Encyclopedia of Transportation

Shery Hinkle

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Email: info@wtbooks.com

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Introduction

Ximen Station of the Taipei Metro in Taiwan

People walking in front of the bulk carrier *BW Fjord*

French National Police use several modes of transport, each with their distinct advantages

Transport or **transportation** is the movement of people and goods from one location to another. Modes of transport include air, rail, road, water, cable, pipeline, and space. The field can be divided into infrastructure, vehicles, and operations.

Transport infrastructure consists of the fixed installations necessary for transport, and may be roads, railways, airways, waterways, canals and pipelines, and terminals such as airports, railway stations, bus stations, warehouses, trucking terminals, refueling depots (including fueling docks and fuel stations), and seaports. Terminals may be used both for interchange of passengers and cargo and for maintenance.

Vehicles traveling on these networks may include automobiles, bicycles, buses, trains, trucks, people, helicopters, and aircraft. Operations deal with the way the vehicles are operated, and the procedures set for this purpose including financing, legalities and policies. In the transport industry, operations and ownership of infrastructure can be either public or private, depending on the country and mode.

Passenger transport may be public, where operators provide scheduled services, or private. Freight transport has become focused on containerization, although bulk transport is used for large volumes of durable items. Transport plays an important part in economic growth and globalization, but most types cause air pollution and use large amounts of land. While it is heavily subsidized by governments, good planning of transport is essential to make traffic flow, and restrain urban sprawl.

Mode

A mode of transport is a solution that makes use of a particular type of vehicle, infrastructure and operation. The transport of a person or of cargo may involve one mode or several modes, with the latter case being called intermodal or multimodal transport. Each mode has its advantages and disadvantages, and will be chosen for a trip on the basis of cost, capability, route, and speed.

Function

Relocation of travelers and cargo are the most common uses of transport. However, other uses exist, such as the strategic and tactical relocation of armed forces during warfare, or the civilian mobility construction or emergency equipment.

Borivali station platform numbers 3 and 4 during peak hours (8-9 a.m.). Note the crowd waiting on the left platform. From this platform trains depart for Churchgate, where the offices are located. Location: Borivali Station, Mumbai, India

A local transit bus operated by ACTION in Canberra, Australia

Passenger

Passenger transport, or travel, is divided into public and private transport. Public is scheduled services on fixed routes, while private is vehicles that provide ad hoc services at the riders desire. The latter offers better flexibility, but has lower capacity, and a higher environmental impact. Travel may be as part of daily commuting, for business, leisure or migration.

Short-haul transport is dominated by the automobile and mass transit. The latter consists of buses in rural and small cities, supplemented with commuter rail, trams and rapid transit in larger cities. Long-haul transport involves the use of the automobile, trains, coaches and aircraft, the last of which have become predominantly used for the longest, including intercontinental, travel. Intermodal passenger transport is where a journey is performed through the use of several modes of transport; since all human transport normally starts and ends with walking, all passenger transport can be considered intermodal. Public transport may also involve the intermediate change of vehicle, within or across modes, at a transport hub, such as a bus or railway station.

Taxis and Buses can be found on both ends of Public Transport spectrum, whereas Buses remain the cheaper mode of transport but are not necessarily flexible, and Taxis being very flexible but more expensive. In the middle is Demand responsive transport offering flexibility whilst remaining affordable.

International travel may be restricted for some individuals due to legislation and visa requirements.

Freight

Freight transport, or shipping, is a key in the value chain in manufacturing. With increased specialization and globalization, production is being located further away from consumption, rapidly increasing the demand for transport. While all modes of transport are used for cargo transport, there is high differentiation between the nature of the cargo transport, in which mode is chosen. Logistics refers to the entire process of transferring products from producer to consumer, including storage, transport, transshipment, warehousing, material-handling and packaging, with associated exchange of information. Incoterm deals with the handling of payment and responsibility of risk during transport.

Freight train with shipping containers in the United Kingdom.

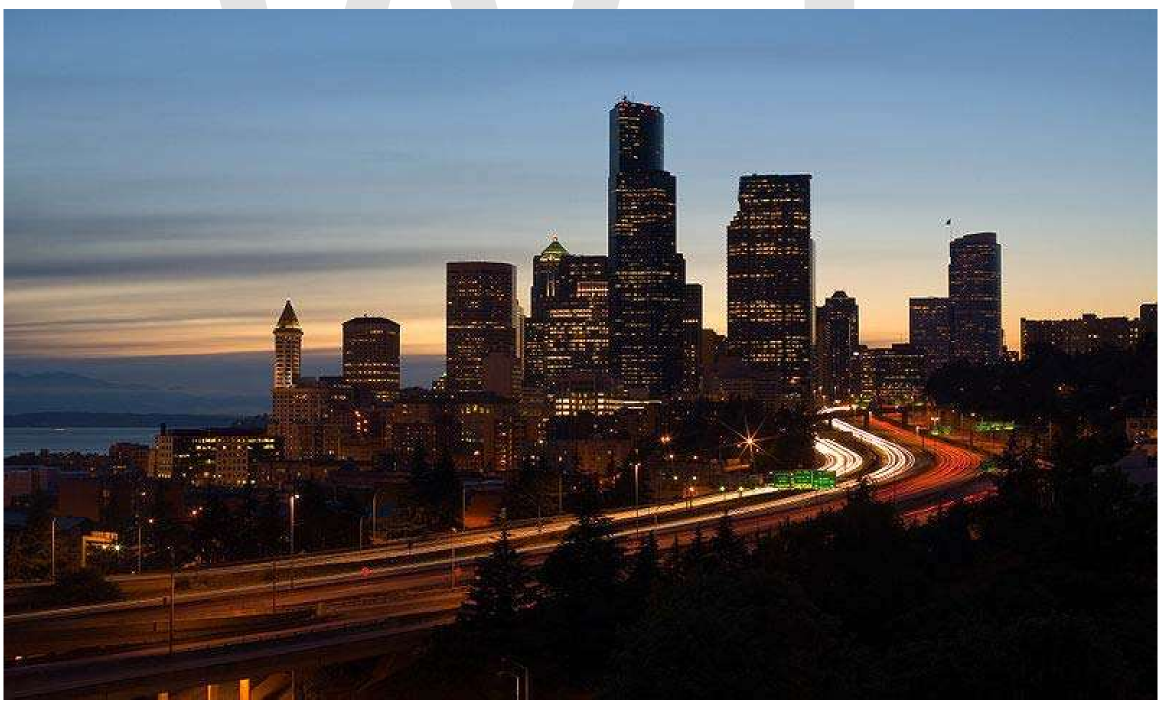
Containerization, with the standardization of ISO containers on all vehicles and at all ports, has revolutionized international and domestic trade, offering huge reduction in transshipment costs. Traditionally, all cargo had to be manually loaded and unloaded into the haul of any ship or car; containerization allows for automated handling and transfer between modes, and the standardized sizes allow for gains in economy of scale in vehicle operation. This has been one of the key driving factors in international trade and globalization since the 1950s.

Bulk transport is common with cargo that can be handled roughly without deterioration; typical examples are ore, coal, cereals and petroleum. Because of the uniformity of the product, mechanical handling can allow enormous quantities to be handled quickly and efficiently. The low value of the cargo combined with high volume also means that economies of scale become essential in transport, and gigantic ships and whole trains are commonly used to transport bulk. Liquid products with sufficient volume may also be transported by pipeline.

Air freight has become more common for products of high value; while less than one percent of world transport by volume is by airline, it amounts to forty percent of the value. Time has become especially important in regards to principles such as postponement and just-in-time within the value chain, resulting in a high willingness to pay for quick delivery of key components or items of high value-to-weight ratio. In addition to mail, common items send by air include electronics and fashion clothing.

Impact

Economic



Transport is a key component of growth and globalization, such as in Seattle, United States

Transport is a key necessity for specialization—allowing production and consumption of products to occur at different locations. Transport has throughout history been a spur to expansion; better transport allows more trade and a greater spread of people. Economic growth has always been dependent on increasing the capacity and rationality of transport. But the infrastructure and operation of transport has a great impact on the land and is the largest drainer of energy, making transport sustainability a major issue.

Modern society dictates a physical distinction between home and work, forcing people to transport themselves to places of work or study, as well as to temporarily relocate for other daily activities. Passenger transport is also the essence of tourism, a major part of recreational transport. Commerce requires the transport of people to conduct business, either to allow face-to-face communication for important decisions or to move specialists from their regular place of work to sites where they are needed.

Planning

Transport planning allows for high utilization and less impact regarding new infrastructure. Using models of transport forecasting, planners are able to predict future transport patterns. On the operative level, logistics allows owners of cargo to plan transport as part of the supply chain. Transport as a field is studied through transport economics, the backbone for the creation of regulation policy by authorities. Transport engineering, a sub-discipline of civil engineering, and must take into account trip generation, trip distribution, mode choice and route assignment, while the operative level is handles through traffic engineering.

The engineering of this roundabout in Bristol, United Kingdom, attempts to make traffic flow free-moving

Because of the negative impacts made, transport often becomes the subject of controversy related to choice of mode, as well as increased capacity. Automotive transport can be seen as a tragedy of the commons, where the flexibility and comfort for the individual deteriorate the natural and urban environment for all. Density of development depends on mode of transport, with public transport allowing for better spacial utilization. Good land use keeps common activities close to peoples homes and places higher-density development closer to transport lines and hubs; minimize the need for transport. There are economies of agglomeration. Beyond transportation some land uses are more efficient when clustered. Transportation facilities consume land, and in cities, pavement (devoted to streets and parking) can easily exceed 20 percent of the total land use. An efficient transport system can reduce land waste.

Too much infrastructure and too much smoothing for maximum vehicle throughput means that in many cities there is too much traffic and many—if not all—of the negative impacts that come with it. It is only in recent years that traditional practices have started to be questioned in many places, and as a result of new types of analysis which bring in a much broader range of skills than those traditionally relied on—spanning such areas as environmental impact analysis, public health, sociologists as well as economists who increasingly are questioning the viability of the old mobility solutions. European cities are leading this transition.

Environment

Traffic congestion persists in São Paulo, Brazil despite the no-drive days based on license numbers.

Transport is a major use of energy, and burns most of the world's petroleum. This creates air pollution, including nitrous oxides and particulates, and is a significant contributor to global warming through emission of carbon dioxide, for which transport is the fastest-growing emission sector. By subsector, road transport is the largest contributor to global warming. Environmental regulations in developed countries have reduced the individual vehicles emission; however, this has been offset by an increase in the number of vehicles, and more use of each vehicle. Some pathways to reduce the carbon emissions of road vehicles considerably have been studied. Energy use and emissions vary largely between modes, causing environmentalists to call for a transition from air and road to rail and human-powered transport, and increase transport electrification and energy efficiency.

Other environmental impacts of transport systems include traffic congestion and automobile-oriented urban sprawl, which can consume natural habitat and agricultural lands. By reducing transportation emissions globally, it is predicted that there will be significant positive effects on Earth's air quality, acid rain, smog and climate change.

Chapter-1

Human-powered and Animal-powered Transport

Human-powered Transport

Sherpa carrying wood to Mount Everest base camp

Human-powered transport is the transport of person(s) and/or goods using human muscle power. Like animal-powered transport, human-powered transport has existed since time immemorial in the form of walking, running and swimming. Modern technology has allowed machines to enhance human-power.

Although motorization has increased speed and load capacity, many forms of human-powered transport remain popular for reasons of lower cost, leisure, physical exercise and environmentalism. Human-powered transport is sometimes the only type available, especially in underdeveloped or inaccessible regions.

Available muscle power

Road cyclist

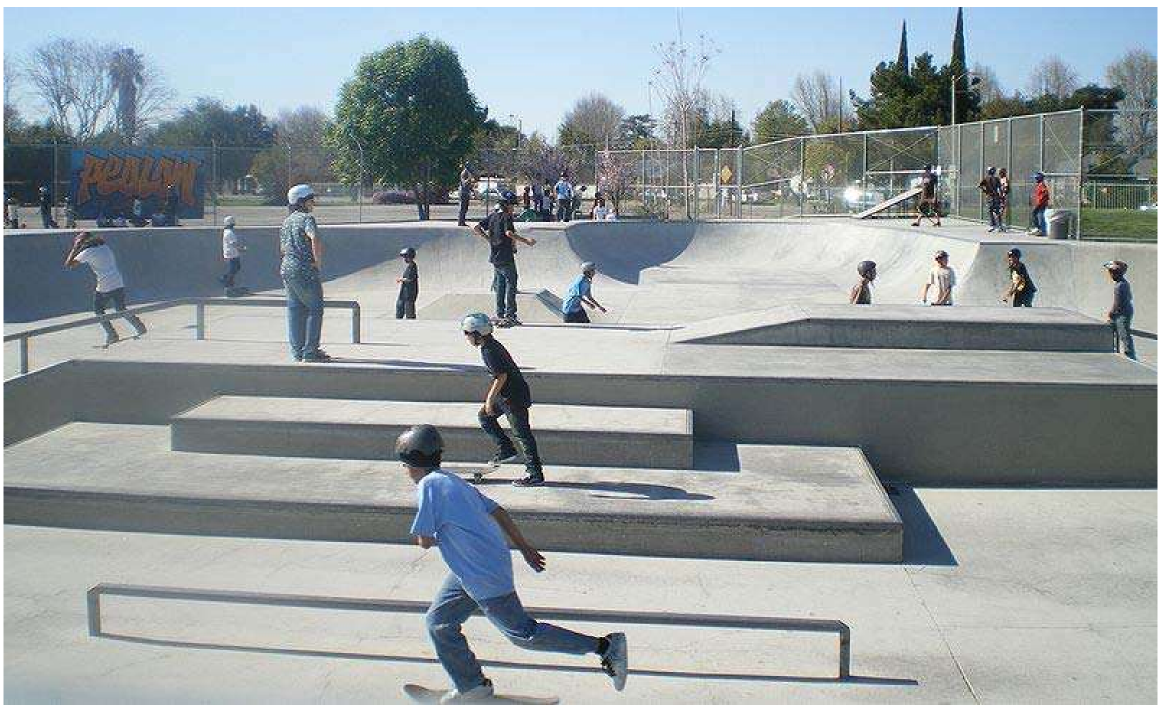
In the 1989 Race Across America, one team (Team Strawberry) used an experimental device that consisted of a rear wheel hub, a sensor and a handlebar mounted processor. The device measured each cyclist's power output in watts. In lab experiments an average "in-shape" cyclist can produce about 3 watts/kg for more than an hour (e.g., around 200 watts for a 70 kg rider), with top amateurs producing 5 watts/kg and elite athletes achieving 6 watts/kg for similar lengths of time. Elite track sprint cyclists are able to attain an instantaneous maximum output of around 2,000 watts, or in excess of 25 watts/kg; elite road cyclists may produce 1,600 to 1,700 watts as an instantaneous maximum in their burst to the finish line at the end of a five-hour long road race.

Modes

Non-vehicular

- Crawling
- Walking (240 watts)
- Running (1000 watts)
- Sprinting (1700 watts at 25 km/h)
- Swimming and diving
- Climbing as in mountaineering and abseiling

Human-powered vehicles (HPV)



The Skateboard is propelled by pushing it (one foot riding on board, one foot pushing on ground) or by the natural effects of gravity.

The Trikke works by shifting the rider's body weight.

- Canoeing and kayaking
- Caster Board
- Chariot skating
- Cross-country skiing
- Cycling using a bicycle, unicycle, tricycle, quadracycle, velomobile or similar wheeled vehicle, including collective variations such as tandem bicycle and side-car
- Draisine
- Handcycles
- Human-powered hydrofoil
- Ice skating
- Inline Skating
- Kick scooter
- Kicksled
- Human-powered aircraft
- Powerbocking
- Punting
- Roller skating
- Rowbike
- Rowing

- Skateboarding
- Trikke

Vehicles for transporting others

- Stretcher
- Travois
- Litters, e.g. Sedan chair
- Rickshaw
- Cycle rickshaw
- Handcar
- Bicycle
- Gondola
- Galley
- Gurney, for medical transport

Some of the vehicles also transport cargo and/or passengers.

Human-powered land vehicles

The bicycle is the most popular human-powered vehicle

Surrey style rental quadracycle built by the International Surrey Company

Human-powered land vehicles, such as the handcar (a human-powered railroad car), normally travel at ground level but can also travel above (for example, on a trestle) and below ground (such as when used in mining).

Skateboards have the advantage of being so small and light that users can easily carry them when not skating.

The most efficient human-powered land vehicle is the bicycle. Compared to the much more common upright bicycle, the recumbent bicycle may be faster on level ground or down hills due to better aerodynamics while having similar power transfer efficiency. In

2009, Sam Whittingham pedaled a streamliner (a fully-faired recumbent) for 200 m at 133.284 km/h (82.819 mph) in the Varna Tempest.

Velomobiles and cabin cycles are increasingly popular in colder and/or wetter countries due to the protection they offer against the environment. Freight bicycles are used as low-cost, zero-emission vehicles to haul cargo. Cycle rickshaws can be used as taxicabs.

Dutch cyclist, Fred Rompelberg set a 268.8 km/h (166.9 mph) speed record at the Bonneville Salt Flats in Utah on October 3, 1995 while cycling in the wake of a motor dragster pace-car. The wake of the pace-car reduced the aerodynamic drag against which Rompelberg pedalled to almost zero.

Greg Kolodziejzyk set two world records recognized by both the International Human Powered Vehicle Association and Guinness (TM) World Records on July 17, 2006 on a race track in Eureka, California. The first record is for the most distance traveled in 24 hours by human power (647 miles, 1041 km), and the second for the worlds fastest 1000 km time trial (23 hours, 2 minutes).

In 1969, artists in a small Northern California town began the Kinetic sculpture race which has grown to a 42-mile (67.2-km), three-day all terrain, human-powered sculpture race and county wide event. It is held every year on the last weekend in May.

Human-powered aircraft

Fixed-wing aircraft

MIT Daedalus human powered aircraft

A **human-powered aircraft** (HPA) is an aircraft powered by direct human energy and the force of gravity; the thrust provided by the human may be the only source; however, a hang glider that is partially powered by pilot power is a human-powered aircraft where the flight path can be enhanced more than if the hang glider had not been assisted by human power. Likewise, HPA inevitably experience assist from thermals or rising air currents. Pure HPA do not use hybrid flows of energy (solar energy, wound rubber band, fuel cell, etc.) for thrust. In nil wind, a flatland-long-gliding aircraft is a form of HPA where the thrust in the nil wind is provided by the running of the pilot; when the pilot loses touch with the ground, his or her thrusting ceases to add energy to the flight system and a glide begins; the pilot may or may not add energy after the pilot stops touching the ground. Humans who tow up a manned kite form one type of human-powered aircraft.

Early attempts at human-powered flight were unsuccessful because of the difficulty of achieving the high power-to-weight ratio. Prototypes often used ornithopter principles which were not only too heavy to meet this requirement but aerodynamically unsatisfactory.

As of 2008, human-powered aircraft have been successfully flown over considerable distances. However, they are primarily constructed as an engineering challenge rather than for any kind of recreational or utilitarian purpose.

The Royal Aeronautical Society Human Powered Flight Group

The Royal Aeronautical Society's 'Man Powered Aircraft Group' was formed in 1959 by the members of the Man Powered Group of the College of Aeronautics at Cranfield when they were invited to join the Society. Its title was changed from 'Man' to 'Human' in 1988 because of the many successful flights made by female pilots.

Under the auspices of the Society, in 1959 the industrialist Henry Kremer offered the Kremer Prizes of £50,000 for the first human-powered aeroplane to fly a figure-of-eight course round two markers half-a-mile apart.

First flights

A craft called *HV-1 Mufli* (Muskelkraft-Flugzeug) built by Helmut Hässler and Franz Villinger [(de)] first flew on 30 August 1935: a distance of 235 metres at Halle an der Saale. 120 flights were made, the longest being 712 metres in 1937. However it was launched using a tensioned cable and so was not strictly human-powered.

A team of Enea Bossi (designer), Vittorio Bonomi (builder), and Emilio Casco (pilot) met a challenge by the Italian Government for a flight of one kilometre using their *Pedaliante* in March 1937. The aircraft apparently flew short distances fully under human power, but the distances were not significant enough to win the competition's prize. Furthermore there has been much dispute as to whether it ever took off under the pedal-power of the pilot alone, in particular because there is no record of official observation of it having done so. Some of the arguments for and against the validity of Bossi's claim to have done so are presented by Sherwin (1976). At the time the fully human-powered flights were deemed to be a result of the pilot's significant strength and endurance; and ultimately not attainable by a typical human. As with the *HV-1 Mufli*, additional attempts were therefore made using a catapult system. By being catapulted to a height of 9 metres (30 ft), the aircraft met the distance requirement of 1 kilometre (0.62 mi) but was declined the prize due to the launch method.

Human-powered aircraft display at the National Air and Space Museum

The first officially authenticated take-off and landing of a man powered aircraft (one capable of powered take-offs, unlike a glider) was made on 9 November 1961 by Derek Piggott in Southampton University's Man Powered Aircraft (SUMPAC). The best flight out of 40 tried was 650 metres. The SUMPAC was substantially rebuilt by Imperial College with a new transmission system but was damaged beyond repair in November 1965.

The Hatfield Puffin first flew in 16 November 1961, one week after SUMPAC. The Hatfield Man Powered Aircraft Club was formed of employees of de Havilland Aircraft Company and had access to company support. Eventually its best distance was 908 metres. John Wimpenny landed in a state of physical exhaustion. His record stood for 10 years.

Puffin 2 was a new fuselage and wing around the transmission recovered from the original Puffin. It flew on 27 August 1965 and made several flights over a half-mile, including a climb to 5.2 metres. In 1967 Kremer increased his prize money tenfold to £500,000, for no-one had even attempted his challenging course. He also opened the competition to all nationalities as it had previously been restricted to British entries only. After Puffin 2 was damaged it was handed over to Liverpool University who used it to build the Liverpuffin

After this date several less successful aircraft flew, until 1972 when the Jupiter flew 1,070 metres and 1,239 metres in June 1972.

On 23 August 1977 the Gossamer Condor 2 flew the first figure-eight, a distance of 2,172 metres winning the first Kremer prize. It was built by Dr Paul B. MacCready. and piloted by amateur cyclist and hang-glider pilot Bryan Allen.

Later flights

The second Kremer prize of £100,000 was won on June 12, 1979, again by Paul MacCready, when Bryan Allen flew MacCready's Gossamer Albatross from England to France: a straight distance of 35.82 km (22 miles 453 yards) in 2 hours, 49 minutes.

A Kremer prize of £20,000 for speed went on 1 May 1984 to a design team of the Massachusetts Institute of Technology for flying their MIT Monarch B craft on a triangular 1.5 km course in under three minutes (for an average speed of 32 km/h): pilot Frank Scarabino. Further prizes of £5,000 are awarded to each subsequent entrant improving the speed by at least five percent.

The first human-powered passenger flight occurred on 1 October 1984 when Holger Rochelt carried his sister Katrin in Musculair 1.

The current distance record recognised by the FAI was achieved on 23 April 1988 from Iraklion on Crete to Santorini in an MIT Daedalus 88 piloted by Kanellos Kanellopoulos: a straight distance of 119 km (74 miles).

On 10 December 1989 the first human-powered helicopter, the California Polytechnic State University Da Vinci III, flew for 7.1 seconds and reached a height of 20 cm.

Current activity

Machines have been built and flown in Japan, Germany, Greece, Australia, New Zealand, South Africa, Austria, Canada, Singapore, the United States and the United Kingdom, with their total number approaching a hundred.

With further funds from the late Henry Kremer, the Royal Aeronautical Society has announced four new prizes:

- £50,000 for the Kremer International Marathon Competition for a flight round a specified twenty six mile Marathon distance course, in a time of under one hour,
- £100,000 for the Kremer International Sporting Aircraft Competition for a sporting aeroplane able to operate in normal weather conditions, as encountered in the United Kingdom
- £1,000 for the Schools Competition
- £500 for The Robert Graham Competition for students for experimental research or engineering design

The eventual aim is to achieve Olympic recognition as a sport.

There are at least three current attempts underway to claim the £100,000 Kremer Sport prize. One team from Virginia Polytechnic Institute has been active for a number of years designing an aircraft as part of their AE4065/6 class; recent attempts to assemble a wing structure had resulted in critical failure. A second team from the Pennsylvania State University is designing and constructing the PSU Zephyrus as part of their AERSP 404H class. Finally, as of 2010, the Aeronautics Department at Imperial College London is undertaking the premise of Human Powered Flight for one of their 3rd Year Group Design Projects, to investigate its feasibility in the sporting world.

Helicopters

The first officially observed human-powered helicopter to have left the ground was the Da Vinci III in 1989. It was designed and built by students at Cal Poly San Luis Obispo in California, USA. It flew for 7.1 seconds and reached a height of 8 inches (20 cm). The second was the Yuri I in 1994, designed and built by students at Nihon University in Japan. It flew for 19.46 seconds and reached an altitude of 20 cm. Both were attempts to win the Sikorsky Prize.

Airships and balloons

French inventors have built man-powered airships and balloons. Solar hot air balloons and solar hot air airships are new types of balloons and airships. Because lift is supplied through buoyancy, human power can be devoted to thrust.

Human-powered watercraft

A Punt Pedalo

Birchbark canoe

Human-powered watercraft include prehistoric and well-known traditional and sporting craft such as canoes, rowing boats and galleys. The term *human-powered boat* is often used for more modern craft using propellers and water wheels for propulsion. These can be more efficient than paddles or oars and especially allow the use of the leg muscles which are generally strong also with non-athletes. In addition, there is little skill required for forward propulsion while looking forwards and such craft are popular at resorts as pedalos.

Hydrofoil

Hydrofoils have less water resistance at the highest speeds just obtainable by humans and are thus usually faster than displacement boats on short courses. The world speed record on water was set 27 October 1991 by MIT Professor Mark Drela who pedalled a human-powered hydrofoil, "Decavitator", to 18.5 knots (21.3 mph)(9.53 meters/second) over a 100 meter race course in Boston, Massachusetts.

Submarines

In 1989, the first human-powered International Submarine Race (ISR) was held in Florida with 17 craft. Since then nine more races have been held. The races themselves have been moved from the waters of Florida to the United States Naval Surface Warfare Center's Carderock Division David Taylor Model Basin in Bethesda, Maryland, and are held biennially. At the 9th ISR in 2007 (in which 23 submarines participated) several new records were set: A single-person craft, Omer5 achieved a record speed of 8.035 knots breaking the Omer team's previous record of 7.19 knots set by Omer 4 in 2004. Also Omer 6 snatched up a record for non-propeller driven craft with a speed of 4.642 knots.

Animal-powered transport

Shopping for groceries, Astipalea, Greece, 2005

Animal-powered transport is a broad category of the human use of non-human working animals (also known as "beasts of burden") for the movement of people and goods.

Humans may ride some of the larger of these animals directly, use them as pack animals for carrying goods, or harness them, singly or in teams, to pull (or haul) sleds or wheeled vehicles.

Animals domesticated for transport

In the air

- pigeon

As the heaviest living flying animal weighs about 20 kg. people cannot fly on an animal.

Fiction

- Banshee and Toruk in Avatar (2009 film)
- Dragonriders of Pern
- crow
- Appa in Avatar: the Last Airbender

On land

- camel, Arabian and Bactrian
- carabao
- dog
    - sled dog
    - Dogcart (dog-drawn)
- elephant
- equine
    - pack horse
    - draught horse
    - riding horse
    - coach horse
    - donkey
    - mule
    - hinny
- llama
- moose
- ostrich
- ox
- reindeer
- sheep
- yak

On water

- Not common outside mythology, but note the use of dolphins to carry markers to attach to detected mines.
- Horse-powered ferries have been recovered from underwater: horses turned a mechanism that propelled the craft.

