshops and other lines of the same gauge to which they are not otherwise connected. Piggyback operation by the trainload occurred as a temporary measure between Port Augusta and Marree during gauge conversion works in the 1950s, to bypass steep gradients and washaways in the Flinders Ranges.

Narrow gauge railways were favoured in the underground slate quarries of North Wales, as tunnels could be smaller. The Padarn Railway operated transporter wagons on their 4 ft (1,219 mm) gauge railway, each carrying four 1 ft 10 ¾ in (578 mm) slate trams. When the Great Western Railway acquired one of the narrow gauge lines in Blaenau Ffestiniog, they used a similar type of transporter wagon in order to use the quarries' existing slate wagons.

Transporter wagons are most commonly used to transport narrow gauge stock over standard gauge lines. More rarely, standard gauge vehicles are carried over narrow gauge tracks using adaptor vehicles; examples include the Rollbocke transporter wagon arrangements in Germany, Austria and the Czech Republic and the milk transporter wagons of the Leek and Manifold Valley Light Railway in England.

In 2010, Japan is developing the Train on Train piggyback concept.

Containerisation

The widespread use of containers since the 1960s has made break of gauge less of a problem, since containers are efficiently transferred from one mode to another by suitable large cranes.

Consider the transfer from a train of one gauge to another train of a different gauge. It helps if the lengths of the wagons on each gauge are the same so the containers can be transferred from one train to the other with no transverse movement along the train. The different wagons should carry the same number of containers. Delays to each train depends on how many cranes can operate simultaneously.

Container cranes are relatively portable, so that if the break of gauge transshipment hub changes from time to time, the cranes can be moved around as required. Fork lift trucks can also be used.

There is a gauge transshipment station at Kidatu in Tanzania.

Examples of breaks of gauge

Some examples of breaks of gauge between systems include:

Africa

- Rail lines linked by ferries on convenient rivers or lakes.
- Dar es Salaam is one of the few places in Africa where different gauges actually meet.
- Kidatu in Tanzania has a container transshipment facility to move freight containers between TAZARA (1067 mm) and Tanzania Railways Corporation trains (1000 mm)
- Angola originally had 1,000 mm (3 ft 3 ⅜ in), 600 mm (1 ft 11 ⅝ in) and 3 ft 6 in (1,067 mm) lines, but the 1,000 mm and 600 mm lines were converted to 1,067 mm in the 1950s in expectation that the lines would meet, but this has never happened.
- DRCongo originally had both 1,000 mm (3 ft 3 ⅜ in) and 3 ft 6 in (1,067 mm) lines, but when these lines met in the 1950s, the 1,000 mm (3 ft 3 ⅜ in) line was converted to 3 ft 6 in (1,067 mm).

Asia

Bangladesh

Bangladesh has decided to resolve most of its break-of-gauge problem by converting most of its broad and narrow gauge tracks to dual gauge.

China

China has a standard gauge network; neighbouring countries Mongolia, Russia and Kazakhstan use 1520 mm and Vietnam uses metre gauge, so there are some breaks of gauge. Dual gauge reaches into Vietnam as far as Hanoi. There is currently a break of gauge at Dostyk on the Kazakh border, but Kazakhstan is building an additional line, in standard gauge, line between Dostyk and Aktogay

Hong Kong

Hong Kong's railway, the MTR, has 1,432 mm gauge for its original network, whereas its East Rail Line, West Rail Line and Ma On Shan Line use the standard gauge. The standard gauge lines are leased from another railway company, the KCR Corporation. The Light Rail is also standard gauge.

India

Indian Railways has decided to convert a significant proportion of its metre gauge and narrow gauge systems to broad gauge. This is called Project unigauge.

Iran

Iran, with its standard gauge rail system, has break-of-gauge at the borders with Azerbaijan and Turkmenistan, and now also has a new break-of-gauge with Pakistan at Zahedan. Pakistan has a broad gauge railway system.

The break-of-gauge station at Zahedan was built outside the city, as the existing station was hemmed in by built up areas.

Japan

Most high speed lines in Japan have been built as standard gauge lines. A few routes have been planned as narrow-gauge, and the conventional (non-high-speed) is mostly narrow gauge 3 ft 6 in (1,067 mm), so there are some breaks of gauge and dual gauge is used in some places. Private railways often use other gauges.

In 2010, Hokkaidō Railway Company was working on a transporter train by trainload concept called Train on Train to carry narrow gauge freight trains at faster speeds on standard gauge flatcars.

North Korea

A break of gauge occurs across the Tumen River which forms the border between North Korea and Russia.

- Russia (Khasan)
- North Korea (Tumangang)

Taiwan (Republic of China)

Like Japan, the Republic of China use the 1,067 mm gauge for the majority of its railway network, but 1,435 mm standard gauge for high-speed rail; however, gauge differences are less of a problem as Taiwan High Speed Rail generally uses separate rolling stock and separate rights of way.

Thailand

Several countries bordering Thailand use meter gauge track, but there are missing links between Thailand and Vietnam via Cambodia.

Europe

Russian gauge meeting Standard gauge

- Poland, Slovakia, Hungary and Romania (1,435 mm).

  vs. Former Soviet Union countries: Russia, Lithuania, Belarus, Ukraine, Moldova (1,520 mm). Night trains are common, and they are often bogie-exchanged.

- Finland (1,524 mm) and Sweden (1,435 mm), between Tornio and Haparanda via a short dual-gauge bridge. Freight is generally transloaded. No passenger trains. There is also a SeaRail ferry (with 1,435 mm onboard) linking Turku, Finland with Stockholm, Sweden; the Turku terminal handles both gauges.
- Bulgaria (1,435 mm) railroad ferries to Ukraine, Russia and Georgia (1,520 mm)
- Germany (1,435 mm) railroad ferries (with 1,520 mm onboard) to Finland, Russia and Baltic States (1,520 mm)
- While breaks of gauge are generally located near borders, a line carrying iron ore from Ukraine extends into Slovakian territory to a steelworks near Košice and there are plans to extend the line further west, to Vienna.

Other breaks-of-gauges

- France (1,435 mm) and Spain (1,668 mm), for example at Cerbère (FR) - Portbou (ES); Hendaye (FR) - Irun (ES) and Latour-de-Carol. From 2010 the Spanish high-speed network (1,435 mm) is connected to the French railways without a break-of gauge.

Oceania

Australia

The break-of-gauge platform for the Sydney-Melbourne railway at Albury station; SG on left; BG on right.

- Queensland (3 ft 6 in (1,067 mm)) and New South Wales (4 ft 8 $\frac{1}{2}$ in (1,435 mm))
- New South Wales (1,435 mm) and Victoria (5 ft 3 in (1,600 mm))
- Southern South Australia uses broad gauge, like Victoria. Northern South Australia had a number of narrow gauge 3 ft 6 in (1,067 mm) lines, leading to several break-of-gauge stations at various times including Hamley Bridge,

Terowie, Peterborough, Gladstone, Port Pirie, Port Augusta, Marree, Wolseley and Mount Gambier.

- In the latter part of the 20th century, all mainland capital cities were connected by a standard gauge 4 ft 8 ½ in (1,435 mm) network, leading to more breaks of gauge (or branch line closures) in states where this is not the norm
- Perth's railway system is narrow gauge (3 ft 6 in (1,067 mm)), while the Indian Pacific is standard gauge. The line between East Perth and Midland, the eastern suburban terminus, and inland to the major rail junction at Northam is dual gauge. All rail east of this is standard gauge.
- Since the 1990s, new concrete sleepers installed in the Adelaide suburban area have been gauge convertible (the difference between the gauges are too close to allow dual gauge).
- In May 2008, agreement reached to convert the declining trafficked broad gauge line of a BG/SG pair for 200 km between Seymour and Albury to double track Standard gauge for growing interstate traffic.
- Since the 1930s, most Victoria steam locomotives were designed for ease of conversion to standard gauge, but except for R766, this has never happened.
- Note that the lines of the same gauge do not all join up, being separated by other gauges, deserts or oceans. Rolling stock is often transferred on low-loaders or by ship.

Military

Military depots where arms, fuel, etc. are stored are best located at break-of-gauge stations so that stores can be loaded onto the correct gauge directly. Such depots were created at Albury, Tocumwal, amongst others.

New Zealand

New Zealand originally has small lengths of lines of 1,067 mm (3 ft 6 in), 1,435 mm (4 ft 8 ½ in) and 1,600 mm (5 ft 3 in), but quickly converted to 1,067 mm (3 ft 6 in) which better suited this sparsely populated and mountainous country.

North America

- The United States of America had broad, narrow and standard gauge tracks in the 19th century, but is now almost entirely 1,435 mm (4 ft 8 ½ in) standard gauge. Narrow-gauge operations are generally isolated rail systems. The notable exception would be the break-of-gauge in Antonito, Colorado between the standard gauge Rio Grande Scenic Railroad and the narrow gauge Cumbres and Toltec Scenic Railroad, billed as the Toltec Gorge Limited.
- Similarly, Canada and Mexico are standard gauge.
- A break-of-gauge, 3 ft (914 mm) to 4 ft 8 ½ in (1,435 mm), between Mexico and Guatemala is currently closed.

South America

- Argentina and Chile both use 5 ft 6 in (1,676 mm) broad gauge tracks, but the link railway uses 1,000 mm (3 ft 3 ⅜ in) narrow gauge with rack railway sections. So there are two break-of-gauge stations, one at Los Andes, Chile and the other at Mendoza, Argentina. It was planned to reopen this currently closed railway in summer 2007 and re-gauge from small to broad to be in future without break-of-gauge
- A break-of-gauge between Argentina and Brazil, 1,435 mm (4 ft 8 ½ in) to 1,000 mm (3 ft 3 ⅜ in)
- A break-of-gauge between Uruguay and Brazil, 1,435 mm (4 ft 8 ½ in) to 1,000 mm (3 ft 3 ⅜ in) at Santana do Livramento.

