Section II

LEGAL REGULATION OF INTERNATIONAL TRANSPORTATION

Topic 7. International legal regulation of rail transportation

1. The meaning and history of Rail transport
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1. The meaning and history of Rail transport

Rail transport is a means of conveyance of passengers and goods on wheeled vehicles running on rails, also known as tracks. It is also commonly referred to as train transport. In contrast to road transport, where vehicles run on a prepared flat surface, rail vehicles (rolling stock) are directionally guided by the tracks on which they run. Tracks usually consist of steel rails, installed on ties (sleepers) and ballast, on which the rolling stock, usually fitted with metal wheels, moves. Other variations are also possible, such as slab track, where the rails are fastened to a concrete foundation resting on a prepared subsurface.

Rolling stock in a rail transport system generally encounters lower frictional resistance than road vehicles, so passenger and freight cars (carriages and wagons) can be coupled into longer trains. The operation is carried out by a railway company, providing transport between train stations or freight customer facilities. Power is provided by locomotives which either draw electric power from a railway electrification system or produce their own power, usually by diesel engines. Most tracks are accompanied by a signalling system. Railways are a safe land transport system when compared to other forms of transport. Railway transport is capable of high levels of passenger and cargo utilization and energy efficiency, but is often less flexible and more capital-intensive than road transport, when lower traffic levels are considered.

The oldest, man-hauled railways date back to the 6th century BC, with Periander, one of the Seven Sages of Greece, credited with its invention. Rail transport blossomed after the British development of the steam locomotive as a viable source of power in the 18th and 19th centuries. With steam engines, one could construct mainline railways, which were a key component of the Industrial Revolution. Also, railways reduced the costs of shipping, and allowed for fewer lost goods, compared with water transport, which faced occasional sinking of ships. The change from canals to railways allowed for "national markets" in which prices varied very little from city to city. The invention and development of the railway in Europe was one of the most important technological inventions of the 19th century; in the United States, it is estimated that without rail, GDP would have been lower by 7% in 1890.

In the 1880s, electrified trains were introduced, and also the first tramways and rapid transit systems came into being. Starting during the 1940s, the non-electrified railways in most countries had their steam locomotives replaced by diesel-electric locomotives, with the process being almost complete by 2000. During the 1960s, electrified high-speed railway systems were introduced in Japan and later in some other countries. Other forms of guided ground transport outside the traditional railway definitions, such as monorail or maglev, have been tried but have seen limited use. Following decline after World War II due to competition from cars, rail transport has had a revival in recent decades due to road congestion and rising fuel prices, as well as governments investing in rail as a means of reducing CO_2 emissions in the context of concerns about global warming.

The history of the growth, decline and restoration to use of rail transport can be divided up into several discrete periods defined by the principal means of motive power used.

Pre-steam. The earliest evidence of a railway was a 6-kilometre (3.7 mi) Diolkos wagonway, which transported boats across the Corinth isthmus in Greece during the 6th century BC. Trucks pushed by slaves ran in grooves in limestone, which provided the track element. The Diolkos operated for over 600 years.

Railways began reappearing in Europe after the Dark Ages. The earliest known record of a railway in Europe from this period is a stained-glass window in the Minster of Freiburg im Breisgau in Germany, dating from around 1350. In 1515, Cardinal Matthäus Lang wrote a description of the Reisszug, a funicular railway at the Hohensalzburg Castle in Austria. The line originally used wooden rails and a hemp haulage rope, and was operated by human or animal power. The line still exists, albeit in updated form, and is one of the oldest railways still to operate.

By 1550, narrow gauge railways with wooden rails were common in mines in Europe. By the early 17th century, wooden wagonways were common in England and Wales for transporting coal from mines to canal wharfs for transshipment to boats. The world's oldest working railway, built in 1758, is the Middleton Railway in Leeds. In 1764, the first gravity railroad in the United States was built in Lewiston, New York. The first permanent tramway was the Leiper Railroad in 1810.

The first iron plate railway, made with wrought iron plates on top of wooden rails, came into use in 1768. This allowed a variation of gauge to be used. At first only balloon loops could be used for turning, but later, movable points were taken into use that allowed for switching. From the 1790s, iron edge rails began to appear in Great Britain. In 1803, William Jessop opened the Surrey Iron Railway in south London, arguably the world's first horse-drawn public railway. The invention of the wrought iron rail by John Birkinshaw in 1820 allowed the short, brittle, and often uneven, cast iron rails to be extended to 15 feet (4.6 m) lengths. These were succeeded by steel in 1857.

Age of steam. The development of the steam engine during the Industrial Revolution in Great Britain, initially for pumping water, spurred ideas for mobile steam locomotives that could haul heavy weights on tracks. James Watt's patented steam engines of 1769 (patent revised in 1782) were heavy low-pressure engines which were not suitable for use in locomotives. However, in 1804, using high-pressure steam, Richard Trevithick demonstrated the first locomotive-hauled train at Merthyr Tydfil, in South Wales. Accompanied with Andrew Vivian, it ran with mixed success, breaking some of the brittle cast-iron plates. Two years later, the first passenger horse-drawn railway was opened nearby between Swansea and Mumbles.

Earliest British steam railways. In 1811, John Blenkinsop designed the first successful and practical railway locomotive —a rack railway worked by a steam locomotive between Middleton Colliery and Leeds on the Middleton Railway. His first locomotive, called *Salamanca*, was built the following year. In 1825, George Stephenson built the *Locomotion* for the Stockton and Darlington Railway, north east England, which was the first public steam railway in the world. In 1829, he built the *Rocket*, which was entered in and won the Rainhill Trials. This success led to Stephenson establishing his company as the pre-eminent builder of steam locomotives for Railways in Great Britain and Ireland, the United States, and much of Europe.

In 1830, the first intercity route, the Liverpool and Manchester Railway, was opened. The gauge was that used for the early wagon-ways, which had been adopted for the Stockton and Darlington Railway, with a 1,435 mm (4 ft 8 ½ in) width which became known as the international standard gauge, still used by about 60% of the world's railways. This spurred the spread of rail transport outside the British Isles.

By the early 1850s, Great Britain had over 7,000 miles (11,000 km) of railway, a stunning achievement given that only twenty years had elapsed since the opening of the Liverpool and Manchester Railway.

Early railroads in the US. Railroads (as they are known in the US) were built on a far larger scale than those in Continental Europe, both in terms of the distances covered, and also in the loading gauge adopted, which allowed for heavier locomotives and double-deck trains. The railroad era in the United States began in 1830 when Peter Cooper's locomotive, *Tom Thumb*, first steamed along 13 miles (21 km) of Baltimore and Ohio railroad track. In 1833, the nation's second railroad ran 136 miles (219 km) from Charleston to Hamburg in South Carolina. Not until the 1850s, though, did railroads offer long distance service at reasonable rates. A journey from Philadelphia to Charleston involved eight different gauges, which meant that passengers and freight had to change trains seven times. Only at places like Bowling Green, Kentucky, were the railroads connected to one another.

The Baltimore and Ohio Railroad that opened in 1830 was the first to evolve from a single line to a network in the United States. By 1831, a steam railway connected Albany and Schenectady, New York, a distance of 16 miles (26 km), which was covered in 40 minutes.

The years between 1850 and 1890 saw phenomenal growth in the US railroad system, which at its peak constituted one third of the world's total mileage. Although the American Civil War placed a temporary halt to major new developments, the conflict did demonstrate the enormous strategic importance of railways at times of war. After the war, major developments include the first elevated railway built in New York in 1867 as well as the symbolically important first transcontinental railroad completed in 1869.

Electrification and Dieselization. Experiments with electrical railways were started by Robert Davidson in 1838. He completed a battery-powered carriage capable of 6.4 km/h (4 mph). The Gross-Lichterfelde Tramway was the first to use electricity fed to the trains en route, when it opened in 1881. Overhead wires were taken into use in the Mödling and Hinterbrühl Tram in Austria in October 1883. At first, this was taken into use on tramways that, until then, had been horse-drawn tramcars. The first conventional completely electrified railway mainline was the 106 km Valtellina line in Italy that was opened on 4 September 1902.

During the 1890s, many large cities, such as London, Paris and New York City used the new technology to build rapid transit for urban commuting. In smaller cities, tramways became common and were often the only mode of public transport until the introduction of buses in the 1920s. In North America, interurbans became a common mode to reach suburban areas. At first, all electric railways used direct current but, in 1904, the Stubaital Line in Austria opened with alternating current.

Steam locomotives require large pools of labour to clean, load, maintain and run. After World War II, dramatically increased labour costs in developed countries made steam an increasingly costly form of motive power. At the same time, the war had forced improvements in internal combustion engine technology that made diesel locomotives cheaper and more powerful. This caused many railway companies to initiate programmes to convert all unelectrified sections from steam to diesel locomotion.