Animal powered vehicles

- barge (sometimes pulled by humans)
- berlin (vehicle)
- brancard
- Brougham (carriage)
- caravan
- carriage
- cart
- chaise
- charabanc
- chariot (ancient form sometimes used in combat, later a racing machine, later a name for something entirely different in carriages)
- coach
- cocking cart
- Conestoga wagon
- cutter
- curricle
- dogcart
- dormeuse
- dray
- ferry
- float
- gig
- governess cart
- Hansom cab
- horsecar
- horse-drawn boat
- horse-powered boat
- howdah

Chapter-2

Rail Transport and Air Transport

Rail Transport

BNSF Railway freight service in the United States

German InterCityExpress

Rail transport is the means of conveyance of passengers and goods by way of wheeled vehicles running on rail tracks. In contrast to road transport, where vehicles merely run on a prepared surface, rail vehicles are also directionally guided by the tracks they run on. Track usually consists of steel rails installed on sleepers/ties and ballast, on which the rolling stock, usually fitted with metal wheels, moves. However, 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 railway transportation systems generally has lower frictional resistance when compared with highway vehicles, and the 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 electrical 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 transportation system when compared to other forms of transportation. Railway transportation is capable of high levels of passenger and cargo utilization and energy efficiency, but is often less flexible and more capital-intensive than highway transportation is, when lower traffic levels are considered.

The oldest, man-hauled railways date to the 6th century B.C, with Periander, one of the Seven Sages of Greece, credited with its invention. With the British development of the steam engine, it was possible to construct mainline railways, that were a key component of the industrial revolution. Also, railways reduced the costs of shipping, and allowed for fewer lost goods. The change from canals to railways allowed for "national markets" in which prices varied very little from city to city. Studies have shown that the invention and development of the railway in Europe was one of the most important technological inventions of the late 19th century for the United States, without which, GDP would have been lower by 7.0% 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 a few other countries. Other forms of guided ground transportation outside the traditional railway definitions, such as monorail or maglev, have been tried but have seen limited use.

History

Horsecar in Brno, Czech Republic

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 9th century BC. Trucks pushed by slaves ran in grooves in limestone, which provided the track element. The Diolkos ran 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 probably the oldest railway still to operate.

By 1550, narrow gauge railways with wooden rails were common in mines in Europe. By the 17th century, wooden wagonways were common in the United Kingdom for transporting coal from mines to canal wharfs for transshipment to boats. The world's oldest continually 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 was the 1810 Leiper Railroad.

The first iron plate rail way made with cast iron plats on top of wooden rails, was taken 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 the United Kingdom. In 1803, William Jessop opened the Surrey Iron Railway in south London, arguably the world's first horse-drawn public railway. Hot rolling iron allowed the brittle, and often uneven, cast iron rails to be replaced by wrought iron in 1805. These were succeeded by steel in 1857.

Age of steam

A British steam locomotive-hauled train

The development of the steam engine spurred ideas for mobile steam locomotives that could haul trains on tracks. The first was patented by James Watt in 1794. In 1804, Richard Trevithick demonstrated the first locomotive-hauled train in Merthyr Tydfil, United Kingdom. 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. 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. The locomotive, *The 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 used on railways in the United Kingdom, the United States and much of Europe. In 1830, the first intercity railway, the Liverpool and Manchester Railway, opened. The gauge was that used for the early wagonways and had been adopted for the Stockton and Darlington Railway. The 1,435 mm (4 ft 8 ½ in) width became known as the international standard gauge, used by about 60% of the world's railways. This spurred the spread of rail transport outside the UK. The Baltimore and Ohio 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, which was covered in 40 minutes. In 1867, the first elevated railway was built in New York. The symbolically important first transcontinental railway was completed in 1869.

Elevated section of the Chicago L

Electrification and dieselisation

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 Giant's Causeway Tramway was the first to use electricity fed to the trains en-route, using a third rail, when it opened in 1883. Overhead wires were taken into use in 1888. At first this was taken into use on tramways, that until then had been horse-hauled tramcars. The first conventional electrified railway was the Roslag Line in Sweden. During the 1890s, many large cities, such as London, Paris and New York 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 Spubeital 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 programs to convert all unelectrified sections from steam to diesel locomotion.

Luas in Dublin, Ireland

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 transits 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 1962 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.

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 railroad engineer or engine driver controls the locomotive or other power cars, although people movers and some rapid transits are driverless.

Russian 2TE10U diesel locomotive

Haulage

Traditionally, trains are pulled using a locomotive. This involved a single or multiple powered vehicles being located at the front of the train, and providing sufficient adhesion to haul the weight of the full train. This 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 the engineer can remote-control the locomotive. This allows one of the locomotive hauled trains drawbacks to be removed, since the locomotive need not be moved to the end 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. This the 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. 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 build under the coach. There are only a few freight multiple units, most of which are high-speed post trains.

Motive power

A RegioSwinger multiple unit of the Croatian Railways

Steam locomotives are locomotives with a steam engine that provides adhesion. Coal, petroleum, or wood is burned in a firebox. The heat warms up water in the fire-tube boiler to create pressurized steam. The steam travels through the smokebox before leaving via the chimney. 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.

Electric locomotives draw power from a stationary source via overhead wire or a third rail. Some also or instead use a battery. A transformer in the locomotive converts the high voltage, low current power to low voltage, high current used in the electric motors that power the wheels. Modern locomotives use three-phase AC induction motors. Electric locomotives are the most powerful traction. They are also the cheapest to run and provide less noise and no local air pollution. However, they require high capital investments both for the catenary and the supporting infrastructure. 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 an electric locomotive 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 conductor. Passenger trains are part of public transport, and often make up the stem of the service, with buses feeding to stations.

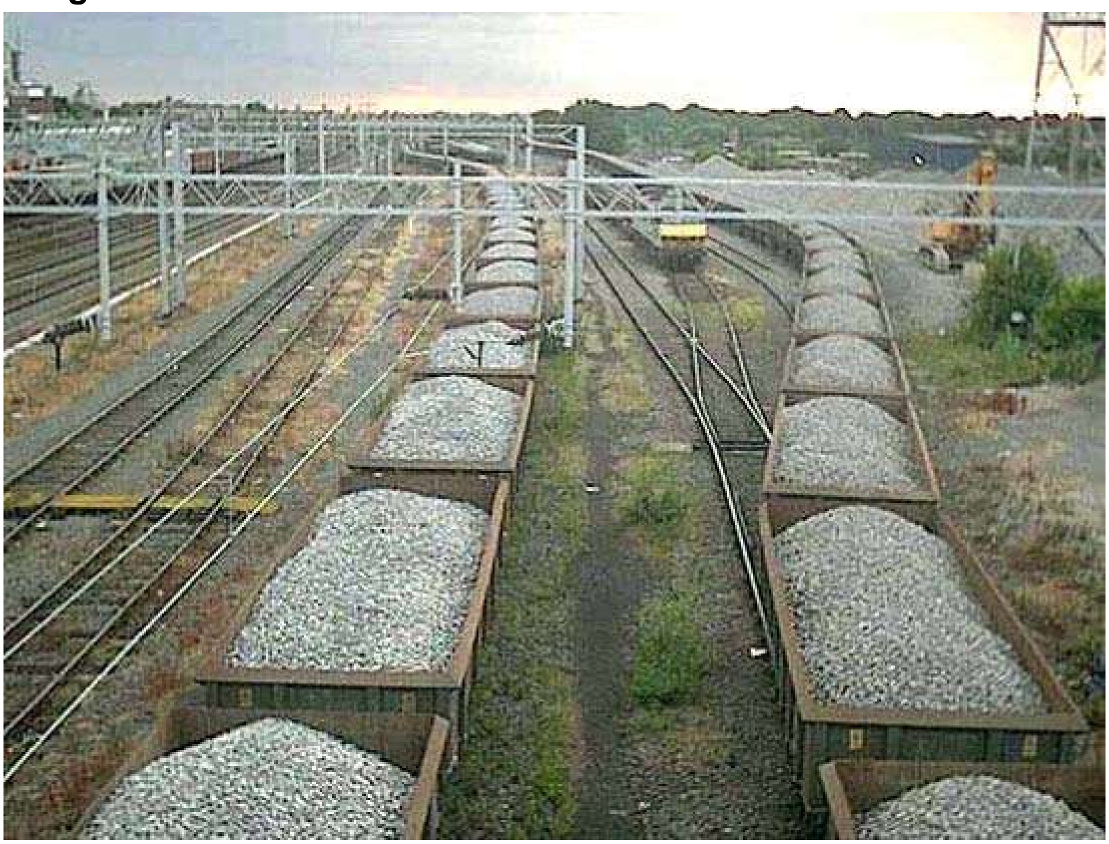
Interior view of the top deck of a VR InterCity2 double-deck carriage

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 been given a specific name. Regional trains are medium distance trains that connect cities with outlying, surrounding areas, or provide a regional service. Trains make more stops and have 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.

Rapid transit is built in large cities and has the highest capacity of any passenger transport system. It is 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 operate as elevated, medium capacity systems. A people mover is a driverless, grade-separated train that serves only a few stations, as a shuttle.

High-speed rail operate at much higher speeds than conventional railways, the limit being regarded at 200 to 320 km/h. 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.

Freight train



Bulk cargo of minerals

A freight train hauls cargo using freight cars specialized for the type of goods. Freight trains can be very efficient, with economy of scale and high energy efficiency. However, their use is reduced by lack of flexibility, often by the 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. 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 semi-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 and tank cars.

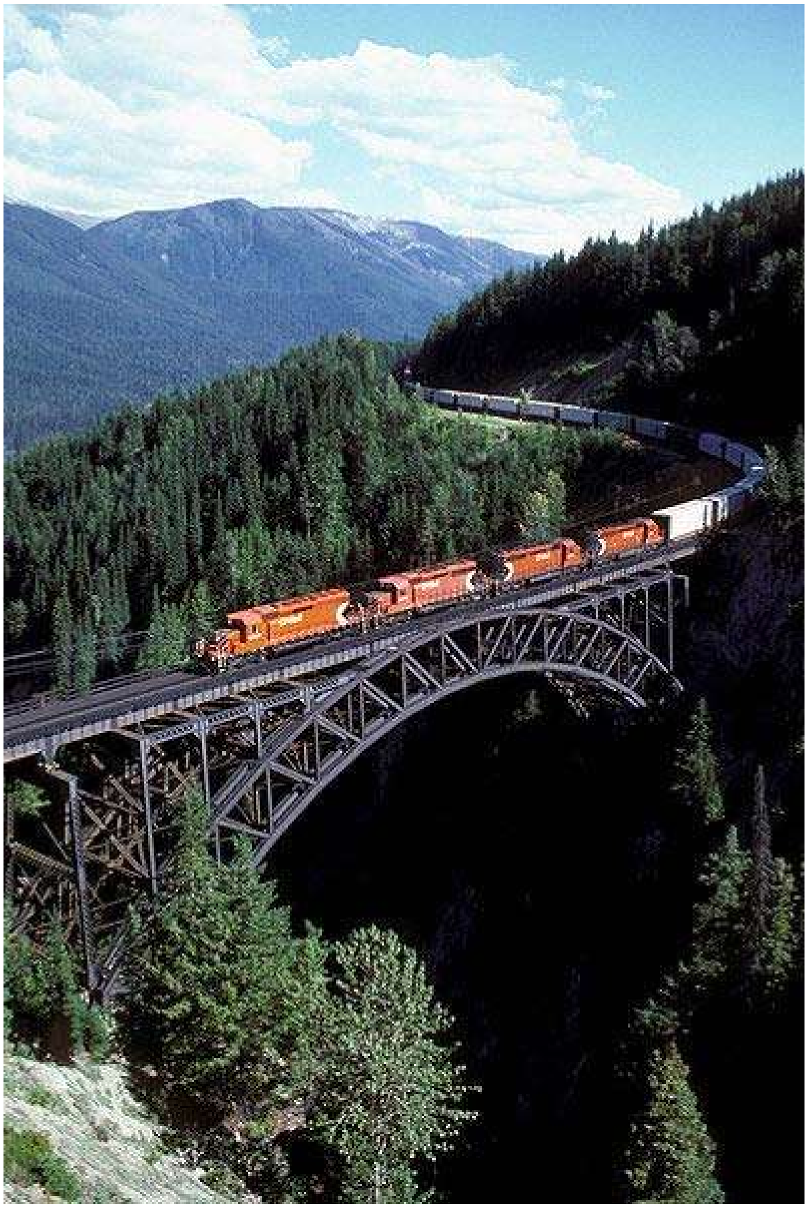
Infrastructure

(Up): Railway turnouts; **(Down)**: Chicago Transit Authority control tower 18 guides elevated Chicago 'L' north and southbound Purple and Brown lines intersecting with east and westbound Pink and Green lines and the looping Orange line above the Wells and Lake street intersection in the loop at an elevated right of way.

Right of way

Railway tracks are laid upon land owned or leased by the railway company. Owing to the desirability of maintaining modest grades, rails will often be laid in circuitous routes in hilly or mountainous terrain. Route length and grade requirements can be reduced by the use of alternating cuttings, bridges and tunnels—all of which can greatly increase the capital expenditures required to develop a right of way, while significantly reducing operating costs and allowing higher speeds on longer radius curves. In densely urbanized areas, railways are sometimes laid in tunnels to minimize the effects on existing properties.

Trackage

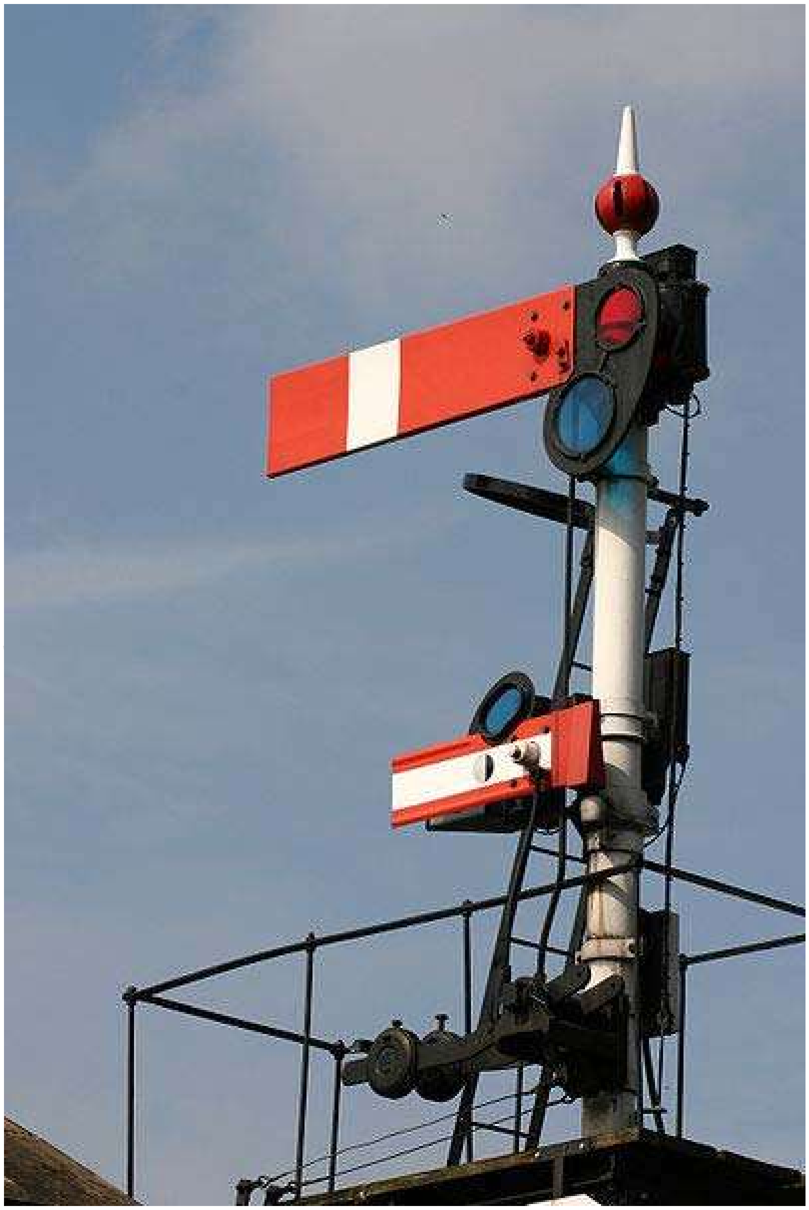


Long freight train crossing the Stoney Creek viaduct on the Canadian Pacific Railway in southern British Columbia

Track consists of two parallel steel rails, anchored perpendicular to members called ties (sleepers) of timber, concrete, steel, or plastic to maintain a consistent distance apart, or gauge. The track guides the conical, flanged wheels, keeping the cars on the track without active steering and therefore allowing trains to be much longer than road vehicles. The rails and ties are usually placed on a foundation made of compressed earth on top of which is placed a bed of ballast to distribute the load from the ties and to prevent the track from buckling as the ground settles over time under the weight of the vehicles passing above. The ballast also serves as a means of drainage. Some more modern track in special areas is attached by direct fixation without ballast. Track may be prefabricated or assembled in place. By welding rails together to form lengths of continuous welded rail, additional wear and tear on rolling stock caused by the small surface gap at the joints between rails can be counteracted; this also makes for a quieter ride (passenger trains). On curves the outer rail may be at a higher level than the inner rail. This is called superelevation or cant. This reduces the forces tending to displace the track and makes for a more comfortable ride for standing livestock and standing or seated passengers. A given amount of superelevation will be the most effective over a limited range of speeds.

Turnouts, also known as points and switches, are the means of directing a train onto a diverging section of track. Laid similar to normal track, a point typically consists of a frog (common crossing), check rails and two switch rails. The switch rails may be moved left or right, under the control of the signalling system, to determine which path the train will follow.

Spikes in wooden ties can loosen over time, but split and rotten ties may be individually replaced with new wooden ties or concrete substitutes. Concrete ties can also develop cracks or splits, and can also be replaced individually. Should the rails settle due to soil subsidence, they can be lifted by specialized machinery and additional ballast tamped under the ties to level the rails. Periodically, ballast must be removed and replaced with clean ballast to ensure adequate drainage. Culverts and other passages for water must be kept clear lest water is impounded by the trackbed, causing landslips. Where trackbeds are placed along rivers, additional protection is usually placed to prevent streambank erosion during times of high water. Bridges require inspection and maintenance, since they are subject to large surges of stress in a short period of time when a heavy train crosses.



Great Western Railway semaphore-type signal

Signalling

Railway signalling is a system used to control railway traffic safely to prevent trains from colliding. Being guided by fixed rails with low friction, trains are uniquely susceptible to collision since they frequently operate at speeds that do not enable them to stop quickly or within the driver's sighting distance. Most forms of train control involve movement authority being passed from those responsible for each section of a rail network to the train crew. Not all methods require the use of signals, and some systems are specific to single track railways. The signalling process is traditionally carried out in a signal box, a small building that houses the lever frame required for the signalman to operate switches and signal equipment. These are placed at various intervals along the route of a railway, controlling specified sections of track. More recent technological developments have made such operational doctrine superfluous, with the centralization of signalling operations to regional control rooms. This has been facilitated by the increased use of computers, allowing vast sections of track to be monitored from a single location. The common method of block signalling divides the track into zones guarded by combinations of block signals, operating rules, and automatic-control devices so that only one train may be in a block at any time.

Electrification

The electrification system provides electrical energy to the trains, so they can operate without a prime mover onboard. This allows lower operating costs, but requires large capital investments along the lines. Mainline and tram systems normally have overhead wires, which hang from poles along the line. Grade-separated rapid transit sometimes use a ground third rail. Power may be fed as direct or alternating current. The most common currencies are 600 and 750 V for tram and rapid transit systems, and 1,500 and 3,000 V for mainlines. The two dominant AC systems are 15 kV AC and 25 kV AC.

Stations

Secunderabad Railway Station in Hyderabad, India

A railway station serves as an area where passengers can board and alight from trains. A goods station is a yard which is exclusively used for loading and unloading cargo. Large passenger stations have at least one building providing conveniences for passengers, such as purchasing tickets and food. Smaller stations typically only consist of a platform. Early stations were sometimes built with both passenger and goods facilities. Platforms are used to allow easy access to the trains, and are connected to each other via underpasses, footbridge and level crossings. Some large stations are built as cul-de-sac, with trains only operating out from one direction. Smaller stations normally serve local residential areas, and may have connection to feeder bus services. Large stations, in particular central stations, serve as the main public transport hub for the city, and have transfer available between rail services, and to rapid transit, tram or bus services.

Operations

In the United States, railways, such as Union Pacific, are privately owned

Ownership

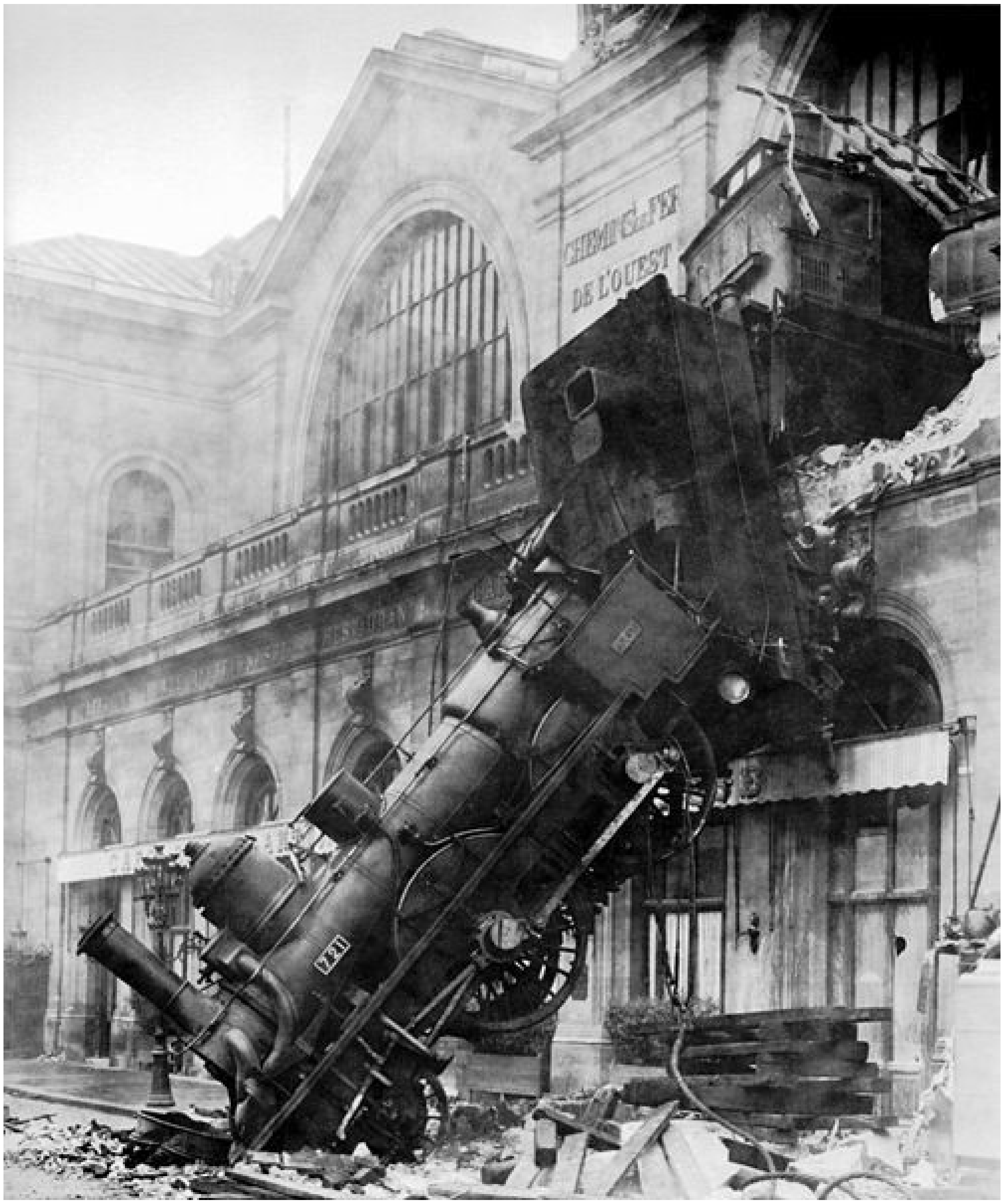
Traditionally, the infrastructure and rolling stock are owned and operated by the same company. This has often been by a national railway, while other companies have had private railways. Since the 1980s, there has been an increasing tendency to split up railway companies, with separate companies owning the stock from those owning the infrastructure, particularly in Europe, where this is required by the European Union. This has allowed open access by any train operator to any portion of the European railway network.

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. 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.

Government 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 an 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.

Safety



Train wreck at Montparnasse Station, Paris, France, in 1895.

Rail transport is one of the safest forms of land travel. 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 an automobile or other vehicle at level crossings. The latter 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 and pedestrians, vastly reduces the likelihood of collision with other trains, and helps ensure services remain timely.

Impact

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 minimum of friction. As an example, a typical modern wagon can hold up to 113 tonnes of freight on two four-wheel bogies. The contact area between each wheel and the rail is a strip no more than a few millimetres wide, which minimizes friction. 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 transportation, such as road transport, which depends on the friction between rubber tires 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, even around curves, which allows for economies of scale in energy use; by contrast, in road transport, more than two articulations causes fishtailing and makes the vehicle unsafe.

Railway tracks running through Stanhope, United Kingdom

Usage

Due to these benefits, rail transport is a major form of passenger and freight transport in many countries. In India, China, South Korea and Japan, many millions use trains as regular transport. It is widespread in European countries. Freight rail transport is widespread and heavily used in North America, but intercity passenger rail transport on that continent is relatively scarce outside the Northeast Corridor.

Africa and South America have some extensive networks such as in South Africa, Northern Africa and Argentina; but some railway on these continents are isolated lines connecting two places. 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. The western Europe region has the highest railway density in the world, and has many individual trains which operate through several countries despite technical and organizational differences in each national network.

Of 236 countries and dependencies globally, 143 have rail transport (including several with very little), of which about 90 have passenger services.

Air Transport

Airline

A Boeing 767-300ER of Delta Air Lines, The world's largest passenger airline that operates under a single operating certificate, largest fleet of 767 and the most destinations 358

A FedEx Express McDonnell Douglas MD-11. FedEx Express is the world's largest airline in terms of freight tons flown.

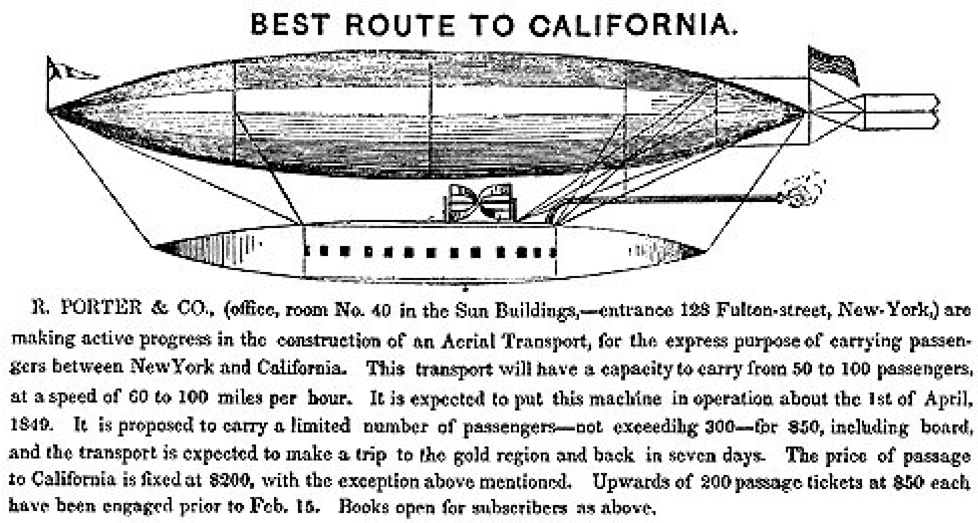
Ryanair Boeing 737-800 shortly after take-off. Ryanair is the world's largest airline in terms of number of international passengers carried.

An **airline** provides air transport services for passengers and/or freight. Airlines lease or own their aircraft with which to supply these services and may form partnerships or alliances with other airlines for mutual benefit. Generally, airline companies are recognized with an air operating certificate or license issued by a governmental aviation body.

Airlines vary from those with a single aircraft carrying mail or cargo, through full-service international airlines operating hundreds of aircraft. Airline services can be categorized as being intercontinental, intra-continental, domestic, regional, or international, and may be operated as scheduled services or charters.