Minor breaks of gauge

Wherever there are narrow gauge lines that connect with a standard gauge line, there is technically a break-of-gauge. If the amount of traffic transferred between lines is small, this might be a small inconvenience only. In Austria and Switzerland there are numerous breaks-of-gauge between standard-gauge main lines and narrow-gauge railways.

Many internal Swiss railways that operate in the more mountainous regions are 1,000 mm (3 ft 3 ⅜ in) Metre gauge and most are equipped for rack assistance to deal with the relatively steep gradients encountered. Through running of standard gauge trains on rack sections would not be possible, but dual gauge track exists in many places where the gradient is relatively flat to carry standard and metre guage stock. There also exists 800 mm (2 ft 7 ½ in) gauge railways which are entirely rack operated.

The line between Finland and Russia has a minor break-of-gauge. Finnish gauge is 1,524 mm (5 ft) and Russian 1,520 mm (4 ft 11 ⅚ in) but this does not stop through-running.

The effects of a minor break-of-gauge can be minimized by placing it at the point where a cargo must be removed from cars anyway. An example of this is the *East Broad Top Railroad* in the United States of America, which had a coal wash and preparation plant at its break-of-gauge in Mount Union, Pennsylvania. The coal was unloaded from narrow gauge cars of the EBT, and after processing was loaded into standard gauge cars of the Pennsylvania Railroad.

Gauge orphan

When a main line is converted to a different gauge, such as with Unigauge in India, branch lines can be cut off and made relatively useless, at least for freight trains, until they too are converted to the new gauge. These severed branches can be called **gauge orphans**.

Gauge outreach

The opposite of a gauge orphan is a line of one gauge which reaches into the territory composed mainly of another gauge. Examples include five broad gauge lines of Victoria which crossed the border into otherwise standard gauge New South Wales. Similarly the standard gauge line from Albury to Melbourne in 1962 which eliminated most transshipment at Albury, especially the need for passengers to change trains in the middle of the night. A Russian broad gauge line reaches out from Ukraine into Slovakia to carry minerals; another broad gauge line reaches also from Ukraine into Poland to carry heavy iron ore and steel products without the need for transshipment as would be the case if there were a break of gauge at the border. In 2008, it was proposed to extend the Slovak line to Vienna. The gauge outreach from Kalgoorlie to Perth, Western Australia partly replaced the original narrow gauge line, and partly rebuilt that line with better curves and gradients at double dual gauge.

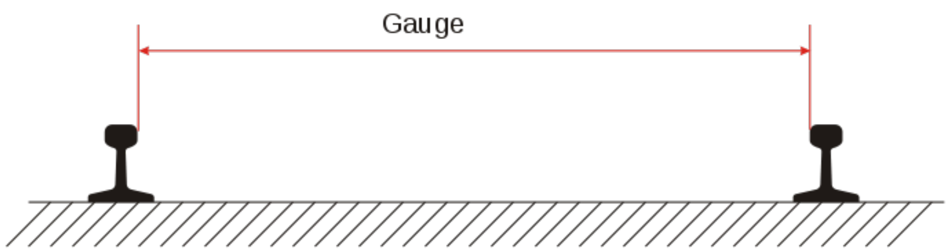
In 2010, a proposal surfaced to build a broad gauge line from an iron ore mine at Kaunisvaara in Sweden (whose rail network is otherwise standard gauge) to Finland which has a broad gauge network.

Other issues

While track gauge is the most important factor preventing through running between adjacent systems, other issues can also be a hindrance, including loading gauge, axleloads, couplings, brakes, electrification systems, signalling systems, multiple unit controls, rules and regulations, and language. The loading gauge problem is solved by simply using the smaller one for through running, the other issues are more problematic.

Chapter- 6

Dual Gauge



Sunlight reflects off dual-gauge tracks near Chur, Switzerland

Mixed-gauge track and pointwork (4 ft 8 ½ in (1,435 mm) and 3 ft 6 in (1,067 mm)) at Odawara in Japan

Dual-gauge tram tracks in Katwijk, Netherlands

A **dual-gauge** or **mixed-gauge** railway has railway track that allows trains of different gauges to use the same track. Generally dual-gauge railway consists of three rails, rather than the standard two rails. The two outer rails give the wider gauge, while one of the outer rails and the inner rail give a narrower gauge. Thus one of the three rails is common to all traffic.

Reasoning

In railways, the most important specification is that of gauge, the distance between the inner surfaces of the heads of the travel rails (diagram below). Both track and wheels bogies must be built to the same gauge; unless the two fit together within a tolerance of 13 mm (0.51 in) on the track, the train will either fall off the track or it will be impossible to go through switches or cross overs. For instance, the Hong Kong MTR 1,432 mm (4 ft 8 3⁄8 in)-gauge EMU's may run on KCR 1,435 mm (4 ft 8 1⁄2 in)-gauge rails, with a locomotive or a KCR EMU pulling due to different electrify voltages. A problem arises when different gauges meet one another, a situation known as a break of gauge. Either the track or the train must be built to handle different gauges, or passengers and freight must be taken off one train and loaded on to the next.

In allowing railway tracks of different gauges to share the same alignment, costs can be reduced, especially where there are bridges and tunnels. Dual gauge can replace two separate tracks, having two rails each, with one track with three rails. This allows one rail fewer for the stretch of the dual gauge line, but there are complications and costs that may offset the savings.

One issue is points (US: switches). Complicated arrangements are necessary to ensure traffic of both gauges can safely utilise points. Signalling may also be complicated somewhat, as all three rails must be connected to track circuits or mechanical interlocking arrangements. Mixed gauge is simpler to signal with electric signals than with mechanical signals. Since rails wear very slowly, the extra tonnage on the common rail is generally not a problem.

Dual-gauge turnouts will be complicated, expensive, and suitable for low speeds only.

Configuration

For dual-gauge track to be achievable using three rails, the difference between the gauges needs to be at least as wide as the foot of the rail, otherwise there is no room for the rail fastening hardware (spikes, clips, and the like). Thus standard gauge (1,435 mm (4 ft 8 1⁄2 in)) and Indian gauge 1,676 mm (5 ft 6 in) can be dual gauged without problem, as are 914 mm (3 ft) and 1,067 mm (3 ft 6 in) (Cape gauge), or 1,524 mm (5 ft) and 1,829 mm (6 ft) , while 1,435 mm (4 ft 8 1⁄2 in) and 1,600 mm (5 ft 3 in) (Irish gauge) can also be dual-gauged, albeit with lighter narrow footed rails, as in Victoria, Australia. On the other hand, metre gauge 1,000 mm (3 ft 3 3⁄8 in) and cape gauge 1,067 mm (3 ft 6 in) as in Africa, or 1,000 mm (3 ft 3 3⁄8 in) and 3 ft (914 mm), as in South America, are too close to be combined into three-rail dual gauge, as are 1,435 mm (4 ft 8 1⁄2 in) and 1,524 mm (5 ft) , or 1,524 mm (5 ft) and 1,676 mm (5 ft 6 in), as in Afghanistan, Central Asia, northern-, central- and eastern Europe, North America, Iran, and China. This last combination is of particular historical interest, as one of the main reasons that 1520mm was adopted in Russia was to stop western trains from being able to use Russian railways during an invasion. It was of strategic significance during World War II.

If three-rail dual gauge is impossible (e.g. between 1,435 mm (4 ft 8 $\frac{1}{2}$ in) and 1,524 mm (5 ft)), four-rail dual gauge has to be used.

Examples in Africa

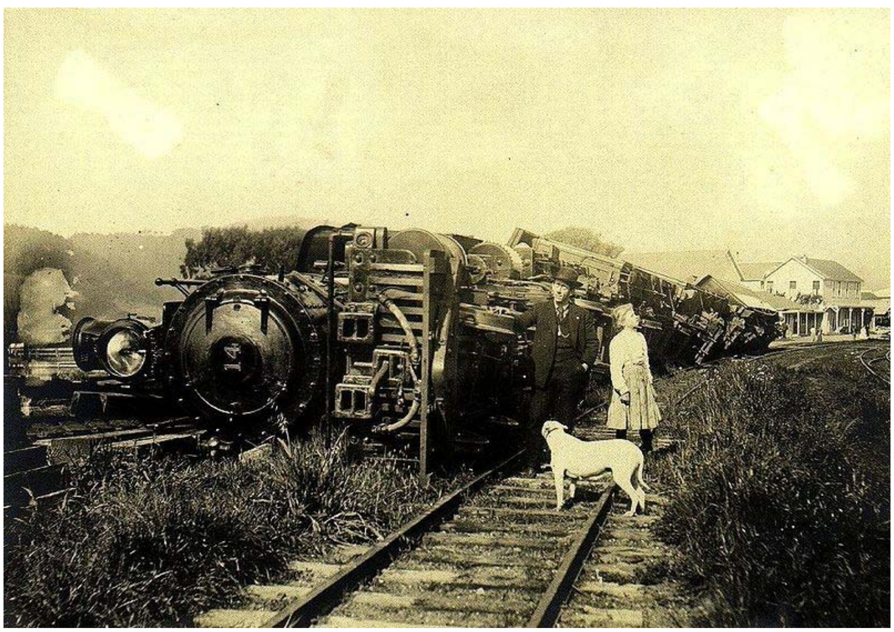
2007

- Tanzania -Central line to have standard gauge? proposed by Dr. Maua Daftari. The first step would be to install dual gauge as part of an upgrade in heavier rail.