Following the large-scale construction of motorways after the war, rail transport became less popular for commuting and air transport started taking large market shares from long-haul passenger trains. Most tramways were either replaced by rapid transit or buses, while high transshipment costs caused short-haul freight trains to become uncompetitive. The 1973 oil crisis led to a change of mind set and most tram systems that had survived into the 1970s remain today. At the same time, containerization allowed freight trains to become more competitive and participate in intermodal freight transport. With the 1964 introduction of the Shinkansen high-speed rail in Japan, trains could again have a dominant position on intercity travel. During the 1970s, the introduction of automated rapid transit systems allowed cheaper operation. The 1990s saw an increased focus on accessibility and low-floor trains. Many tramways have been upgraded to light rail and many cities that closed their old tramways have reopened new light railway systems.

Innovations. Many benchmarks in equipment and infrastructure led to the growing use of railways. Some innovative features taking place in the 19th and 20th centuries included wood cars replaced with all-steel cars, which provided better safety and maintenance; iron rails replaced with steel rails, which provided higher speed and capacity with lower weight and cost; stove-heated cars to steam-heating cars, piped from locomotive; gas lighting to electric lighting, with use of battery/alternator unit beneath the car; development of air-conditioning with additional underbody equipment and ice compartment. Some innovative rolling stock included the lightweight, diesel-powered streamliner, which was a modernistic, aerodynamically styled train with flowing contours; then came the ultra-lightweight car with internal combustion engine in each train's power car; others included the dome car, turbined-powered trains, bi-level rolling stock, and the high-tech/high-speed electric trains.

Even more, in the first half of the 20th century, infrastructure elements adopted technological changes including the continuously welded rail that was ¼ mile (0.40 km) long; concrete tie usage; double tracking major lines; intermodal terminal and handling technology; advances in diesel-electric propulsion to include AC traction systems and propulsion braking systems; and just-in-time inventory control. Beyond technology, even management of systems saw improvements with the adoption of environmental impact concerns; heightened concern of employee and public safety; introduction of urban area rail networks and public agencies to manage them; and downsizing of industry employment with greater use of contractors and consultants.

Rail Transportation in the 21st Century. Although railways are a product of the industrial revolution, they have been affected by continuous innovations, technical, regulatory and commercial changes which have improved their capacity and efficiency. Rail transportation is thus as important in the 21st century as it was in the late 19th century. One innovation relates to the quality of the rail infrastructure, particularly rail tracks (e.g. better steel, concrete ties), which determines the operational characteristics of their use such as speed, permitted weight, maintenance and resilience to the environment. Increasing electrification and automation also improve the efficiency of rail transportation, passenger and freight alike. A few new rail lines are being built, but mainly in developing countries. Railway speed records have constantly improved with the introduction of high speed rail systems. For instance, portions of the French high speed rail system (also known as TGV: Tres Grande Vitesse) can reach speeds up to 515 km/hr. Variable wheel-base axles permit rail transport between different gauges. However, freight trains run at a considerably lower speed, in the range of 30-35 km/hr. In some cases, as the rail system gets more used, operational speed may decline because of congestion.

Longer and heavier rail coupled with major engineering achievements allow the suppression of natural obstacles, which enhance network continuity. The Seikan tunnel between the islands of Honshu and Hokkaido in Japan has a length of 53.8 kilometers while the Channel tunnel between France and England reaches 50.5 kilometers. One of the most technically challenging rail segment ever built was completed in 2006 in China. The 1,142 kilometers line links Golmud in Qinghai province to Lhasa in Tibet. Some parts go through permafrost and altitudes of 16,000 feet, conferring its status of the world's highest rail line.

Rail transport has comparative advantages in carrying heavy bulk traffic on specific itineraries over long distances. For instance, a 10 car freight train can carry as much cargo as 600 trucks. Beside its emphasis on safety and reliability, rail transport favors the fast commuting of suburbanites during peak hours and has become an important mode supporting passenger movements in large cities.

The global trend involves the closure of unprofitable lines as well as the elimination of several stops. Over the last 50 years, with downsizing of rail transportation, while traffic was moving to other modes, rail companies abandoned lines (or sold them to local rail companies), removed excess terminals and warehousing capacity and sold off property. The process of rationalization (deregulation) of the rail network is now completed in a number of countries, such as in the United States. This has implied significant labor savings with the reduction of train crews (from 3-4 to 2), more flexible working hours and the usage of subcontractors for construction and maintenance. In addition to energy efficient (the fuel efficiency of locomotives has increased by 68% between 1980 and 2000) and lighter equipment, the usage of **double-stack cars** has revolutionized rail transportation with additional fuel efficiency and cost reductions of about 40%. Depending on the service and type of commodity carried rail can be 1.9 to 5.5 more energy efficient than trucking.

Unit trains, carrying one commodity-type only, allow scale economies and efficiencies in bulk shipments, and double stacking has greatly promoted the advantages of rail for container shipments.

Trends concerning cargo transport using trailers on flat cars (TOFC) and containers on flat cars (COFC) well illustrate the increasing adoption of intermodal transport. Still, TOFC services are being phased down and COFC increasingly dominates. An active market for niche services such as Roadrailers mounting truck trailers as train convoys remains. Due to its great versatility, the container is highly favored as such a means of cargo transport; loading trailers unto rail cars is prone to inefficiencies, particularly a much lower load factor than containers.

Double-stack rail technology is a major challenge for the rail transport system as it is effective for long distances where additional terminal costs are compensated by lower transport costs. North America has a notable advantage over Europe on this issue since a full double-stacked unit train can carry between 400 and 600 TEU (200 to 300 containers) and can have a length exceeding 10,000 feet (about 3,000 meters). The average intermodal train length in the United States is around 6,500 feet (about 2,000 meters). European trains are generally limited to 750 meters and can carry 80 TEU of single stacked containers while some rail segments can accommodate 850 meters.

Further, most railroads were constructed early in the 20th century and have an overhead clearance that is inadequate for the usage of double-stack trains. This is notably the case for tunnels and bridges. Even if improving clearance is a major investment, several rail companies, notably in North America, have invested massively on double-stacking projects. The economies and improved capacity of double-stacking have justified investments of raising the clearance from 5.33 meters (17'6") to 8.1 meters (20'6") along major long distance rail corridors. Europe is less advanced in this process because most of its rail facilities were built in the middle of the 19th century. Clearance thus forbids the usage of double-stacking on most European rail corridors.

The emergence of high-speed rail networks and increasing rail speed had significant impacts on passenger transportation, especially in Europe and Japan (high speed freight trains are not currently being considered; see Application 1 for a more detailed overview). For instance, the French TGV has an operational speed of about 300 km/h. High-speed passenger trains require special lines, but can also use the existing lines at a lower speed. In many cases it permitted a separation between rail passenger traffic rolling at high speed and freight traffic using the conventional rail network. The efficiency of both the passengers and freight rail network was thus improved significantly. Since high-speed trains require some time to accelerate and decelerate, the average distance between stations has increased significantly, by-passing several centers of less importance. Over average distances, they have proved to be able to compete effectively with air transportation.

Other strategies include improving the speed of existing passenger services without building a high speed corridor. This involves upgrading the equipment and improving the infrastructure at specific locations along the corridor. The benefits of offering a passenger rail service above 120 km/h can be substantial to improve the quality and efficiency of inter-city services in high density urban regions.

Trains. A train is a connected series of rail vehicles that move along the track. Propulsion for the train is provided by a separate locomotive or from individual motors in self-propelled multiple units. Most trains carry a revenue load, although non-revenue cars exist for the railway's own use, such as for maintenance-of-way purposes. The engine driver (engineer in North America) controls the locomotive or other power cars, although people movers and some rapid transits are under automatic control.

Haulage. Traditionally, trains are pulled using a locomotive. This involves one or more powered vehicles being located at the front of the train, providing sufficient tractive force to haul the weight of the full train. This arrangement remains dominant for freight trains and is often used for passenger trains. A push-pull train has the end passenger car equipped with a driver's cab so that the engine driver can remotely control the locomotive. This allows one of the locomotive-hauled train's drawbacks to be removed, since the locomotive need not be moved to the front of the train each time the train changes direction. A railroad car is a vehicle used for the haulage of either passengers or freight.

A multiple unit has powered wheels throughout the whole train. These are used for rapid transit and tram systems, as well as many both short- and long-haul passenger trains. A railcar is a single, self-powered car, and may be electrically-propelled or powered by a diesel engine. Multiple units have a driver's cab at each end of the unit, and were developed following the ability to build electric motors and engines small enough to fit under the coach. There are only a few freight multiple units, most of which are high-speed post trains.

Motive power. Steam locomotives are locomotives with a steam engine that provides adhesion. Coal, petroleum, or wood is burned in a firebox, boiling water in the boiler to create pressurized steam. The steam travels through the smokebox before leaving via the chimney or smoke stack. In the process, it powers a piston that transmits power directly through a connecting rod (US: main rod) and a crankpin (US: wristpin) on the driving wheel (US main driver) or to a crank on a driving axle. Steam locomotives have been phased out in most parts of the world for economical and safety reasons, although many are preserved in working order by heritage railways.