History

The first airlines



Failed attempt at an airline before DELAG

American aviation pioneers, such as Rufus Porter and Frederick Marriott, attempted to start airlines using airships in the mid-19th century, focusing on the New York–California route. Those attempts floundered due to such mishaps as the airships catching fire and the aircraft being ripped apart by spectators. DELAG, *Deutsche Luftschiffahrts-Aktiengesellschaft* was the world's first airline. It was founded on November 16, 1909 with government assistance, and operated airships manufactured by The Zeppelin Corporation. Its headquarters were in Frankfurt. The four oldest non-dirigible airlines that still exist are Netherlands' KLM, Colombia's Avianca, Australia's Qantas, and the Czech Republic's Czech Airlines. KLM first flew in May 1920, while Qantas (which stands for *Queensland and Northern Territory Aerial Services Limited*) was founded in Queensland, Australia, in late 1920.

U.S. airline industry

Early development

TWA Douglas DC-3 in 1940. The DC-3, often regarded as one of the most influential aircraft in the history of commercial aviation, revolutionized the aviation industry.

Tony Jannus conducted the United State's first scheduled commercial airline flight on 1 January 1914 for the St. Petersburg-Tampa Airboat Line. The 23-minute flight traveled between St. Petersburg, Florida and Tampa, Florida, passing some 50 feet (15 m) above Tampa Bay in Jannus' Benoist XIV biplane flying boat. Chalk's International Airlines began service between Miami and Bimini in the Bahamas in February 1919. Based in Ft. Lauderdale, Chalk's claimed to be the oldest continuously operating airline in the United States until its closure in 2008.

Following World War I, the United States found itself swamped with aviators. Many decided to take their war-surplus aircraft on barnstorming campaigns, performing acrobatic maneuvers to woo crowds. In 1918, the United States Postal Service won the financial backing of Congress to begin experimenting with air mail service, initially using Curtiss Jenny aircraft that had been procured by the United States Army for reconnaissance missions on the Western Front. Private operators were the first to fly the mail but due to numerous accidents the US Army was tasked with mail delivery. During the course of the Army's involvement they proved to be too unreliable and lost their air mail duties. By the mid-1920s, the Postal Service had developed its own air mail network, based on a transcontinental backbone between New York and San Francisco. To supplant this service, they offered twelve contracts for spur routes to independent bidders. Some of the carriers that won these routes would, through time and mergers, evolve into Pan Am, Delta Air Lines, Braniff Airways, American Airlines, United Airlines (originally a division of Boeing), Trans World Airlines, Northwest Airlines, and Eastern Air Lines.

Service during the early 1920s was sporadic: most airlines at the time were focused on carrying bags of mail. In 1925, however, the Ford Motor Company bought out the Stout Aircraft Company and began construction of the all-metal Ford Trimotor, which became the first successful American airliner. With a 12-passenger capacity, the Trimotor made passenger service potentially profitable. Air service was seen as a supplement to rail service in the American transportation network.

At the same time, Juan Trippe began a crusade to create an air network that would link America to the world, and he achieved this goal through his airline, Pan American World Airways, with a fleet of flying boats that linked Los Angeles to Shanghai and Boston to London. Pan Am and Northwest Airways (which began flights to Canada in the 1920s) were the only U.S. airlines to go international before the 1940s.

With the introduction of the Boeing 247 and Douglas DC-3 in the 1930s, the U.S. airline industry was generally profitable, even during the Great Depression. This trend continued until the beginning of World War II.

Development since 1945

In October 1945, the American Export Airlines became the first airline to offer regular commercial flights between North America and Europe. Shown here is Am Ex Boeing 377 *Stratocruiser* in 1949.

As governments met to set the standards and scope for an emergent civil air industry toward the end of the war, the U.S. took a position of maximum operating freedom; U.S. airline companies were not as hard-hit as European and the few Asian ones had been. This preference for "open skies" operating regimes continues, within limitations, to this day.

World War II, like World War I, brought new life to the airline industry. Many airlines in the Allied countries were flush from lease contracts to the military, and foresaw a future explosive demand for civil air transport, for both passengers and cargo. They were eager to invest in the newly emerging flagships of air travel such as the Boeing Stratocruiser, Lockheed Constellation, and Douglas DC-6. Most of these new aircraft were based on American bombers such as the B-29, which had spearheaded research into new technologies such as pressurization. Most offered increased efficiency from both added speed and greater payload.

In the 1950s, the De Havilland Comet, Boeing 707, Douglas DC-8, and Sud Aviation Caravelle became the first flagships of the Jet Age in the West, while the Soviet Union bloc had Tupolev Tu-104 and Tupolev Tu-124 in the fleets of state-owned carriers such as Czechoslovak ČSA, Soviet Aeroflot and East-German Interflug. The Vickers Viscount and Lockheed L-188 Electra inaugurated turboprop transport.

The next big boost for the airlines would come in the 1970s, when the Boeing 747, McDonnell Douglas DC-10, and Lockheed L-1011 inaugurated widebody ("jumbo jet") service, which is still the standard in international travel. The Tupolev Tu-144 and its Western counterpart, Concorde, made supersonic travel a reality. Concorde first flew in 1969 and operated through 2003. In 1972, Airbus began producing Europe's most commercially successful line of airliners to date. The added efficiencies for these aircraft were often not in speed, but in passenger capacity, payload, and range. Airbus also features modern electronic cockpits that were common across their aircraft to enable pilots to fly multiple models with minimal cross-training.

Pan Am Boeing 747 *Clipper Neptune's Car* in 1985. The deregulation of the American airline industry increased the financial troubles of the iconic airline which ultimately filed for bankruptcy in December 1991.

1978's U.S. airline industry deregulation lowered barriers for new airlines just as a downturn occurred. New start-ups entered during the downturn, during which time they found aircraft and funding, contracted hangar and maintenance services, trained new employees, and recruited laid off staff from other airlines.

As the business cycle returned to normalcy, major airlines dominated their routes through aggressive pricing and additional capacity offerings, often swamping new startups. Only America West Airlines (which has since merged with US Airways) remained a significant survivor from this new entrant era, as dozens, even hundreds, have gone under.

In many ways, the biggest winner in the deregulated environment was the air passenger. Indeed, the U.S. witnessed an explosive growth in demand for air travel, as many millions who had never or rarely flown before became regular fliers, even joining frequent flyer loyalty programs and receiving free flights and other benefits from their flying. New services and higher frequencies meant that business fliers could fly to another city, do business, and return the same day, for almost any point in the country. Air travel's advantages put intercity bus lines under pressure, and most have withered away.

By the 1980s, almost half of the total flying in the world took place in the U.S., and today the domestic industry operates over 10,000 daily departures nationwide.

Toward the end of the century, a new style of low cost airline emerged, offering a no-frills product at a lower price. Southwest Airlines, JetBlue, AirTran Airways, Skybus Airlines and other low-cost carriers began to represent a serious challenge to the so-called "legacy airlines", as did their low-cost counterparts in many other countries. Their commercial viability represented a serious competitive threat to the legacy carriers. However, of these, ATA and Skybus have since ceased operations.

Increasingly since 1978, US airlines have been reincorporated and spun off by newly created and interally led manangement companies, and thus becoming nothing more than operating units and subsidiaries with limited finanically decisive control. Among some of these holding companies and parent companies that are the relatively well known, are the UAL Corporation, along with the AMR Corporation, among a long list of airline holding companies sometime recognized world wide. Less recognized are the private equity firms which often seize managerial, financial, and board of directors control of distressed airline companies by temporarily investing large sums of capital in air carriers, so as to rescheme an airlines assets into a profitable organization or liquidating an air carrier of their profitable and worthwhile routes and business operations.

Thus the last 50 years of the airline industry have varied from reasonably profitable, to devastatingly depressed. As the first major market to deregulate the industry in 1978, U.S. airlines have experienced more turbulence than almost any other country or region. Today, American Airlines is the only U.S. legacy carrier to survive bankruptcy-free.

The Airline Industry Bailout

Congress passed the Air Transportation Safety and System Stabilization Act (P.L. 107-42) in response to a severe liquidity crisis facing the already-troubled airline industry in the aftermath of the September 11th terrorist attacks. Congress sought to provide cash infusions to carriers for both the cost of the four-day federal shutdown of the airlines and the incremental losses incurred through December 31, 2001 as a result of the terrorist attacks. This resulted in the first government bailout of the 21st century. Between 2000 and 2005 US airlines lost $30 billion with wage cuts of over $15 billion and 100,000 employees laid off.

In recognition of the essential national economic role of a healthy aviation system, Congress authorized partial compensation of up to $5 billion in cash subject to review by the Department of Transportation and up to $10 billion in loan guarantees subject to review by a newly created Air Transportation Stabilization Board (ATSB). The applications to DOT for reimbursements were subjected to rigorous multi-year reviews not only by DOT program personnel but also by the Government Accountability Office and the DOT Inspector General.

Ultimately, the federal government provided $4.6 billion in one-time, subject-to-income-tax cash payments to 427 U.S. air carriers, with no provision for repayment, essentially a gift from the taxpayers. (Passenger carriers operating scheduled service received approximately $4 billion, subject to tax.) In addition, the ATSB approved loan guarantees to six airlines totaling approximately $1.6 billion. Data from the Treasury Department show that the government recouped the $1.6 billion and a profit of $339 million from the fees, interest and purchase of discounted airline stock associated with loan guarantees.

European airline industry

The Imperial Airways Empire Terminal, Victoria, London. Trains ran from here to flying boats in Southampton, and to Croydon Airport.

The first countries in Europe to embrace air transport were Austria, Belgium, Finland, France, Germany, the Netherlands and the United Kingdom.

Austria initiated the first regularly scheduled airmail service on March 31, 1918 in the midst of World War I. The route provided airmail service spanning Vienna to Krakow (now in Poland) to Lviv (now in Ukraine), as was often also extended to Kiev and Odessa.

KLM, the oldest carrier still operating under its original name, was founded in 1919. The first flight (operated on behalf of KLM by Aircraft Transport and Travel) transported two English passengers to Schiphol, Amsterdam from London in 1920. Like other major European airlines of the time, KLM's early growth depended heavily on the needs to service links with far-flung colonial possessions (Dutch Indies). It is only after the loss of the Dutch Empire that KLM found itself based at a small country with few potential passengers, depending heavily on transfer traffic, and was one of the first to introduce the hub-system to facilitate easy connections.

France began an air mail service to Morocco in 1919 that was bought out in 1927, renamed Aéropostale, and injected with capital to become a major international carrier. In 1933, Aéropostale went bankrupt, was nationalized and merged with several other airlines into what became Air France.

In Finland, the charter establishing Aero O/Y (now Finnair) was signed in the city of Helsinki on September 12, 1923. Junkers F 13 D-335 became the first aircraft of the company, when Aero took delivery of it on March 14, 1924. The first flight was between Helsinki and Tallinn, capital of Estonia, and it took place on March 20, 1924, one week later.

Germany's Lufthansa began in 1926. Lufthansa, unlike most other airlines at the time, became a major investor in airlines outside of Europe, providing capital to Varig and Avianca. German airliners built by Junkers, Dornier, and Fokker were the most advanced in the world at the time. In 1931, the airship Graf Zeppelin began offering regular scheduled passenger service between Germany and South America, usually every two weeks, which continued until 1937. In 1936, the airship Hindenburg entered passenger service and successfully crossed the Atlantic 36 times before crashing at Lakehurst, New Jersey on May 6, 1937.

The British company Aircraft Transport and Travel commenced a London to Paris service on August 25, 1919, this was the world's first regular international flight. The United Kingdom's flag carrier during this period was Imperial Airways, which became BOAC (British Overseas Airways Co.) in 1939. Imperial Airways used huge Handley-Page biplanes for routes between London, the Middle East, and India: images of Imperial aircraft in the middle of the Rub'al Khali, being maintained by Bedouins, are among the most famous pictures from the heyday of the British Empire.

In Soviet Union the Chief Administration of the Civil Air Fleet was established in 1921. One of its first acts was to help found Deutsch-Russische Luftverkehrs A.G. (Deruluft), a German-Russian joint venture to provide air transport from Russia to the West. Domestic air service began around the same time, when Dobrolyot started operations on 15 July 1923 between Moscow and Nizhni Novgorod. Since 1932 all operations had been carried under the name Aeroflot. By the end of the 1930s Aeroflot had become the world's largest airline, employing more than 4,000 pilots and 60,000 other service personnel and operating around 3,000 aircraft (of which 75% were considered obsolete by its own standards). During the Soviet era Aeroflot was synonymous with Russian civil aviation, as it was the only air carrier. It became the first airline in the world to operate sustained regular jet services on 15 September 1956 with the Tupolev Tu-104.

Deregulation

Deregulation of the European Union airspace in the early 1990s has had substantial effect on structure of the industry there. The shift towards 'budget' airlines on shorter routes has been significant. Airlines such as EasyJet and Ryanair have grown at the expense of the traditional national airlines.

There has also been a trend for these national airlines themselves to be privatised such as has occurred for Aer Lingus and British Airways. Other national airlines, including Italy's Alitalia, have suffered - particularly with the rapid increase of oil prices in early 2008.

Asian airline industry

Although Philippine Airlines (PAL) was officially founded on February 26, 1941, its license to operate as an airliner was derived from merged Philippine Aerial Taxi Company (PATCO) established by mining magnate Emmanuel N. Bachrach on December 3, 1930, making it Asia's oldest scheduled carrier still in operation. Commercial air service commenced three weeks later from Manila to Baguio, making it Asia's first airline route. Bachrach's death in 1937 paved the way for its eventual merger with Philippine Airlines in March 1941 and made it Asia's oldest airline. It is also the oldest airline in Asia still operating under its current name. Bachrach's majority share in PATCO was bought by beer magnate Andres R. Soriano in 1939 upon the advice of General Douglas McArthur and later merged with newly formed Philippine Airlines with PAL as the surviving entity. Soriano has controlling interest in both airlines before the merger. PAL restarted service on March 15, 1941 with a single Beech Model 18 NPC-54 aircraft, which started its daily services between Manila (from Nielson Field) and Baguio, later to expand with larger aircraft such as the DC-3 and Vickers Viscount.

India was also one of the first countries to embrace civil aviation. One of the first West Asian airline companies was Air India, which had its beginning as Tata Airlines in 1932, a division of Tata Sons Ltd. (now Tata Group). The airline was founded by India's leading industrialist, JRD Tata. On October 15, 1932, J. R. D. Tata himself flew a single engined De Havilland Puss Moth carrying air mail (postal mail of Imperial Airways) from Karachi to Bombay via Ahmedabad. The aircraft continued to Madras via Bellary piloted by Royal Air Force pilot Nevill Vintcent. Tata Airlines was also one of the world's first major airlines which began its operations without any support from the Government.

With the outbreak of World War II, the airline presence in Asia came to a relative halt, with many new flag carriers donating their aircraft for military aid and other uses. Following the end of the war in 1945, regular commercial service was restored in India and Tata Airlines became a public limited company on July 29, 1946 under the name Air India. After the independence of India, 49% of the airline was acquired by the Government of India. In return, the airline was granted status to operate international services from India as the designated flag carrier under the name Air India International.

On July 31, 1946, a chartered Philippine Airlines (PAL) DC-4 ferried 40 American servicemen to Oakland, California from Nielson Airport in Makati City with stops in Guam, Wake Island, Johnston Atoll and Honolulu, Hawaii, making PAL the first Asian airline to cross the Pacific Ocean. A regular service between Manila and San Francisco was started in December. It was during this year that the airline was designated as the flag carrier of Philippines.

During the era of decolonization, newly-born Asian countries started to embrace air transport. Among the first Asian carriers during the era were Cathay Pacific of Hong Kong (founded in September 1946), Orient Airways (later Pakistan International Airlines; founded in October 1946), Malayan Airlines (later Singapore and Malaysia Airlines; founded in 1947), El Al in Israel in 1948, Garuda Indonesia in 1949, Japan Airlines in 1951,Thai Airways International in 1960, and Korean Air in 1962.

Latin American airline industry

TAM Airlines is the largest airline in Latin America in terms of number of annual passengers flown.

Among the first countries to have regular airlines in Latin America were Cuba with Cubana de Aviación, Colombia with Avianca, Brazil with Varig, Chile with LAN Chile (today LAN Airlines), Dominican Republic with Dominicana de Aviación, Mexico with Mexicana de Aviación, and TACA as a brand of several airlines of Central American countries (Honduras, El Salvador, Costa Rica, Guatemala and Nicaragua). All the previous airlines started regular operations before World War II.

The air travel market has evolved rapidly over recent years in Latin America. Some industry estimations over 2000 new aircraft will begin service over the next five years in this region.

These airlines serve domestic flights within their countries, as well as connections within Latin America and also overseas flights to North America, Europe, Australia, Africa and Asia.

Just three airlines: LAN (Latin American Networks), Oceanair and TAM Airlines have international subsidiaries with Chile as the central operation along with Peru, Ecuador, Argentina and some operations in the Dominican Republic and TAM with TAM Mercosur have a base in Asuncion, Paraguay. Avianca have the control of Oceanair, VIP Airlines and also have an estrategic alliance with TACA.

Regulatory considerations

National

Garuda Indonesia Boeing 747-400 parked at Narita International Airport. This Indonesian Flag carrier is wholly owned by the Indonesian Government

Many countries have national airlines that the government owns and operates. Fully private airlines are subject to a great deal of government regulation for economic, political, and safety concerns. For instance, governments often intervene to halt airline labor actions in order to protect the free flow of people, communications, and goods between different regions without compromising safety.

The United States, Australia, and to a lesser extent Brazil, Mexico, India, the United Kingdom and Japan have "deregulated" their airlines. In the past, these governments dictated airfares, route networks, and other operational requirements for each airline. Since deregulation, airlines have been largely free to negotiate their own operating arrangements with different airports, enter and exit routes easily, and to levy airfares and supply flights according to market demand.

Cyprus Airways national airline of Cyprus

The entry barriers for new airlines are lower in a deregulated market, and so the U.S. has seen hundreds of airlines start up (sometimes for only a brief operating period). This has produced far greater competition than before deregulation in most markets, and average fares tend to drop 20% or more. The added competition, together with pricing freedom, means that new entrants often take market share with highly reduced rates that, to a limited degree, full service airlines must match. This is a major constraint on profitability for established carriers, which tend to have a higher cost base.

As a result, profitability in a deregulated market is uneven for most airlines. These forces have caused some major airlines to go out of business, in addition to most of the poorly established new entrants.

International

Singapore Airlines Airbus A380 lands at Changi Airport. Singapore Airlines was the first international airline to operate the A380, the world's largest passenger airliner.

Groups such as the International Civil Aviation Organization establish worldwide standards for safety and other vital concerns. Most international air traffic is regulated by bilateral agreements between countries, which designate specific carriers to operate on specific routes. The model of such an agreement was the Bermuda Agreement between the US and UK following World War II, which designated airports to be used for transatlantic flights and gave each government the authority to nominate carriers to operate routes.

Bilateral agreements are based on the "freedoms of the air", a group of generalized traffic rights ranging from the freedom to overfly a country to the freedom to provide domestic flights within a country (a very rarely granted right known as cabotage). Most agreements permit airlines to fly from their home country to designated airports in the other country: some also extend the freedom to provide continuing service to a third country, or to another destination in the other country while carrying passengers from overseas.

In the 1990s, "open skies" agreements became more common. These agreements take many of these regulatory powers from state governments and open up international routes to further competition. Open skies agreements have met some criticism, particularly within the European Union, whose airlines would be at a comparative disadvantage with the United States' because of cabotage restrictions.

Economic considerations

Juan Trippe, the founder of Pan American World Airways, surveying his globe. The collapse of Pan Am, an airline often credited for shaping the international airline industry, in December 1991 highlighted the financial complexities faced by major airline companies.

Historically, air travel has survived largely through state support, whether in the form of equity or subsidies. The airline industry as a whole has made a cumulative loss during its 100-year history, once the costs include subsidies for aircraft development and airport construction.

One argument is that positive externalities, such as higher growth due to global mobility, outweigh the microeconomic losses and justify continuing government intervention. A historically high level of government intervention in the airline industry can be seen as part of a wider political consensus on strategic forms of transport, such as highways and railways, both of which receive public funding in most parts of the world. Profitability is likely to improve in the future as privatization continues and more competitive low-cost carriers proliferate.

Although many countries continue to operate state-owned or parastatal airlines, many large airlines today are privately owned and are therefore governed by microeconomic principles in order to maximize shareholder profit.

Ticket revenue

Airlines assign prices to their services in an attempt to maximize profitability. The pricing of airline tickets has become increasingly complicated over the years and is now largely determined by computerized yield management systems.

Because of the complications in scheduling flights and maintaining profitability, airlines have many loopholes that can be used by the knowledgeable traveler. Many of these airfare secrets are becoming more and more known to the general public, so airlines are forced to make constant adjustments.

Most airlines use differentiated pricing, a form of price discrimination, in order to sell air services at varying prices simultaneously to different segments. Factors influencing the price include the days remaining until departure, the booked load factor, the forecast of total demand by price point, competitive pricing in force, and variations by day of week of departure and by time of day. Carriers often accomplish this by dividing each cabin of the aircraft (first, business and economy) into a number of travel classes for pricing purposes.

A complicating factor is that of origin-destination control ("O&D control"). Someone purchasing a ticket from Melbourne to Sydney (as an example) for AU$200 is competing with someone else who wants to fly Melbourne to Los Angeles through Sydney on the same flight, and who is willing to pay AU$1400. Should the airline prefer the $1400 passenger, or the $200 passenger plus a possible Sydney-Los Angeles passenger willing to pay $1300? Airlines have to make hundreds of thousands of similar pricing decisions daily.

Lufthansa Boeing 747-400.

The advent of advanced computerized reservations systems in the late 1970s, most notably Sabre, allowed airlines to easily perform cost-benefit analyses on different pricing structures, leading to almost perfect price discrimination in some cases (that is, filling each seat on an aircraft at the highest price that can be charged without driving the consumer elsewhere).

The intense nature of airfare pricing has led to the term "fare war" to describe efforts by airlines to undercut other airlines on competitive routes. Through computers, new airfares can be published quickly and efficiently to the airlines' sales channels. For this purpose the airlines use the Airline Tariff Publishing Company (ATPCO), who distribute latest fares for more than 500 airlines to Computer Reservation Systems across the world.

The extent of these pricing phenomena is strongest in "legacy" carriers. In contrast, low fare carriers usually offer preannounced and simplified price structure, and sometimes quote prices for each leg of a trip separately.

Computers also allow airlines to predict, with some accuracy, how many passengers will actually fly after making a reservation to fly. This allows airlines to overbook their flights enough to fill the aircraft while accounting for "no-shows," but not enough (in most cases) to force paying passengers off the aircraft for lack of seats. Since an average of ⅓ of all seats are flown empty, stimulative pricing for low demand flights coupled with overbooking on high demand flights can help reduce this figure. This is especially crucial during tough economic times as airlines undertake massive cuts to ticket prices in order to retain demand.

Operating costs

An Airbus A340-600 of Virgin Atlantic Airways. In October 2008, Virgin Atlantic offered to combine its operations with BMI in an effort to reduce operating costs.

Full-service airlines have a high level of fixed and operating costs in order to establish and maintain air services: labor, fuel, airplanes, engines, spares and parts, IT services and networks, airport equipment, airport handling services, sales distribution, catering, training, aviation insurance and other costs. Thus all but a small percentage of the income from ticket sales is paid out to a wide variety of external providers or internal cost centers.

Moreover, the industry is structured so that airlines often act as tax collectors. Airline fuel is untaxed because of a series of treaties existing between countries. Ticket prices include a number of fees, taxes and surcharges beyond the control of airlines. Airlines are also responsible for enforcing government regulations. If airlines carry passengers without proper documentation on an international flight, they are responsible for returning them back to the original country.

Analysis of the 1992–1996 period shows that every player in the air transport chain is far more profitable than the airlines, who collect and pass through fees and revenues to them from ticket sales. While airlines as a whole earned 6% return on capital employed (2-3.5% less than the cost of capital), airports earned 10%, catering companies 10-13%, handling companies 11-14%, aircraft lessors 15%, aircraft manufacturers 16%, and global distribution companies more than 30%. (Source: Spinetta, 2000, quoted in Doganis, 2002)

In contrast, Southwest Airlines has been the most profitable of airline companies since 1973.

The widespread entrance of a new breed of low cost airlines beginning at the turn of the century has accelerated the demand that full service carriers control costs. Many of these low cost companies emulate Southwest Airlines in various respects, and like Southwest, they are able to eke out a consistent profit throughout all phases of the business cycle.

As a result, a shakeout of airlines is occurring in the U.S. and elsewhere. United Airlines, Continental Airlines (twice), US Airways (twice), Delta Air Lines, and Northwest Airlines have all declared Chapter 11 bankruptcy. Some argue that it would be far better for the industry as a whole if a wave of actual closures were to reduce the number of "undead" airlines competing with healthy airlines while being artificially protected from creditors via bankruptcy law. On the other hand, some have pointed out that the reduction in capacity would be short lived given that there would be large quantities of relatively new aircraft that bankruptcies would want to get rid of and would re-enter the market either as increased fleets for the survivors or the basis of cheap planes for new startups.

Where an airline has established an engineering base at an airport then there may be considerable economic advantages in using that same airport as a preferred focus (or "hub") for its scheduled flights.

Assets and financing

The 'Golden Lounge' of Malaysia Airlines at Kuala Lumpur International Airport (KLIA). The airline has ownership of special slots at KLIA giving it a competitive edge over other airlines operating at the airport.

Airline financing is quite complex, since airlines are highly leveraged operations. Not only must they purchase (or lease) new airliner bodies and engines regularly, they must make major long-term fleet decisions with the goal of meeting the demands of their markets while producing a fleet that is relatively economical to operate and maintain. Compare Southwest Airlines and their reliance on a single airplane type (the Boeing 737 and derivatives), with the now defunct Eastern Air Lines which operated 17 different aircraft types, each with varying pilot, engine, maintenance, and support needs.

A second financial issue is that of hedging oil and fuel purchases, which are usually second only to labor in its relative cost to the company. However, with the current high fuel prices it has become the largest cost to an airline. Legacy airlines, compared with new entrants, have been hit harder by rising fuel prices partly due to the running of older, less fuel efficient aircraft. While hedging instruments can be expensive, they can easily pay for themselves many times over in periods of increasing fuel costs, such as in the 2000–2005 period.

In view of the congestion apparent at many international airports, the ownership of slots at certain airports (the right to take-off or land an aircraft at a particular time of day or night) has become a significant tradable asset for many airlines. Clearly take-off slots at popular times of the day can be critical in attracting the more profitable business traveler to a given airline's flight and in establishing a competitive advantage against a competing airline. If a particular city has two or more airports, market forces will tend to attract the less profitable routes, or those on which competition is weakest, to the less congested airport, where slots are likely to be more available and therefore cheaper. Other factors, such as surface transport facilities and onward connections, will also affect the relative appeal of different airports and some long distance flights may need to operate from the one with the longest runway.

Airline partnerships

A Japan Airlines Boeing 777-300 with special Oneworld livery. Oneworld is the third largest airline alliance after Star Alliance and SkyTeam.