2004

On 12 October 2004, a proposal was announced to develop an electrified rail link connecting Kenya, Uganda and south Sudan. Even though Kenya and Uganda use 1000 mm gauge and Sudan uses 1067 mm, the new project was proposing to use standard gauge (1435 mm). Fortunately, all three gauges can be supported by the same sleepers, as described above.

Gauge conversion



This locomotive was derailed by the 1906 San Francisco earthquake. The locomotive had three link and pin coupler pockets for moving standard and narrow gauge cars.

The complications and difficulties outlined show how important it is to ensure that railway gauges are standardised in the first place, if at all possible. If a railway operator seeks to convert from one gauge to another, then it helps if a dual-gauge intermediate step can be done (this has often been practised in the past).

If the gauge is to be reduced, then the sleepers can continue to protrude from the side of the rails. If the gauge is to be increased, then the sleepers used for narrow gauge may be too short, and some at least of these 'short' sleepers will have to be replaced with longer ones. Alternatively the rails may be too light for the loads imposed by broader-gauge railcars. Such potential problems can rule out dual-gauge as a feasible option. Another issue is affixing the rails to the sleepers (spikes, nails or bolts are used). If existing sleepers are wooden, extra holes can be drilled without problems. If the existing sleepers are concrete, then drilling extra holes is impractical, and the whole sleeper has to be replaced, unless extra boltholes are already allowed for.

The embankment could need widening too. It is possible that viaducts and tunnels are too narrow and too low. This could cost a lot and need the closing of the line for a year or two.

During the conversion of the Melbourne-Adelaide railway in Australia from 5 ft 3 in (1,600 mm) to 4 ft 8 $^1/_2$ in (1,435 mm), dual gauge with heavy rails was not possible as the rail footings were too wide. A special gauge-convertible sleeper with a reversible chair for the Pandrol clip allowed a two-week conversion process.

Dual gauge track in Melbourne, Australia. Note guard rails which force standard-gauge trains to change side.

Dual gauge track in Perth, Australia. Narrow gauge train on left; Standard gauge train on right.

In the Adelaide metropolitan area, broad-gauge timber sleepers are being replaced with gauge-convertible concrete sleepers. On June 5, 2008, the South Australian Government announced that the Metropolitan Network would be converted to standard gauge (1435 mm) in 2012.

Dual-gauge lines in Java were regauged from 4 ft 8 $^1\!/_2$ in (1,435 mm) to 3 ft 6 in (1,067 mm) (Cape gauge) during the Japanese administration in 1942-1943. Regauging occurred only on the relatively short Brumbung-Kedungjati-Gundih main line and the Kedungjati-Ambarawa branch line, as the rest of the line was already dual-gauge (some only recently dual-gauged).

Proposed or current gauge conversions

- **Australia** - the new port of Oakajee was previously to be served by separate narrow gauge and standard gauge lines, but Westnet, the track authority, has proposed a common network with a significant length of double track dual gauge, which has greater flexibility.
- **Australia** - South Australia plans to convert its suburban 1,600 mm (5 ft 3 in) (broad gauge) network to 1,435 mm (4 ft 8 $^1\!/_2$ in) (standard gauge), in 2012, when it is proposed that electrification will be completed. The Outer Harbour Line and Belair Lines have already been rebuilt with gauge convertible sleepers, whilst

resleepering of the Gawler Central line commenced in 2010. The Noarlunga Line Gawler Central line will commence once the Gawler line is completed.

- **India**, Project Unigauge conversion of narrow gauge to Indian broad gauge.
- **Russia** - the railways of Sakhalin Island (Russian: Сахалинская железная дорога) are to be converted from 1,067 mm (3 ft 6 in) (Cape gauge) to 1,520 mm (4 ft 11 $^{5}\!/_{6}$ in) (Russian gauge). As the conversion is going to be done in sections, the conversion plans provide for first laying the third (outer) rail, making rail lines usable by both Japanese- and Russian-gauge trains. Once the railways throughout the island have been converted to the Russian gauge (by 2012), the inner rail will be removed.

- **Spain** is building dual gauge track to allow access to high speed trains and freight trains from Europe.

- **Brazil** is proposing to build dual gauge gauge to connect ports in the north east.

- **Alaska** and **British Columbia** are proposing dual gauge track so that a narrow gague tourist train and standard gauge ore trains can share the right of way.

Examples

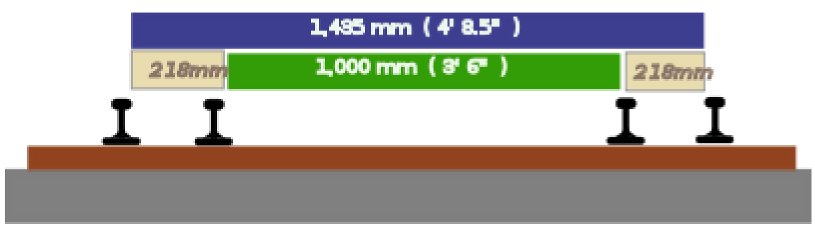
A train on mixed-gauge track near Jindřichův Hradec, Czech Republic, using the narrower gauge – not running on the outer rail, seen in the foreground.

In the Czech Republic, there is dual gauge (1,435 mm/4 ft 8 ½ in and 760 mm/2 ft 5 ⅞ in) track near Jindřichův Hradec. The two gauges are used by different railway companies.

In Britain, the Great Western Railway was initially broad gauge, 7 ft 0 ¼ in (2,140 mm). After the "gauge war", it was decided to regauge the GWR. As the broad gauge was sufficiently dissimilar from standard gauge and used wooden sleepers, dual gauge was easily introduced. The Metropolitan Railway, now part of the London Underground system, started as dual gauge: its present *third and fourth rails* are for electricity supply, not dual gauge. A small section of broad gauge, 7 ft 0 ¼ in (2,140 mm) and standard gauge 1,435 mm (4 ft 8 ½ in) demonstration line exists at the Great Western Society site at Didcot.

In Ireland, dual-gauge track was not used in regauging the Ulster Railway (UR). When it regauged its double-track route from 6 ft 2 in (1,880 mm) to the new Irish standard of 5 ft 3 in (1,600 mm) it performed the task in two stages. The Dublin & Drogheda Railway (D&DR) meanwhile was regauging from 5 ft 2 in (1,575 mm), too similar to the new gauge to allow dual gauge. Dual gauge was used in Derry, by the Port Authority, in an on-street network to transfer goods, on either gauge, between the city's four stations (two 3 ft /914 mm narrow gauge, two 5 ft 3 in/1,600 mm in broad gauge).

In Italy, dual-gauge track is used in the Potenza - Avigliano Lucania line, 1,435 mm (4 ft 8 ½ in) and 950 mm (3 ft 1 ⅜ in).



Metre gauge within standard gauge

In France, the Chemin de Fer de la Baie de Somme is dual gauge between Noyelles-sur-Mer and Saint-Valery-sur-Somme, metre gauge laid within standard gauge, thus having four rails.

In Western Australia there is a double-track dual-gauge (3 ft 6 in/1,067 mm & 4 ft 8 ½ in/1,435 mm) main line from East Perth to Northam, about 120 km. Dual-gauge track is also used from the triangle at Woodbridge to Cockburn, Western Australia Cockburn Junction, then to Kwinana on one branch, and North Fremantle on the other.

In Brisbane, Australia, shorter stretches of dual-gauge track (3 ft 6 in/1,067 mm & 4 ft 8 ½ in/1,435 mm) exist between the rail freight yards at Acacia Ridge and the Port of Brisbane, for freight trains. A dual-gauge line branches off at Park Road Station to run alongside the electric suburban narrow gauge Citytrain line over the Merivale Bridge into Platform 1 at Roma Street Station. This is used by standard-gauge interstate CountryLink XPT services to Sydney.

In Belgium, some sections of tram track in Brussels combined 1,000 mm (3 ft 3 $^3\!/_8$ in) metre gauge for the interurban trams with 1,435 mm (4 ft 8 $^1\!/_2$ in) standard gauge for the urban trams. Since the closure of the former, these have been replaced with standard gauge track.

Two class DT-8 Stadtbahn cars on dual-gauge track in Stuttgart, Germany

In Germany, the Stuttgart tram lines were 1,000 mm (3 ft 3 $^3\!/_8$ in) gauge. In the 1970s it was decided to convert the streetcar system to a modern Stadtbahn and regauge it to standard gauge to increase capacity. Inner-city tunnels replacing street-level sections in busy streets were built with a cross-section suitable for standard-gauge cars. After the conversion started in 1981 with the commissioning of the first three class DT-8 Stadtbahn cars, the tunnels and all other sections used by multiple lines were fitted with

1,435 mm (4 ft 8 ½ in)/1,000 mm (3 ft 3 ⅜ in) dual-gauge track, to allow both old-style streetcars and new Stadtbahn cars to share those sections while lines were converted one by one over the next decades. In 2006, conversion of line 15 (the last line to be converted) is under way and was completed in 2008, although some sections will retain their dual-gauge track indefinitely as a courtesy to the streetcar museum of Stuttgart, which will operate old 1,000 mm (3 ft 3 ⅜ in) gauge streetcars on weekends and special occasions.

Also in Germany, in Krefeld on Ostwall the tram lines are dual-gauge track, to allow both standard 1,435 mm (4 ft 8 ½ in) Rheinbahn U76 Stadtbahn cars to share this section with Krefeld's metre 1,000 mm (3 ft 3 ⅜ in) gauge. At the north end of the street at the junction with Rheinstraße, Rheinbahn trams reverse, so the standard gauge ends, while the metre gauge lines continue. The dual-gauge track continues along Oppumer Straße in front of Krefeld Hauptbahnhof (Main Rail Station), where at both ends of this street, the metre 1,000 mm (3 ft 3 ⅜ in) and standard 1,435 mm (4 ft 8 ½ in) tracks diverge.