Electric locomotives draw power from a stationary source via an overhead wire or third rail. Some also or instead use a battery. In locomotives that are powered by high voltage alternating current, a transformer in the locomotive converts the high voltage, low current power to low voltage, high current used in the traction motors that power the wheels. Modern locomotives may use three-phase AC induction motors or direct current motors. Under certain conditions, electric locomotives are the most powerful traction.[*citation needed*] They are also the cheapest to run and provide less noise and no local air pollution.[*citation needed*] However, they require high capital investments both for the overhead lines and the supporting infrastructure, as well as the generating station that is needed to produce electricity. Accordingly, electric traction is used on urban systems, lines with high traffic and for high-speed rail.

Diesel locomotives use a diesel engine as the prime mover. The energy transmission may be either diesel-electric, diesel-mechanical or diesel-hydraulic but diesel-electric is dominant. Electro-diesel locomotives are built to run as diesel-electric on unelectrified sections and as electric locomotives on electrified sections. Alternative methods of motive power include magnetic levitation, horse-drawn, cable, gravity, pneumatics and gas turbine.

Passenger trains. A passenger train travels between stations where passengers may embark and disembark. The oversight of the train is the duty of a guard/train manager/conductor. Passenger trains are part of public transport and often make up the stem of the service, with buses feeding to stations. Passenger trains provide long-distance intercity travel, daily commuter trips, or local urban transit services. They even include a diversity of vehicles, operating speeds, right-of-way requirements, and service frequency. Passenger trains usually can be divided into two operations: intercity railway and intracity transit. Whereas as intercity railway involve higher speeds, longer routes, and lower frequency (usually scheduled), intracity transit involves lower speeds, shorter routes, and higher frequency (especially during peak hours).

Intercity trains are long-haul trains that operate with few stops between cities. Trains typically have amenities such as a dining car. Some lines also provide over-night services with sleeping cars. Some long-haul trains have been given a specific name. Regional trains are medium distance trains that connect cities with outlying, surrounding areas, or provide a regional service, making more stops and having lower speeds. Commuter trains serve suburbs of urban areas, providing a daily commuting service. Airport rail links provide quick access from city centres to airports.

High-speed rail are special inter-city trains that operate at much higher speeds than conventional railways, the limit being regarded at 200 to 320 kilometres per hour (120 to 200 mph). High-speed trains are used mostly for long-haul service and most systems are in Western Europe and East Asia. The speed record is 574.8 km/h (357.2 mph), set by a modified French TGV. Magnetic levitation trains such as the Shanghai airport train use under-riding magnets which attract themselves upward towards the underside of a guideway and this line has achieved somewhat higher peak speeds in day-to-day operation than conventional high-speed railways, although only over short distances. Due to their heightened speeds, route alignments for high-speed rail tend to have shallower grades and broader curves than conventional railways.

Their high kinetic energy translates to higher horsepower-to-ton ratios (e.g. 20 horsepower per short ton or 16 kilowatts per tonne); this allows trains to accelerate and maintain higher speeds and negotiate steep grades as momentum builds up and recovered in downgrades (reducing cut, fill, and tunnelling requirements). Since lateral forces act on curves, curvatures are designed with the highest possible radius. All these features are dramatically different from freight operations, thus justifying exclusive high-speed rail lines if it is economically feasible.

Higher-speed rail services are intercity rail services that have top speeds higher than conventional intercity trains but the speeds are not as high as those in the high-speed rail services. These services are provided after improvements to the conventional rail infrastructure in order to support trains that can operate safely at higher speeds.

High speed railway (High Speed Railroad/Railway & Railroad/Railway high speed) commonly referred to as the High-speed Rail, is a kind of operating speed of at least 80% more than in the whole operation process of distance over 200 km/h (120 mph). As of 2014, the operating speed of High-speed Rail systems in the world are running about all set at 300 km/h (190 mph), a few systems have relatively high speed. For High-speed Rail speed can be considered:

- High-speed Rail lines after transformation from common railroad, such High-speed Rail maximum speed of approximately 250 km/h (160 mph).

- Construction standards for the ballasted bed (stone ballast) high-speed railway was built, such High-speed Rail maximum speed of approximately 320 km/h (200 mph).
- Construction of ballastless track technology standards (that is popular opinion of to lay the rail on the reinforced concrete pavement directly) was built, to China High-speed Rail represented such High-speed Rail mostly built in high-speed bridge (overhead bridge), so called air railway (air railroad), such High-speed Rail maximum speed of approximately 400 km/h (250 mph).

High speed railway is a high-tech integrated system, including 6 aspects:

- infrastructure, also including the station construction.
- high speed train.
- electricity and telecommunications, including electrical and contact network, safe and reliable communication, signal, dispatching centre console.
- safety control part, including meteorological conditions monitoring, line monitoring, automatic train control and retrieval, road, vehicle automatic monitoring and response system.
- maintenance and maintenance section, including the line maintenance, high speed train (highspeed divided dynamic train abbre: HDDT) maintenance and repair, involving a variety of instrumentation maintenance and repair, and maintenance of equipment and monitoring instruments.
- the other parts, including passenger safety assessment sent, High-speed Rail prospective study, the new High-speed Rail line and the new high speed train or high speed train test, High-speed Rail financial, High-speed Rail operational data storage and analysis, etc.

Rapid transit is an intracity system built in large cities and has the highest capacity of any passenger transport system. It is usually grade-separated and commonly built underground or elevated. At street level, smaller trams can be used. Light rails are upgraded trams that have step-free access, their own right-of-way and sometimes sections underground. Monorail systems are elevated, medium-capacity systems. A people mover is a driverless, grade-separated train that serves only a few stations, as a shuttle. Due to the lack of uniformity of rapid transit systems, route alignment varies, with diverse rights-of-way (private land, side of road, street median) and geometric characteristics (sharp or broad curves, steep or gentle grades). For instance, the Chicago 'L' trains are designed with extremely short cars to negotiate the sharp curves in the Loop. New Jersey's PATH has similar-sized cars to accommodate curves in the trans-Hudson tunnels. San Francisco's BART operates large cars on its well-engineered routes.

Freight train. A freight train hauls cargo using freight cars specialized for the type of goods. Freight trains are very efficient, with economy of scale and high energy efficiency. However, their use can be reduced by lack of flexibility, if there is need of transshipment at both ends of the trip due to lack of tracks to the points of pick-up and delivery. Authorities often encourage the use of cargo rail transport due to its environmental profile.

Container trains have become the dominant type in the US for non-bulk haulage. Containers can easily be transshipped to other modes, such as ships and trucks, using cranes. This has succeeded the boxcar (wagon-load), where the cargo had to be loaded and unloaded into the train manually. The intermodal containerization of cargo has revolutionized the supply chain logistics industry, reducing ship costs significantly. In Europe, the sliding wall wagon has largely superseded the ordinary covered wagons. Other types of cars include refrigerator cars, stock cars for livestock and autoracks for road vehicles. When rail is combined with road transport, a roadrailer will allow trailers to be driven onto the train, allowing for easy transition between road and rail.

Bulk handling represents a key advantage for rail transport. Low or even zero transshipment costs combined with energy efficiency and low inventory costs allow trains to handle bulk much cheaper than by road. Typical bulk cargo includes coal, ore, grains and liquids. Bulk is transported in open-topped cars, hopper cars and tank cars.

2. Rail Transportation and Rail Lines

Rail freight transport is the use of railroads and trains to transport cargo as opposed to human passengers.

A **freight train** or **goods train** is a group of freight cars (US) or goods wagons (UIC) hauled by one or more locomotives on a railway, transporting cargo all or some of the way between the shipper and the intended destination as part of the logistics chain. Trains may haul bulk material, intermodal containers, general freight or specialized freight in purpose-designed cars.[1] Rail freight practices and economics vary by country and region.

When considered in terms of ton-miles or tonne-kilometers hauled per unit of energy consumed, rail transport can be more efficient than other means of transportation. Maximum economies are typically realized with bulk commodities (e.g., coal), especially when hauled over long distances. However, shipment by rail is not as flexible as by highway, which has resulted in much freight being hauled by truck, even over long distances. Moving goods by rail often involves transshipment costs, particularly when the shipper or receiver lack direct rail access. These costs may exceed that of operating the train itself, a factor that practices such as containerization aim to minimize.

Traditionally, large shippers build factories and warehouses near rail lines and have a section of track on their property called a siding where goods are loaded onto or unloaded from rail cars. Other shippers have their goods hauled (drayed) by wagon or truck to or from a goods station (freight station in US). Smaller locomotives transfer the rail cars from the sidings and goods stations to a classification yard, where each car is coupled to one of several long distance trains being assembled there, depending on that car's destination. When long enough, or based on a schedule, each long distance train is then dispatched to another classification yard. At the next classification yard, cars are resorted. Those that are destined for stations served by that yard are assigned to local trains for delivery. Others are reassembled into trains heading to classification yards closer to their final destination. A single car might be reclassified or switched in several yards before reaching its final destination, a process that made rail freight slow and increased costs. Many freight rail operators are trying to reduce these costs by reducing or eliminating switching in classification yards through techniques such as unit trains and containerization. In many countries, railroads have been built to haul one commodity, such as coal or ore, from an inland point to a port.