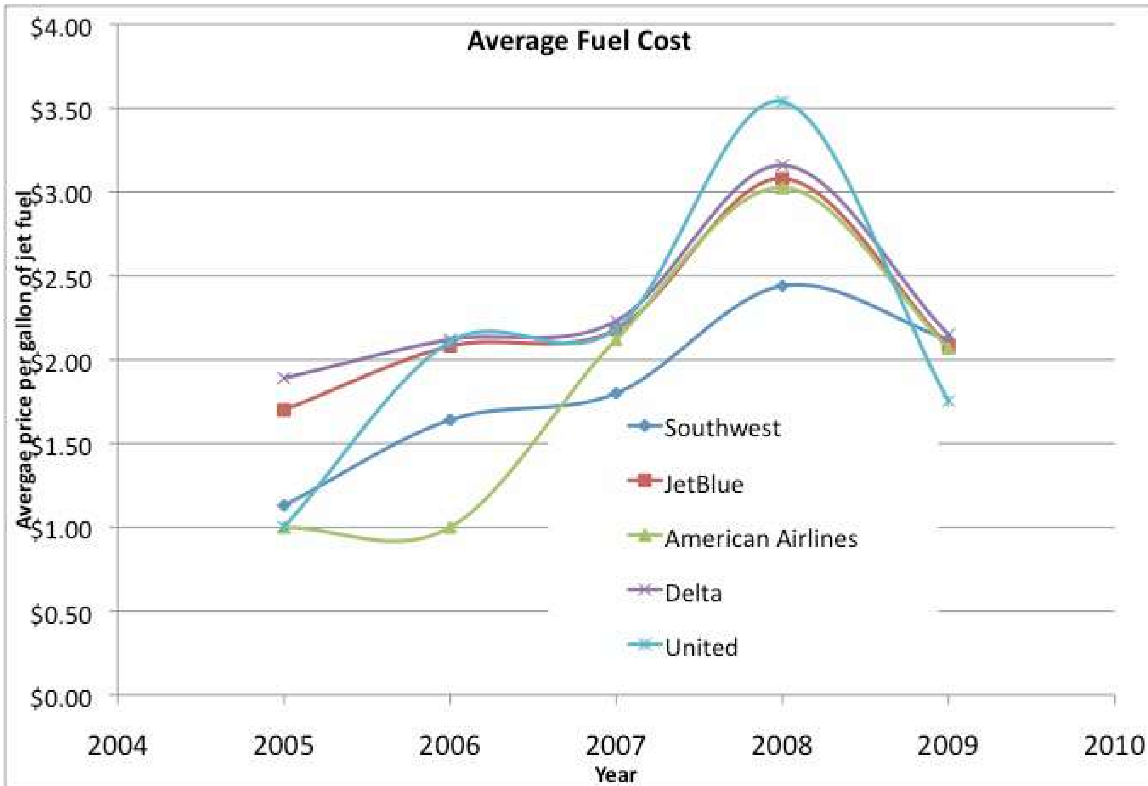
Codesharing is the most common type of airline partnership; it involves one airline selling tickets for another airline's flights under its own airline code. An early example of this was Japan Airlines' (JAL) codesharing partnership with Aeroflot in the 1960s on Tokyo–Moscow flights; Aeroflot operated the flights using Aeroflot aircraft, but JAL sold tickets for the flights as if they were JAL flights. This practice allows airlines to expand their operations, at least on paper, into parts of the world where they cannot afford to establish bases or purchase aircraft. Another example was the Austrian– Sabena partnership on the Vienna–Brussels–New York/JFK route during the late '60s, using a Sabena Boeing 707 with Austrian livery.

Since airline reservation requests are often made by city-pair (such as "show me flights from Chicago to Düsseldorf"), an airline who is able to codeshare with another airline for a variety of routes might be able to be listed as indeed offering a Chicago–Düsseldorf flight. The passenger is advised however, that airline no. 1 operates the flight from say Chicago to Amsterdam, and airline no. 2 operates the continuing flight (on a different airplane, sometimes from another terminal) to Düsseldorf. Thus the primary rationale for code sharing is to expand one's service offerings in city-pair terms so as to increase sales.

A more recent development is the airline alliance, which became prevalent in late 1990s. These alliances can act as virtual mergers to get around government restrictions. Groups of airlines such as the Star Alliance, Oneworld and SkyTeam coordinate their passenger service programs (such as lounges and frequent-flyer programs), offer special interline tickets, and often engage in extensive codesharing (sometimes systemwide). These are increasingly integrated business combinations—sometimes including cross-equity arrangements—in which products, service standards, schedules, and airport facilities are standardized and combined for higher efficiency. One of the first airlines to start an alliance with another airline was KLM, who partnered with Northwest Airlines. Both airlines later entered the SkyTeam alliance after the fusion of KLM and Air France in 2004.

Often the companies combine IT operations, or purchase fuel and aircraft as a bloc in order to achieve higher bargaining power. However, the alliances have been most successful at purchasing invisible supplies and services, such as fuel. Airlines usually prefer to purchase items visible to their passengers to differentiate themselves from local competitors. If an airline's main domestic competitor flies Boeing airliners, then the airline may prefer to use Airbus aircraft regardless of what the rest of the alliance chooses.

Fuel hedging

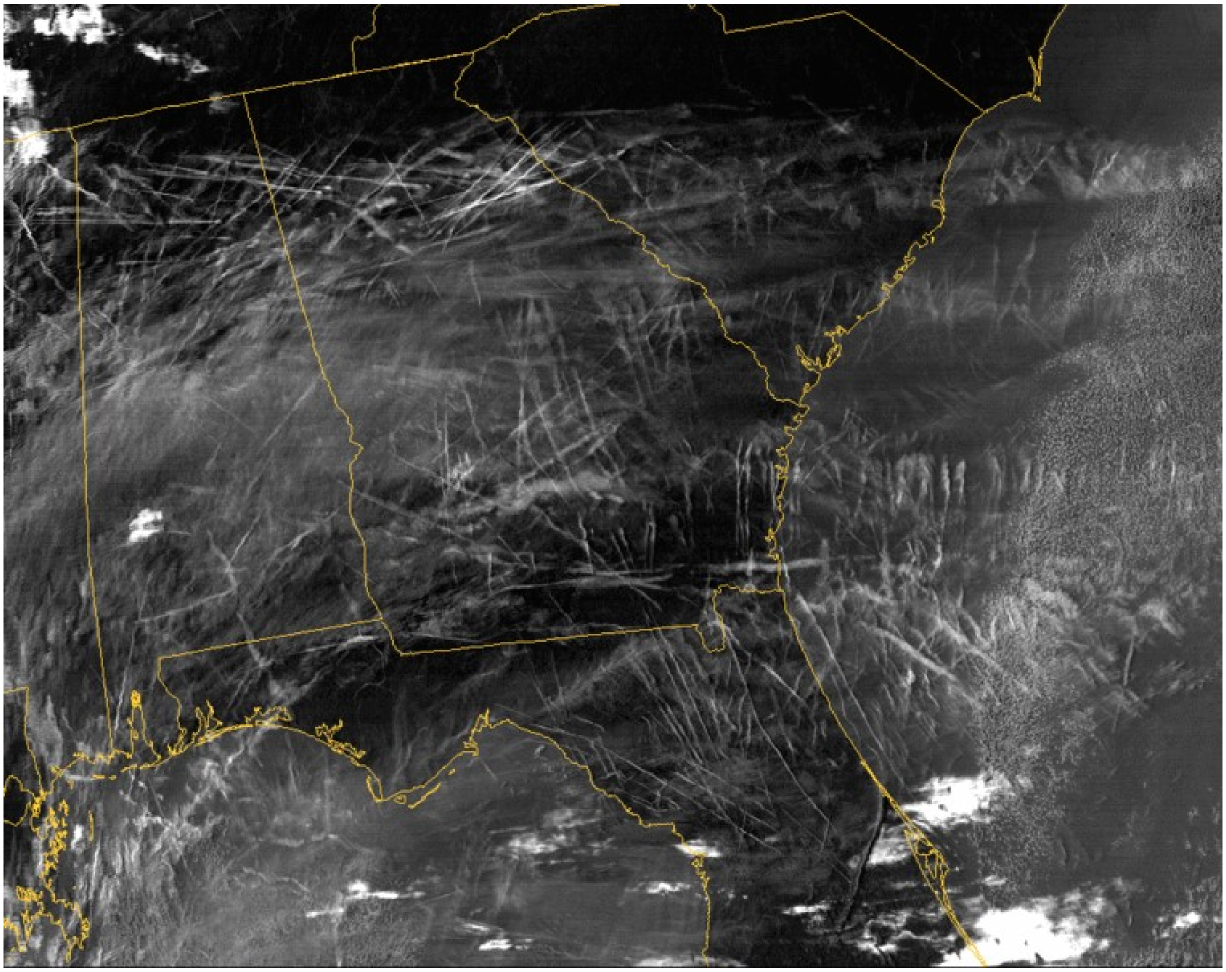


Average jet fuel prices per gallon for major United States airlines.

Southwest is credited with maintaining strong business profits between 1999 and the early 2000s due to its fuel hedging policy. Looking at the annual reports many other airlines are replicating Southwest's hedging policy to control their fuel costs.

Average fuel cost per gallon	2005	2006	2007	2008	2009
Southwest Airlines	$1.13	$1.64	$1.80	$2.44	$2.12
JetBlue Airways	$1.70	$2.08	$2.18	$3.08	$2.08
American Airlines			$2.12	$3.03	$2.07
Delta Air Lines	$1.89	$2.12	$2.23	$3.16	$2.15
United Airlines		$2.11	$2.18	$3.54	$1.75

Environmental impacts



MODIS tracking of contrails generated by air traffic over the southeastern United States on January 29, 2004.

Aircraft engines emit noise pollution, gases and particulate emissions, and contribute to global warming and global dimming.

Modern turbofan and turboprop engines are considerably more fuel-efficient and less polluting than earlier models. However, despite this, the rapid growth of air travel in recent years contributes to an increase in total pollution attributable to aviation, offsetting some of the reductions achieved by automobiles. In the EU greenhouse gas emissions from aviation increased by 87% between 1990 and 2006.

CO2 emissions from the jet fuel burned per passenger on an average 3200 kilometers (1992 miles) airline flight is about 353 kilograms (776 pounds). Loss of natural habitat potential associated with the jet fuel burned per passenger on a 3200 kilometers (1992 miles) airline flight is estimated to be 250 square meters (2700 square feet).

In the context of purported climate change and peak oil, there is a debate about possible taxation of air travel and the inclusion of aviation in an emissions trading scheme, with a view to ensuring that the total external costs of aviation are taken into account.

The airline industry is responsible for about 11 percent of greenhouse gases emitted by the U.S. transportation sector. Boeing estimates that biofuels could reduce flight-related greenhouse-gas emissions by 60 to 80 percent. The solution would be blending algae fuels with existing jet fuel:

- Boeing and Air New Zealand are collaborating with leading Brazilian biofuels maker Tecbio and Aquaflow Bionomic of New Zealand and other jet biofuel developers around the world.
- Virgin Atlantic and Virgin Green Fund are looking into the technology as part of a biofuels initiative.
- KLM has made the first commercial flight with bio-fuel in 2009.

Call signs

Each operator of a scheduled or charter flight uses an airline call sign when communicating with airports or air traffic control centres. Most of these call-signs are derived from the airline's trade name, but for reasons of history, marketing, or the need to reduce ambiguity in spoken English (so that pilots do not mistakenly make navigational decisions based on instructions issued to a different aircraft), some airlines and air forces use call-signs less obviously connected with their trading name. For example, British Airways uses a *Speedbird* call-sign, named after the logo of its predecessor, BOAC, while SkyEurope used *Relax*.

Chapter-3

Road Transport

A truck transporting a container on Interstate 95 in South Florida

Disruptions in organized traffic flow can create delays lasting hours.

Road transport (British English) or **road transportation** (American English) is transport on roads of passengers or goods. A hybrid of road transport and ship transport is the historic horse-drawn boat.

History

The first methods of road transport were horses, oxen or even humans carrying goods over dirt tracks that often followed game trails. As commerce increased, the tracks were often flattened or widened to accommodate the activities. Later, the travois, a frame used to drag loads, was developed. The wheel came still later, probably preceded by the use of logs as rollers. Early stone-paved roads were built in Mesopotamia and the Indus Valley Civilization. The Persians later built a network of Royal Roads across their empire.

With the advent of the Roman Empire, there was a need for armies to be able to travel quickly from one area to another, and the roads that existed were often muddy, which greatly delayed the movement of large masses of troops. To resolve this issue, the Romans built great roads. The Roman roads used deep roadbeds of crushed stone as an underlying layer to ensure that they kept dry, as the water would flow out from the crushed stone, instead of becoming mud in clay soils. The Islamic Caliphate later built tar-paved roads in Baghdad.

During the Industrial Revolution, and because of the increased commerce that came with it, improved roadways became imperative. The problem was rain combined with dirt roads created commerce-miring mud. John Loudon McAdam (1756-1836) designed the first modern highways. He developed an inexpensive paving material of soil and stone aggregate (known as macadam), and he embanked roads a few feet higher than the surrounding terrain to cause water to drain away from the surface. At the same time, Thomas Telford, made substantial advances in the engineering of new roads and the construction of bridges, particularly, the London to Holyhead road.

Various systems had been developed over centuries to reduce bogging and dust in cities, including cobblestones and wooden paving. Tar-bound macadam (tarmac) was applied to macadam roads towards the end of the 19th century in cities such as Paris. In the early 20th century tarmac and concrete paving were extended into the countryside.

Transportation

A public transport Bus

Transport on roads can be roughly grouped into two categories: transportation of goods and transportation of people. In many countries licencing requirements and safety regulations ensure a separation of the two industries.

The nature of road transportation of goods depends, apart from the degree of development of the local infrastructure, on the distance the goods are transported by road, the weight and volume of the individual shipment and the type of goods transported. For short distances and light, small shipments a van or pickup truck may be used. For large shipments even if less than a full truckload (Less than truckload) a truck is more appropriate. In some countries cargo is transported by road in horse-drawn carriages, donkey carts or other non-motorized mode. Delivery services are sometimes considered a separate category from cargo transport. In many places fast food is transported on roads by various types of vehicles. For inner city delivery of small packages and documents bike couriers are quite common.

People (Passengers) are transported on roads either in individual cars or automobiles or in mass transit/public transport by bus / Coach (vehicle). Special modes of individual transport by road like rickshaws or velotaxis may also be locally available.

Trucking and hauling

Sheep in a B Double truck, Moree, New South Wales, Australia.

Trucking companies (AE) or haulers/hauliers (BE) accept cargo for road transport. Truck drivers operate either independently working directly for the client or through freight carriers or shipping agents. Some big companies (e.g. grocery store chains) operate their own internal trucking operations.

In the U.S. many truckers own their truck (rig), and are known as owner-operators. Some road transportation is done on regular routes or for only one consignee per run, while others transport goods from many different loading stations/shippers to various consignees. On some long runs only cargo for one lag of the route (to) is known when the cargo is loaded. Truckers may have to wait at the destination for the return cargo (from).

A Bill of Lading issued by the shipper provides the basic document for road freight. On cross-border transportation the trucker will present the cargo and documentation provided by the shipper to customs for inspection. This also applies to shipments that are transported out of a Free port.

To avoid accidents caused by fatigue, truckers have to keep to strict rules for drivetime and required rest periods. Known in the U.S. as hours of service, and in the E.U. as drivers working hours. E.g. "Hours of Work and Rest Periods (Road Transport) Convention, 1979" or . Tachographs record the times the vehicle is in motion and stopped. Some companies use two drivers per truck to ensure uninterrupted transportation; with one driver resting or sleeping in a bunk in the back of the cab while the other is driving.

Truck drivers often need special licences to drive, known in the U.S. as a commercial driver's license. In the U.K. a Large Goods Vehicle licence is required.

For transport of hazardous materials truckers need a licence, which usually requires them to pass an exam (e.g. in the EU). They have to make sure they affix proper labels for the respective hazard(s) to their vehicle. Liquid goods are transported by road in tank trucks (AE) or tanker lorries (BE) (also road-tankers) or special tankcontainers for intermodal transport. For unpackaged goods and liquids weigh stations confirm weight after loading and before delivery. For transportation of live animals special requirements have to be met in many countries to prevent cruelty to animals. For fresh and frozen goods refrigerator trucks or reefer (container)s are used.

In Australia road trains replace rail transport for goods on routes throughout the center of the country. B-doubles and semi-trailers are used in urban areas because of their smaller size. Low-loader or flat-bed trailers are used to haul containers.

Modern roads

The Makran Coastal Highway was an ancient road within Pakistan. Now it's a major road leading to the city of Gwadar

Today roadways are principally asphalt or concrete. Both are based on McAdam's concept of stone aggregate in a binder, asphalt cement or Portland cement respectively. Asphalt is known as a flexible pavement, one which slowly will "flow" under the pounding of traffic. Concrete is a rigid pavement, which can take heavier loads but is more expensive and requires more carefully prepared subbase. So, generally, major roads are concrete and local roads are asphalt. Often concrete roads are covered with a thin layer of asphalt to create a wearing surface.

Modern pavements are designed for heavier vehicle loads and faster speeds, requiring thicker slabs and deeper subbase. Subbase is the layer or successive layers of stone, gravel and sand supporting the pavement. It is needed to spread out the slab load bearing on the underlying soil and to conduct away any water getting under the slabs. Water will undermine a pavement over time, so much of pavement and pavement joint design are meant to minimize the amount of water getting and staying under the slabs.

Shoulders are also an integral part of highway design. They are multipurpose; they can provide a margin of side clearance, a refuge for incapacitated vehicles, an emergency lane, and parking space. They also serve a design purpose, and that is to prevent water from percolating into the soil near the main pavement's edge. Shoulder pavement is designed to a lower standard than the pavement in the traveled way and won't hold up as well to traffic. (Which is why driving on the shoulder is generally prohibited.)

Pavement technology is still evolving, albeit in not easily noticed increments. For instance, chemical additives in the pavement mix make the pavement more weather resistant, grooving and other surface treatments improve resistance to skidding and hydroplaning, and joint seals which were once tar are now made of low maintenance neoprene.

Traffic control

Nearly all roadways are built with devices meant to control traffic. Most notable to the motorist are those meant to communicate directly with the driver. Broadly, these fall into three categories: signs, signals or pavement markings. They help the driver navigate; they assign the right-of-way at intersections; they indicate laws such as speed limits and parking regulations; they advise of potential hazards; they indicate passing and no passing zones; and otherwise deliver information and to assure traffic is orderly and safe.

200 years ago these devices were signs, nearly all informal. In the late 19th century signals began to appear in the biggest cities at a few highly congested intersections. They were manually operated, and consisted of semaphores, flags or paddles, or in some cases colored electric lights, all modeled on railroad signals. In the 20th century signals were automated, at first with electromechanical devices and later with computers. Signals can be quite sophisticated: with vehicle sensors embedded in the pavement, the signal can control and choreograph the turning movements of heavy traffic in the most complex of intersections. In the 1920s traffic engineers learned how to coordinate signals along a thoroughfare to increase its speeds and volumes. In the 1980s, with computers, similar coordination of whole networks became possible.

In the 1920s pavement markings were introduced. Initially they were used to indicate the road’s centerline. Soon after they were coded with information to aid motorists in passing safely. Later, with multi-lane roads they were used to define lanes. Other uses, such as indicating permitted turning movements and pedestrian crossings soon followed.

In the 20th century traffic control devices were standardized. Before then every locality decided on what its devices would look like and where they would be applied. This could be confusing, especially to traffic from outside the locality. In the United States standardization was first taken at the state level, and late in the century at the federal level. Each country has a Manual of Uniform Traffic Control Devices (MUTCD) and there are efforts to blend them into a worldwide standard.

Besides signals, signs, and markings, other forms of traffic control are designed and built into the roadway. For instance, curbs and rumble strips can be used to keep traffic in a given lane and median barriers can prevent left turns and even U-turns.

Toll roads

Early toll roads were usually built by private companies under a government franchise. They typically paralleled or replaced routes already with some volume of commerce, hoping the improved road would divert enough traffic to make the enterprise profitable. Plank roads were particularly attractive as they greatly reduced rolling resistance and mitigated the problem of getting mired in mud. Another improvement, better grading to lessen the steepness of the worst stretches, allowed draft animals to haul heavier loads.

A *toll road* in the United States is often called a *turnpike*. The term *turnpike* probably originated from the gate, often a simple pike, which blocked passage until the fare was paid at a *toll house* (or *toll booth* in current terminology). When the toll was paid the pike, which was mounted on a swivel, was turned to allow the vehicle to pass. Tolls were usually based on the type of cargo being transported, not the type of vehicle. The practice of selecting routes so as to avoid tolls is called shunpiking. This may be simply to avoid the expense, as a form of economic protest (or boycott), or simply to seek a road less traveled as a bucolic interlude.

Companies were formed to build, improve, and maintain a particular section of roadway, and tolls were collected from users to finance the enterprise. The enterprise was usually named to indicate the locale of its roadway, often including the name of one of both of the termini. The word *turnpike* came into common use in the names of these roadways and companies, and is essentially used interchangeably with *toll road* in current terminology.

In the United States, toll roads began with the Lancaster Turnpike in the 1790s, within Pennsylvania, connecting Philadelphia and Lancaster.

In New York State, the Great Western Turnpike was started in Albany in 1799 and eventually extended, by several alternate routes, to near what is now Syracuse, New York.

Toll roads peaked in the mid 19th century, and by the turn of the twentieth century most toll roads were taken over by state highway departments. The demise of this early toll road era was due to the rise of canals and railroads, which were more efficient (and thus cheaper) in moving freight over long distances. Roads wouldn't again be competitive with rails and barges until the first half of the 20th century when the internal combustion engine replaces draft animals as the source of motive power.

With the development, mass production, and popular embrace of the automobile, faster and higher capacity roads were needed. In the 1920s limited access highways appeared. Their main characteristics were dual roadways with access points limited to (but not always) grade-separated interchanges. Their dual roadways allowed high volumes of traffic, the need for no or few traffic lights along with relatively gentle grades and curves allowed higher speeds.

The first limited access highways were *Parkways*, so called because of their often park-like landscaping and, in the metropolitan New York City area, they connected the region's system of parks. When the German Autobahns built in the 1930s introduced higher design standards and speeds, road planners and road-builders in the United States started developing and building toll roads to similar high standards. The Pennsylvania Turnpike, which largely followed the path of a partially-built railroad, was the first, opening in 1940.

After 1940 with the Pennsylvania Turnpike, toll roads saw a resurgence, this time to fund limited access highways. In the late 1940s and early 1950s, after World War II interrupted the evolution of the highway, the US resumed building toll roads. They were to still higher standards and one road, the New York State Thruway, had standards that became the prototype for the U.S. Interstate Highway System. Several other major toll-roads which connected with the Pennsylvania Turnpike were established before the creation of the Interstate Highway System. These were the Indiana Toll Road, Ohio Turnpike, and New Jersey Turnpike.

US Interstate Highway system

In the United States, beginning in 1956, Dwight D. Eisenhower National System of Interstate and Defense Highways, commonly called the Interstate Highway System was built. It uses 12 foot (3.65m) lanes, wide medians, a maximum of 4% grade, and full access control, though many sections don't meet these standards due to older construction or constraints. This system created a continental-sized network meant to connect every population center of 50,000 people or more.

By 1956, most limited access highways in the eastern United States were toll roads. In that year, the federal Interstate highway program was established, funding non-toll roads with 90% federal dollars and 10% state match, giving little incentive for states to expand their turnpike system. Funding rules initially restricted collections of tolls on newly funded roadways, bridges, and tunnels. In some situations, expansion or rebuilding of a toll facility using Interstate Highway Program funding resulted in the removal of existing tolls. This occurred in Virginia on Interstate 64 at the Hampton Roads Bridge-Tunnel when a second parallel roadway to the regional 1958 bridge-tunnel was completed in 1976.

Since the completion of the initial portion of the interstate highway system, regulations were changed, and portions of toll facilities have been added to the system. Some states are again looking at toll financing for new roads and maintenance, to supplement limited federal funding. In some areas, new road projects have been completed with public-private partnerships funded by tolls, such as the Pocahontas Parkway (I-895) near Richmond, Virginia.

Pneumatic tires

As the horse-drawn carriage was replaced by the car and lorry or truck, and speeds increased, the need for smoother roads and less vertical displacement became more apparent, and pneumatic tires were developed to decrease the apparent roughness. Wagon and carriage wheels, made of wood, had a tire in the form of an iron strip that kept the wheel from wearing out quickly. Pneumatic tires, which had a larger footprint than iron tires, also were less likely to get bogged down in the mud on unpaved roads.

Road transport and the environment

By subsector, road transport is the largest contributor to global warming (74% of total emissions from transport).

Chapter-4

Ship Transport

Automobile ferry in Croatia

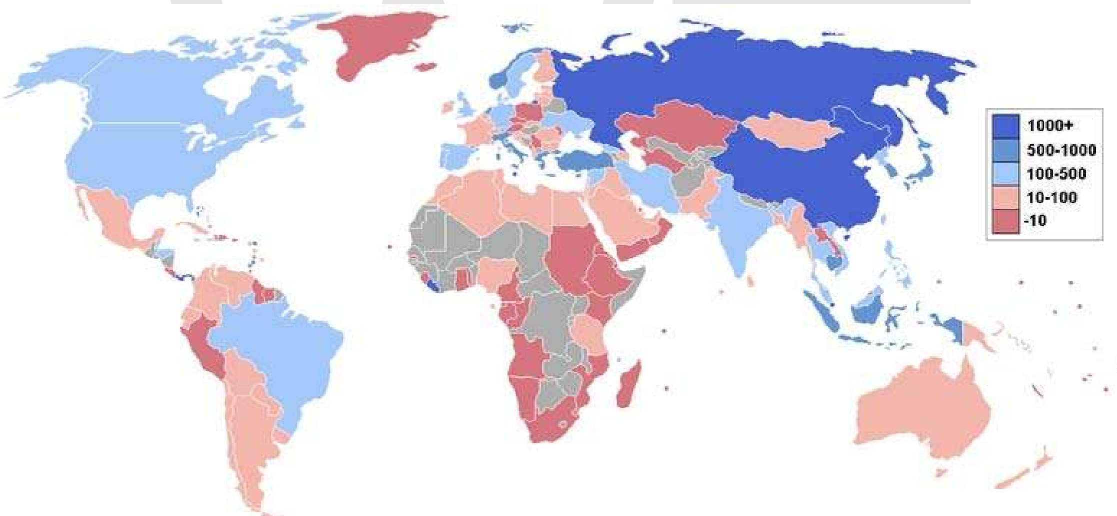
Harbour cranes unload cargo from a container ship at the Jawaharlal Nehru Port in Navi Mumbai, India

A container ship belonging to the Canadian cargo company, Asia Pacific Marine Container Lines

Ship transport is watercraft carrying people (passengers) or goods (cargo). Sea transport has been the largest carrier of freight throughout recorded history. Although the importance of sea travel for passengers has decreased due to aviation, it is effective for short trips and pleasure cruises. Transport by water is cheaper than transport by air.

Ship transport can be over any distance by boat, ship, sailboat or barge, over oceans and lakes, through canals or along rivers. Shipping may be for commerce, recreation or the military. Virtually any material that can be moved, can be moved by water, however water transport becomes impractical when material delivery is highly time-critical. "General cargo" is goods packaged in boxes, cases, pallets, and barrels. Containerization revolutionized ship transport in the 1960s. When a cargo is carried in more than one mode, it is intermodal or co-modal.

Merchant shipping



2005 registration of merchant ships (1,000 gross register tons (GRT) and over) per country.

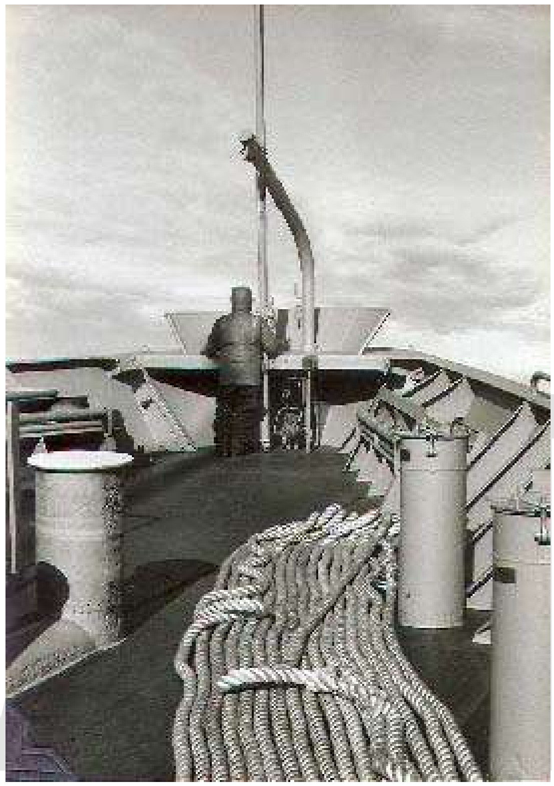
A nation's shipping fleet (merchant navy, merchant marine, merchant fleet) consists of the ships operated by civilian crews to transport passengers or cargo. Professionals are merchant seaman, merchant sailor, and merchant mariner, or simply seaman, sailor, or mariner. The terms "seaman" or "sailor" may refer to a member of a country's navy.

According to the 2005 CIA World Factbook, the world total number of merchant ships of 1,000 Gross Register Tons or over was 30,936. Statistics for individual countries are available at the List of merchant marine capacity by country.

Professional mariners

A ship's complement can be divided into four categories: the deck department, the engineering department, the steward's department, and other.

Deck department



An able seaman stands iceberg lookout on the bow of the freighter USNS Southern Cross during a re-supply mission to McMurdo Station, Antarctica; circa 1981.