In Switzerland dual gauge track (1,435 mm/4 ft 8 ½ in standard and 1,000 mm/3 ft 3 ⅜ in meter) is used in (Lucerne and Interlaken) stations at both ends of the Brünigbahn and on the RhB between Chur and Domat Ems, among other places.

In Japan, dual gauge is used when standard gauge Shinkansen lines joins the narrow-gauge (1,067 mm/3 ft 6 in) system, which is the national standard. For example, part of the Ōu line became part of the Akita Shinkansen and was upgraded to dual gauge.

In Dutch East Indies (later Indonesia), dual-gauge track was installed in 1899 between Yogyakarta and Solo. The track was owned by the ***Nederlandsch-Indische Spoorweg Maatschappij***, a private company, which built the 4 ft 8 ½ in (1,435 mm) gauge line in 1867. The third rail was installed to allow passengers and goods traveling over the 3 ft 6 in (1,067 mm) gauge ***Staatsspoorweg*** (State Railway) a direct connection without requiring transfer at both cities. Later, a separate pair of tracks were installed at the government's cost to allow greater capacity and higher speeds.

In 1940 a third rail was installed between Solo and Gundih on the line to Semarang, allowing 3 ft 6 in (1,067 mm) gauge trains to travel between Semarang, Solo and Yogyakarta (via Gambringan, on the line to Surabaya instead of via Kedungjati on the original line).

A short section of dual-gauge 3 ft 6 in (1,067 mm) and 2 ft 5 ½ in (750 mm) line existed in North Sumatra on a joint line of the **Deli Railway** and the **Aceh Tramway**. This line survived in to the 1970s.

Some sugar mill railways in Java have dual-gauge sections.

In Vietnam, there is dual gauge (1,000 mm/3 ft 3 ⅜ in meter and 1,435 mm/4 ft 8 ½ in standard) between Hanoi and the Chinese border.

At the Swedish-Finnish border the railway has four rails because the difference is too small for three rails.

In Sweden and Finland, there is 2 km of dual gauge, 1,435 mm (4 ft 8 ½ in) and 1,524 mm (5 ft) , between Haparanda and Tornio across the bridges over the border. At each end of the dual-gauge section there are yards with standard and Finnish gauge areas to allow for transshipment. The four-rail method is used because the gauges are close together. The bridge structure needs to be wider than normal to allow for the offset from the centreline by each gauge. At the Tornio yard is a Rafil gauge changer. Similar arrangements exist on the approach to Kaliningrad, where 1435mm track penetrates from the Polish border with some dual gauge stretches.

In Los Angeles the 3 ft 6 in (1,067 mm) Los Angeles Railway and the 4 ft 8 ½ in (1,435 mm) Pacific Electric Railway (both defunct) ran on dual gauge track on some downtown streets.

In Spain, there is dual gauge in the AVE line from Zaragoza to Huesca, usable for both high speed trains (1,435 mm/4 ft 8 ½ in) and standard Spanish trains (1,668 mm/5 ft 5 ⅔ in). ADIF is to call tenders for the installation of a third rail for 1,435 mm gauge trains on the 22 km between Castellbisbal and the Can Tunis freight terminal in Barcelona, within a budget of €19·1m.

Double dual gauge

In Australia, the new railway line between Perth and Northam was being planned in the 1960s. The improved alignment was originally intended to have separate standard gauge and narrow gauge tracks running parallel, with crossing loops at intervals. However, the capacity of each of these lines would have been poor. By adopting double-track dual-gauge throughout, the line capacity was greatly increased, at only the relatively small extra cost of providing a third rail was needed for dual gauge.

Triple gauge

There have been a few instances of triple-gauge break-of-gauge stations.

Area	Gauge 1	Gauge 2	Gauge 3	Note
Port Pirie, South Australia	1,067 mm (3 ft 6 in)	1,435 mm (4 ft $8\frac{1}{2}$ in)	1,600 mm (5 ft 3 in)	1938–1970, .
Gladstone, South Australia	1,067 mm (3 ft 6 in)	1,435 mm (4 ft $8\frac{1}{2}$ in)	1,600 mm (5 ft 3 in)	1968-1980s
Peterborough, South Australia	1,067 mm (3 ft 6 in)	1,435 mm (4 ft $8\frac{1}{2}$ in)	1,600 mm (5 ft 3 in)	1968-1980s some survives in the Steamtown Heritage Rail Centre
Latour-de-Carol, France	1,000 mm (3 ft $3\frac{3}{8}$ in)	1,435 mm (4 ft $8\frac{1}{2}$ in)	1,668 mm (5 ft $5\frac{2}{3}$ in)	still in use
Hendaye, France	1,000 mm (3 ft $3\frac{3}{8}$ in)	1,435 mm (4 ft $8\frac{1}{2}$ in)	1,668 mm (5 ft $5\frac{2}{3}$ in)	still in use
Växjö, Sweden	891 mm (2 ft $11\frac{1}{10}$ in)	1,067 mm (3 ft 6 in)	1,435 mm (4 ft $8\frac{1}{2}$ in)	until at least 1974
Montreux, Switzerland	800 mm (2 ft $7\frac{1}{2}$ in)	1,000 mm (3 ft $3\frac{3}{8}$ in)	1,435 mm (4 ft $8\frac{1}{2}$ in)	still in use
Capolago, Switzerland	800 mm (2 ft $7\frac{1}{2}$ in)	1,000 mm (3 ft $3\frac{3}{8}$ in)	1,435 mm (4 ft $8\frac{1}{2}$ in)	the metre gauge line closed in 1950
Volos, Greece	600 mm (1 ft $11\frac{5}{8}$ in)	1,000 mm (3 ft $3\frac{3}{8}$ in)	1,435 mm (4 ft $8\frac{1}{2}$ in)	600mm gauge closed on 70's, 1000mm gauge closed on 1998

Because these three triple-gauge examples were yards operating at low speed, light rail could be used to space the rails closely together if required. Main line operation at high speeds is another matter.

The Niagara Falls Suspension Bridge originally carried trains of three different gauges.

The National Railway Museum (Port Adelaide) in Adelaide, Australia has the three main-line gauges and a 1 ft 6 in (457 mm) gauge tourist line.

Accidents on dual-gauge railways

Switch - bifurcation of dual-gauge track near Jindřichův Hradec, Czech Republic.

On September 9, 2004, an accident happened on a switch in Jindřichův Hradec, Czech Republic where a dual-gauge railway bifurcates. A *Junák* express from Plzeň to Brno derailed due to a signalling error. The standard gauge train was switched onto the narrow gauge track. The express train driver was slightly injured.

In Western Australia, the signalling system detects the gauge of the approaching trains and puts the signals to stop if the route is set for the wrong gauge.

Complexity of dual-gauge switches

A metre gauge point within standard gauge track, Chemin de Fer de la Baie de Somme, France

Dual-gauge turnouts (also known as switches or points), where both gauges have a choice of routes, are quite complicated, with more moving parts than single-gauge turnouts. They impose very low speed limits. If dual-gauge points are operated and detected by electrical circuits, their reliability will be high.

Where two gauges separate (i.e. each gauge has only one route, as in the picture at right), few if any moving parts are needed.

Third-rail was proposed around 1900 as a solution for the break of gauge problems in Australia, but there was a problem with the design of turnouts due to the closeness of standard gauge and irish gauge of only 6.5 inches. After one or two decades on increasing rancour, the dual gauge option was rejected as unacceptable.

Operation and Detection

The separate ends of dual gauge turnouts are easier to arrange if the ends are electrically operated rather than mechanically operated.

Paradox

If the two gauges of a dual gauge turnout are very similar and the difference between them is small, turnouts will have many small pieces that are difficult to support and the turnout will be weak and limited in speed. Paradoxically, the larger the difference the better. The difference between the gauges should as a rule of thumb be 50 mm greater than the width of the base of the rails. The difference between standard and East European/Russian gauge is too narrow.

Gauge splitters

One way of avoiding complicated and weak dual gauge turnouts, provided there is room, is to separate the gauges and then design the yard with single gauge turnouts and dual gauge diamond crossings. Gauge splitters assume that trains have a single gauge. Gauge splitters may be fixed, meaning they have no moving parts and are intended for low speed use, or they be power operated like ordinary turnouts.

Separate gauge

If dual-gauge turnouts are too slow, or too difficult because the gauges are too similar, then an option is to build two separate lines, one of each gauge, side by side. This choice also depends on the amount of traffic. Dual-gauge could continue to be employed at an expensive bridge or tunnel.

Examples include:

- Albury, New South Wales to Melbourne, Victoria, 300 km
    - As the old and original broad gauge track declines in use, it is slated for conversion to standard gauge, replacing parallel standard-gauge single track and broad-gauge double track with a double-track standard-gauge line. This will reduce delays on the standard-gauge line at crossing loops.
- Melbourne Victoria, to Geelong, Victoria, 80 km, a single standard-gauge line parallel to double-track broad gauge.
- Yogyakarta-Solo in Java, Dutch East Indies during pre-WW II days, 58 km. This had a single 3 ft 6 in (1,067 mm) line parallelling a dual-gauge 4 ft 8 $^{1}/_{2}$ in (1,435 mm) and 3 ft 6 in (1,067 mm) line.

- In 2005 a proposed standard gauge line connecting Iran with China via several broad gauge Central Asian countries will use a mixture of parallel separate lines and dual gauge (denied by Russia and India).

- Australia - in 1960, the Perth to Northam line was originally to be separate side-by-side narrow gauge and standard gauge lines, but it was realised that line capacity would be much higher if it were built as double dual gauge.

Overlapping gauges

Bangladesh is tackling its break of gauge problem by adding a third rail to its broad and narrow gauge lines, so that it becomes a mainly dual-gauge system. The new Jamuna Bridge that links the east and west rail systems is four rail dual gauge so that both gauges use the same centre-line. At some stage Bangladesh may choose one gauge over the other and convert to a single gauge, but there are no immediate plans for this.