Rail freight uses many types of goods wagon (UIC) or freight car (US). These include box cars (US) or covered wagons (UIC) for general merchandise, flat cars (US) or flat wagons (UIC) for heavy or bulky loads, well wagons or "low loader" wagons for transporting road vehicles; there are refrigerator vans for transporting food, simple types of open-topped wagons for transporting bulk material, such as minerals and coal, and tankers for transporting liquids and gases. Most coal and aggregates are moved in hopper wagons or gondolas (US) or open wagons (UIC) that can be filled and discharged rapidly, to enable efficient handling of the materials.

A major disadvantage of rail freight is its lack of flexibility. In part for this reason, rail has lost much of the freight business to road transport. Many governments are now trying to encourage more freight onto trains, because of the environmental benefits that it would bring; rail transport is very energy efficient.[3] Compared to road transport which employs the use of trucks, rail transportation ensures that goods that could otherwise be transported on a number of trucks are transported in a single shipment. This saves a lot as far as cost connected to the transportation are concerned.

In Europe (particularly Britain) many manufacturing towns developed before the railway. Many factories did not have direct rail access. This meant that freight had to be shipped through a goods station, sent by train and unloaded at another goods station for onward delivery to another factory. When lorries (trucks) replaced horses it was often economic and faster to make one movement by road. In the United States, particularly in the West and Mid-West towns developed with railway and factories often had direct rail connection. Despite the closure of many minor lines carload shipping from one company to another by rail remains common.

Railroads were early users of automatic data processing equipment, starting at the turn of the twentieth century with punched cards and unit record equipment. Many rail systems have turned to computerized scheduling and optimization for trains which has reduced costs and helped add more train traffic to the rails.

Freight railroads relationship with other modes of transportation varies widely. There is almost no interaction with airfreight, close cooperation with ocean-going freight and a mostly competitive relationship with long distance trucking and barge transport. Many businesses ship their products by rail if they are shipping long distance because it can be cheaper to ship in large quantities by rail than by truck; however barge shipping remains a viable competitor where water transport is available.

Freight trains are sometimes illegally boarded by individuals who do not wish, or do not have the money, to travel by ordinary means, a practice referred to as "hopping." Most hoppers sneak into train yards and stow away in boxcars. Bolder hoppers will catch a train "on the fly," that is, as it is moving, leading to occasional fatalities, some of which go unrecorded. The act of leaving a town or area by hopping a freight train is sometimes referred to as "catching-out", as in catching a train out of town.

Regional differences

Railroads are subject to the network effect: the more points they connect to, the greater the value of the system as a whole. Early railroads were built to bring resources, such as coal, ores and agricultural products from inland locations to ports for export. In many parts of the world, particularly the southern hemisphere, that is still the main use of freight railroads. Greater connectivity opens the rail network to other freight uses including non-export traffic. Rail network connectivity is limited by a number of factors, including geographical barriers, such as oceans and mountains, technical incompatibilities, particularly different track gauges and railway couplers, and political conflicts. The largest rail networks are located in North America and Eurasia. Long distance freight trains are generally longer than passenger trains, with greater length improving efficiency. Maximum length varies widely by system.

North America. Canada, Mexico and the United States are connected by an extensive, unified standard gauge rail network. The one notable exception is the isolated Alaska Railroad, which is connected to the main network by rail barge.

Rail freight is well standardized in North America, with Janney couplers and compatible air brakes. The main variations are in loading gauge and maximum car weight. Most trackage is owned by private companies that also operate freight trains on those tracks. Since the Staggers Rail Act of 1980, the freight rail industry in the U.S. has been largely deregulated. Freight cars are routinely interchanged between carriers, as needed, and are identified by company reporting marks and serial numbers. Most have computer readable automatic equipment identification transponders. With isolated exceptions, freight trains in North America are hauled by diesel locomotives, even on the electrified Northeast Corridor.

Ongoing freight-oriented development includes upgrading more lines to carry heavier and taller loads, particularly for double-stack service, and building more efficient intermodal terminals and transload facilities for bulk cargo. Many railroads interchange in Chicago, and a number of improvements are underway or proposed to eliminate bottlenecks there. The U.S. Rail Safety Improvement Act of 2008 mandates eventual conversion to Positive Train Control signaling.

The Guatemala railroad is currently inactive, preventing rail shipment south of Mexico. Panama has freight rail service, recently converted to standard gauge, that parallels the Panama Canal. A few other rail systems in Central America are still in operation, but most have closed. There has never been a rail line through Central America to South America, but a connection, FERISTSA, from Mexico to Panama, has been proposed in the past.

Eurasia. There are four major interconnecting rail networks on the Eurasian land mass, along with other smaller national networks.

- Most countries in the European Union participate in a standard-gauge network. The United Kingdom is linked to this network via the Channel Tunnel. The Marmaray project connects Europe with eastern Turkey, Iran, and the Middle East via a rail tunnel under the Bosphorus. The 57-km Gotthard Base Tunnel will improve north-south rail connections when it opens in 2016. Spain and Portugal are mostly broad gauge, though Spain has built some standard gauge lines that connect with the European high-speed passenger network. A variety of electrification and signaling systems is in use, though this is less of an issue for freight; however, overhead electrification prevents double-stack service on most lines. Buffer-and-screw couplings are generally used between freight vehicles, although there are plans to develop an automatic coupler compatible with the Russian SA3. *See* Railway coupling conversion.
- The countries of the former Soviet Union, along with Finland and Mongolia, participate in a Russian gauge-compatible network, using SA3 couplers. Major lines are electrified. Russia's Trans-Siberian Railroad connects Europe with Asia, but does not have the clearances needed to carry double-stack containers.
- China has an extensive standard-gauge network. Its freight trains use Janney couplers.
- India and Pakistan operate extensive broad gauge networks. India also has substantial metre gauge trackage, but it has a Project Unigauge to convert much to broad gauge. Indo-Pakistani wars and conflicts currently restrict rail traffic between the two countries to two passenger lines. There are also links to Bangladesh and Nepal. Broad gauge enables Indian Railways to operate double stack service without the use of the special well cars needed elsewhere.

The four major Eurasian networks link to neighboring countries and to each other at several break of gauge points. Containerization has facilitated greater movement between networks, including a Eurasian Land Bridge.

South America. Brazil has a large rail network, mostly metre gauge, with some broad gauge. It runs some of the heaviest iron ore trains in the world on its metre gauge network.

Chile and Argentina have Indian gauge networks in the south and metre gauge networks in the north. The metre gauge networks are connected at one point, but there has never been a broad gauge connection. (A metre-gauge connection between the two broad gauge networks, the Transandine Railway was constructed but is not currently in service. *See also Trans-Andean railways*.) Most other countries have few rail systems, if any.

Africa. The railways of Africa were mostly started by colonial powers to bring inland resources to port. There was little regard for eventual interconnection. As a result, there are a variety of gauge and coupler standards in use. A 3 ft 6 in (1,067 mm) gauge network with Janney couplers serves southern Africa. East Africa uses metre gauge. North Africa uses standard gauge, but potential connection to the European standard gauge network is blocked by the Arab-Israeli conflict.

Oceania. Rail developed independently in different parts of Australia and, as a result, three major rail gauges are in use. A standard gauge Trans-Australian Railway spans the continent.

Bulk cargo

Bulk cargo constitutes the majority of tonnage carried by most freight railroads. Bulk cargo is commodity cargo that is transported unpackaged in large quantities. These cargo are usually dropped or poured, with a spout or shovel bucket, as a liquid or solid, into a railroad car. Liquids, such as petroleum and chemicals, and compressed gases are carried by rail in tank cars.

Hopper cars are freight cars used to transport dry bulk commodities such as coal, ore, grain, track ballast, and the like. This type of car is distinguished from a gondola car (US) or open wagon (UIC) in that it has opening doors on the underside or on the sides to discharge its cargo. The development of the hopper car went along with the development of automated handling of such commodities, with automated loading and unloading facilities. There are two main types of hopper car: open and covered; Covered hopper cars are used for cargo that must be protected from the elements (chiefly rain) such as grain, sugar, and fertilizer. Open cars are used for commodities such as coal, which can get wet and dry out with less harmful effect. Hopper cars have been used by railways worldwide whenever automated cargo handling has been desired. Rotary car dumpers simply invert the car to unload it, and have become the preferred unloading technology, especially in North America; they permit the use of simpler, tougher, and more compact (because sloping ends are not required) gondola cars instead of hoppers.

Heavy-duty ore traffic

The heaviest trains in the world carry bulk traffic such as iron ore and coal. Loads can be 130 tonnes per wagon and tens of thousands of tonnes per train. Daqin Railway transports more than 1 million tonnes of coal to the east sea shore of China every day and in 2009 is the busiest freight line in the world[15] Such economies of scale drive down operating costs. Some freight trains can be over 7 km long.