Officer positions in the deck department include but not limited to: Master and his Chief, Second, and Third officers. The official classifications for unlicensed members of the deck department are Able Seaman and Ordinary Seaman.

A common deck crew for a ship includes:

- (1) Chief Officer/Chief Mate
- (1) Second Officer /Second Mate
- (1) Third Officer / Third Mate
- (1) Boatswain
- (2-6) Able Seamen
- (0-2) Ordinary Seamen

A deck cadet is person who is carrying out mandatory seatime to achieve their officer of the watch certificate. Their time onboard is spent learning the operations and tasks of everyday life on a merchant vessel.

Engineering department

A ship's engineering department consists of the members of a ship's crew that operate and maintain the propulsion and other systems on board the vessel. Marine Engineering staff also deal with the "Hotel" facilities on board, notably the sewage, lighting, air conditioning and water systems. They deal with bulk fuel transfers, and require training in firefighting and first aid, as well as in dealing with the ship's boats and other nautical tasks- especially with cargo loading/discharging gear and safety systems, though the specific cargo discharge function remains the responsibility of deck officers and deck workers. On LPG and LNG tankers however, a cargo engineer works with the deck department during cargo operations, as well as being a watchkeeping engineer.

A common Engineering crew for a ship includes:

- (1) Chief Engineer
- (1) Second Engineer / First Assistant Engineer
- (1) Third Engineer / Second Assistant Engineer
- (1-2) Fourth Engineer / Third Assistant Engineer
- (0-2) Fifth Engineer / Junior Engineer
- (1-3) Oiler (unlicensed qualified rating)
- (0-3) Greaser/s (unlicensed qualified rating)
- (1-5) Entry-level rating (such as Wiper (occupation), Utilityman, etc)

Many American ships also carry a Qualified Member of the Engine Department. Other possible positions include Motorman, Machinist, Electrician, Refrigeration Engineer, and Tankerman. Engine Cadets are trainee engineers who are completing sea time necessary before they can obtain a watchkeeping license.

Steward's department

A typical Steward's department for a cargo ship would be composed of a Chief Steward, a Chief Cook, and a Steward's Assistant. All three positions are typically filled by unlicensed personnel.

The chief steward directs, instructs, and assigns personnel performing such functions as preparing and serving meals; cleaning and maintaining officers' quarters and steward department areas; and receiving, issuing, and inventorying stores.

On large passenger vessels, the Catering Department is headed by the Chief Purser and managed by assistant pursers. Although they enjoy the benefits of having officer rank, they generally progress through the ranks to become pursers. Under the pursers are the department heads - such as chief cook, head waiter, head barman etc. They are responsible for the administration of their own areas.

The chief steward also plans menus; compiles supply, overtime, and cost control records. May requisition or purchase stores and equipment. May bake bread, rolls, cakes, pies, and pastries.

A chief steward's duties may overlap with those of the Steward's Assistant, the Chief Cook, and other Steward's Department crewmembers.

In the United States Merchant Marine, in order to be occupied as a chief steward a person has to have a Merchant Mariner's Document issued by the United States Coast Guard. Because of international conventions and agreements, all chief cooks who sail internationally are similarly documented by their respective countries.

Other Departments

Staff officer positions on a ship, including Junior Assistant Purser, Senior Assistant Purser, Purser, Chief Purser, Medical Doctor, Professional Nurse, Marine Physician Assistant, and Hospital Corpsman, are considered administrative positions and are therefore regulated by Certificates of Registry issued by the United States Coast Guard. Pilots are also merchant marine officers and are licensed by the Coast Guard. Formerly, there was also a radio department, headed by a chief radio officer and supported by a number of radio officers. Since the introduction of GMDSS (Satellite communications) and the subsequent exemptions from carrying radio officers if the vessel is so equipped, this department has fallen away, although many ships do still carry specialist radio officers, particularly passenger vessels. Many radio officers became 'electro-technical officers', and transferred into the engineering department.

Life at sea

Mariners live much of their life spent beyond the reach of land. They face sometimes dangerous conditions at sea. Yet men and women still go to sea. For some, the attraction is a life unencumbered with the restraints of life ashore. Sea-going adventure and a chance to see the world also appeal to many seafarers. Whatever the calling, those who live and work at sea invariably confront social isolation.

Findings by the Seafarer's International Research Center indicate a leading cause of mariners leaving the industry is "almost invariably because they want to be with their families." U.S. merchant ships typically do not allow family members to accompany seafarers on voyages. Industry experts increasingly recognize isolation, stress, and fatigue as occupational hazards. Advocacy groups such as International Labour Organization, a United Nations agency, and the Nautical Institute are seeking improved international standards for mariners.

Ocean voyages are steeped in routine. Maritime tradition dictates that each day be divided into six four-hour periods. Three groups of watchkeepers from the engine and deck departments work four hours on then have eight hours off watchkeeping. However there are many overtime jobs to be done daily. This cycle repeats endlessly, 24 hours a day while the ship is at sea. Members of the steward department typically are day workers who put in at least eight-hour shifts. Operations at sea, including repairs, safeguarding against piracy, securing cargo, underway replenishment, and other duties provide opportunities for overtime work. Service aboard ships typically extends for months at a time, followed by protracted shore leave. However, some seamen secure jobs on ships they like and stay aboard for years.

In rare cases, veteran mariners choose never to go ashore when in port. Further, the often quick turnaround of many modern ships, spending only a matter of hours in port, limits a seafarer's free-time ashore. Moreover, some foreign seamen entering U.S. ports from a watchlist of 25 high-risk countries face restrictions on shore leave due to security concerns in a post 9/11 environment. However, shore leave restrictions while in U.S. ports impact American seamen as well. For example, the International Organization of Masters, Mates & Pilots notes a trend of U.S. shipping terminal operators restricting seamen from traveling from the ship to the terminal gate. Further, in cases where transit is allowed, special "security fees" are at times assessed.

Such restrictions on shore leave coupled with reduced time in port by many ships translate into longer periods at sea. Mariners report that extended periods at sea living and working with shipmates who for the most part are strangers takes getting used to. At the same time, there is an opportunity to meet people from other ethnic and cultural backgrounds. Recreational opportunities have improved aboard some U.S. ships, which may feature gyms and day rooms for watching movies, swapping sea stories, and other activities. And in some cases, especially tankers, it is made possible for a mariner to be accompanied by members of his family. However, a mariner’s off duty time is largely a solitary affair, pursuing hobbies, reading, writing letters, and sleeping.

On modern ocean going vessels, typically registered with a flag of convenience, life has changed immensely in the last 20 years. Most large vessels include a gym and often a swimming pool for use by the crew. Since the Exxon Valdez incident, the focus of leisure time activity has shifted from having officer and crew bars, to simply having lounge-style areas where officers or crew can sit to watch movies. With many companies now providing TVs and DVD players in cabins, and enforcing strict smoking policies, it is not surprising that the bar is now a much quieter place on most ships. In some instances games consoles are provided for the officers and crew. The officers enjoy a much higher standard of living on board ocean going vessels. Crews are generally poorly paid, poorly qualified and have to complete contracts of approx 9 months before returning home on leave. They often come from countries where the average industrial wage is still very low, such as the Philippines or India. Officers however, come from all over the world and it is not uncommon to mix the nationality of the officers on board ships. Officers are often the recipients of university degrees and have completed vast amounts of training in order to reach their rank. Officers benefit on board by having larger, more comfortable cabins, table service for their meals, etc. Contracts average at the 4 month mark for officers, with generous leave. Most Ocean going vessels now operate an Unmanned Engineroom System allowing engineers to work days only. The engine room is computer controlled by night, although the duty engineer will make inspections during unmanned operation. Engineers work in a hot, humid, noisy atmosphere. Communication in the engineroom is therefore by hand signals and lip-reading, and good teamwork often stands in place of any communication at all.

Ships and watercraft

Ships and other watercraft are used for ship transport. Types can be distinguished by propulsion, size or cargo type. Recreational or educational craft still use wind power, while some smaller craft use internal combustion engines to drive one or more propellers, or in the case of jet boats, an inboard water jet. In shallow draft areas, such as the Everglades, some craft, such as the hovercraft, are propelled by large pusher-prop fans.

Most modern merchant ships can be placed in one of a few categories, such as:

Bulk carriers, such as the Sabrina I seen here, are cargo ships used to transport bulk cargo items such as ore or food staples (rice, grain, etc.) and similar cargo. It can be recognized by the large box-like hatches on its deck, designed to slide outboard for loading. A bulk carrier could be either dry or wet. Most lakes are too small to accommodate bulk ships, but a large fleet of lake freighters has been plying the Great Lakes and St. Lawrence Seaway of North America for over a century.

Container ships are cargo ships that carry their entire load in truck-size containers, in a technique called containerization. They form a common means of commercial intermodal freight transport. Informally known as "box boats," they carry the majority of the world's dry cargo. Most container ships are propelled by diesel engines, and have crews of between 10 and 30 people. They generally have a large accommodation block at the stern, directly above the engine room.

Tankers are cargo ships for the transport of fluids, such as crude oil, petroleum products, liquefied petroleum gas, liquefied natural gas and chemicals, also vegetable oils, wine and other food - the tanker sector comprises one third of the world tonnage.

Reefer ships are cargo ships typically used to transport perishable commodities which require temperature-controlled transportation, mostly fruits, meat, fish, vegetables, dairy products and other foodstuffs.

Roll-on/roll-off ships, such as the Chi-Cheemaun, are cargo ships designed to carry wheeled cargo such as automobiles, trailers or railway carriages. RORO (or ro/ro) vessels have built-in ramps which allow the cargo to be efficiently "rolled on" and "rolled off" the vessel when in port. While smaller ferries that operate across rivers and other short distances still often have built-in ramps, the term RORO is generally reserved for larger ocean-going vessels.

Coastal trading vessels, also known as **coasters**, are shallow-hulled ships used for trade between locations on the same island or continent. Their shallow hulls mean that they can get through reefs where sea-going ships usually cannot (sea-going ships have a very deep hull for supplies and trade etc.).

Ferries are a form of transport, usually a boat or ship, but also other forms, carrying (or *ferrying*) passengers and sometimes their vehicles. Ferries are also used to transport freight (in lorries and sometimes unpowered freight containers) and even railroad cars. Most ferries operate on regular, frequent, return services. A foot-passenger ferry with many stops, such as in Venice, is sometimes called a waterbus or water taxi. Ferries form a part of the public transport systems of many waterside cities and islands, allowing direct transit between points at a capital cost much lower than bridges or tunnels. Many of the ferries operating in Northern European waters are ro/ro ships.

Cruise ships are passenger ships used for pleasure voyages, where the voyage itself and the ship's amenities are considered an essential part of the experience. Cruising has become a major part of the tourism industry, with millions of passengers each year as of 2006. The industry's rapid growth has seen nine or more newly built ships catering to a North American clientele added every year since 2001, as well as others servicing European clientele. Smaller markets such as the Asia-Pacific region are generally serviced by older tonnage displaced by new ships introduced into the high growth areas. On the Baltic sea this market is served by **cruiseferries**.

Cable layer is a deep-sea vessel designed and used to lay underwater cables for telecommunications, electricity, and such. A large superstructure, and one or more spools that feed off the transom distinguish it.

A **tugboat** is a boat used to manoeuvre, primarily by towing or pushing other vessels in harbours, over the open sea or through rivers and canals. They are also used to tow barges, disabled ships, or other equipment like towboats.

A **dredger** (sometimes also called a dredge) is a ship used to excavate in shallow seas or fresh water areas with the purpose of gathering up bottom sediments and disposing of them at a different location.

A **barge** is a flat-bottomed boat, built mainly for river and canal transport of heavy goods. Most barges are not self-propelled and need to be moved by tugboats towing or towboats pushing them. Barges on canals (towed by draft animals on an adjacent towpath) contended with the railway in the early industrial revolution but were outcompeted in the carriage of high value items due to the higher speed, falling costs, and route flexibility of rail transport.

A Multi-purpose ship (sometimes called a general cargo ship) is used to transport a variety of goods from bulk commodities to break bulk and heavy cargoes. To provide maximum trading flexibility they are usually geared and modern examples are fitted for the carriage of containers and grains. Generally they will have large open holds and tweendecks to facilitate the carriage of different cargoes on the same voyage. The crew will be highly competent in the securing of break bulk cargoes and the ship will be equipped with various lashings and other equipment for sea fastening.

Ships that fall outside these categories include Semi-submersible heavy-lift ships or OHGC.

Typical in-transit times

A cargo ship sailing from a European port to a US one will typically take 10–12 days depending on water currents and other factors.

Ship transport infrastructure

Container port facilities in Newark Bay, seen from Bayonne, New Jersey

For a port to efficiently send and receive cargo, it requires infrastructure. Harbors, seaports and marinas host watercraft, and consist of components such as piers, wharfs, docks and roadsteads.

Chapter-5

Pipe Line and Cable Transport

Pipe Line Transport

An elevated section of the Alaska Pipeline

District heating pipeline in Austria with a length of 31 km

Pipeline transport is the transportation of goods through a pipe. Most commonly, liquid and gases are sent, but pneumatic tubes that transport solid capsules using compressed air are also used.

As for gases and liquids, any chemically stable substance can be sent through a pipeline. Therefore sewage, slurry, water, or even beer pipelines exist; but arguably the most valuable are those transporting fuels: oil (oleoduct), natural gas (gas grid), and biofuels.

Dmitri Mendeleev first suggested using a pipe for transporting petroleum in 1863.

Types by transported substance

For oil or natural gas

A "Pig" launcher/receiver, belonging to the natural gas pipeline in Switzerland.

There is some argument as to when the first crude oil pipeline was built However, some say pipeline transport was pioneered by Vladimir Shukhov and the Branobel company in the late 19th century. Others say oil pipelines originated when the Oil Transport Association first constructed a 2-inch (51 mm) wrought iron pipeline over a 6-mile (9.7 km) track from an oil field in Pennsylvania to a railroad station in Oil Creek, in the 1860s. Pipelines are generally the most economical way to transport large quantities of oil, refined oil products or natural gas over land. Compared to shipping by railroad, they have lower cost per unit and higher capacity. Although pipelines can be built under the sea, that process is economically and technically demanding, so the majority of oil at sea is transported by tanker ships.

Oil pipelines are made from steel or plastic tubes with inner diameter typically from 4 to 48 inches (100 to 1,200 mm). Most pipelines are buried at a typical depth of about 3 to 6 feet (0.91 to 1.8 m). The oil is kept in motion by pump stations along the pipeline, and usually flows at speed of about 1 to 6 metres per second (3.3 to 20 ft/s). Multi-product pipelines are used to transport two or more different products in sequence in the same pipeline. Usually in multi-product pipelines there is no physical separation between the different products. Some mixing of adjacent products occurs, producing interface. At the receiving facilities this interface is usually absorbed in one of the product based on pre-calculated absorption rates.

Crude oil contains varying amounts of wax, or paraffin, and in colder climates wax buildup may occur within a pipeline. Often these pipelines are inspected and cleaned using pipeline inspection gauges *pigs*, also known as *scrapers* or *Go-devils*. Smart pigs (also known as intelligent or intelligence pigs) are used to detect anomalies in the pipe such as dents, metal loss caused by corrosion, cracking or other mechanical damage. These devices are launched from pig-launcher stations and travel through the pipeline to be received at any other station down-stream, either cleaning wax deposits and material that may have accumulated inside the line or inspecting and recording the condition of the line.

For natural gas, pipelines are constructed of carbon steel and varying in size from 2 to 60 inches (51 to 1,500 mm) in diameter, depending on the type of pipeline. The gas is pressurized by compressor stations and is odorless unless mixed with a mercaptan odorant where required by a regulating authority.

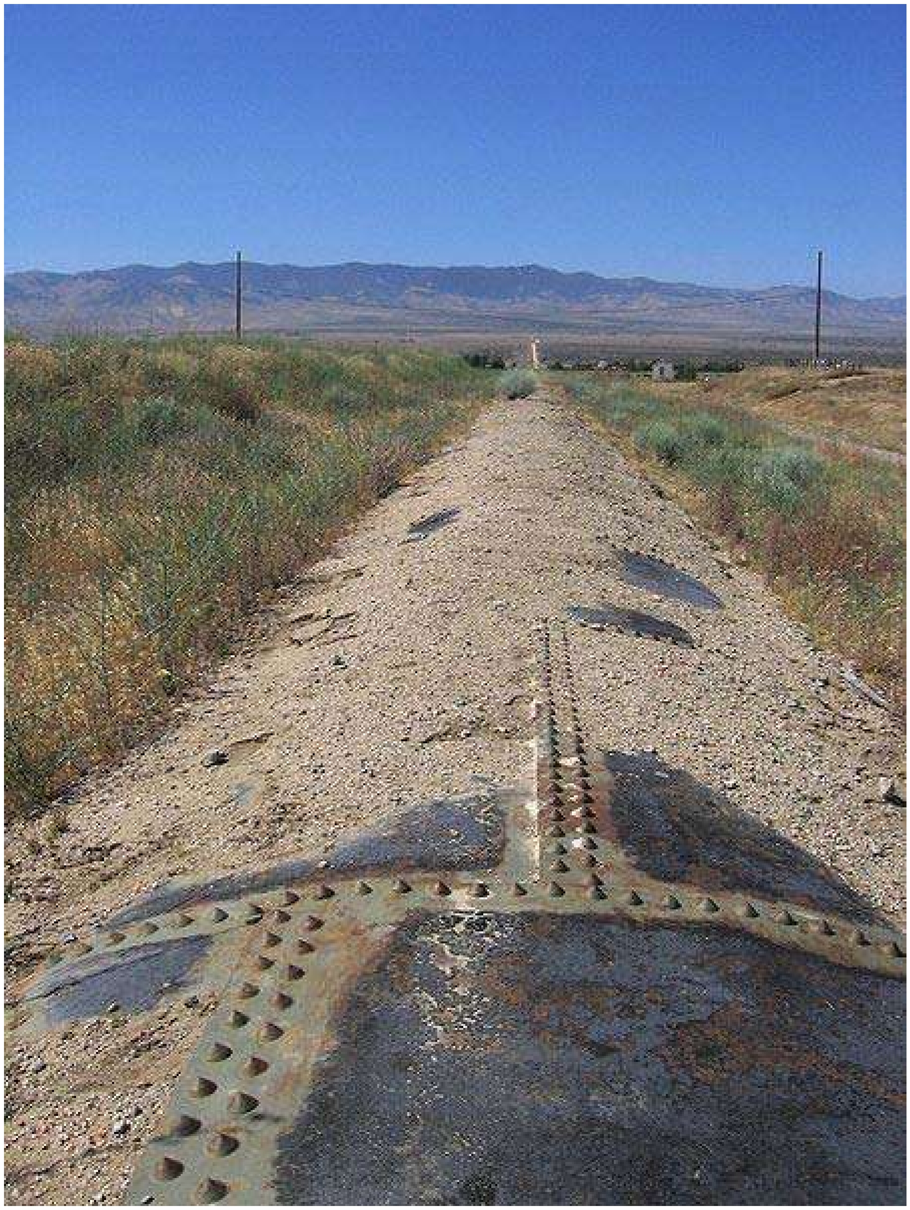
For biofuels (ethanol and biobutanol)

Pipelines have been used for transportation of ethanol in Brazil, and there are several ethanol pipeline projects in Brazil and the United States. Main problems related to the shipment of ethanol by pipeline are its high oxygen content, which makes it corrosive, and absorption of water and impurities in pipelines, which is not a problem with oil and natural gas. Insufficient volumes and cost-effectiveness are other considerations limiting construction of ethanol pipelines.

For hydrogen

Hydrogen pipeline transport is a transportation of hydrogen through a pipe as part of the hydrogen infrastructure. Hydrogen pipeline transport is used to connect the point of hydrogen production or delivery of hydrogen with the point of demand, with transport costs similar to CNG, the technology is proven,. Most hydrogen is produced at the place of demand with every 50 to 100 miles (160 km) an industrial production facility. The 1938 - Rhine-Ruhr 240 km hydrogen pipeline is still in operation. As of 2004 there are 900 miles (1450 km) of low pressure hydrogen pipelines in the USA and 930 miles (1,500 km) in Europe.

For water



The Los Angeles Aqueduct in Antelope Valley.

Two millennia ago the ancient Romans made use of large aqueducts to transport water from higher elevations by building the aqueducts in graduated segments that allowed gravity to push the water along until it reached its destination. Hundreds of these were built throughout Europe and elsewhere, and along with flour mills were considered the lifeline of the Roman Empire. The ancient Chinese also made use of channels and pipe systems for public works. The infamous Han Dynasty court eunuch Zhang Rang (d. 189 AD) once ordered the engineer Bi Lan to construct a series of square-pallet chain pumps outside the capital city of Luoyang. These chain pumps serviced the imperial palaces and living quarters of the capital city as the water lifted by the chain pumps were brought in by a stoneware pipe system.

Pipelines are useful for transporting water for drinking or irrigation over long distances when it needs to move over hills, or where canals or channels are poor choices due to considerations of evaporation, pollution, or environmental impact.

The 530 km (360 mile) Goldfields Water Supply Scheme in Western Australia using 750 mm (30 inch) pipe and completed in 1903 was the largest water supply scheme of its time.

Examples of significant water pipelines in South Australia are the Morgan-Whyalla (completed 1944) and Mannum-Adelaide (completed 1955) pipelines.

There are two Los Angeles, California aqueducts, the *First Los Angeles Aqueduct* (completed 1913) and the *Second Los Angeles Aqueduct* (completed 1970) which also include extensive use of pipelines.

For beverages

For beer

Thor Pipeline in Randers, Denmark

Bars in the Veltins-Arena, a major football ground in Gelsenkirchen, Germany, are interconnected by a 5 km long beer pipeline. It is the favorite method for distributing beer in such large stadiums, because the bars have to overcome big differences between demands during various stages of a match; this allows them to be supplied by a central tank.

In Randers city in Denmark, the so-known Thor beer pipeline still exists. Originally copper pipes were running directly from the brewery, and, when in 90-ies the brewery moved out the city, Thor beer replaced the center of a star with a giant tank.

For other uses

The town of Hallstatt in Austria claims to contain "the oldest industrial pipeline in the world", dating back to 1595. It was constructed from 13,000 trunks to transport saline solution for 40 kilometers from Hallstatt to Ebensee.

Types by transport function

In general, pipelines can be classified in three categories depending on purpose:

Gathering pipelines

Group of smaller interconnected pipelines forming complex networks with the purpose of bringing crude oil or natural gas from several nearby wells to a treatment plant or processing facility. In this group, pipelines are usually short- a couple of hundred meters- and with small diameters. Also sub-sea pipelines for collecting product from deep water production platforms are considered gathering systems.

Transportation pipelines

Mainly long pipes with large diameters, moving products (oil, gas, refined products) between cities, countries and even continents. These transportation networks include several compressor stations in gas lines or pump stations for crude and multiproducts pipelines.

Distribution pipelines

Composed of several interconnected pipelines with small diameters, used to take the products to the final consumer. Feeder lines to distribute gas to homes and businesses downstream. Pipelines at terminals for distributing products to tanks and storage facilities are included in this group.

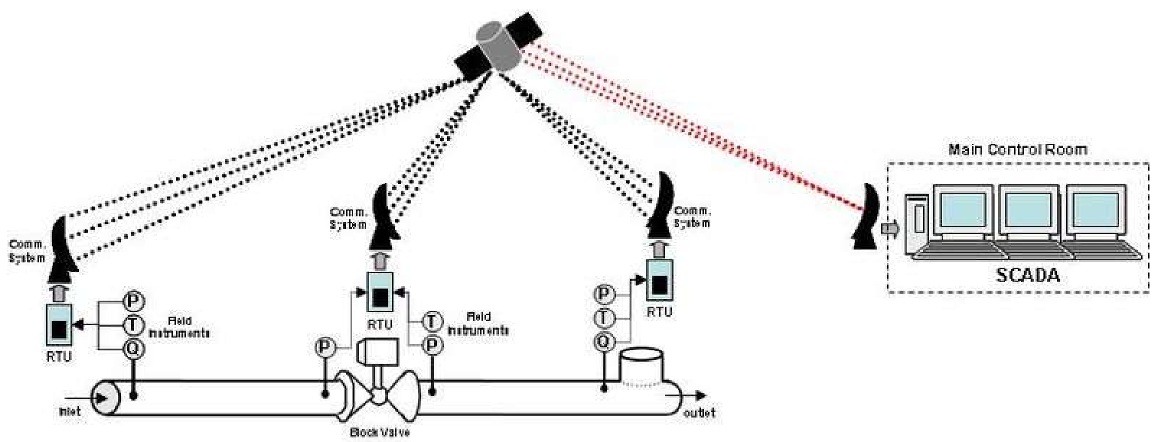
Operation

When a pipeline is built, the construction project not only covers the civil work to lay the pipeline and build the pump/compressor stations, it also has to cover all the work related to the installation of the field devices that will support remote operation.

Field devices are instrumentation, data gathering units and communication systems. The field Instrumentation includes flow, pressure and temperature gauges/transmitters, and other devices to measure the relevant data required. These instruments are installed along the pipeline on some specific locations, such as injection or delivery stations, pump stations (liquid pipelines) or compressor stations (gas pipelines), and block valve stations.

The information measured by these field instruments is then gathered in local Remote Terminal Units (RTU) that transfer the field data to a central location in real time using communication systems, such as satellite channels, microwave links, or cellular phone connections.

Pipelines are controlled and operated remotely, from what is usually known as *The Main Control Room*. In this center, all the data related to field measurement is consolidated in one central database. The data is received from multiple RTUs along the pipeline. It is common to find RTUs installed at every station along the pipeline.



The SCADA System for pipelines.

The SCADA system at the Main Control Room receives all the field data and presents it to the pipeline operator through a set of screens or Human Machine Interface, showing the operational conditions of the pipeline. The operator can monitor the hydraulic conditions of the line, as well as send operational commands (open/close valves, turn on/off compressors or pumps, change setpoints, etc.) through the SCADA system to the field.

To optimize and secure the operation of these assets, some pipeline companies are using what is called *Advanced Pipeline Applications*, which are software tools installed on top of the SCADA system, that provide extended functionality to perform leak detection, leak location, batch tracking (liquid lines), pig tracking, composition tracking, predictive modeling, look ahead modeling, operator training and more.

Technology

Components

The Trans Alaska Pipeline crossing under the Tanana River and over ridge of the Alaska Range

Pipeline networks are composed of several pieces of equipment that operate together to move products from location to location. The main elements of a pipeline system are:

Initial injection station

Known also as *supply* or *inlet* station, is the beginning of the system, where the product is injected into the line. Storage facilities, pumps or compressors are usually located at these locations.

Compressor/pump stations

Pumps for liquid pipelines and Compressors for gas pipelines, are located along the line to move the product through the pipeline. The location of these stations is defined by the topography of the terrain, the type of product being transported, or operational conditions of the network.

Partial delivery station

Known also as *intermediate* stations, these facilities allow the pipeline operator to deliver part of the product being transported.

Block valve station

These are the first line of protection for pipelines. With these valves the operator can isolate any segment of the line for maintenance work or isolate a rupture or leak. Block valve stations are usually located every 20 to 30 miles (48 km), depending on the type of pipeline. Even though it is not a design rule, it is a very usual practice in liquid pipelines. The location of these stations depends exclusively on the nature of the product being transported, the trajectory of the pipeline and/or the operational conditions of the line.

Regulator station

This is a special type of valve station, where the operator can release some of the pressure from the line. Regulators are usually located at the downhill side of a peak.

Final delivery station

Known also as **outlet** stations or terminals, this is where the product will be distributed to the consumer. It could be a tank terminal for liquid pipelines or a connection to a distribution network for gas pipelines.

Leak detection systems

Since oil and gas pipelines are an important asset of the economic development of almost any country, it has been required either by government regulations or internal policies to ensure the safety of the assets, and the population and environment where these pipelines run.

Pipeline companies face government regulation, environmental constraints and social situations. Pipeline companies should comply with government regulations which may define minimum staff to run the operation, operator training requirements, up to specifics including pipeline facilities, technology and applications required to ensure operational safety. As an example, in the State of Washington, it is mandatory for pipeline operators to be able to detect and locate leaks of 8 percent of maximum flow within 15 minutes or less.