Bangladesh's neighbour to the east is also 1000 mm gauge, should the missing link ever be built.

A variation of overlapping gauge is to extend a railway of one gauge into territory that is mainly of another gauge so as to avoid transhipment of specific traffic. For example a 1524 mm gauge line from an iron ore mine in Ukraine to a steelworks in Slovakia, which now may be extended into Austria.

Other methods of handling multiple gauges

Other methods of handling multiple gauges include:

- Transporter wagons or transporter trucks, which carry equipment of one gauge on the other's tracks. This can be also done by the trainload. Bridges and tunnels need to be about one metre higher than they would otherwise be.
- Bogie exchange systems, where the railroad car is lifted and the trucks/bogies under it are swapped. This system is not suitable for four-wheel wagons.
- Adjustable gauge equipment (variable gauge axles), in which the wheel gauge can be widened or narrowed.
- Transshipment, where containers or people are transferred from one set of railroad cars to another.

Dual gauge dual voltage

A mini-metro in Gijon, Spain is to be both dual gauge (1000 mm/1668 mm) and dual voltage (1500 V DC/3000 V DC).

Chapter- 7

Track

Twin rail tracks in a wooded area

The **track** on a railway (non-US) or railroad (US), also known as the **permanent way**, is the structure consisting of the rails, fasteners, sleepers and ballast (or slab track), plus the underlying subgrade. For clarity it is often referred to as **railway track** (British English and UIC terminology) or **railroad track** (predominantly in North America).

The term *permanent way* also refers to the track in addition to lineside structures such as fences etc.

Track structure

Traditional track structure

Railroad tracks on traditional wooden sleepers

Notwithstanding modern technical developments, the overwhelmingly dominant track form worldwide consists of flat-bottom steel rails supported on timber or pre-stressed concrete sleepers (referred to as railroad ties in the US), which are themselves laid on crushed stone ballast.

Most railroads with heavy traffic use continuously welded rails supported by sleepers (ties) attached via baseplates (tieplates) which spread the load. A plastic or rubber pad is usually placed between the rail and the tieplate where concrete sleepers (ties) are used. The rail is usually held down to the sleeper (tie) with resilient fastenings, although cut spikes are widely used in North American practice.

Timber sleepers (ties) are of many available timbers, and are often treated with creosote, copper-chrome-arsenic, or other wood preservative. Pre-stressed concrete sleepers (ties) are often used where timber is scarce and where tonnage and/or speeds are high. Steel is used in some applications.

On this Japanese high speed line mats have been added to stabilize the ballast

The track ballast is customarily crushed stone, and the purpose of this is to support the ties and allow some adjustment of their position, while allowing free drainage.

Ballastless track

China high speed rail ballastless tracks

A disadvantage of traditional track structures is the heavy demand for maintenance, particularly surfacing (tamping) and lining to restore the desired track geometry and smoothness of vehicle running. Weakness of the subgrade and drainage deficiencies also lead to heavy maintenance costs. This can be overcome by using ballastless track. In its simplest form this consists of a continuous slab of concrete (like a highway structure) with the rails supported directly on its upper surface (using a resilient pad).

There are a number of proprietary systems, and variations include continuous in situ placing of a reinforced concrete slab, or alternatively the use of pre-cast pre-stressed concrete units laid on a base layer. Many permutations of design have been put forward.

However ballastless track is very expensive in first cost, and in the case of existing railroads requires closure of the route for a somewhat long period. Its whole life cost can be lower because of the great reduction in maintenance requirement. Ballastless track is usually considered for new very high speed or very high loading routes, in short extensions that require additional strength (i.e. rail station), or for localised replacement in the case of exceptional maintenance difficulties.

Ladder track

Ladder track utilizes longitudinal sleepers with gauge restraining cross members, it can be considered a development of Baulk road. Both ballasted and ballastless types exist.

Obsolescent track types

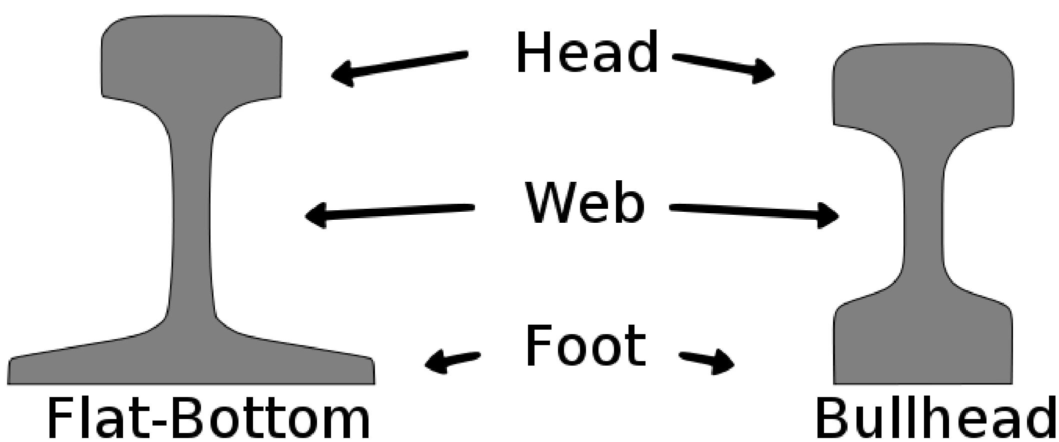
For much of the 20th century, rail track used softwood timber ties and jointed rails, and considerable extents of this track type remains on secondary and tertiary routes. The rails were typically of flat bottom section fastened to the ties with dogspikes through a flat tieplate in North America and Australia, and typically of bullhead section carried in cast iron chairs in British and Irish practice.

Jointed rails were used, at first because the technology did not offer any alternative. However the intrinsic weakness in resisting vertical loading results in the ballast support becoming depressed and a heavy maintenance workload is imposed to prevent unacceptable geometrical defects at the joints. The joints also required to be lubricated, and wear at the fishplate (joint bar) mating surfaces needed to be rectified by shimming. For this reason jointed track is not financially appropriate for heavily operated railroads.

Historical development

The technology of rail tracks developed over a long period, starting with primitive timber rails in mines in the 17th century.

Rail



Cross-sections of flat-bottomed rail, which can rest directly on the sleepers, and bullhead rail which sits in a chair (not shown)

Hot rolled steel in the profile (cross section) of an asymmetrical I-beam is usually used as the surface on which railway wheels run. Unlike some other uses of iron and steel, railway rails are subject to very high stresses and have to be made of very high quality steel alloy. It took many decades to improve the quality of the materials, including the change from iron to steel. The heavier the rails and the rest of the trackwork, the heavier and faster the trains the track can carry.

Profiles of rail include:

- Bullhead rail
- Grooved rail
- Vignoles rail *(flat-bottomed rail)*
- Flanged T rail
- Bridge rail (inverted U)
- Barlow rail (inverted V)

North American railroads until the mid- to late-20th century used rails 39 ft (11.89 m) long so they could be carried to and from a worksite in gondola cars (open wagons), often 40 ft (12 m) long; as gondola sizes increased, so did rail lengths.

The world's longest rail sections are 120m long and are made by various companies.

Rail classification (weight)

Weight mark on a jointed segment of 155 lb/yd (76.9 kg/m) "Pennsylvania Special" rail, the heaviest grade of rail to be mass-produced

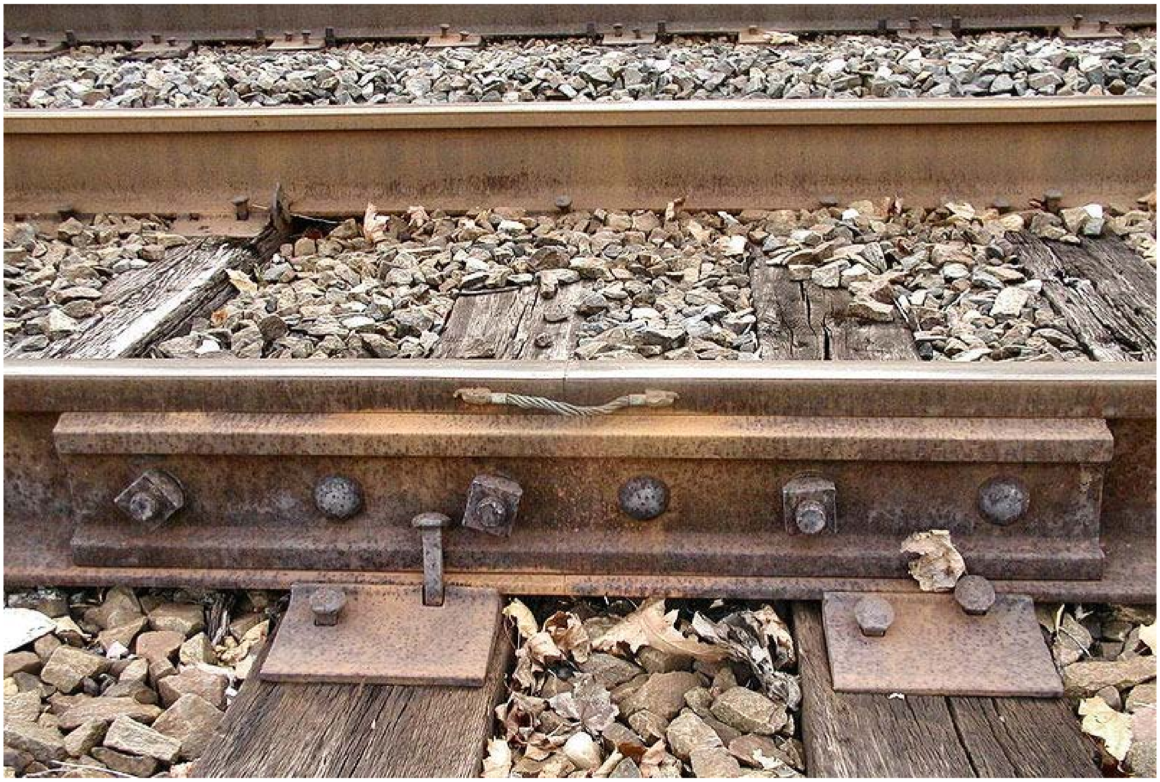
Rail is graded by weight over a standard length. Heavier rail can support greater axle loads and higher train speeds without sustaining damage than lighter rail, but at a greater cost. In North America and the UK, rail is graded in pounds per yard (usually shown as *pound* or *lb*), so *130-pound rail* would weigh 130 lb/yd (64.5 kg/m). The usual range is 115 to 141 lb/yd (57.0 to 69.9 kg/m). In Europe, rail is graded in kg/m and the usual range is 40 to 60 kg/m (80.6 to 121.0 lb/yd). The heaviest rail mass-produced was 155 pounds per yard (76.9 kg/m) and was rolled for the Pennsylvania Railroad. The UK is in the process of transition from the imperial to metric rating of rail.