Containerization

Containerization is a system of intermodal freight transport using standard shipping containers (also known as 'ISO containers' or 'isotainers') that can be loaded with cargo, sealed and placed onto container ships, railroad cars, and trucks. Containerization has revolutionized cargo shipping. As of 2009 approximately 90% of non-bulk cargo worldwide is moved by containers stacked on transport ships; 26% of all container transshipment is carried out in China. As of 2005, some 18 million total containers make over 200 million trips per year.

Use of the same basic sizes of containers across the globe has lessened the problems caused by incompatible rail gauge sizes in different countries by making transshipment between different gauge trains easier.

While typically containers travel for many hundreds or even thousands kilometers on the railway, Swiss experience shows that with properly coordinated logistics, it is possible to operate a viable intermodal (truck + rail) cargo transportation system even within a country as small as Switzerland.

Double-stack containerization

Most flatcars (US) or flat wagons (UIC) cannot carry more than one standard 40-foot (12.2 m) container on top of another because of limited vertical clearance, even though they usually can carry the weight of two. Carrying half the possible weight is inefficient. But if the rail line has been built with sufficient vertical clearance, a double-stack car can accept a container and still leave enough clearance for another container on top. This usually precludes operation of double-stacked wagons on lines with overhead electric wiring. China runs double stack trains with overhead wiring, but does not allow two maximum height containers to be stacked.

In the United States, Southern Pacific Railroad (SP) with Malcom McLean came up with the idea of the first double-stack intermodal car in 1977. SP then designed the first car with ACF Industries that same year. At first it was slow to become an industry standard, then in 1984 American President Lines started working with the SP and that same year, the first all "double stack" train left Los Angeles, California for South Kearny, New Jersey, under the name of "Stacktrain" rail service. Along the way the train transferred from the SP to Conrail. It saved shippers money and now accounts for almost 70 percent of intermodal freight transport shipments in the United States, in part due to the generous vertical clearances used by U.S. railroads. These lines are diesel operated with no overhead wiring.

Double stacking is also used in Australia between Adelaide, Parkes, Perth and Darwin. These are diesel only lines with no overhead wiring. Saudi Arabian Railways use double-stack in its Riyadh-Damman corridor. Double stacking is used in India for selected freight-only lines.

Rolling highways and piggy back service

In some countries rolling highway, or rolling road, trains are used; trucks can drive straight onto the train and drive off again when the end destination is reached. A system like this is used on the Channel Tunnel between the United Kingdom and France, as well as on the Konkan Railway in India. In other countries, the tractor unit of each truck is not carried on the train, only the trailer.

Piggy back trains are common in the United States, where they are also known as *trailer on flat car* or TOFC trains, but they have lost market share to containers (COFC), with longer, 53-foot containers frequently used for domestic shipments. There are also roadrailer vehicles, which have two sets of wheels, for use in a train, or as the trailer of a road vehicle.

Special cargo

Several types of cargo are not suited for containerization or bulk; these are transported in special cars custom designed for the cargo.

- Automobiles are stacked in open or closed autoracks, the vehicles being driven on or off the carriers.
- Steel plates are transported in modified gondolas called coil cars.
- Goods that require certain temperatures during transportation can be transported in refrigerator cars (or reefers - US) or refrigerated vans (UIC), but refrigerated containers are becoming more dominant.
- Center beam flat cars are used to carry lumber and other building supplies.
- Extra heavy and oversized loads are carried in Schnabel cars

Rail transportation refer to the movement of on guideways. The most common guideways are rails, but recent technological developments have also made available monorails as was as magnetic levitation trains. Although primitive rail systems existed by the 17th century to move materials in quarries and mines, it is not until the early 19th century that the first real rail transportation systems came into existence. Rail transportation has been the product of the industrial era, playing a major role in the **economic development** of Western Europe, North America and Japan, where such systems were first massively implemented. It represented a major improvement in land transport technology and has obviously introduced important changes in the movement of freight and passengers. This was not necessarily because of its capacity to carry heavy loads, since maritime transportation excelled at doing so, but because of its higher level of ubiquity and its speed. Rail transport systems dramatically improved travel time as well as the possibility to offer **reliable and consistent schedules** that could be included in the planning of economic activities such as production and distribution. The coherence of economic activities and social interactions was thus substantially improved.

With the introduction of the steam locomotive in 1829, a mechanized land transport system became available for the first time. However, geography played an important role in the nature and function of the first rail systems. According to the geographical settings, rail lines were established differently because of the variety of strategies to be achieved, namely access to resources (penetration lines), servicing regional economies (regional networks) and to achieve territorial control (transcontinental lines). The first rail lines to be built were portage segments within canal systems or routes aiming at complementing existing canals and filling their service gaps. Because of its cost and time advantages, rail was able to supplant canal services in inland transportation to become the main driver of spatial change in industrializing regions of the world.

The capital intensiveness of building and operating rail services required the setting of corporations. The first railway companies were mainly point to point ventures with the company often taking the name of the serviced destinations. As the rail system expanded, several mergers took place, which lead to rather peculiar semantic results. For instance BNSF Railway (Burlington Northern Santa Fe; the company uses the acronym to avoid confusion), a major rail operator in the western part of the United States, is the outcome of some 390 different railroad lines that merged or were acquired over a period of more than 150 years.

Rail transportation is characterized by a high level of economic and territorial control since most rail companies are operating in situation of monopoly, as in Europe, or oligopoly, as in North America where seven large rail freight carriers control and operate large networks. Operating a rail system involves using regular (scheduled), but rigid, services. Rail transportation, like roads, has an important relationship with space, since it is the transport mode the most constrained by the physiography. These constraints are mainly technical and operational:

- **Space consumption**. Rail transportation has a low level of space consumption along lines, but its terminals are can occupy large portions of real estate, especially in urban areas. This increases operation costs substantially. Still, rail terminals tend to be centrally located and accessible. A major issue concerns rights of way that represent a significant sunk costs for rail, which has fixed the network structure and impede future developments because of the difficulty of securing them along corridors.
- **Gradient and turns**. Rail transport is particularly susceptible to the heterogeneity of the geography, which imposes constraints such a gradient and track alignment. Rail transportation can support a gradient of up to 4% (e.g. 40 meters per kilometer), but freight trains rarely tolerate more than 1%. This implies that an operational freight rail line requires 50 kilometers to climb 500 meters. Gradient are also important as they involve more energy consumption, particularly for freight trains traveling over long distances. For turns, the minimal curvature radius is 100 meters, but radiuses of 1 km for a speed of 150 km/hr and 4 km for a speed of 300 km/hr are needed.
- **Vehicles**. For traction, the locomotion technology ranges from steam (almost abandoned), to diesel (mainly for freight in the United States) and electric (mainly for passengers in Europe). Rail transportation is very flexible in terms of vehicles and there is a wide variety of them filling different purposes. Among the most common vehicle assets are open wagons (hopper cars) used for bulk cargo (e.g. minerals), box cars to carry general and refrigerated goods, and tank cars to carry liquids. Intermodal transportation has also permitted the development of a new class of flat railcars that can carry containers and trailers (less common). The recent trend has thus been towards a specialization of freight wagons, such as hopper wagons (grain, potash and fertilizers), triple hopper wagons (sand, gravel, sulfur and coal), flat wagons (wood, agricultural equipment, manufactured goods, containers), tanker wagons (petrochemical products), box wagons (livestock, paper, manufactured goods, refrigerated goods), car wagons and passengers wagons (first class, second class, third class cabins, sleeper cars, restaurant cars).

- **Gauge**. They are heterogeneous across jurisdictions since because of historical and political reasons, different nations and regions have adopted different gauges. The standard gauge of 1.435 meters has been adopted in many parts of the world, across North America and most of Western Europe for example. It accounts for about 60% of the railways. But other gauges have been adopted in other areas, such as the broad gauge (1.520 meters) in Russia and Eastern Europe accounting for about 17% of the railways. This makes the integration of rail services complex, since both freight and passengers are required to change from one railway system to the other. As attempts are being made to extend rail services across continents and regions, this is an important obstacle, as for example between France and Spain, Eastern and Western Europe, and between Russia and China. The potential of the Eurasian land bridge is impaired in part by these gauge differences.
- **Network structure**. Relates to the ownership of tracks and rolling stock, maximum train length, signaling equipment, maintenance schedule and the traffic mix. These factors will influence the capacity of the rail system, particularly if well managed. When tracks are privately owned, the operator is free to allocate its services without much competitive hindrance. However, if the tracks are publically owned, they are often reserved for a national rail carrier or service slots are leased to private operators through a bidding process.

Other factors that inhibit the movement of trains between different countries include signaling and electrification standards. These are particular problems for the European Union where the lack of interoperability of the rail systems between the member states is a factor limiting the wider use of the rail mode. There is also a trend where the passengers and freight markets are being separated. First, it is occurring at the management level. The liberalization of the railway system that is being forced by the European Commission is resulting in the separation of passenger and freight operations. This had already taken place in the UK when British Rail was privatized. Second, the move towards high speed passenger rail services necessitated the construction of separate rights of way for the high speed trains. This has tended to move passenger train services from the existing tracks, thereby opening up more daytime slots for freight trains. Third, the Dutch completed in 2007 a freight only track, the Betuwe Line, from the port of Rotterdam to the German border, having already sold the freight business of the Netherlands railway (NS) to DB, and having opened up the freight business to other firms.