The social situation also affects the operation of pipelines. In third world countries, product theft is a problem for pipeline companies. It is common to find unauthorized extractions in the middle of the pipeline. In this case, the detection levels should be under 2 percent of maximum flow, with a high expectation for location accuracy.

Different types of technologies and strategies have been implemented, from physically walking the lines to satellite surveillance. The most common technology to protect these lines from occasional leaks is known as Computational Pipeline Monitoring Systems or CPM. CPM takes information from the field related to pressures, flows, and temperatures to estimate the hydraulic behavior of the product being transported. Once the estimation is done, the results are compared to other field references to detect the presence of an anomaly or unexpected situation, which may be related to a leak.

The American Petroleum Institute has published several articles related to the performance of CPM in liquids pipelines, the API Publications are:

- API 1130 – Computational pipeline monitoring for liquids pipelines
- API 1155 – Evaluation methodology for software based leak detection systems
- API 1149 – Pipeline variable uncertainties & their effects on leak detectability

Implementation

As a rule pipelines for all uses are laid in most cases underground. However in some cases it is necessary to cross a valley or a river on a pipeline bridge. Pipelines for centralized heating systems are often (why?)(why not?) laid on the ground or overhead. Pipelines for petroleum running through permafrost areas as Trans-Alaska-Pipeline are often run overhead in order to avoid melting the frozen ground by hot petroleum which would result in sinking the pipeline in the ground.

Regulation

An underground petroleum pipeline running through a park

In the US, pipelines are regulated by the Pipeline and Hazardous Materials Safety Administration (PHMSA). Offshore pipelines are regulated by the Minerals Management Service (MMS). In Canada, pipelines are regulated by either the provincial regulators or, if they cross provincial boundaries or the Canada/US border, by the National Energy Board (NEB). Government regulations in Canada and the United States require that buried fuel pipelines must be protected from corrosion. Often, the most economical method of corrosion control is by use of pipeline coating in conjunction with cathodic protection and technology to monitor the pipeline. Above ground, cathodic protection is not an option. The coating is the only external protection.

Pipelines and geopolitics

Natural gas pipelines from Russia to the European Union, 2009

Pipelines for major energy resources (petroleum and natural gas) are not merely an element of trade. They connect to issues of geopolitics and international security as well, and the construction, placement, and control of oil and gas pipelines often figure prominently in state interests and actions. A notable example of pipeline politics occurred at the beginning of the year 2009, wherein a dispute between Russia and Ukraine ostensibly over pricing led to a major political crisis. Russian state-owned gas company Gazprom cut off natural gas supplies to Ukraine after talks between it and the Ukrainian government fell through.

Oil and gas pipelines also figure prominently in the politics of Central Asia and the Caucasus.

Dangers

Accidents

Pipelines conveying flammable or explosive material, such as natural gas or oil, pose special safety concerns.

- 1982 - One of the largest non-nuclear explosions in history occurred along the Trans-Siberian Pipeline in the former Soviet Union. It has been alleged that the explosion was the result of CIA sabotage of the Trans-Siberian Pipeline.
- June 4, 1989 - sparks from two passing trains detonated gas leaking from an LPG pipeline near Ufa, Russia. Up to 645 people were reported killed.
- October 17, 1998 - 1998 Jesse pipeline explosion at Jesse in the Niger Delta in Nigeria, a petroleum pipeline exploded killing about 1,200 villagers, some of whom were scavenging gasoline - the worst of several similar incidents in this country.
- June 10, 1999 - a pipeline rupture in a Bellingham, Washington park led to the release of 277,200 gallons of gasoline. The gasoline was ignited, causing an explosion that killed two children and one adult.
- August 19, 2000 - natural gas pipeline rupture and fire near Carlsbad, New Mexico; this explosion and fire killed 12 members of the same family. The cause was due to severe internal corrosion of the pipeline.
- July 30, 2004 - a major natural gas pipeline exploded in Ghislenghien, Belgium near Ath (thirty kilometres southwest of Brussels), killing at least 24 people and leaving 132 wounded, some critically. (CNN) (Expatica)
- May 12, 2006 - an oil pipeline ruptured outside Lagos, Nigeria. Up to 200 people may have been killed.
- November 1, 2007 - a propane pipeline exploded near Carmichael, Mississippi, about 30 miles (48 km) south of Meridian, Mississippi. Two people were killed instantly and an additional four were injured. Several homes were destroyed and sixty families were displaced. The pipeline is owned by Enterprise Products Partners LP, and runs from Mont Belvieu, Texas, to Apex, North Carolina, according to an Enterprise spokesman.

As targets

Pipelines can be the target of vandalism, sabotage, or even terrorist attacks. In war, pipelines are often the target of military attacks, as destruction of pipelines can seriously disrupt enemy logistics.

Cable Transport

Cable car at Zell am See in the Austrian Alps

Cable transport refers to the broad class of transport modes that rely on vehicles pulled by cables, rather than having an internal power source. The use of pulleys and balancing of loads going up and down are sometimes elements of cable transport.

Common modes include:

- Aerial tramway
- Cable car
- Cable ferry
- Chairlift
- Elevator
- Funicular
- Funitel
- Gondola lift
- Ski Lift

Chapter-6

Vehicle

Buses are a popular form of vehicles used for public transport

Automobiles are among the most commonly used engine-powered vehicles

A **vehicle** (Latin: *vehiculum*) is a device that is designed or used to transport people or cargo. Most often vehicles are manufactured (e.g. bicycles, cars, motorcycles, trains, ships, boats, and aircraft).

Vehicles that do not travel on land often are called craft, such as watercraft, sailcraft, aircraft, hovercraft, and spacecraft.

Land vehicles are classified broadly by what is used to apply steering and drive forces against the ground: wheeled, tracked, railed, or skied.

Legal definitions

As part of laws regulating road traffic most jurisdictions define what is and is not a vehicle for legal purposes. For instance the Canadian province of Ontario is fairly typical in defining:

"vehicle" includes a motor vehicle, trailer, traction engine, farm tractor, road-building machine, bicycle and any vehicle drawn, propelled or driven by any kind of power, including muscular power, but does not include a motorized snow vehicle or a street car

Standards

ISO 3833- 1977 is the standard, also internationally used in legislation, for road vehicles types, terms and definitions

History of vehicles

- The oldest boats to be found by archaeological excavation are logboats from around 7,000–9,000 years ago,
- a 7,000 year-old seagoing boat made from reeds and tar has been found in Kuwait.
- Boats were used between 4000BCE-3000BCE in Sumer, ancient Egypt and in the Indian Ocean.
- There is evidence of camel pulled wheeled vehicles about 3000–4000 BCE.
- The earliest evidence of a wagonway, a predecessor of the railway, found so far was the 6 to 8.5 km long *Diolkos* wagonway, which transported boats across the Isthmus of Corinth in Greece since around 600 BC. Wheeled vehicles pulled by men and animals ran in grooves in limestone, which provided the track element, preventing the wagons from leaving the intended route.

- 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 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, through a treadwheel.

- 1769 Nicolas-Joseph Cugnot is often credited with building the first self-propelled mechanical vehicle or automobile in about 1769, by adapting an existing horse-drawn vehicle, this claim is disputed by some, who doubt Cugnot's three-wheeler ever ran or was stable.

- In Russia, in the 1780s, Ivan Kulibin developed a human-pedalled, three-wheeled carriage with modern features such as a flywheel, brake, gear box, and bearings; however, it was not developed further.

- 1783 Montgolfier brothers first Balloon vehicle

- 1801 Richard Trevithick built and demonstrated his *Puffing Devil* road locomotive, believed by many to be the first demonstration of a steam-powered road vehicle, although it was unable to maintain sufficient steam pressure for long periods, and would have been of little practical use.

- 1817 push bikes draisines, or hobby horses were the first human means of transport to make use of the two-wheeler principle, the draisine (or *Laufmaschine*, "running machine"), invented by the German Baron Karl von Drais, is regarded as the forerunner of the modern bicycle (and motorcycle). It was introduced by Drais to the public in Mannheim in summer 1817.

- 1885 Otto Lilienthal began experimental gliding, and achieved the first sustained, controlled, reproducible flights.

- 1903 Wright brothers flew the first controlled, powered aircraft

- 1907 First helicopters Gyroplane no.1 (tethered) and Cornu helicopter (free flight)

- 1928 Opel RAK.1 rocket car

- 1929 Opel RAK.1 rocket glider

- 1961 Vostok vehicle carried first man (Yuri Gagarin) into space

- 1969 Apollo Program first manned vehicle lands on the moon

Power source

Vehicles may be powered by fuels, such as petroleum or diesel, nuclear power, wind, waves, batteries, electrical power, solar energy, gravity, human or animal power and other chemical reactions and physical sources of energy have seen some use.

Motors

The power is converted into some kind of motion by a "motor". Engines commonly include steam engines, internal combustion engines (including jet engines and gas turbines) or electric motors. Muscles perform this function in animals. Other schemes are sometimes used.

Movement

Vehicles use different means to permit or ease movement. These are commonly in the form of wheels, boat or submarine hulls, skis, caterpillar tracks, skates, wings, rotors or cushions of air or jets of air. Lighter than air lifting and rocket power have also been used. Trains use tracks, either with wheels resting on them, or in a few cases using magnetic levitation. Cable cars are suspended from cables which move. Legs are used on experimental mechanical systems.

One of the studies of vehicle movement is vehicle dynamics. In terms of dynamics, some vehicles such as bicycles and motorcycles leave essentially a single track and are unstable at rest.

Steering

Steering is the term applied to the collection of components, linkages, etc. which will allow for a vessel (ship, boat) or vehicle (car, motorcycle) to follow the desired course. An exception is the case of rail transport by which rail tracks combined together with railroad switches (and also known as 'points' in British English) provide the steering function.

Part of car steering mechanism: tie rod, steering arm, king pin axis (using ball joints).

Propulsion

Propulsion is achieved in different ways. It can be achieved by an animal's legs that pulls a vehicle or by wheels that provide torque, by jet propulsion, a propeller or sometimes linear electric motors. Cables can also be attached to a vehicle, as in some funiculars. Wind powered vehicles such as yachts are nearly always directly propelled by the wind, but some unusual forms use the power of the wind to turn wheels.

Some gravity powered vehicles such as glider aircraft, street luge and soapbox cars have no in-built propulsion system.

Friction

All vehicles, with the exception of some space vehicles, experience significant frictional drag, typically mainly air or water drag and rolling resistance. Via this friction the work generated by the vehicle's propulsion system is ultimately turned to waste heat. Friction also occurs in many braking systems, although some braking systems are *regenerative* which permits recovery of some of the energy from the vehicle's motion.

Energy

The friction generated by the vehicle acting over the distance it travels very typically determines the energy needed to be expended.

For a vehicle that is travelling at constant speed, from the definition of mechanical energy to move a given distance the energy needed is simply:

$$E = Fxs$$

where E is the energy, F is the friction force and s is the distance.

This determines the minimum amount of energy the power source must provide and usually determines the vehicle's range.

Vehicle metrics

There are a broad range of metrics that denote the relative capabilities of various vehicles. Most of them apply to all vehicles while others are type-specific.

Types of vehicles

Pousse-pousse in Madagascar

A pedal-powered quadracycle parked on a Canadian urban street amongst the cars

A teenage girl holding a skateboard.

Air

- Aircraft
- Ground effect vehicle

Land

- Automobile
- Auto rickshaw
- Bicycle
- Bus
- Skateboard
- Snowmobile
- Sled
- Steam car

- Coach
- Electric vehicle
- Land yacht
- Motorcycle
- Motorcycle sidecar
- Quadracycle
- Rickshaw
- Road train
- Steam tricycle
- Train
- Tram
- Tricycle
- Truck
- Van
- Velomobile
- Wagon

Space

- Launch escape capsule
- Rocket
- Spacecraft

Water

- Amphibious vehicle
- Amphibious ATV
- Boat
- Diving bell
- Diving chamber
- Hovercraft
- Ship
- Submarine
- Submersible
- Yacht

Legislation

Motor vehicle and trailer categories are defined according to the following international classification:

- Category M: passenger vehicles.
- Category N: motor vehicles for the carriage of goods.
- Category O: trailers and semi-trailers.

Chapter-7

Public Transport and Private Transport

Public Transport

Shinkansen high-speed train, Japan

Public transport Bus in Chandigarh, India

Tram, Melbourne, Australia

RIT bus rapid transit system in Curitiba, Brasil

Trolleybus in Genoa, Italy

Public transport over water, Rotterdam, the Netherlands

Public transport (also **public transportation**, **public transit**, or **mass transit**) is a shared passenger transportation service which is available for use by the general public, as distinct from modes such as Taxicab and car pooling which are not shared by strangers without private arrangement.

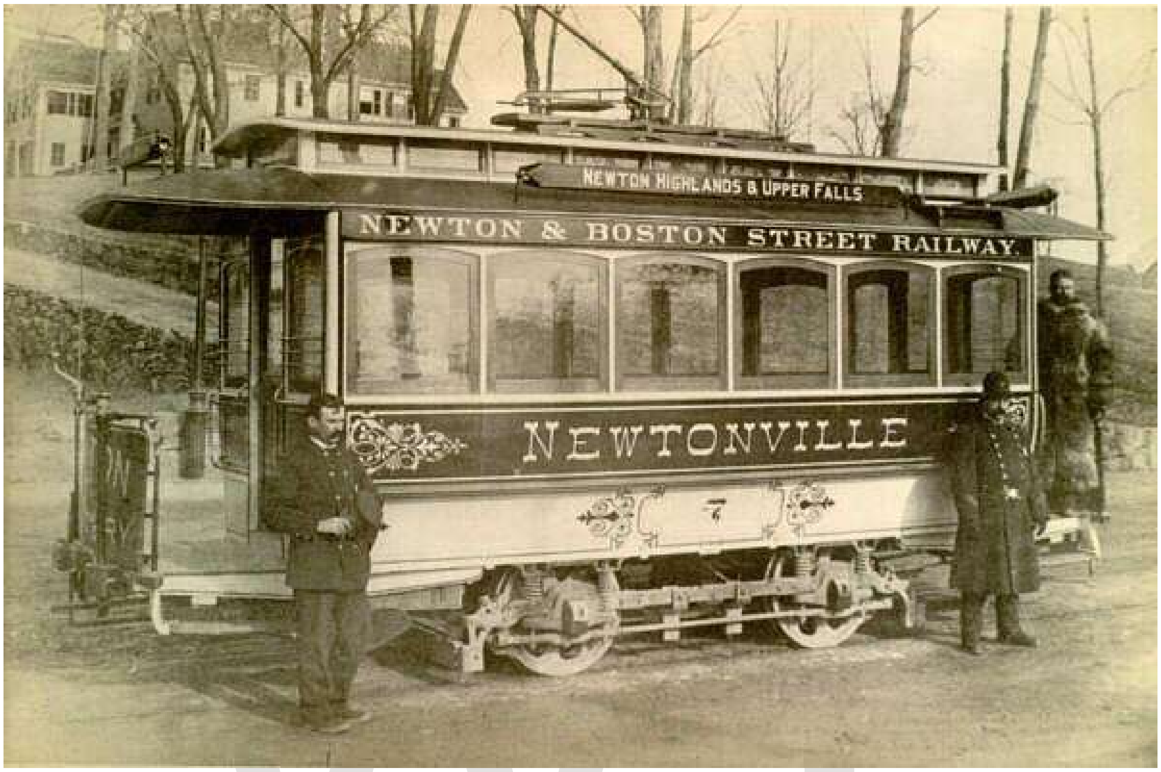
Public transport modes include buses, trolleybuses, trams and trains, 'rapid transit' (metro/subways/undergrounds etc) and ferries. Intercity public transport is dominated by airlines, coaches, and intercity rail. High-speed rail networks are being developed in many parts of the world.

Most public transport runs to a scheduled timetable with the most frequent services running to a headway. Share taxi offers on-demand services in many parts of the world and some services will wait until the vehicle is full before it starts. Paratransit is sometimes used in areas of low-demand and for people who need a door-to-door service.

Urban public transport may be provided by one or more private transport operators or by a transit authority. Public transport services are usually funded by fares charged to each passenger. Services are normally regulated and possibly subsidized from local or national tax revenue. Fully-subsidized, zero-fare services operate in some towns and cities.

For historical and economic reasons, there are differences internationally regarding use and extent of public transport. While countries in Old World tend to have extensive and frequent systems serving their old and dense cities, most cities of the New World have more sprawl and much less comprehensive public transport.

History



Early trolley car in Newton, Massachusetts.

Conveyances for public hire are as old as the first ferries, and the earliest public transport was water transport: on land people walked (sometimes in groups and on pilgrimages, as noted in sources such as the Bible and Canterbury Tales) or (at least in the Old World) rode an animal. Ferries are part of Greek mythology — corpses in ancient Greece were buried with a coin underneath their tongue to pay the ferryman Charon to take them to Hades.

Some historical forms of public transport are the stagecoach, traveling a fixed route from coaching inn to coaching inn, and the horse-drawn boat carrying paying passengers, which was a feature of European canals from their 17th-century origins. (The canal itself is a form of infrastructure dating back to antiquity — it was used at least for freight transportation in ancient Egypt to bypass the Aswan cataract — and the Chinese also built canals for transportation as far back as the Warring States period. Whether or not those canals were used for for-hire public transport is unknown; the Grand Canal was primarily used for shipping grain.)

The omnibus, the first organized public transit system within a city, appears to have originated in Paris, France, in 1662, although the service in question failed a few months after its founder died; omnibuses are next known to have appeared in Nantes, France, in 1826. The omnibus was introduced to London in July 1829.

Mode

Airline

An airline provides scheduled service with aircraft between airports. Air travel has high up to very high speeds, but incurs large waiting times prior and after travel, and is therefore often only feasible over longer distances or in areas where lack of ground infrastructure makes other modes of transport impossible. Bush airlines work more similar to bus stops; an aircraft waits for passengers and takes off when the aircraft is full.

Bus and coach

Transmilenio buses in Bogotá, Colombia

Bus services use buses on conventional roads to carrying numerous passengers on shorter journeys. Buses operate with low capacity (i.e. compared with trams or trains), and can operate on conventional roads, with relatively inexpensive bus stops to serve passengers. Therefore buses are commonly used in smaller cities and towns, in rural areas as well for shuttle services supplementing in large cities. Bus rapid transit is an ambiguous term used for buses operating on dedicated right-of-way, much like a light rail. Trolleybuses are electric buses that employ overhead wires to get power for traction. Online Electric

Vehicles are buses that run on a conventional battery, but are recharged frequently at certain points via underground wires.

Coach services use coaches (long-distance buses) for suburb-to-CBD or longer distance transportation. The vehicle are normally equipped with more comfortable seating, a separate luggage compartment, video and possibly also a toilet. They have higher standards than city buses, but a limited stopping pattern.

Trains

(Up): Tokyo's Yamanote Line, one of the world's busiest commuter rail lines**. (Down)** Chicago Transit Authority control tower 18 guides elevated Chicago 'L' northbound Purple and Brown lines intersecting with westbound Pink and Green lines and the looping Orange line above the Wells and Lake street intersection in the loop.

Passenger rail transport is the conveyance of passengers by means of wheeled vehicles specially designed to run on railways. Trains allow high capacity on short or long distance, but require track infrastructure and stations to be built. Urban rail transit consists of trams, light rail, rapid transit, people movers, commuter rail and funiculars.

Commuter, intercity, and high-speed rail

Chhatrapati Shivaji Terminus in Mumbai, India

Commuter rail is part of an urban area's public transport; it provides faster services to outer suburbs and neighboring towns and villages. Trains stop at all stations, that are located to serve a smaller suburban or town center. The stations often being combined with shuttle bus or park and ride systems at each station. Frequency may be up to several times per hour, and commuter rail systems may either be part of the national railway, or operated by local transit agencies.

Intercity rail is long-haul passenger services that connect multiple urban areas. They have few stops, and aim at high average speeds, typically only making one of a few stops per city. These services may also be international.

High-speed rail is passenger trains operating significantly faster than conventional rail—typically defined as at least 200 kilometres per hour (120 mph). The most predominant systems have been built in Europe and Japan, and compared with air travel, offer long-distance rail journeys as quick as air services, have lower prices to compete more effectively and uses electricity instead of combustion.

Trams and light rail

TTC Streetcar in Toronto exiting Neville Park Loop

Trams are railborne vehicles that run in city streets or dedicated tracks. They have higher capacity than buses, but must follow dedicated infrastructure with rails and wires either above or below the track, limiting their flexibility.

Light rail is a modern development (and use) of the tram, with dedicated right-of-way not shared with other traffic, step-free access and increased speed. Light rail lines are, thus, essentially modernized interurbans.

Metro/Underground/Rapid transit

The Vancouver Skytrain is the longest automated rapid transit system in the world. It also includes the longest mass transit-only bridge, the Skybridge.

A rapid transit Metro/Underground/Elevated railway operates in an urban area with high capacity and frequency, and grade separation from other traffic.

Systems are able to transport large amounts of people quickly over short distances with little land use. Variations of rapid transit include people movers, small-scale light metro and the commuter rail hybrid S-Bahn. More than 160 cities have rapid transit systems, totalling more than 8,000 km (4,971 mi) of track and 7,000 stations. Twenty-five cities have systems under construction.

Personal rapid transit

A vehicle on WVU's Morgantown Personal Rapid Transit.

Personal rapid transit is an automated cab service that runs on rails or a guideway. This is an uncommon mode of transportation (excluding elevators) due to the complexity of automation. A fully implemented system might provide most of the convenience of individual automobiles with the efficiency of public transit. The crucial innovation is that the automated vehicles carry just a few passengers, turn off the guideway to pick up passengers (permitting other PRT vehicles to continue at full speed), and drop them off to the location of their choice (rather than at a stop). Conventional transit simulations show that PRT might attract many auto users in problematic medium density urban areas. A number of experimental systems are in progress. One might compare personal rapid transit to the more labor-intensive taxi or paratransit modes of transportation, or to the (by now automated) elevators common in many publicly accessible areas.

Ferry

A ferry is a boat or ship, used to carry (or *ferry*) passengers, and sometimes their vehicles, across a body of water. A foot-passenger ferry with many stops is sometimes called a water bus. Ferries form a part of the public transport systems of many waterside cities and islands, allowing direct transit between points at a capital cost much lower than bridges or tunnels, though at a lower speed. Ship connections of much larger distances (such as over long distances in water bodies like the Mediterranean Sea) may also be called ferry services.

Operation

Bus ride through Downtown Seattle (time-lapse)

Infrastructure

All public transport runs on infrastructure, either on roads, rail, airways or seaways; all consists of interchanges and way. The infrastructure can be shared with other modes of transport, freight and private transport, or it can be dedicated to public transport. The latter is especially true in cases where there are capacity problems for private transport. Investments in infrastructure are high, and make up a substantial part of the total costs in systems that are expanding. Once built, the infrastructure will further require operating and maintenance costs, adding to the total costs of public transport. Sometimes governments subsidize infrastructure by providing it free of charge, just like is common with roads for automobiles.

Interchanges

An ACTION steer-tag bus at Woden Bus Interchange in Canberra, Australia

Interchanges are locations where passengers can switch mode. Most interchanges are predominantly for passenger to change from being pedestrians to passengers (such as a bus stop), while each system will have a few hubs that allow passengers to change between vehicles. This may be between vehicles of the same mode (like a bus interchange), or it can be between local and intercity transport (such as at a central station or airport). Other interchange facilities include car parks and bicycle parking.

Schedules

All public transport must either operate after a predefined schedule, or operate at a sufficient frequency that travelers do not need to use a schedule to correspond with the services. Operators will publish timetables, often supplemented with maps and fare schemes to help travelers coordinate their travel. Online public transport route planners, sometimes combined with pre-sold tickets, help make planning task more user-friendly. To further aid travelers, operators often run at fixed times of the hour, so passengers only need to memorize the minutes past the hour the service leaves, and can apply that to most hours of the day (this is known as *clock-face* scheduling). In most locations, extra services or even extra routes are operated during the morning and evening rush hours.

Coordination between services at intersections is important to reduce the total travel time for passengers. This can be done by coordinating shuttle services with main routes, or by creating a fixed time (for instance twice per hour) when all bus and rail routes meet at a station and exchange passengers.

Financing

The main sources of financing are ticket revenue, government subsidies and advertisement. The percentage of revenue from passenger charges is known as the farebox recovery ratio. A limited amount of income may come from land development and rental income from stores and vendors, parking fees, and leasing tunnels and rights-of-way to carry fiber optic communication lines.

Fare and ticketing

A contactless ticket validator used in Oslo, Norway

Most—but not all—public transport required the purchase of a ticket to generate revenue for the operators. Tickets may either be bought in advance, at the time of the ride, or the carrier may allow both methods. Passengers may be issued with a paper ticket, metal or plastic token, or an electronic card (smart card, contactless smart card). Sometimes a ticket has to be validated, e.g. a paper ticket that has to be stamped, or an electronic ticket that has to be checked in.

Tickets may be valid for a single (or return) trip, or valid within a certain area for a period of time. The fare is based on the travel class, either as a function of the traveled distance, or based on a zone pricing.

The tickets may have to be shown or checked automatically at the station platform or when boarding, or during the ride by a conductor. Operators may choose to control all riders, allowing sale of the ticket at the time of ride. Alternatively, a proof-of-payment system allows riders to enter the vehicles without showing the ticket, but riders may or may not be controlled by a ticket controller; if the rider fails to show proof of payment, the operator may fine the rider at the magnitude of the fare.

Multi-use tickets allow travel more than once. In addition to return tickets, this includes period cards allowing travel within a certain area (for instance month cards), or during a given number of days that can be chosen within a longer period of time (for instance eight days within a month). Passes aimed at tourists, allowing free or discounted entry at many tourist attractions, typically include zero-fare public transport within the city. Period tickets may be for a particular route (in both directions), or for a whole network. A free travel pass allowing free and unlimited travel within a system is sometimes granted to particular social sectors, for example students, elderly, children, employees (*job ticket*) and the physical or mentally disabled.

Zero-fare public transport services are funded in full by means other than collecting a fare from passengers, normally through heavy subsidy or commercial sponsorship by businesses. Several mid-size European cities and many smaller towns around the world have converted their entire bus networks to zero-fare. Local zero-fare shuttles or inner-city loops are far more common than city-wide systems. There are also zero-fare airport circulators and university transportation systems.

Subsidies

Governments, of any variety, may opt to subsidize public transport, for social, environmental or economical reasons. Key motivations are the need to provide transport to people those who cannot afford or are physically or legally incapable of using an automobile, and to reduce congestion, land use and emissions of local air pollution and greenhouse gases. Other motives may be related to promote business and economic growth, or urban renewal in formerly deprived areas of the city. Some systems are owned and operated by a government agency; other transportation services may be commercial, but receive greater benefits from the government compared to a normal company.

Subsidies may take the form of direct payments to financially unprofitable services, but also indirect subsidies are used. This may include allowing use of state-owned infrastructure without payment or for less than cost-price (may apply for railways and roads), to stimulate public transport's economic competitiveness over private transport, that normally also has free infrastructure (subsidized through such things as gas taxes). Other subsidies include tax advantages (for instance aviation fuel is typically not taxed), bailouts if companies that are likely to collapse (often applied to airlines) and reduction of competition through licensing schemes (often applied to taxis and airlines). Private transport is normally subsidized indirectly through free roads (paid for largely by gas taxes) and infrastructure, as well as incentives to build car factories and, on occasion, directly via bailouts of automakers.

Land development schemes may be initialized, where operators are given the rights to use lands near stations, depots, or tracks for property development. For instance, in Hong Kong, MTR Corporation Limited and KCR Corporation generate profits from land development to cover the partial cost of construction, but not operation, of the urban rail systems.

Some government officials believe that use of taxpayer capital to fund mass transit will ultimately save taxpayer money in other ways, and therefore, state-funded mass transit is a benefit to the taxpayer. (Such a belief has been backed up by research, although the measurement of benefits and costs is a complex and controversial issue.) A lack of mass transit results in more traffic (perhaps, although right-wing think tanks disagree), pollution, and road construction to accommodate more vehicles, all costly to taxpayers; providing mass transit will therefore alleviate these costs.

Safety and security

Expansion of public transportation systems is often opposed (particularly in North America) by critics who see them as vehicles for violent criminals and homeless persons to expand into new areas (to which they would otherwise have to walk). According to the Transportation Research Board, "[v]iolent crime is perceived as pandemic .... Personal security affects many peoples' [sic] decisions to use public transportation." Despite the occasional highly publicized incident, the vast majority of modern public transport systems are well designed and patrolled and generally have low crime rates. Many systems are monitored by CCTV, mirrors, or patrol.