Joining rails

Rails are produced in fixed lengths and need to be joined end-to-end to make a continuous surface on which trains may run. The traditional method of joining the rails is to bolt them together using metal fishplates, producing *jointed track*. For more modern usage, particularly where higher speeds are required, the lengths of rail may be welded together to form **continuous welded rail** (CWR).

Jointed track

Fishplate between two sections of jointed bullhead rail



Bonded main line 6-bolt rail joint on a segment of 155 lb/yd (76.9 kg/m) rail. Note how bolts are oppositely oriented to prevent complete separation of the joint in the event of being struck by a wheel during a derailment.

Jointed track is made using lengths of rail, usually around 20 m (66 ft) long (in the UK) and 39 or 78 feet (11.9 or 23.8 m) long (in North America), bolted together using perforated steel plates known as *fishplates* (UK) or *joint bars* (North America).

Fishplates are usually 600 mm (1.97 ft) long, used in pairs either side of the rail ends and bolted together (usually four, but sometimes six bolts per joint). The bolts may be oppositely-oriented so that in the event of a derailment and a wheel flange striking the joint, only some of the bolts will be sheared, reducing the likelihood of the rails misaligning with each other and exacerbating the seriousness of the derailment. (This technique is not applied universally, British practice being to have all the bolt heads on the same side of the rail.) Small gaps known as expansion joints are deliberately left between the rail ends to allow for expansion of the rails in hot weather. The holes through which the fishplate bolts pass are oval to allow for movement with expansion.

British practice was to have the rail joints on both rails adjacent to each other, while North American practice is to stagger them.

Because of the small gaps left between the rails, when trains pass over jointed tracks they make a "clickety-clack" sound. Unless it is well-maintained, jointed track does not have the ride quality of welded rail and is less desirable for high speed trains. However, jointed track is still used in many countries on lower speed lines and sidings, and is used extensively in poorer countries due to the lower construction cost and the simpler equipment required for its installation and maintenance.

A major problem of jointed track is cracking around the bolt holes, which can lead to the rail head (the running surface) breaking. This was the cause of the Hither Green rail crash which caused British Railways to begin converting much of its track to Continuous Welded Rail.

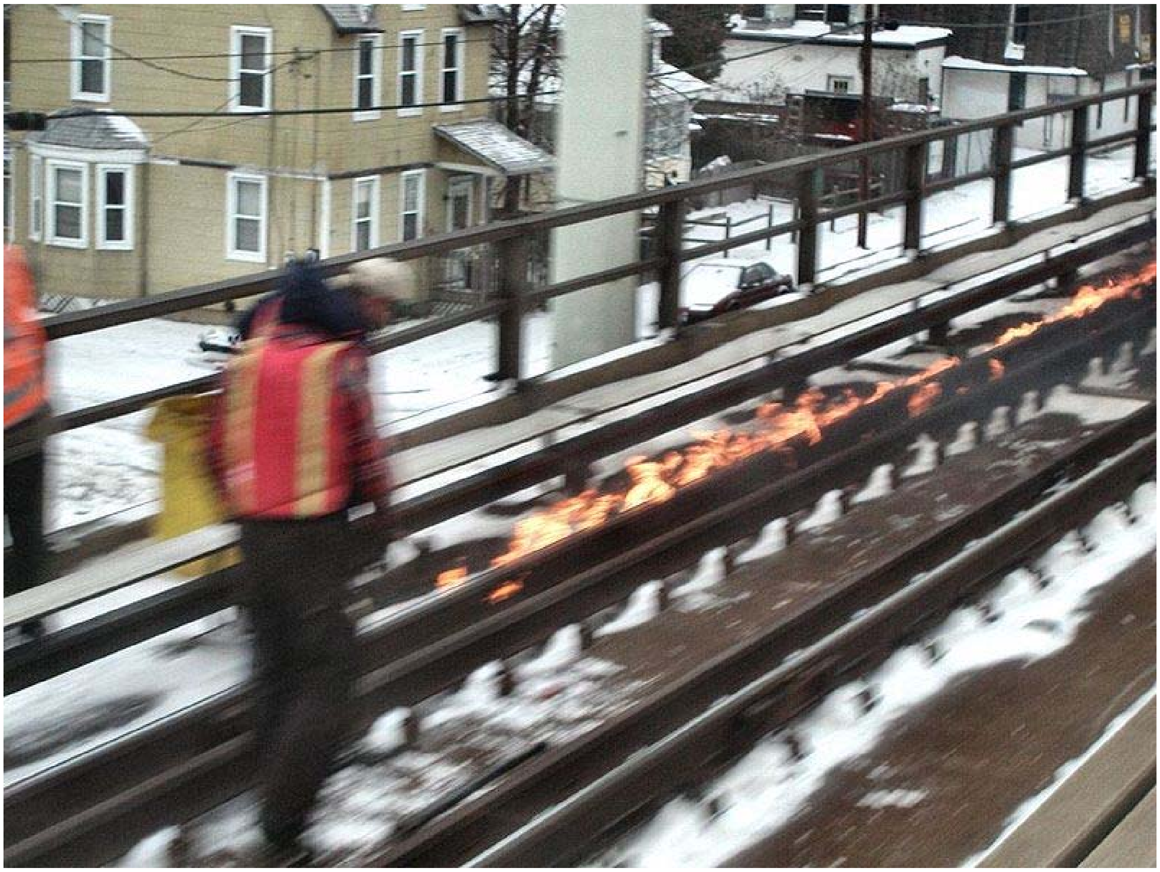
Insulated joints

Where track circuits exist for signalling purposes, insulated block joints are required. These compound the weaknesses of ordinary joints. Specially-made glued joints, where all the gaps are filled with epoxy resin, increase the strength again.

As an alternative to the insulated joint, audio frequency track circuits can be employed using a tuned loop formed in approximately 20 m of the rail as part of the blocking circuit. Another alternative is the axle counter, which can reduce the number of track circuits and thus the number of insulated rail joints required.

Continuous welded rail

Welded rail joint



A pull-apart on the Long Island Rail Road Babylon Branch being repaired by using flaming rope to expand the rail back to a point where it can be joined together

An expansion joint on CWR at Montague Gardens, Cape Town, South Africa

Most modern railways use **continuous welded rail** (CWR), sometimes referred to as **ribbon rails**. In this form of track, the rails are welded together by utilising flash butt welding to form one continuous rail that may be several kilometres long, or thermite welding to repair or splice together existing CWR segments. Because there are few joints, this form of track is very strong, gives a smooth ride, and needs less maintenance; trains can travel on it at higher speeds and with less friction. Welded rails are more expensive to lay than jointed tracks, but have much lower maintenance costs. The first welded track was used in Germany in 1924 and the US in 1930 and has become common on main lines since the 1950s.

Flash butt welding is the preferred process which involves an automated track-laying machine running a strong electrical current through the touching ends of two unjoined pieces of rail. The ends become white hot due to electrical resistance and are then pressed together forming a strong weld. Thermite welding is a manual process requiring a reaction crucible and form to contain the molten iron. Thermite-bonded joints are also seen as less reliable and more prone to fracture or break.

If not restrained, rails would lengthen in hot weather and shrink in cold weather. To provide this restraint, the rail is prevented from moving in relation to the sleeper by use of clips or anchors. Anchors are more common for wooden sleepers, whereas most concrete or steel sleepers are fastened to the rail by special clips which resist longitudinal movement of the rail. There is no theoretical limit to how long a welded rail can be.

However, if longitudinal and lateral restraint are insufficient, the track could become distorted in hot weather and cause a derailment. Distortion due to heat expansion is known in North America as sun kink, and elsewhere as buckling. In North America a rail broken due to cold-related contraction is known as a *pull-apart*. Attention needs to be paid to compacting the ballast effectively, including under, between, and at the ends of the sleepers, to prevent the sleepers from moving. In extreme hot weather special inspections are required to monitor sections of track known to be problematic.

After new segments of rail are laid, or defective rails replaced (welded-in), the rails are artificially stressed. The stressing process involves either heating the rails causing them to expand, or stretching the rails with hydraulic equipment. They are then fastened (clipped) to the sleepers in their expanded form. This process ensures that the rail will not expand much further in subsequent hot weather. In cold weather the rails try to contract, but because they are firmly fastened, cannot do so. In effect, stressed rails are a bit like a piece of stretched elastic firmly fastened down.