3. The Spatial Economy of Rail Transportation

The ability of trains to haul large quantities of goods and significant numbers of people over long distances is the mode's primary asset. Overall, rail transportation is more efficient than road transportation, although its main drawback is flexibility as traffic must follow fixed routes and transshipment must be done at terminals. Once the cars have been assembled or the passengers have boarded, trains can offer a high capacity service at a reasonable speed (with some high speed systems). It was this feature that led to the train's pre-eminence in opening the interior of the continents in the 19th century, and is still its major asset.

With containerized unit trains, economies of scale can readily be achieved while road have limited ability to benefit from this advantage. Each additional container being carried by road involves the same marginal cost increase, while for rail there is a declining marginal cost per additional container until the unit train size is reached. The same applies to passengers as for road transportation, an additional movement usually involves an additional vehicle, while for rail there is declining marginal costs as a passenger train gets filled. Passenger service is thus effective where population densities are high.

Freight traffic is dominated by bulk cargo shipments, agricultural and industrial raw materials in particular. Rail transport is a greener inland mode, in that its consumption of energy per unit load per km is lower than road modes.

The **initial capital costs of rail are high** because the construction of rail tracks and the provision of rolling stock are expensive. Historically, the investments have been made by the same source (either governments or the private sector). These expenditures have to be made before any revenues are realized and thus represent important entry barriers that tend to limit the number of operators. It also serves to delay innovation, compared with road transport, since rail rolling stock has a service life of at least twenty years. This can also be an advantage since the rolling stock is more durable and offer better opportunities at amortization. On average, rail companies need to invest about 45% of their operating revenues each year in capital and maintenance expenses of their infrastructure and equipment.

Capital expenditures alone account for about 17% of revenue, while this share is around 3 to 4% for manufacturing activities. One successful strategy to deal with high capital expenditures has been the setting of equipment pools such as TTX in North America that account for about 70% of the intermodal railcar assets used by North American rail companies.

Since the end of the 1950s, railway systems in advanced economies have faced an increasing competition from road transport, with varying results. In all cases, the breakeven distance, which is a threshold above which rail becomes most cost effective than road, was changed to the advantage of road transport. The more efficient road transport became, the higher its breakeven distance. In the current context, the breakeven distance between intermodal rail and truck is between 600 and 800 miles (950 and 1,300 km). Under 500 miles (800 km), drayage costs from the terminal usually account for 70% of total costs.

In several countries such as China, India, and Japan, rail transportation accounts for the majority of interurban passenger transportation. Among developed countries, there are acute geographical differences in the economic preference of rail transportation.

For Europe, China and Japan rail transportation is still very important, mainly for passenger transportation, but has declined over the last decades. High-speed passenger rail projects are however improving its popularity, but the competition was mainly being felt on air transportation services rather than road transport. For North America, rail transportation is strictly related to freight, with passengers playing a marginal role only along a few major urban corridors. Passenger trains are even getting delayed because priority is given to freight, impairing the reliability of the service. It is only in the northeastern part of the United States that passenger services are running on time since Amtrak (the federally owned passenger rail operator) owns the tracks.

Even if rail transportation was primarily developed to service national economies, globalization is having significant impacts on rail freight systems. These impacts are scale specific:

- At the **macro scale**, new long distance alternatives are emerging in the form of land bridges in North America and between Europe and Asia. In North America, rail has been very successful at servicing long distance intermodal markets, underlining the efficiency of rail over long distance and high volume flows.
- At the **meso scale**, the railway transportation network is influenced by the pattern of energy consumption. Many countries still rely overwhelmingly on foreign suppliers for their source of fuel while other are building major fuel moving transport arteries. Another important trend has been the growing integration of rail and maritime transport systems. Rail transportation has thus become the extension of maritime supply chains. A key issue is the concentration of investments in shaping rail corridors.
- At the **micro scale**, extended metropolitan regions reveals a specialization of rail traffic as well as a transfer of certain types of commodities from the rail network to the fluvial and road network systems. Railways servicing ports increasingly tend to concentrate container movements. This strategy followed by rail transport operators allows on the one hand, an increase in the delivery of goods and on the other hand, the establishment of door-to-door services through a better distribution of goods among different transport modes.

Rail freight services are also facing the challenge of improving their **reliability**, which leads to a fragmentation of the types of services being offered. For conventional rail freight markets such as coal, grain, forest products or chemicals, the priority has consistently been the provision of high capacity and low cost forms of transportation. However, these services were unreliable but could be easily accommodated by stockpiling, a strategy common in the resource sector (e.g. power plants, grain elevators). An emerging freight market for rail mostly concern intermodal services that require a much higher level of reliability, similar to what is expected in trucking. Commercial changes such as large volumes of retail import containerized cargo and just in time manufacturing require high reliability levels.

Financing. The main source of income for railway companies is from ticket revenue (for passenger transport) and shipment fees for cargo. Discounts and monthly passes are sometimes available for frequent travellers (e.g. season ticket and rail pass). Freight revenue may be sold per container slot or for a whole train. Sometimes, the shipper owns the cars and only rents the haulage. For passenger transport, advertisement income can be significant.

Governments may choose to give subsidies to rail operation, since rail transport has fewer externalities than other dominant modes of transport. If the railway company is state-owned, the state may simply provide direct subsidies in exchange for increased production. If operations have been privatized, several options are available. Some countries have a system where the infrastructure is owned by a government agency or company—with open access to the tracks for any company that meets safety requirements. In such cases, the state may choose to provide the tracks free of charge, or for a fee that does not cover all costs. This is seen as analogous to the government providing free access to roads. For passenger operations, a direct subsidy may be paid to a public-owned operator, or public service obligation tender may be helt, and a time-limited contract awarded to the lowest bidder. Total EU rail subsidies amounted to €73 billion in 2005.

Amtrak, the US passenger rail service, and Canada's Via Rail are private railroad companies chartered by their respective national governments. As private passenger services declined because of competition from automobiles and airlines, they became shareholders of Amtrak either with a cash entrance fee or relinquishing their locomotives and rolling stock. The government subsidizes

Amtrak by supplying start-up capital and making up for losses at the end of the fiscal year.

Safety

Fatality risk of passenger per mode of transport in European Union	
Transport mode used by user	Fatalities per billion passenger kilometers
Airline passenger	0.101
Railway passenger	0.156
Bus/Coach occupant	0.433
Car occupant	4.450
Powered two-wheelers	52.593

Fatality risk ratios for transports	Airline passenger	Railway passenger	Bus/Coach occupant	Car occupant	Powered two-wheelers
Powered two-wheelers	520	337	121	12	1
Car occupant	44	28.5	10	1	
Bus/Coach occupant	4.3	2.8	1		
Railway passenger	1.5	1			
Airline passenger	1				

Sources: Intermediate report on the development of railway safety in the Eropean Union, European Railway agency; EU transport in figures (Statistical Pocketbook 2012), DG MOVE 2012, European Commission

According to Eurostat and European Railway Agency, on European railways, there is a fatality risk for passengers and occupants 28 times lower compared with car usage. Based on data by EU-27 member nations, 2008-2010.

Trains can travel at very high speed, but they are heavy, are unable to deviate from the track and require a great distance to stop. Possible accidents include derailment (jumping the track), a collision with another train or collision with automobiles, other vehicles or pedestrians at level crossings. The last accounts for the majority of rail accidents and casualties. The most important safety measures to prevent accidents are strict operating rules, e.g. railway signalling and gates or grade separation at crossings. Train whistles, bells or horns warn of the presence of a train, while trackside signals maintain the distances between trains.

An important element in the safety of many high-speed inter-city networks such as Japan's Shinkansen is the fact that trains only run on dedicated railway lines, without level crossings. This effectively eliminates the potential for collision with automobiles, other vehicles or pedestrians, vastly reduces the likelihood of collision with other trains and helps ensure services remain timely.

Maintenance. As in any infrastructure asset, railways must keep up with periodic inspection and maintenance in order to minimize effect of infrastructure failures that can disrupt freight revenue operations and passenger services. Because passengers are considered the most *crucial cargo* and usually operate at higher speeds, steeper grades, and higher capacity/frequency, their lines are especially important. Inspection practices include track geometry cars or walking inspection. Curve maintenance especially for transit services includes gauging, fastener tightening, and rail replacement.

Rail corrugation is a common issue with transit systems due to the high number of light-axle, wheel passages which result in grinding of the wheel/rail interface. Since maintenance may overlap with operations, maintenance windows (nighttime hours, off-peak hours, altering train schedules or routes) must be closely followed. In addition, passenger safety during maintenance work (inter-track fencing, proper storage of materials, track work notices, hazards of equipment near states) must be regarded at all times. At times, maintenance access problems can emerge due to tunnels, elevated structures, and congested cityscapes. Here, specialized equipment or smaller versions of conventional maintenance gear are used.