Nevertheless, some systems attract vagrants who use the stations or trains as sleeping shelters, though most operators have practices that discourage this.

Though public transit accidents attract far more publicity than car wrecks, public transport is much safer, due to far lower accident rates. Annually, public transit prevents 200,000 deaths, injuries, and accidents had equivalent trips been made by car. The National Safety Council estimates riding the bus as over 170 times safer than private car.

Impact

Environmental

A 2002 study by the Brookings Institution and the American Enterprise Institute found that public transportation in the U.S uses approximately half the fuel required by cars, SUV's and light trucks. In addition, the study noted that "private vehicles emit about 95 percent more carbon monoxide, 92 percent more volatile organic compounds and about twice as much carbon dioxide and nitrogen oxide than public vehicles for every passenger mile traveled".

A controversial 2004 study from Lancaster University concluded that a family of four in a modern car traveling from London to Edinburgh would be more efficient than traveling in a diesel-powered UK trains. The study showed that trains had failed to keep up with the advances that the automotive and aviation industries had made in improved fuel efficiency. A representative from *Modern Railways* magazine said: Studies have shown that there is a strong inverse correlation between urban population density and energy consumption per capita, and that public transport could play a key role in increasing urban population densities, and thus reduce travel distances and fossil fuel consumption.

Going "green"

Public transportation has been a key aspect of the green initiative. The idea of going green, which basically entails commissioning more eco-friendly systems, is essentially new. Gases emitted by automobiles have been cited as major contributors to the issues addressed in green initiatives. A study conducted in Milan, Italy in 2004 during and after a transportation strike serves to illustrate the impact that mass transportation has on the environment. Air samples were taken between January 2 and January 9, and then tested for Methane, Carbon Monoxide, non-methane Hydrocarbons (NMHCs), and other gases identified as harmful to the environment. The figure below is a computer simulation showing the results of the study "with January 2nd showing the lowest concentrations as a result of decreased activity in the city during the holiday season. January 9th showed the highest NMHC concentrations because of increased vehicular activity in the city due to a public transportation strike."

Public Transportation allows for cars to be removed from the road. This lowers gas emissions and traffic congestions. Influenced by the previous, the state of New Jersey released *Getting to Work: Reconnecting Jobs with Transit*. This initiative, as suggested by its title, attempts to relocate new jobs into areas with higher public transportation accessibility. The initiative cites the use of public transportation as being a means of reducing traffic congestion, providing an economic boost to the areas of job relocation, and most importantly, contributing to a green environment by reducing Carbon Dioxide (CO_2) emissions.

CO_2 and Energy Impact

Using Public transportation can result in a reduction of an individual's carbon footprint. A single person, 20-mile round trip by car can be replaced using public transportation and result in a net CO_2 emissions reduction of 4,800 lbs/year. Using public transportation saves CO_2 emissions in more ways than simply travel as public transportation can help to alleviate traffic congestion as well as promote more efficient land use. When all three of these are considered, it is estimated that 37 million metric tones of CO_2 will be saved annually. Another study claims that using public transit instead of private in the U.S. in 2005 would have reduced CO_2 emissions by 3.9 million metric tones and that the resulting traffic congestion reduction accounts for an additional 3.0 million metric tons of CO_2 saved. This is a total savings of about 6.9 million metric tones per year given the 2005 values.

In order to compare energy impact of public transportation to private transportation, the amount of energy per passenger mile must be calculated. The reason that comparing the energy expenditure per person is necessary is to normalize the data for easy comparison. Here, the units are in per 100 p-km (read as person kilometer or passenger kilometer). In terms of energy consumption, public transportation is better than individual transport in a personal vehicle. In England, bus and rail are popular methods of public transportation, especially London. Rail provides rapid movement into and out of the city of London while busing helps to provide transport within the city itself. As of 2006-2007, the total energy cost of London's trains was 15 kWh per 100 p-km, about 5 times better than a personal car. For busing in London, it was 32 kWh per 100 p-km, or about 2.5 times that of a personal car. This includes lighting, depots, inefficiencies due to capacity (i.e., the train or bus may not be operating at full capacity at all times), and other inefficiencies. Efficiencies of transport in Japan in 1999 were 68 kWh per 100 p-km for a personal car, 19 kWh per 100 p-km for a bus, 6 kWh per 100 p-km for rail, 51 kWh per 100 p-km for air, and 57 kWh per 100 p-km for sea. These numbers from either country can be used in energy comparison calculations and/or life cycle assessment calculations.

Public transportation also provides an arena to test environmentally friendly fuel alternatives, such as hydrogen-powered vehicles. Swapping out materials to create lighter public transportation vehicles with the same or better performance will increase environmental friendliness of public transportation vehicles while maintaining current standards or improving them. Informing the public about the positive environmental effects of using public transportation in addition to pointing out the potential economic benefit is an important first step towards making a difference.

Area

Traffic jam in São Paulo

Urban space is a precious commodity and public transport consumes it more efficiently than a car dominant society, allowing cities to be built more compactly than if they were dependent on automobile transport. If public transport planning is at the core of urban planning, it will also force cities to be built more compactly to create efficient feeds into the stations and stops of transport. This will at the same time allow the creation of centers around the hubs, serving passengers' need for their daily commercial needs and public services. This approach significantly reduces urban sprawl.

Social

An important social role played by public transport is to ensure that all members of society are able to travel, not just those with a driving license and access to an automobile—which include groups such as the young, the old, the poor, those with medical conditions, and people banned from driving. Automobile dependency is a name given by policy makers to places where those without access to a private vehicle do not have access to independent mobility.

Above that, public transportation opens to its users the possibility of meeting other people, as no concentration is diverted from interacting with fellow-travelers due to any steering activities. Adding to the above-said, public transport becomes a location of inter-social encounters across all boundaries of social, ethnic and other types of affiliation.

Economic

Public transport allows transport at an economy of scale not available through private transport. Through stimulating public transport it is possible to reduce the total transport cost for the public. Time costs can also be reduced as cars removed from the road through public transit options translate to less congestion and faster speeds for remaining motorists. Transit-oriented development can both improve the usefulness and efficiency of the public transit system as well as result in increased business for commercial developments.

Well-designed transit systems can have a positive effect on real estate prices. The Hong Kong metro MTR generates a profit by redeveloping land around its stations. Much public opposition to new transit construction can be based on the concern about the impact on neighborhoods of this new economic development. Few localities have the ability to seize and reassign development rights to a private transit operator, as Hong Kong has done. Increased land desirability has resulted around stations in places such as Washington, D.C.

Investment in public transport also stimulates the economy locally, with between $4 and $9 of economic activity resulting from every dollar spent. Many businesses rely on access to a transit system, in particular in cities and countries where access to cars is less widespread, businesses which require large amounts of people going to a same place may not be able to accommodate a large number of cars (concert venues, sport stadia, airports, exhibitions centres,...), or businesses where people are not able to use a car (bars, hospitals, or industries in the tourism sector whose customers may not have their cars).

Conversely, the existence of a transit system can lower land values, either through influence on a region's demographics and crime rate (actual or perceived) or simply through the ambient noise and other discomforts the system creates.

Regulations

Food and drink

Longer distance public transport sometimes sell food and drink on board, and/or have a dedicated buffet car and/or dining car. However, some urban transport systems forbid the consumption of food, drink, or even chewing gum when riding on public transport. Sometimes only types of food are forbidden with more risk of making the vehicles dirty, e.g. ice creams and French fries, and sometimes potato chips.

Some systems prohibit carrying open food or beverage containers, even if the food or beverage is not being consumed during the ride.

Smoking

In the United States, Canada, most of the European Union, Australia, and New Zealand, smoking is prohibited in all or some parts of most public transportation systems due to safety and health issues. Generally smoking is not allowed on buses and trains, while rules concerning stations and waiting platforms differ from system to system. The situation in other countries varies widely.

Noise

Many mass transit systems prohibit the use of audio devices, such as radios, CD players, and MP3 players unless used with an earphone through which only the user can hear the device.

Some mass transit systems have restricted the use of mobile phones. Long distance train services, such as the Amtrak system in the US, have "quiet cars" where mobile phone usage is prohibited.

Some systems prohibit passengers from engaging in conversation with the operator. Others require that passengers who engage in any conversation must keep the noise level low enough that it not be audible to other passengers.

Some systems have regulations on the use of profanity. In the United States, this has been challenged as a free speech issue.

Banned items

Certain items considered to be problematic are prohibited or regulated on many mass transit systems. These include firearms and other weapons (unless licensed to carry), explosives, flammable items, or hazardous chemicals and substances.

Many systems prohibit live animals, but allow those that are in carrying cases or other closed containers. Additionally, service animals for the blind or disabled are permitted.

Some systems prohibit items of a large size that may take up a lot of space, such as bicycles. But more systems in recent years have been permitting passengers to bring bikes.

In Sydney, it is illegal to carry spray cans or permanent markers on public transport, as they can be used to vandalise the vehicles and stations. This rule also applies to sharp instruments that could damage the train, such as screwdrivers that could be used to make "scratchitti", a form of vandalism where tags are carved into a window.

Other regulations

Many systems have regulations against behavior deemed to be unruly or otherwise disturbing to other passengers. In such cases, it is usually at the discretion of the operator, police officers, or other transit employees to determine what behaviors fit this description.

Some systems have regulations against photography or videography of the system's vehicles, stations, or other property. Those seen holding a mobile phone in a manner consistent with photography are considered to be suspicious for breaking this rule.

Sleeping

In the era when long distance trips took several days, sleeping accommodations were an essential part of transportation. (On land, the lodging involved was often part of the infrastructure: the inn or ryokan, which didn't move, sheltered travelers. People also slept on ships at sea.) Today, most airlines, inter-city trains and coaches offer reclining seats and many provide pillows and blankets for overnight travelers. Better sleeping arrangements are commonly offered for a premium fare and include sleeping cars on overnight trains, larger private cabins on ships and airplane seats that convert into beds. Budget-conscious tourists sometimes plan their trips using overnight train or bus trips in lieu of paying for a hotel. The ability to get additional sleep on the way to work is attractive to many commuters using public transport.

Because night trains or coaches can be cheaper than motels, homeless persons often use these as overnight shelters, as with the famous Line 22 ("Hotel 22") in Silicon Valley. Specifically, a local transit route with a long overnight segment and which accepts inexpensive multi-use passes will acquire a reputation as a "moving hotel" for people with limited funds. Most transportation agencies actively discourage this. For this and other reasons passengers are often required to exit the vehicle at the end of the line; they can board again in the same or another vehicle, after some waiting.Even a low fare in some cases often deters the poorest individuals, including homeless people.

Private Transport

Private transport, as opposed to public transport, is transportation service which is not available for use by the general public. Examples of private transport are

Carpool

The start of a carpooling journey

Carpooling (also known as **car-sharing**, **ride-sharing**, **lift-sharing** and **covoiturage**), is the sharing of car journeys so that more than one person travels in a car.

Description

Carpooling reduces the costs involved in car travel by sharing journey expenses such as fuel, tolls, and car rental between the people travelling. Carpooling is also seen as a more environmentally friendly and sustainable way to travel as sharing journeys reduces carbon emissions, traffic on the roads, and the need for parking spaces. Authorities often encourage carpooling, especially during high pollution periods and after fuel rises. Carpooling where the driving is shared can also decrease driving stress as each driver gets a break from being at the wheel.

Carpooling uses private or jointly hired vehicles, for private shared journeys. The vehicle is not used in a general public transport capacity such as in car sharing, share taxis or taxicabs. Carpooling also differs from other sharing schemes such as where company/government or private vehicles are used by several people at different times.

How it works

Drivers and passengers offer and search for journeys through one of the several mediums available. After finding a match they contact each other to arrange any details for the journey(s). Costs, meeting points and other details like space for luggage are discussed and agreed on. They then meet and carry out their shared car journey(s) as planned.

Carpooling is commonly implemented for commuting but is also popular for longer one-off journeys, with the formality and regularity of arrangements varying between schemes and journeys.

Carpooling is not always arranged for the whole length of a journey. Especially on long journeys, it is common for passengers to only join for parts of the journey, and give a contribution based on the distance that they travel. This gives carpooling extra flexibility, and enables more people to share journeys and save money.

The arrangements for carpooling can be made through many different mediums, including:

- Public websites
- Closed website schemes
- Carpooling software
- Manned carpooling agencies
- Pick-up points (not pre-arranged)

Initiatives

In an effort to reduce traffic and encourage carpooling some countries have introduced high-occupancy vehicle (HOV) lanes in which only vehicles with one or more passengers are allowed to drive. In some countries it is also common to find parking spaces that are reserved especially for carpoolers. Many companies and local authorities have introduced carpooling schemes, often as part of wider transport programs.

History

Carpooling schemes have been around since the mid-1970s, but have reached new levels since the arrival of the internet. The popularity of the internet and mobile phones has greatly helped carpooling to expand, by enabling people to offer and find rides more easily, and easily contact each other to arrange them.

Forms of carpooling

Carpooling also exists in other forms such as Slugging which is a form of ad-hoc carpooling between strangers. No money changes hands, but a mutual benefit still exists between the driver and passenger(s) making the practice worthwhile.

Challenges for carpooling

Carpooling can struggle to be flexible enough to accommodate en-route stops or changes to working times/patterns. To counter this some schemes offer 'sweeper services' with later running options, or a 'guaranteed ride home' arrangement with a local taxi company. Another problem for carpooling is the reliability of the informal arrangements made between the parties involved. Due to the lack of formality, occasionally passengers or drivers do not turn up for the journeys that they have arranged, wasting the time of and increasing the costs for others involved. Several internet carpooling schemes are addressing this problem by introducing booking systems, enabling payments to be made even if passengers do not turn up, and blocks to be more easily put in place if drivers are found to be unreliable.

Taxi

Taxis played a key part in the First Battle of the Marne. Of the 10,000 French reserve infantry troops ferried from Paris, 6,000 were transported by the 600 strong taxi fleet.

The Birmingham pub bombings, which killed 21 people and injured 182, presented emergency services with unprecedented peace time demands. According to eye witness accounts, the fire officer in charge, knowing the 40 ambulances he requested were unlikely to be available, requested the Taxi Owners Association to transport the injured to the nearby Birmingham Accident Hospital and Birmingham General Hospital.

Chapter-8

History of Transport

Bullock team hauling wool in Australia

A busy street crowded with vehicles in Bangkok. As the population of Earth increases, so does the strain on transport

The **history of transport** evolved with the development of human culture. Long distance walking tracks developed as trade routes in paleolithic times. For most of human history the only forms of transport apart from walking were using domesticated animals or transport in small boats.

Road transport

The **history of road transport** started with the development of tracks by humans and their beasts of burden.

Early roads

The first forms of road transport were horses, oxen or even humans carrying goods over tracks that often followed game trails, such as the Natchez Trace. In the Stone Age humans did not need constructed tracks in open country. The first improved trails would have been at fords, mountain passes and through swamps. The first improvements would have consisted largely of clearing trees and big stones from the path. As commerce increased, the tracks were often flattened or widened to accommodate human and animal traffic. Some of these dirt tracks were developed into fairly extensive networks, allowing communications, trade and governance over wide areas. The Incan Empire in South America and the Iroquois Confederation in North America, neither of which had the wheel, are examples of effective use of such paths.

The first goods transport was on human backs and heads, but the use of pack animals, including donkeys and horses, developed during the Stone Age. The first vehicle is believed to have been the travois, a frame used to drag loads, which probably developed in Eurasia after the first use of bullocks (castrated cattle) for pulling ploughs. In about 5000 BC, sleds developed, which are more difficult to build than travois, but are easier to propel over smooth surfaces. Pack animals, ridden horses and bullocks dragging travois or sleds require wider paths and higher clearances than people on foot and improved tracks were required. As a result by about 5000 BC roads, including the Ridgeway, developed along ridges in England to avoid crossing rivers and bogging. In central Germany, such ridgeways remained the predominant form of long-distance road till the mid 18th century.

Harappan roads

Street paving has been found from the first human settlements around 4000 BC in cities of the Indus Valley Civilization on the Indian subcontinent, such as Harrapa and Mohenjo-daro.

Wheeled transport

Wheels appear to have been developed in ancient Sumer in Mesopotamia around 5000 BC, perhaps originally for the making of pottery. Their original transport use may have been as attachments to travois or sleds to reduce resistance. It has been argued that logs were used as rollers under sleds prior to the development of wheels, but there is no archeological evidence for this. Most early wheels appear to have been attached to fixed axles, which would have required regular lubrication by animal fats or vegetable oils or separation by leather to be effective. The first simple two-wheel carts, apparently developed from travois, appear to have been used in Mesopotamia and northern Iran in about 3000 BC and two-wheel chariots appeared in about 2800 BC. They were hauled by onagers, related to donkeys.

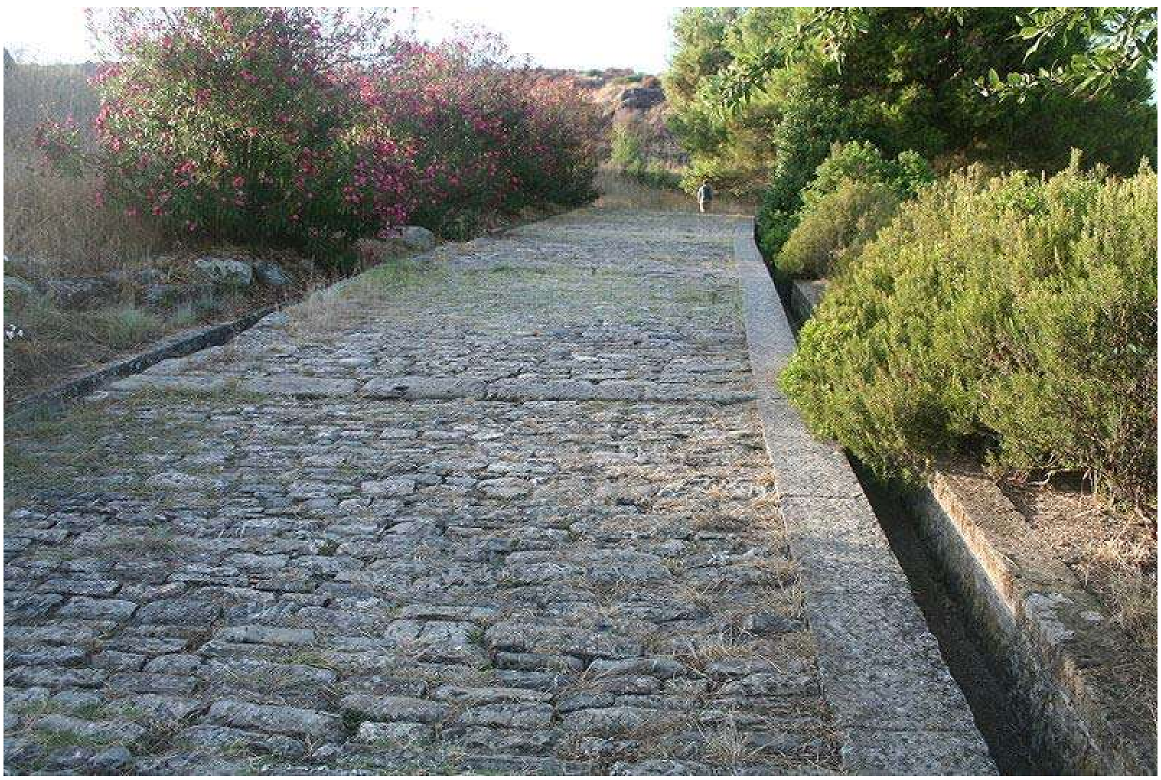
Heavy four-wheeled wagons developed about 2500 BC, which were only suitable for oxen-haulage, and therefore were only used where crops were cultivated, particularly Mesopotamia. Two-wheeled chariots with spoked wheels appear to have been developed around 2000 BC by the Andronovo culture in southern Siberia and Central Asia. At much the same time the first primitive harness enabling horse-haulage was invented.

Wheeled-transport created the need for better roads. Generally natural materials cannot be both soft enough to form well-graded surfaces and strong enough to bear wheeled vehicles, especially when wet, and stay intact. In urban areas it began to be worthwhile to build stone-paved streets and, in fact, the first paved streets appear to have been built in

Ur in 4000 BC. Corduroy roads were built in Glastonbury, England in 3300 BC and brick-paved roads were built in the Indus Valley Civilization on the Indian subcontinent from around the same time. Improvements in metallurgy meant that by 2000 BC stone-cutting tools were generally available in the Middle East and Greece allowing local streets to be paved. Notably, in about 2000 BC, the Minoans built a 50 km paved road from Knossos in north Crete through the mountains to Gortyn and Lebena, a port on the south coast of the island, which had side drains, a 200 mm thick pavement of sandstone blocks bound with clay-gypsum mortar, covered by a layer of basaltic flagstones and had separate shoulders. This road could be considered superior to any Roman road.

Royal Road

In 500 BC, Darius I the Great started an extensive road system for Persia (Iran), including the famous Royal Road which was one of the finest highways of its time. The road was used even after the Roman times. Because of the road's superior quality, mail couriers could travel 2,699 km in seven days.



Greek street - IV-III century BC - Porta Rosa - Velia - Italy The Porta Rosa was the main street of Elea. It connects the northern quarter with the southern quarter. The street is 5 meters wide and has an incline of 18% in the steepest part. It is paved with limestone blocks, griders cut in square blocks, and on one side a smull gutter for the drainage of rain water. The building is dated during the time of the reorganization of the city during Hellenistic age (IV th III th century BC).

Roman roads

With the advent of the Roman Empire, there was a need for armies to be able to travel quickly from one area to another, and the roads that existed were often muddy, which greatly delayed the movement of large masses of troops. To resolve this issue, the Romans built great roads. These 'Roman roads' used deep roadbeds of crushed stone as an underlying layer to ensure that they kept dry, as the water would flow out from the crushed stone, instead of becoming mud in clay soils. The legions made good time on these roads and some are still used millennia later.

On the more heavily traveled routes, there were additional layers that included six sided capstones, or pavers, that reduced the dust and reduced the drag from wheels. The pavers allowed the Roman chariots to travel very quickly, ensuring good communication with the Roman provinces. Farm roads were often paved first on the way into town, to keep produce clean. Early forms of springs and shocks to reduce the bumps were incorporated in horse drawn transport, as the original pavers were sometimes not perfectly aligned.

Roman roads deteriorated in medieval Europe because of lack of resources and skills to maintain them, but many continued to be used. The alignments are still partially used today, for instance, parts of England's A1.

Early tar-paved roads

In the medieval Islamic world, many roads were built throughout the Arab Empire. The most sophisticated roads were those of the Baghdad, Iraq, which were paved with tar in the 8th century. Tar was derived from petroleum, accessed from oil fields in the region, through the chemical process of destructive distillation.

New construction methods in the 18th and 19th centuries

As states developed and became richer, especially with the Renaissance, new roads and bridges began to be built, often based on Roman designs. Although there were attempts to rediscover Roman methods, there was little useful innovation in road building before the 18th century.

Between 1725 and 1737 General George Wade constructed 250 miles (400 km) of road and 40 bridges to improve Britain's control of the Scottish Highlands, using Roman road designs with large stones at the bottom and gravel on top, with a typical overall depth of two metres. They were so poorly aligned and steep, according to Thomas Telford, "as to be unfit for the purposes of civil life" and also rough and poorly drained.

Toll roads

England and Wales

As traffic levels increased in England, roads deteriorated. Toll roads were built by *Turnpike Trusts*, especially between 1730-1770. It has been claimed that as a result the time taken between London, to York, Manchester or Exeter was cut by two-thirds between 1720 and 1780. Blind Jack Metcalf (1717–1810) built about 300 km (180 miles) of turnpike road between 1753 and 1810, mainly in Lancashire, Derbyshire, Cheshire and Yorkshire. He understood the importance of good drainage and surfaced his roads with "a compact layer of small, broken stones with sharp edges", rather than the naturally rounded stones traditionally used in European road building. British turnpike builders began to realise the importance of selecting clean stones for surfacing, and excluding vegetable material and clay to make better lasting roads.

United States of America

Highways in the USA circa 1825

Turnpikes were also later built in the United States. They were usually built by private companies under a government franchise. They typically paralleled or replaced routes already with some volume of commerce, hoping the improved road would divert enough traffic to make the enterprise profitable. Plank roads were particularly attractive as they greatly reduced rolling resistance and mitigated the problem of getting mired in mud. Another improvement, better grading to lessen the steepness of the worst stretches, allowed draft animals to haul heavier loads.

Water transport on rivers and canals carried many farm goods from the frontier U.S. (between the Appalachian mountains and Mississippi River) in the early 19th century, but the shorter route over the mountains had advantages. Successful farms created a demand for imported and manufactured goods from the Atlantic coast. The commercial interests of the East were quick to see the possibilities of this new market. An eager rivalry sprung up between the merchants of New York, Philadelphia, and Baltimore. Everywhere ways and means of cheaper transportation were discussed. In this subject the western farmer was vitally interested, for freight charges added nearly one third to the cost of merchandise transported over the mountains. The cotton planter of the Seaboard States, also, feeling the competition of the Southwest, where riverways were abundant and easily navigable, saw the need of better roads to tidewater, in order to lessen the cost of marketing his produce.

The popular demand for better roads was not recent. All the states had encouraged, directly or indirectly, the building of turnpikes and bridges. Between 1793 and 1812, Pennsylvania had chartered fifty-five turnpike companies, and other states had been scarcely less ready to grant articles of incorporation to stock companies. Private enterprise had, indeed, done much to improve communication along the seaboard. Turnpikes and bridges had shortened the journey by stage from Boston to Washington to four and a quarter days by the year 1815.

The magnitude of the transportation problem was such, however, that neither individual states nor private corporations seemed able to meet the demands of an expanding internal trade. As early as 1807, Albert Gallatin had advocated the construction of a great system of internal waterways to connect East and West, at an estimated cost of $20,000,000. But the only contribution of the national government to internal improvements during the Jeffersonian era was an appropriation in 1806 of two percent of the net proceeds of the sales of public lands in Ohio for the construction of a national road, with the consent of the states through which it should pass. By 1818 the road was open to traffic from Cumberland, Maryland, to Wheeling, West Virginia.

In 1816, with the experiences of the war before him, no well-informed statesman could shut his eyes to the national aspects of the problem. Even President Madison invited the attention of Congress to the need of establishing "a comprehensive system of roads and canals". Soon after Congress met, it took under consideration a bill drafted by Calhoun which proposed an appropriation of $1,500,000 for internal improvements. Because this appropriation was to be met by the moneys paid by the National Bank to the government, the bill was commonly referred to as the "Bonus Bill". But on the day before he left office, President Madison vetoed the bill because it was unconstitutional. The policy of internal improvements by federal aid was thus wrecked on the constitutional scruples of a member of the Virginia dynasty. Having less regard for consistency, the House of Representatives recorded its conviction, by close votes, that Congress could appropriate money to construct roads and canals, but had not the power to construct them. As yet the only direct aid of the national government to internal improvements consisted of various appropriations, amounting to about $1,500,000 for the Cumberland Road.

As the country recovered from financial depression following the Panic of 1819, the question of internal improvements again forged to the front. In 1822, a bill to authorize the collection of tolls on the Cumberland Road had been vetoed by the President. In an elaborate essay Monroe set forth his views on the constitutional aspects of a policy of internal improvements. Congress might appropriate money, he admitted, but it might not undertake the actual construction of national works nor assume jurisdiction over them. For the moment the drift toward a larger participation of the national government in internal improvements was stayed. Two years later, Congress authorized the President to institute surveys for such roads and canals as he believed to be needed for commerce and military defense. No one pleaded more eloquently for a larger conception of the functions of the national government than Clay. He called the attention of his hearers to provisions made for coast surveys and lighthouses on the Atlantic seaboard and deplored the neglect of the interior of the country. Of the other presidential candidates, Jackson voted in the Senate for the general survey bill; and Adams left no doubt in the public mind that he did not reflect the narrow views of his section on this issue. Crawford felt the constitutional scruples which were everywhere being voiced in the South, and followed the old expedient of advocating a constitutional amendment to sanction national internal improvements.