CWR rail is laid (including fastening) at a temperature roughly midway between the extremes experienced at that location (this is known as the "rail neutral temperature"). This installation procedure, along with normal track structure strength, is intended to prevent tracks from buckling in summer heat or pulling apart in winter cold. In North America, because broken rails are typically detected by the signaling system; they are seen as less of a problem than heat kinks which are not detected.

Joints are used in continuous welded rail when necessary, usually for signal circuit gaps. Instead of a joint that passes straight across the rail, the two rail ends are sometimes cut at an angle to give a smoother transition. In extreme cases, such as at the end of long bridges, a breather switch (referred to in North America and Britain as an *expansion joint*) gives a smooth path for the wheel while allowing the end of one rail to expand in relation to the next rail.

Rail support (sleeper/tie)

A railroad tie (also called a cross-tie in North American usage, or a railway sleeper outside North America) is a rectangular object on which the rails are supported and fixed. The tie has two main roles: to transfer the loads from the rails to the track ballast and the ground underneath, and to hold the rails to the correct width apart (to maintain the rail gauge). They are generally laid transverse (perpendicular) to the rails.

Fixing rails to railroad ties

Various methods exist for fixing the rail to the sleeper (railroad tie). Historically spikes gave way to cast iron chairs fixed to the sleeper, more recently springs (such as Pandrol clips) are used to fix the rail to the sleeper chair.

Portable track

Sometimes rail tracks are designed to be portable and moved from one place to another as required.

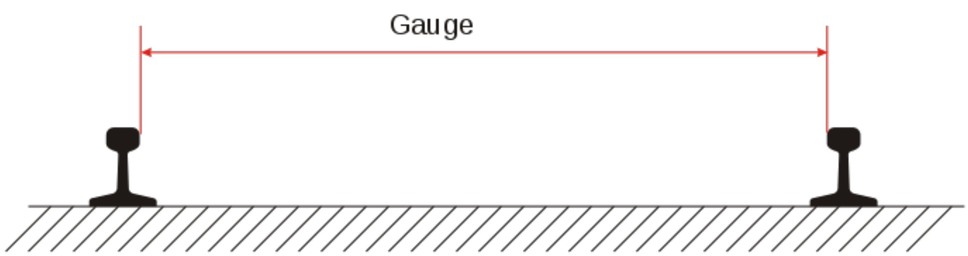
On the Panama Canal, tracks were so lifted around as is seen in moving pictures taken of the excavation works. These tracks were standard gauge, and the rolling stock full size.

Cane railways often had permanent tracks for the main lines, with portable tracks serving the canefields themselves. These tracks were narrow gauge (for example, 2 ft (610 mm)) and the portable track came in straights, curves and turnouts rather like on a model railway.

Decauville was a source of many portable light rail tracks, also used for military purposes.

The **permanent way** is so called because **temporary way** tracks were often used in the construction of that permanent way.

Gauge



Measuring rail gauge

During the early days of rail, there was considerable variation in the gauge used by different systems. Today, 60% of the world's railways use a gauge of 1,435 mm (4 ft 8 $\frac{1}{2}$ in), known as standard or international gauge. Gauges wider than standard gauge are called broad gauge; narrower, narrow gauge. Some stretches of track are dual gauge, with three (or sometimes four) parallel rails in place of the usual two, to allow trains of two different gauges to share the same track.

Gauge can safely vary over a range. For example, U.S. federal safety standards allow standard gauge to vary from 4 ft 8 in (1,422 mm) to 4 ft 9 $\frac{1}{2}$ in (1,460 mm) for operation up to 60 mph (96.6 km/h).

Track maintenance

Maintenance of way equipment in Italy

Track needs regular maintenance to remain in good order, especially when high-speed trains are involved. Inadequate maintenance may lead to a "slow order" (North American terminology, a "slack" or speed restriction in the United Kingdom) being imposed to avoid accidents. Track maintenance was at one time hard manual labour, requiring teams of labourers (US: gandy dancers, UK: platelayers or trackmen, Australia: fettlers), who used lining bars to correct irregularities in horizontal alignment (line) of the track, and tamping and jacks to correct vertical irregularities (surface). Currently, maintenance is facilitated by a variety of specialised machines.

A tie replacement train in Pennsylvania

The surface of the head of each of the two rails can be maintained by using a railgrinder.

Common maintenance jobs include changing crossties (sleepers), lubricating and adjusting switches, tightening loose track components, and surfacing and lining track to keep straight sections straight and curves within maintenance limits.

Spraying ballast with herbicide to prevent weeds growing through and disrupting the ballast is typically done with a special weed killing train.

Rail tracks with vegetation

Flange oilers lubricate wheel flanges to reduce rail wear in tight curves, Middelburg, Mpumalanga, South Africa

Over time, ballast is crushed or moved by the weight of trains passing over it, periodically requiring relevelling ("tamping") and eventually to be cleaned or replaced. If this is not done, the tracks may become uneven causing swaying, rough riding and possibly derailments.

Rail inspections utilize nondestructive testing methods to detect internal flaws in the rails. This is done by using specially equipped HiRail trucks, inspection cars, or in some cases handheld inspection devices.

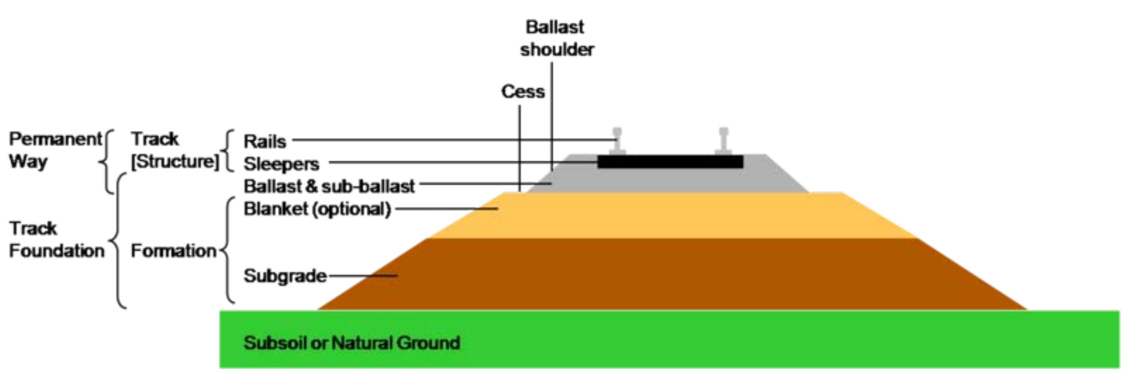
Rails must be replaced before the railhead profile wears to a degree that may trigger a derailment. Worn mainline rails usually have sufficient life to be used on a branch line, siding or stub afterwards and are "cascaded" to those applications.

The environmental conditions along railroad track create a unique railway ecosystem. This is particularly so in the United Kingdom where steam locomotives are only used on special services and vegetation has not been trimmed back so thoroughly. This creates a fire risk in prolonged dry weather.

In the UK, the cess is used by track repair crews to walk to a work site, and as a safe place to stand when a train is passing. This helps when doing work minor work, while needing to keep trains running, by not needing a Hi-railer or transport vehicle blocking the line to transport crew to get to the site.

Track bed and foundation

Railway tracks are generally laid on a bed of stone track ballast or track bed, in turn is supported by prepared earthworks known as the track formation. The formation comprises the subgrade and a layer of sand or stone dust (often sandwiched in impervious plastic), known as the blanket, which restricts the upward migration of wet clay or silt. The track and ballast form the permanent way. The term foundation may be used to refer to the ballast and formation, i.e. all man-made structures below the tracks.



Section through railway track and foundation showing the ballast and formation layers. The layers are slightly sloped to help drainage.

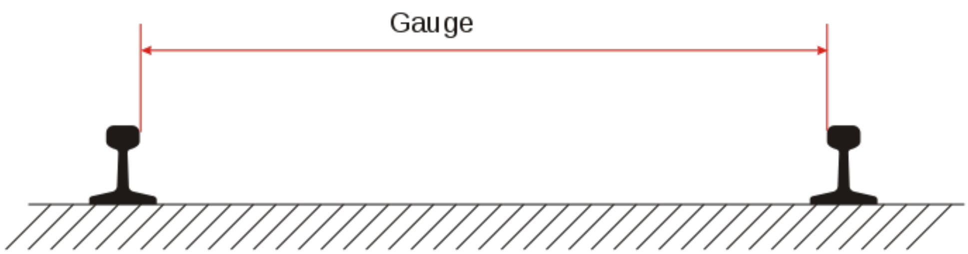
Additional measures are required where the track is laid over permafrost, such as on the railway to Tibet, such as transverse pipes through the subgrade to prevent that subgrade from melting. These pipes allow cold air to penetrate the formation.

The sub-grade layers are slightly sloped to one side to help drainage of water.

Chapter- 8

Gauge Conversion and Tramway Track

Gauge conversion



In rail transportation, **gauge conversion** is the process of converting a railway from one rail gauge to another, through the alteration of the railway tracks. An alternative to gauge conversion is dual gauge track, or gauge conversion of the rail vehicles themselves.

Ideally railways should all be built to the same gauge, since a wide range of gauges from narrow to broad are of similar value in carrying heavy loads at low cost, while small differences of gauge create tremendous break-of-gauge costs and inconvenience.

Rail vehicles

Gauge conversion of coaches and wagons involves the replacement of the wheelsets or entire bogies, such as happened when the 7 ft 0 ¼ in (2,140 mm) gauge of the Great Western Railway was abandoned in May 1892. Where vehicles regularly work to and fro across a permanent change of gauge, for example between the 4 ft 8 ½ in (1,435 mm) system in France and the 1,668 mm (5 ft 5 ⅔ in) in Spain, stations are equipped with special bogie exchange equipment. Some vehicles nowadays are fitted with variable gauge axles which do not require any exchange of the wheelsets, but still require special equipment. This temporary alteration to allow through working is generally referred to as "gauge change".