Unlike highways or road networks where capacity is disaggregated into unlinked trips over individual route segments, railway capacity is fundamentally considered a network system. As a result, many components are causes and effects of system disruptions. Maintenance must acknowledge the vast array of a route's performance (type of train service, origination/destination, seasonal impacts), line's capacity (length, terrain, number of tracks, types of train control), trains throughput (max speeds, acceleration/deceleration rates), and service features with shared passenger-freight tracks (sidings, terminal capacities, switching routes, and design type).

Social, economical, and energetic aspects

Energy. Rail transport is an energy-efficient but capital-intensive, means of mechanized land transport. The tracks provide smooth and hard surfaces on which the wheels of the train can roll with a relatively low level of friction being generated. Moving a vehicle on and/or through a medium (land, sea, or air) requires that it overcomes resistance to its motion caused by friction. A land vehicle's total resistance (in pounds or Newtons) is a quadratic function of the vehicle's speed:

where:

R denotes total resistance

a denotes initial constant resistance

b denotes velocity-related constant

c denotes constant that is function of shape, frontal area, and sides of vehicle

v denotes velocity

v^2 denotes velocity, squared

Essentially, resistance differs between vehicle's contact point and surface of roadway. Metal wheels on metal rails have a significant advantage of overcoming resistance compared to rubber-tyred wheels on any road surface (railway – 0.001g at 10 miles per hour (16 km/h) and 0.024g at 60 miles per hour (97 km/h); truck – 0.009g at 10 miles per hour (16 km/h) and 0.090 at 60 miles per hour (97 km/h)). In terms of cargo capacity combining speed and size being moved in a day:

- human – can carry 100 pounds (45 kg) for 20 miles (32 km) per day, or 1 tmi/day (1.5 tkm/day)
- horse and wheelbarrow – can carry 4 tmi/day (5.8 tkm/day)
- horse cart on good pavement – can carry 10 tmi/day (14 tkm/day)
- fully utility truck – can carry 20,000 tmi/day (29,000 tkm/day)
- long-haul train – can carry 500,000 tmi/day (730,000 tkm/day) Most trains take 250–400 trucks off the road, thus making the road more safe.

In terms of the horsepower to weight ratio, a slow-moving barge requires 0.2 horsepower per short ton (0.16 kW/t), a railway and pipeline requires 2.5 horsepower per short ton (2.1 kW/t), and truck requires 10 horsepower per short ton (8.2 kW/t). However, at higher speeds, a railway overcomes the barge and proves most economical.

As an example, a typical modern wagon can hold up to 113 tonnes (125 short tons) of freight on two four-wheel bogies. The track distributes the weight of the train evenly, allowing significantly greater loads per axle and wheel than in road transport, leading to less wear and tear on the permanent way. This can save energy compared with other forms of transport, such as road transport, which depends on the friction between rubber tyres and the road. Trains have a small frontal area in relation to the load they are carrying, which reduces air resistance and thus energy usage.

In addition, the presence of track guiding the wheels allows for very long trains to be pulled by one or a few engines and driven by a single operator, even around curves, which allows for economies of scale in both manpower and energy use; by contrast, in road transport, more than two articulations causes fishtailing and makes the vehicle unsafe.

Energy efficiency. Considering only the energy spent to move the means of transport, and using the example of the urban area of Lisbon, electric trains seem to be on average 20 times more efficient than automobiles for transportation of passengers, if we consider energy spent per passenger-distance with similar occupation ratios. Considering an automobile with a consumption of around 6 l/100 km (47 mpg_{-imp}; 39 mpg_{-US}) of fuel, the average car in Europe has an occupancy of around 1.2 passengers per automobile (occupation ratio around 24%) and that one litre of fuel amounts to about 8.8 kWh (32 MJ), equating to an average of 441 Wh (1,590 kJ) per passenger-km. This compares to a modern train with an average occupancy of 20% and a consumption of about 8.5 kW·h/km (31 MJ/km; 13.7 kW·h/mi), equating to 21.5 Wh (77 kJ) per passenger-km, 20 times less than the automobile.

Usage. Due to these benefits, rail transport is a major form of passenger and freight transport in many countries. It is ubiquitous in Europe, with an integrated network covering virtually the whole continent. In India, China, South Korea and Japan, many millions use trains as regular transport. In North America, freight rail transport is widespread and heavily used, but intercity passenger rail transport is relatively scarce outside the Northeast Corridor, due to increased preference of other modes, particularly automobiles and airplanes.

South Africa, northern Africa and Argentina have extensive rail networks, but some railways elsewhere in Africa and South America are isolated lines.

Australia has a generally sparse network befitting its population density but has some areas with significant networks, especially in the southeast. In addition to the previously existing east-west transcontinental line in Australia, a line from north to south has been constructed. The highest railway in the world is the line to Lhasa, in Tibet, partly running over permafrost territory. Western Europe has the highest railway density in the world and many individual trains there operate through several countries despite technical and organizational differences in each national network.

Social and economic benefits. Railways are central to the formation of modernity and ideas of progress. Railways contribute to social vibrancy and economic competitiveness by transporting multitudes of customers and workers to city centres and inner suburbs. Hong Kong has recognized rail as "the backbone of the public transit system" and as such developed their franchised bus system and road infrastructure in comprehensive alignment with their rail services. China's large cities such as Beijing, Shanghai, and Guangzhou recognize rail transit lines as the framework and bus lines as the main body to their metropolitan transportation systems. The Japanese Shinkansen was built to meet the growing traffic demand in the "heart of Japan's industry and economy" situated on the Tokyo-Kobe line.

During much of the 20th century, rail was an invaluable element of military mobilization, allowing for the quick and efficient transport of large numbers of reservists to their mustering-points, and infantry soldiers to the front lines. However, by the 21st century, rail transport - limited to locations on the same continent, and vulnerable to air attack - had largely been displaced by the adoption of aerial transport.

Railways channel growth towards dense city agglomerations and along their arteries, as opposed to highway expansion, indicative of the U.S. transportation policy, which incents development of suburbs at the periphery, contributing to increased vehicle miles travelled, carbon emissions, development of greenfield spaces, and depletion of natural reserves. These arrangements revalue city spaces, local taxes, housing values, and promotion of mixed use development.

Modern rail as economic development indicator

European development economists have argued that the existence of modern rail infrastructure is a significant indicator of a country's economic advancement: this perspective is illustrated notably through the Basic Rail Transportation Infrastructure Index (known as BRTI Index).

4. Rail Terminals

The use of the transport capacity offered by rail transportation requires purposely designed terminals where passengers can embark and disembark and where freight can be transferred. Rail terminals, while not quite as space-extensive as airports and ports, suffer less from site constraints. This involves two major issues:

- **Location**. An important distinction concerns passengers and freight rail terminals, which commonly involve very different locations. Many rail terminals were established in the 19th century during the heyday of rail development. While sites may have been on the edge of urban areas at the time, decades of urban development, including residential and industrial areas, have surrounded older rail terminals, leaving limited opportunities for expansion. Passenger terminals tend to occupy central locations and are commonly the defining element of urban centrality while freight terminals have seen a growing separation from central locations, with new facilities often built in an exurban location, particularly for high speed train stations.
- **Setting**. Because of the linear characteristic of the mode they serve, rail terminals are dominantly rectangular shaped facilities. Their capacity is a function of the number of track spurs available, which is a characteristic difficult to change once the terminal has been built. Individually rail terminals may not be as extensive as airports or ports, but cumulatively the area of all the rail sites in a city

may exceed those of the other modes. For example, in Chicago the combined area of rail freight yards exceeds that of the airports.

Rail terminals have a unique characteristic related to shunting (or switching), which requires separate yard facilities often adjacent to the terminal and at times independent facilities. The wagons composing a train often need to be assembled or broken down in classification yards. This is particularly the case for freight trains that need to be assembled at their origin, switched at intermediary locations (if long distance hauling is concerned) and broken down at their destination. While this is less of an issue for passenger rail, as trains tend to remain assembled the way they are, shunting remains fundamental to rail operations.

Rail terminals have significant structuring and agglomeration effects that had an impact in urban land markets since their introduction. This implied related activities, such as retail, restaurants and hotels for passenger terminals or distribution centers for freight terminals. This is in part due to the accessibility they provide and in part because of the traffic they generate. Before the prominence of the automobile and trucking, economic activities tended to cluster around their respective rail terminals. Whole urban districts emerged around rail terminals. However, as the trucking industry matured and highway infrastructure was expanded and improved, rail terminals lost a great deal of their primacy. Even if rail transportation is generally more fuel-efficient than other modes, the mobility of passengers and freight quickly responded to the availability of the ubiquitous highway infrastructure.