Steam locomotives are difficult to convert unless this is already allowed for in the design, such as in some East African Railways Garratts, and in steam locomotives built for Victoria after 1930s. In the event, few have been so converted, but one such is Victorian Railways R class R766.

Sleeper types

Often gauge convertible sleepers are installed before the conversion of the rails themselves. Sleepers have to be long enough to take the wider of the gauges, and secondly, the sleepers must be able to take the fittings of both gauges that allow the rails to be fixed securely to those sleepers. Gauge convertibility can also be a stepping stone to dual gauge. In cases where the differences between the gauges are small, such as 1,000 mm (3 ft 3 ⅜ in)/1,067 mm (3 ft 6 in) and 1,435 mm (4 ft 8 ½ in)/1,524 mm (5 ft) , dual gauge with a third rail is not practicable, in these cases four rail dual gauge is necessary.

- Timber sleepers, provided that they are long enough, are always gauge convertible, since additional holes for the dogspikes can always be drilled later. If the new gauge is wider than the old, a shorter than normal sleeper can be tolerated to a degree.

- Concrete sleepers cannot be converted as an afterthought, but must have the future fittings cast in place at the manufacturing stage.

- Steel sleepers should have the extra fitting incorporated at the initial manufacturing stage, though it might be possible to drill or weld the fitted sleeper after installation albeit with some difficulty.

Loading gauge

Narrow gauge railways often have a significantly smaller loading gauge in both height and width. Conversion to a wider track gauge will often therefore require enlargement of the loading gauge, by raising overbridges and enlarging tunnels, if any.

Also the minimum radius curve of a narrow gauge railway is often less than a wider gauge, which may require deviations to ease such curves.

Track centres at stations with multiple tracks will also have to be widened. This would be less of a problem on the usually single track main lines of the narrow gauge railway.

Gauge orphan

During gauge conversion work such as between Seymour and Albury, branch lines such as Benalla to Oaklands and stations such as Violet Town become gauge orphans as they cannot easily be served by trains until extra costly work is done.

In this instance, the loading gauge of the broad gauge and standard gauge lines are essentially the same.

Examples

During WWI and WWII, gauge conversion occurred backwards and forwards between Germany and Russia as the fronts and national borders changed.

- India conversion of 17,000 km of 1,000 mm (3 ft $3\frac{3}{8}$ in) meter gauge to 1,676 mm (5 ft 6 in) broad gauge under project Unigauge
- Melbourne to Adelaide - 600 km of convertible sleepers installed in 1990 to facilitate quick conversion in 1995.
- Adelaide - convertible sleepers installed should gauge conversion be needed in future.
- Port Harcourt - Onne, Nigeria - convertible sleepers installed since gauge conversion not imminent.
- The Mount Gambier line in South Australia was fitted with some 3-gauge steel sleepers when it was "temporarily" converted from 1,067 mm (3 ft 6 in) to 1,600 mm (5 ft 3 in) in the 1950s, pending later conversion to 1,435 mm (4 ft $8\frac{1}{2}$ in) from 2008.
- Central Asia - while China and Europe are connected by rail, and while both are mainly 1,435 mm (4 ft $8\frac{1}{2}$ in), the intervening Central Asia Railways are 1,520 mm (4 ft $11\frac{5}{6}$ in) gauge. Intervening lines are gradually being made gauge convertible to facilitate an eventual linkage of the Chinese and European standard gauge system. (variable gauge trains)
- Tanzania in 2008 is proposing 1,000 mm (3 ft $3\frac{3}{8}$ in)/1,067 mm (3 ft 6 in) steel sleepers and 1,000 mm (3 ft $3\frac{3}{8}$ in)/1,435 mm (4 ft $8\frac{1}{2}$ in) concrete sleepers to suit gauge conversion.

Conversions to standard gauge

- 1941 Brest-Minsk
- 1970 Indian Pacific
- Spain is building its High Speed lines to 1,435 mm (4 ft $8\frac{1}{2}$ in) gauge, even though the existing system is 1,668 mm (5 ft $5\frac{2}{3}$ in); new cutoff lines are being built with gauge convertible sleepers for easy conversion to standard gauge when required.
- May 2008 - agreement reached to standardise 200 km of 1,600 mm (5 ft 3 in) track carrying declining traffic from Seymour to Albury, making double track 1,435 mm (4 ft $8\frac{1}{2}$ in) route for increasing interstate traffic. The drought affected

wheat-only 1,600 mm (5 ft 3 in) Oaklands branchline will also be converted. The cost of converting this 126 km line has been estimated as just over $13m.

- Peru from Huancayo to Huancavelica from 914 mm (3 ft) to 1,435 mm (4 ft 8 ½ in); 147 km. completed 2009.
- Zabergäu Railway 750 mm (2 ft 5 ½ in) to 1,435 mm (4 ft 8 ½ in)
- Toronto, Grey and Bruce Railway from 1,067 mm (3 ft 6 in) to 1,435 mm (4 ft 8 ½ in)

Proposed

- Port Pepel iron ore line, from derelict 1,067 mm (3 ft 6 in) to 1,435 mm (4 ft 8 ½ in)

Conversion to Cape Gauge

Integrated with Southern African railways

- Beria - Salisbury - 1910 - was 610 mm (2 ft)
- Namibian Railways, 1930s, much of which was 610 mm (2 ft)

Isolated

- Matadi–Kinshasa Railway - 1932 - was 762 mm (2 ft 6 in)
- Luanda Railway, Angola, was 1,000 mm (3 ft 3 ⅜ in)
- Angola Namibe Railway, 1950s, was 600 mm (1 ft 11 ⅝ in)

- Kindu (Lualaba River port) - Kibombo – Kongolo – Kabalo (Lualaba River port and junction with Katanga line) - Nyunzu – Niemba – Kalemie (the port on Lake Tanganika), 1,067 mm (3 ft 6 in). This line was isolated 1,000 mm (3 ft 3 ⅜ in) until 1955, when the gauge was changed for the connection with the Katanga line in 1956.

Conversion to metre gauge

From 1920, the standard gauge part of the Siam railway amounting to 1,000 km was converted first to third rail, and then to 1,000 mm (3 ft 3 ⅜ in) (metre gauge) making the whole system metre gauge.

Conversion rate

- 20 km/day for a battalion of 500-1500 men.

Tramway track

Cross section of tram rail

Tramway track is used on tramways or light rail operations. Grooved rails (or girder rails) are often used in order to make street running feasible. Like standard rail tracks, tram tracks consist of two parallel steel rails.

Tram rails can be placed in several surfaces, such as with standard rails on sleepers like railway tracks, or with grooved rails on concrete sleepers into street surfaces (pavement) for street running. Another environmentally-friendly or ecologically-friendly alternative is to lay tracks into grass turf surfaces; this is known as *grassed track* (or *track in a lawn*), first used in Liverpool in 1924.

History

The first tramways were laid in 1832 in New York by John Stephenson, to assist horses pulling buses through dirt roads, especially in wet weather when muddy. By laying rails, a horse could easily pull a load of 10 tonnes rather than 1 tonne on a dirt road. The evolution of street tramway tracks paralleled the development from horse power to mechanical, especially electric power. In a dirt road, the rails needed a foundation, usually a mass concrete raft. Highway authorities often made tramway companies pave the rest of the road, usually with granite or similar stone blocks, an extra cost.

Laying tram tracks on Sydney's original tram network.

The first tramways had a rail projecting above the road surface, or a step set into the road, both of which were apt to catch the narrow tyres of horse drawn carriages. The invention by Alphonse Loubat in 1852 of grooved rail enabled tramways to be laid without causing a nuisance to other road users, except unsuspecting cyclists, who could get their wheels caught in the groove.

Electrification

Electrification needed other developments, most notably heavier rails to cope with electric tramcars weighing 12 tonnes rather than the 4 tonne horse-drawn variety; switching points, as electric trams could not be pulled onto the correct track by horses; and the need for electrical connections, to provide the return path for the electric current, which was usually supplied through an overhead wire.

Cable haulage

Prior to the universal introduction of electric power, many tramways were cable hauled, with a continuous cable carried in a conduit under the road, and with a slot in the road surface through which the tram could clasp the cable for motion. This system can still be seen in San Francisco in California as well as the system of the Great Orme in Wales. These needed a rather more substantial track formation.

Grassed track on the EuskoTran in Bilbao

Light rail tracks with concrete railroad ties (sleepers)

Conduit and stud systems

In some cities where overhead electric cables were deemed intrusive, underground conduits with electrical conductors were used. Examples of this were New York, Washington DC, Paris, London, Brussels and Budapest. The conduit system of electrical power was very expensive to install and maintain, although Washington did not close until 1962. Attempts were made with alternative systems not needing overhead wires. There were many systems of "surface" contact, where studs were set in the road surface, and energised by a passing tram, either mechanically or magnetically to supply power through a skate carried under the tram. Unfortunately these systems all failed due to the problem of reliability and not always turning off after the tram had passed, resulting in the occasional electrocution of horses and dogs. In the last five years a new system of surface contact has been installed in the Bordeaux tramway by Alstom.

Grooved rail

Cross-section of LR55 rail

A **grooved rail**, **groove rail**, or **girder rail** is a special rail designed for tramway or railway track in pavement or grassed surfaces (grassed track or track in a lawn). This was invented in 1852 by Alphonse Loubat, a French inventor who developed improvements in tram and rail equipment, and helped develop tram lines in New York City and Paris.

Other tram track profiles

An alternative to the conventional girder profiled grooved track is the LR55 profile. This is considerably cheaper and easier to install and maintain than conventional girder rail as it requires a smaller footprint foundation and existing utility services need not be disturbed.

Grooved rail Gauntlet track on a tramway in Mannheim, Germany