Rail terminals were initially developed to complement the shortcomings of other modes, particularly to service gaps in fluvial (canal) and maritime transportation. In the second half of the 20th century, as rail passenger traffic declined, the need for many rail stations diminished, particularly in North America. A rationalization has resulted in the conversion of many stations to other uses, sometimes with striking effects, such as the Musee D’Orsay in Paris and Windsor Station in Montreal. Rail yard conversion has been less spectacular, partly because the sites are less interesting from an architectural standpoint, but nonetheless important. Many former downtown freight facilities have been completely redeveloped in residential developments or commercially. Indeed, the CN Tower-Skydome complexes in Toronto are on former rail land. In other cases, yards can be converted to related activities such as warehouses or even urban logistics centers.

The current setting of rail systems underlines an almost complete separation between rail passenger and freight terminals. Although they can share access to the same rail network they service completely different mobility requirements. Any proximity between passengers and freight terminals tends to be coincidental.

Passengers Terminals

Passenger rail terminals tend to be functionally simple facilities and in their most basic form, they include a quay for passengers to embark or disembark and a common area for ticket purchase, waiting, and for activities servicing large volumes of passengers (e.g. retail and restoration). While some are along a line that requires a stop of a few minutes so that passengers can embark or disembark, others are terminal locations at the head of an intercity corridor. Like any other terminal facility, rail terminals have a size and complexity directly related to the amount of passengers they service. There is a hierarchy of the importance of passenger rail terminals which is illustrated in the rail network structure. It ranges from simple stops with only a platform available for passengers to embark or disembark to central rail stations composed of enclosed facilities with multiple piers and amenities.

Central railway stations are typically in the heart of downtown cores and primary elements of national or regional passenger rail systems. At one time their sites may have been on the edge of the pre-industrial city, as is the case for London and Paris urban growth and the shift of commercial and business activity have conferred many with an important central function. These stations are typically imposing buildings reflecting the power and importance represented by the railway in the 19th and 20th centuries. For many cities, railway stations are the key elements of urban centrality and activity and represent an impressive architectural achievement unmatched in any other type of transportation terminal and occupying a large amount of real estate. Notable examples include the Grand Central Station in New York, St. Pancras station in London, the Gare de Lyon in Paris, or the Shinjuku train station in Tokyo, which is the world's busiest with more that 3.5 million people per day. Since many central rail stations handle large amounts of commuters, that also tend to be the nexus of public transit systems as subway stations are directly connected to the terminal facility. Even if in several cases, particularly in North America, the long distance function has subsided, the imprint of passenger rail terminals on the structure of urban transit systems has endured.

Still, the development of high speed rail systems has offered new opportunities for rail terminals with the renovation of existing facilities, many of which central railway stations, or the construction of new facilities in suburban areas. The centrality of rail stations became a positive factor in the development of high speed rail systems as it confers a direct accessibility to core business activities. In many cases the high speed rail station has become a new nexus of activity with co-located real estate development such as office buildings, retail stores, hotels and parking facilities. An additional level of integration concerns the design of airport terminals with high speed train stations, such as the case of Charles de Gaulle (Paris), Schiphol (Amsterdam) and Pudong (Shanghai), which enables to connect long distance air travel with regional accessibility. Over specific corridors in France, Spain and Germany, high speed rail stations are effectively competing with airports. Some air carriers such as Air France and Lufthansa are starting to offer services that include a rail segment, implying that the train station becomes a proxy for the airport. In some instances, such as Hong Kong, a centrally located public transit station servicing an airport terminal with a rail connection (light or heavy rail) and offer ticket and luggage check-in services.

A better integration between passenger rail and air transportation therefore enables substitution of air travel and the possibility to use satellite airport terminals. This is linked with new forms of airport competitiveness.

Freight Terminals

Unlike passenger terminals, rail freight yards did not have to be quite so centrally located, and because they required a great deal of space for multiple tracks for marshaling they were more likely located on entirely greenfield sites than passenger terminals. However, rail yards tended to attract manufacturing activities able to use the distribution capabilities of rail, and thus became important industrial zones. When dealing with bulk commodities, rail terminals will locate in proximity of the source as they are the main mean for these commodities to be shipped to markets. They also vary in complexity because of the different freight markets they service (e.g. grain, coal, cars, containers) which requires specialized loading/unloading facilities and equipment. Rail freight terminals perform four major functions:

- **Bulk**. These rail terminals are linked with extractive industries such as agriculture, mining and wood products. Terminals are generally designed to be commodity specific. For instance, grain elevators are bulk terminals commonly used to store, mix and load grain into railcars. Another important characteristic of bulk rail terminals is their unidirectional flows, implying that they are designed specifically to either load or unload bulk. Rail terminals doing both are uncommon. This is reflective of the nature of bulk trades.
- **Roll on / roll off**. Used to transport vehicles such as cars, trucks or construction equipment where the vehicles are rolled in a railcar using a ramp. Such terminals commonly require a large amount of parking space to store vehicles, particularly if they concern cars bound for retail outlets and many serve as storage facilities supplying regional markets.
- **Break bulk**. Involves the handling of various cargoes that can be bagged, in drums, rolls or crates. They are commonly related to a specific activity such as a manufacturing plant or a warehouse handling break-bulk cargo and serviced by dedicated rail spurs. Containerization has reduced the need for break bulk terminals.
- **Intermodal**. The function of loading and unloading unitized freight from railcars. Containerization has greatly expanded the intermodal productivity of

rail terminals since it permits quick loading and unloading sequences, but at the expense of more trackside space available. Depending on the type of operation, specific intermodal equipment will be used. Intermodal terminal can be part of a port facility (on-dock or near-dock facilities) or being a stand alone inland terminal.

- **Shunting**. The function of assembling, sorting and breaking of freight trains. Since trains can be composed of up to about 100 railcars (even more in North America), often of various nature, origin and destination, shunting can be a complex task performed on several occasions. Comparatively, unit trains which carry the same commodity, such as coal, cars or containers, require little shunting. Bailey yard in North Platte Nebraska, operated by Union Pacific, is the largest classification yard in the world and handles 10,000 railcars per day. Shunting also takes place for passenger trains, but less common since once a passenger train has been assembled, it will remain as such a period of time.

The first forms of intermodal application to rail appeared in the late 19th century with practices dubbed "circus trains" because lorries were rolled in on flatcars using a ramp, a practice that was pioneered by circuses (Barnum in 1872). This simple ramp-based technique enabled many rail terminals to become "intermodal" by offering "piggy back" services. By the end of the 20th century many of the industries around rail freight yards had relocated or disappeared, and in many cities these former industrial parks have been targets of urban revitalization. At the same time, new intermodal practices emerged, notably lifting trailers or containers directly onto a flatcar. However, this required capital investments in intermodal equipment as well as paved terminal surfaces for storage. Only terminals with sufficient size and volume could be profitable. This has been accompanied by closure of some of the rail yards, either because they were too small for contemporary operating activities, or because a reduction of the local traffic base. In spite of a growth of intermodal traffic, the number of intermodal terminals declined, each covering an extensive market area of about one day of trucking.

In North America and Europe many older rail freight yards have been converted into intermodal facilities because of the burgeoning traffic involving containers and road trailers, a process which started in the 1960s. The ideal configuration for these terminals is different from the typical general freight facility with their need for multiple spurs to permit the assembling of wagons to form train blocks. The loading and unloading of wagons tended to be a manual process, often taking days, tying up terminal rail capacity. Retrofitting conventional rail yards for contemporary intermodal operations proved problematic. Intermodal trains tend to serve a more limited number of cities and are more likely to be dedicated to one destination. They offer the notable advantage of being able to be quickly loaded or unloaded, thus tying up less terminal rail capacity. They however need fewer but longer rail spurs. The configuration typically requires a site over three kilometers in length and over 100 hectares in area. In addition, good access to the highway system is a requisite as well as a degree of automation to handle the transshipment demands of modern intermodal rail operations.

One of the important growth factor of rail transportation has been its closer integration with maritime shipping. This is particularly the case at port terminals with new on-dock container rail facilities. The term "on-dock" can itself be a misleading since a direct ship-to-rail transshipment actually rarely takes place. A dray carries the container from alongside the ship to alongside the rail track (and vice versa), but frequently the containers are brought back and forth from a stack.

Transloading, the practice of transferring loads between truck and rail transportation, has also experienced a remarkable growth in recent years. As long distance trucking is getting increasingly expensive due to growing energy costs and congestion, many shippers see the advantages of using rail transportation to a location in the vicinity of their markets. At this location, freight loads are broken down into LTL and then shipped by short distance trucks to their final destinations.

Former rail terminals and port sites have been among the most important redevelopment areas in most major urban centers. The redevelopment of old port sites, because of their scale (very large), location (adjacent to downtown), and sites (waterfront), have been at the forefront of the process. Their renovation has had a major influence on the surrounding regions. Many cities have experienced significant benefits from waterfront redevelopment in downtown revitalization and economic revival. Similar experiences have occurred in the United States (Boston, New York, Baltimore, San Francisco, Seattle), and Europe (London, Manchester, Bristol, Liverpool, Rotterdam).