In President Adams' first message to Congress, he advocated not only the construction of roads and canals but also the establishment of observatories and a national university. President Jefferson had recommended many of these in 1806 for Congress to consider for creation of necessary amendments to the Constitution. Adams seemed oblivious to the limitations of the Constitution. In much alarm Jefferson suggested to Madison the desirability of having Virginia adopt a new set of resolutions, bottomed on those of 1798, and directed against the acts for internal improvements. In March, 1826, the general assembly declared that all the principles of the earlier resolutions applied "will full force against the powers assumed by Congress" in passing acts to protect manufacturers and to further internal improvements. That the Administration would meet with opposition in Congress was a foregone conclusion.

Trésaguet's work in France

In France, Pierre-Marie-Jérôme Trésaguet is widely credited with establishing the first scientific approach to road building about the year 1764. He wrote a memorandum on his method in 1775, which became general practice in France. It involved a layer of large rocks, covered by a layer of smaller gravel. The lower layer improved on Roman practice in that it was based on the understanding that the purpose of this layer (the sub-base or base course) is to transfer the weight of the road and its traffic to the ground, while protecting the ground from deformation by spreading the weight evenly. Therefore, the sub-base did not have to be a self-supporting structure. The upper running surface provided a smooth surface for vehicles, while protecting the large stones of the sub-base. Trésaguet understood the importance of drainage by providing deep side ditches, but he insisted on building his roads in trenches, so that they could be accessed from the sides, which undermined this principle. Well-maintained surfaces and drains protect the integrity of the sub-base and Trésaguet introduced a system of continuous maintenance, where a roadman was allocated a section of road to be kept up to a standard.

Developments in Britain

Telford

Thomas Telford (1757–1834) a Scottish surveyor and engineer also made substantial advances in the engineering of new roads and the construction of bridges. Under his supervision 1,500 km of roads and 1,000 bridges were built in Scotland between 1802 and 1822. He elaborated on the Trésaguet method by a more complex and costly system of stonework in the subgrade, but his main improvement over Trésaguet was the raising of his roads above the natural level to improve drainage or the drainage of the area around the road.

McAdam

John Loudon McAdam (1756–1836), another Scottish engineer, designed the first modern roads. He developed an inexpensive paving material of soil and stone aggregate (known as macadam), and he embanked roads a few feet higher than the surrounding terrain to cause water to drain away from the surface. He had noticed in his observations that coaches with narrow, iron-tyred wheels and moving at relatively high speed were causing significant damage to roads, but that areas of small broken stones were most resistant to damage, while the areas that had large surface stones degraded fastest. His solution was to create roads with three layers of stones laid on a crowned subgrade with side ditches for drainage. The first two layers consisted of angular hand-broken aggregate, maximum size 3 inches (75 mm), to a total depth of about 8 inches (200 mm). The third layer was about 2 inches (50 mm) thick with a maximum aggregate size of 1 inch (25 mm). Each layer would be compacted with a heavy roller, causing the angular stones to lock together with their neighbours. It is possible that his initial decision not to use the heavy layer of base stones used by Telford in his subgrade reflected lack of suitable stones, but McAdam quickly saw they were not necessary. In practice, his roads proved to be twice as strong as Telford's roads. He also insisted on raising the roads to ensure good drainage and flat crowned surfaces, rather than ridges built into the road to encourage drainage.

McAdam was adamantly opposed to the filling of the voids between his small cut stones with smaller material, possibly as a reaction against the use of poor materials, including soil and vegetable matter, on roads in the past. Nevertheless, in practice road builders began to introduce filler materials such as smaller stones, sand and clay, and it was observed that these roads were stronger as a result. Macadam roads were being built widely in the United States and Australia in the 1820s and in Europe in the 1830s and 1840s.

Development of modern paved roads

Various systems had been developed over centuries to reduce washaways, bogging and dust in cities, including cobblestones and wooden paving. Tar-bound macadam (tarmac) was applied to macadam roads towards the end of the 19th century in cities such as Paris. In the early 20th century tarmac and concrete paving were extended into the countryside.

Incidentally, bicyclists were among the early campaigners on what was called the Good Roads Movement. Bicycling was an extremely popular recreation among the middle and upper classes in the late 19th century and was more fun on paved roads.

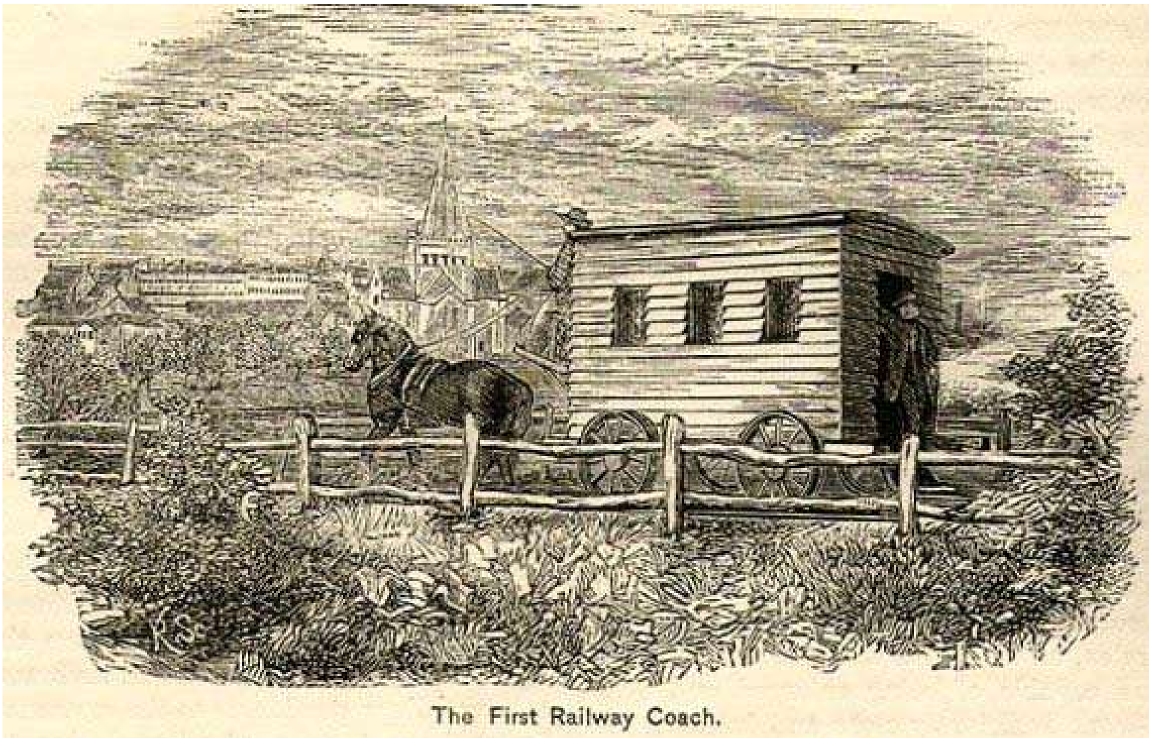
Maritime transport

In the stone ages primitive boats developed to permit navigation of rivers and for fishing in rivers and off the coast. It has been argued that boats suitable for a significant sea crossing was necessary for people to reach Australia an estimated 40,000-45,000 years ago. With the development of civilization, bigger vessels were developed both for trade and war. In the Mediterranean, galleys were developed about 3,000 BC. Galleys were eventually rendered obsolete by ocean-going sailing ships, such as the Arabic caravel in the 13th century, the Chinese treasure ship in the early 15th century, and the Mediterranean man-of-war in the late 15th century. In the industrial revolution, the first steam ships and later diesel-powered ships were developed. Eventually submarines were developed mainly for military purposes.

Meanwhile specialised craft were developed for river and canal transport. Canals were developed in Mesopotamia circa 4000 BC. The Indus Valley Civilization in Pakistan and North India (from circa 2600 BC) had the first canal irrigation system in the world. The longest canal of ancient times was the Grand Canal of China. It is 1794 kilometers (1115 miles) long and was built to carry the Emperor Yang Guang between Beijing and Hangzhou. The project began in 605, although the oldest sections of the canal may have existed since circa 486 BC. Canals were developed in the Middle Ages in Europe in Venice and the Netherlands. Pierre-Paul Riquet began to organise the construction of the 240 km-long Canal du Midi in France in 1665 and it was opened in 1681. In the Industrial Revolution, inland canals were built in England and later the United States before the development of railways. Specialised craft were also developed for fishing and later whaling.

Maritime history also deals with the development of navigation, oceanography, cartography and hydrography.

Rail transport



Horse drawn railway coach, late 18th century

The **history of rail transport** dates back nearly 500 years and includes systems with man or horse power and rails of wood or stone. Modern rail transport systems first appeared in England in the 1820s. These systems, which made use of the steam locomotive, were the first practical forms of mechanized land transport, and they remained the primary form of mechanized land transport for the next 100 years.

Wagonways and tramways

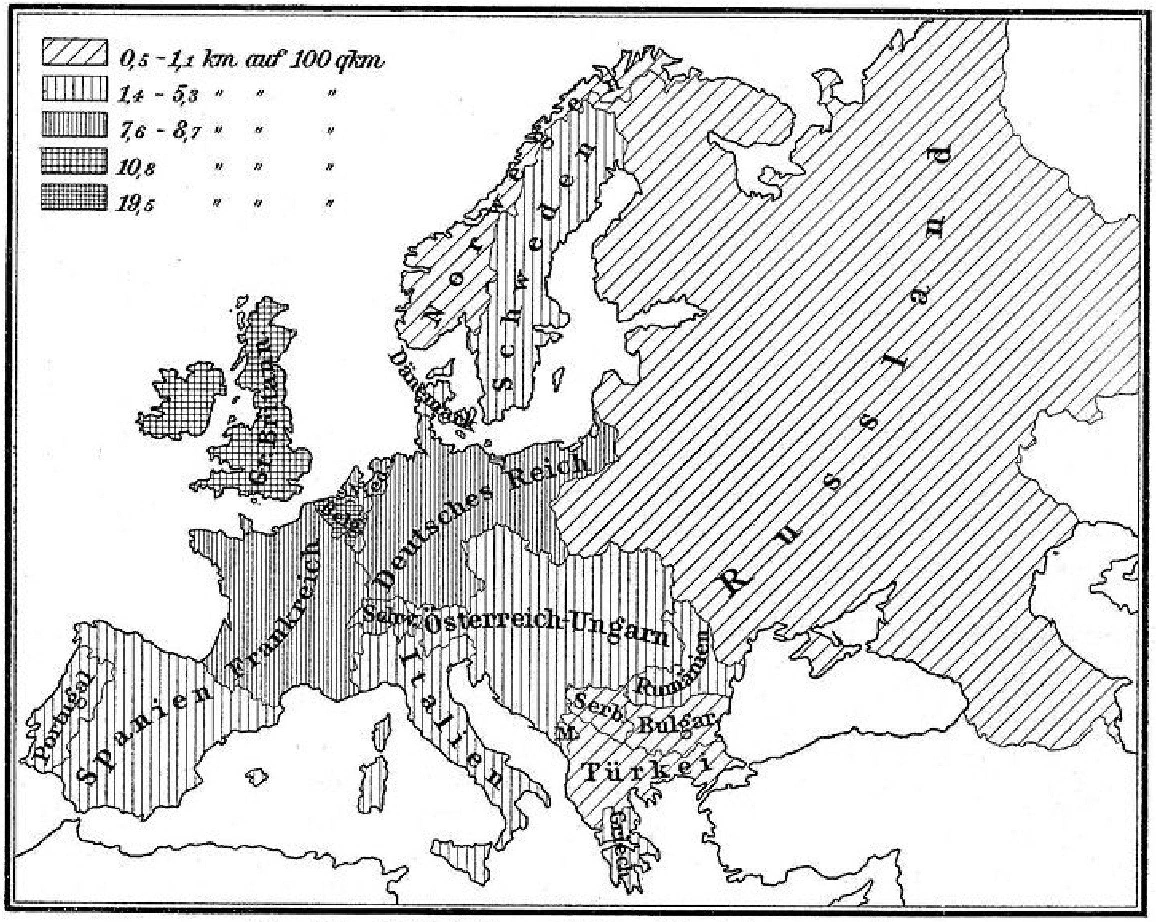


Fig. 168. Dichte des europäischen Eisenbahnnetzes 1896.

Density of the railway net in Europe 1896

Earliest traces

The earliest evidence of a wagonway, a predecessor of the railway, found so far was the 6 to 8.5 km long *Diolkos* wagonway, which transported boats across the Isthmus of Corinth in Greece since around 600 BC. Wheeled vehicles pulled by men and animals ran in grooves in limestone, which provided the track element, preventing the wagons from leaving the intended route. The Diolkos was in use for over 650 years, until at least the 1st century AD. The first horse-drawn wagonways also appeared in ancient Greece, with others to be found on Malta and various parts of the Roman Empire, using cut-stone tracks.

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 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, through a treadwheel. The line still exists, albeit in updated form, and is probably the oldest railway still to operate.

Early wagonways

Wagonways (or '**tramways'**) are thought to have developed in Germany in the 1550s to facilitate the transport of ore tubs to and from mines, utilising primitive wooden rails. Such an operation was illustrated in 1556 by Georgius Agricola. These used the 'hund' system with unflanged wheels running on wooden planks and a vertical pin on the truck fitting into the gap between the planks, to keep it going the right way. Such a transport system was used by German Miners at Caldbeck, Cumbria, perhaps from the 1560s.

The first true railway is now suggested to have been a funicular railway made at Broseley in Shropshire at some time before 1605. This carried coal for James Clifford from his mines down to the river Severn to be loaded on to barges and carried to riverside towns. Though the first documentary record of this is later, its construction proably preceded the Wollaton Wagonway, completed in 1604, hitherto regarded as the earliest British installation. This ran from Strelley to Wollaton near Nottingham. Another early wagonway is noted onwards. Huntingdon Beaumont (who was concerned with mining at Strelley) also laid down broad wooden rails near Newcastle upon Tyne, on which a single horse could haul fifty or sixty bushels (130–150 kg) of coal.

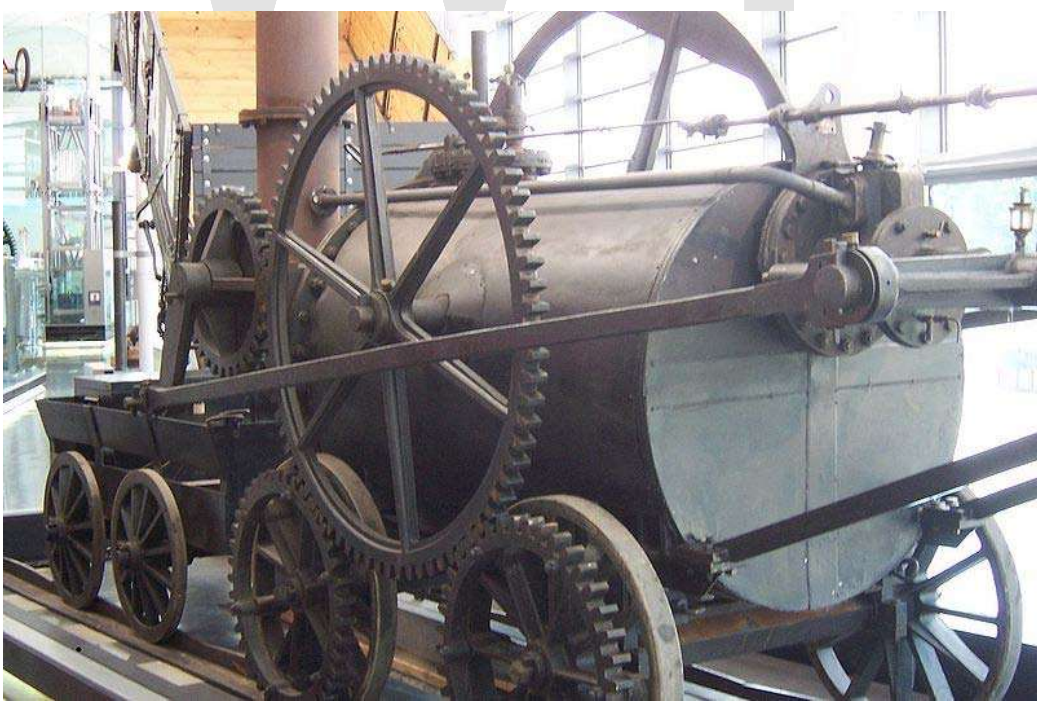
By the eighteenth century, such wagonways and tramways existed in a number of areas. Ralph Allen, for example, constructed a tramway to transport stone from a local quarry to supply the needs of the builders of the Georgian terraces of Bath. The Battle of Prestonpans, in the Jacobite Rebellion, was fought astride a wagonway. This type of transport spread rapidly through the whole Tyneside coal-field, and the greatest number of lines were to be found in the coalfield near Newcastle upon Tyne, where they were known locally as wagonways. Their function in most cases was to facilitate the transport of coal in chaldron wagons from the coalpits to a staithe (a wooden pier) on the river bank, whence coal could be shipped to London by collier brigs. The wagonways were engineered so that trains of coal wagons could descend to the staith by gravity, being braked by a brakesman who would "sprag" the wheels by jamming them. Wagonways on less steep gradients could be retarded by allowing the wheels to bind on curves. As the work became more wearing on the horses, a vehicle known as a dandy wagon was introduced, in which the horse could rest on downhill stretches.

Rails

Because a stiff wheel rolling on a rigid rail requires less energy per ton-mile moved than road transport (with a highly compliant wheel on an uneven surface), railroads are highly suitable for the movement of dense, bulk goods such as coal and other minerals. This was incentive to focus a great deal of inventiveness upon the possible configurations and shapes of wheels and rails. In the late 1760s, the Coalbrookdale Company began to fix plates of cast iron to the upper surface of the wooden rails. These (and earlier railways) had flanged wheels as on modern railways, but another system was introduced, in which unflanged wheels ran on L-shaped metal plates - these became known as plateways. John Curr, a Sheffield colliery manager, invented this flanged rail, though the exact date of this is disputed. The plate rail was taken up by Benjamin Outram for wagonways serving his canals, manufacturing them at his Butterley ironworks. Meanwhile William Jessop, a civil engineer, had used a form of edge rail successfully for an extension to the Charnwood Forest Canal at Nanpantan, Loughborough, Leicestershire in 1789. Jessop became a partner in the Butterley Company in 1790. The flanged wheel eventually proved its superiority due to its performance on curves, and the composite iron/wood rail was replaced by all metal rail, with its vastly superior stiffness, durability, and safety.

Steam power introduced

James Watt, a Scottish inventor and mechanical engineer, was responsible for improvements to the steam engine of Thomas Newcomen, hitherto used to pump water out of mines. Watt developed a reciprocating engine, capable of powering a wheel. Although the Watt engine powered cotton mills and a variety of machinery, it was a large stationary engine. It could not be otherwise; the state of boiler technology necessitated the use of low pressure steam acting upon a vacuum in the cylinder, and this mode of operation needed a separate condenser and an air pump. Nevertheless, as the construction of boilers improved, he investigated the use of high pressure steam acting directly upon a piston. This raised the possibility of a smaller engine, that might be used to power a vehicle, and he actually patented a design for a steam locomotive in 1784. His employee William Murdoch produced a working model of a self propelled steam carriage in that year.



A replica of Trevithick's engine at the National Waterfront Museum, Swansea

The first working model of a steam rail locomotive was designed and constructed by John Fitch in the United States in 1794. The first full scale working railway steam locomotive was built in the United Kingdom in 1804 by Richard Trevithick, an English engineer born in Cornwall. (The story goes that it was constructed to satisfy a bet by Samuel Homfray, the local iron master.) This used high pressure steam to drive the engine by one power stroke. (The transmission system employed a large fly-wheel to even out the action of the piston rod.) On 21 February 1804 the world's first railway journey took place as Trevithick's unnamed steam locomotive hauled a train along the tramway of the Penydarren ironworks, near Merthyr Tydfil in South Wales. Trevithick later demonstrated a locomotive operating upon a piece of circular rail track in Bloomsbury, London, the "Catch-Me-Who-Can", but never got beyond the experimental stage with railway locomotives, not least because his engines were too heavy for the cast-iron plateway track then in use. Despite his inventive talents, Richard Trevithick died in poverty, with his achievement being largely unrecognized.

The impact of the Napoleonic Wars resulted in (amongst other things) a dramatic rise in the price of fodder. This was the imperative that made the locomotive an economic proposition, if it could be perfected.

The first commercially successful steam locomotive was Matthew Murray's rack locomotive *Salamanca* built for the narrow gauge Middleton Railway in 1812. This twin cylinder locomotive was not heavy enough to break the edge-rails track, and solved the problem of adhesion by a cog-wheel utilising teeth cast on the side of one of the rails. It was the first rack railway.

This was followed in 1813 by the *Puffing Billy* built by Christopher Blackett and William Hedley for the Wylam Colliery Railway, the first successful locomotive running by adhesion only. This was accomplished by the distribution of weight by a number of wheels. Puffing Billy is now on display in the Science Museum in London, the oldest locomotive in existence.

In 1814 George Stephenson, inspired by the early locomotives of Trevithick, Murray and Hedley, persuaded the manager of the Killingworth colliery where he worked to allow him to build a steam-powered machine. He built the *Blücher*, one of the first successful flanged-wheel adhesion locomotives. Stephenson played a pivotal role in the development and widespread adoption of the steam locomotive. His designs considerably improved on the work of the earlier pioneers. In 1825 he built the *Locomotion* for the Stockton and Darlington Railway, north east England, which was the first public steam railway in the world. Such success led to Stephenson establishing his company as the pre-eminent builder of steam locomotives used on railways in the United Kingdom, United States and much of Europe.

Britain

As the colliery and quarry tramways and wagonways grew longer, the possibility of using the technology for the public conveyance of goods suggested itself. On 26 July 1803, Jessop opened the Surrey Iron Railway in south London - arguably, the world's first public railway, albeit a horse-drawn one. It was not a railway in the modern sense of the word, as it functioned like a turnpike road. There were no official services, as anyone could bring a vehicle on the railway by paying a toll.

In 1812, Oliver Evans, an American engineer and inventor, published his vision of what steam railways could become, with cities and towns linked by a network of long distance railways plied by speedy locomotives, greatly reducing the time required for personal travel and for transport of goods. Evans specified that there should be separate sets of parallel tracks for trains going in different directions. Unfortunately, conditions in the infant United States did not enable his vision to take hold.

This vision had its counterpart in Britain, where it proved to be far more influential. William James, a rich and influential surveyor and land agent, was inspired by the development of the steam locomotive to suggest a national network of railways. It seems likely in 1808 James attended the demonstration running of Richard Trevithick's steam locomotive *Catch me who can* in London; certainly at this time he began to consider the long-term development of this means of transport. He was responsible for proposing a number of projects that later came to fruition, and he is credited with carrying out a survey of the Liverpool and Manchester Railway. Unfortunately, he became bankrupt and his schemes were taken over by George Stephenson and others. However, he is credited by many historians with the title of "Father of the Railway".

S&DR Locomotion No. 1 preserved at the Darlington Railway Centre and Museum

It was not until 1825 that the success of the Stockton and Darlington Railway proved that the railways could be made as useful to the general shipping public as to the colliery owner. This railway broke new ground by using rails made of rolled wrought iron, produced at Bedlington Ironworks in Northumberland. Such rails were stronger. This railway linked the town of Darlington with the port of Stockton-on-Tees, and was intended to enable local collieries (which were connected to the line by short branches) to transport their coal to the docks. As this would constitute the bulk of the traffic, the company took the important step of offering to haul the colliery wagons or chaldrons by locomotive power, something that required a scheduled or timetabled service of trains. However, the line also functioned as a toll railway, where private horse drawn wagons could be operated upon it. This curious hybrid of a system (which also included, at one stage, a horse drawn passenger wagon) could not last, and within a few years, traffic was restricted to timetabled trains. (However, the tradition of private owned wagons continued on railways in Britain until the 1960s.)

The success of the Stockton and Darlington encouraged the rich investors of the rapidly industrialising North West of England to embark upon a project to link the rich cotton manufacturing town of Manchester with the thriving port of Liverpool. The Liverpool and Manchester Railway was the first modern railway, in that both the goods and passenger traffic was operated by scheduled or timetabled locomotive hauled trains. At the time of its construction, there was still a serious doubt that locomotives could maintain a regular service over the distance involved. A widely reported competition was held in 1829 called the Rainhill Trials, to find the most suitable steam engine to haul the trains. A number of locomotives were entered, including Novelty, Perseverance, and Sans Pareil. The winner was Stephenson's Rocket, which had superior steaming qualities as a consequence of the installation of a multi-tubular boiler (suggested by Henry Booth, a director of the railway company).

A replica of the *Planet*, which ran on the Liverpool and Manchester Railway from 1830

The promoters were mainly interested in goods traffic, but after the line opened on 15 September 1830, they found to their amazement that passenger traffic was just as remunerative. The success of the Liverpool and Manchester railway influenced the development of railways elsewhere in Britain and abroad. The company hosted many visiting deputations from other railway projects, and many railwaymen received their early training and experience upon this line.

It must be remembered that the Liverpool and Manchester line was still a short one (35 miles (56 km)), linking two towns within an English shire county. The world's first trunk line can be said to be the Grand Junction Railway, opening in 1837, and linking a mid point on the Liverpool and Manchester Railway with Birmingham, by way of Crewe, Stafford, and Wolverhampton.

Further development

The earliest locomotives in revenue service were small four-wheeled locos similar to the Rocket. However, the inclined cylinders caused the engine to rock, so they first became horizontal and then, in his "Planet" design, were mounted inside the frames. While this improved stability, the "crank axles" were extremely prone to breakage. Greater speed was achieved by larger driving wheels at expense of a tendency for wheel slip when starting. Greater tractive effort was obtained by smaller wheels coupled together, but speed was limited by the fragility of the cast iron connecting rods. Hence, from the beginning, there was a distinction between the light fast passenger loco and the slower more powerful goods engine. Edward Bury, in particular, refined this design and the so-called "Bury Pattern" was popular for a number of years, particularly on the London and Birmingham.

Meanwhile, by 1840, Stephenson had produced larger, more stable, engines in the form of the 2-2-2 "patentee" and six-coupled goods engines. Locomotives were travelling longer distances and being worked more extensively. The North Midland Railway expressed their concern to Robert Stephenson who was, at that time, their general manager, about the effect of heat on their fireboxes. After some experiments, he patented his so-called Long Boiler design. These became a new standard and similar designs were produced by other manufacturers, particularly Sharp Brothers whose engines became known affectionately as "Sharpies".

The longer wheelbase for the longer boiler produced problems in cornering. For his six-coupled engines, Stephenson removed the flanges from the centre pair of wheels. For his express engines, he shifted the trailing wheel to the front in the 4-2-0 formation, as in his "Great A." There were other problems. One was that the firebox was restricted in size, or had to be mounted behind the wheels. The other problem was that for improved stability most engineers believed that the centre of gravity should be kept low.

The most extreme outcome of this was the Crampton locomotive which mounted the driving wheels behind the firebox and could be made very large in diameter. These achieved the hitherto unheard of speed of 70 mph (110 km/h) but were very prone to wheelslip. With their long wheelbase, they were unsuccessful on Britain's winding tracks, but became popular in the USA and France, where the popular expression became to "prendre le Crampton".

John Gray of the London and Brighton Railway disbelieved the necessity for a low centre of gravity and produced a series of locos that were much admired by David Joy who developed the design at the firm of E. B. Wilson and Company to produce the 2-2-2 Jenny Lind locomotive, one of the most successful passenger locomotives of its day. Meanwhile the Stephenson 0-6-0 Long Boiler locomotive with inside cylinders became the archetypical goods engine.

Expanding network

Railways quickly became essential to the swift movement of goods and labour that was needed for industrialization. In the beginning, canals were in competition with the railways, but the railways quickly gained ground as steam and rail technology improved, and railways were built in places where canals were not practical.

By the 1850s, many steam-powered railways had reached the fringes of built-up London. But the new lines were not permitted to demolish enough property to penetrate the City or the West End, so passengers had to disembark at Paddington, Euston, Kings Cross, Fenchurch Street, Charing Cross, Waterloo or Victoria and then make their own way via hackney carriage or on foot into the centre, thereby massively increasing congestion in the city. A Metropolitan Railway was built under the ground to connect several of these separate railway terminals, and thus became the world's first "Metro."

British Empire

Canada

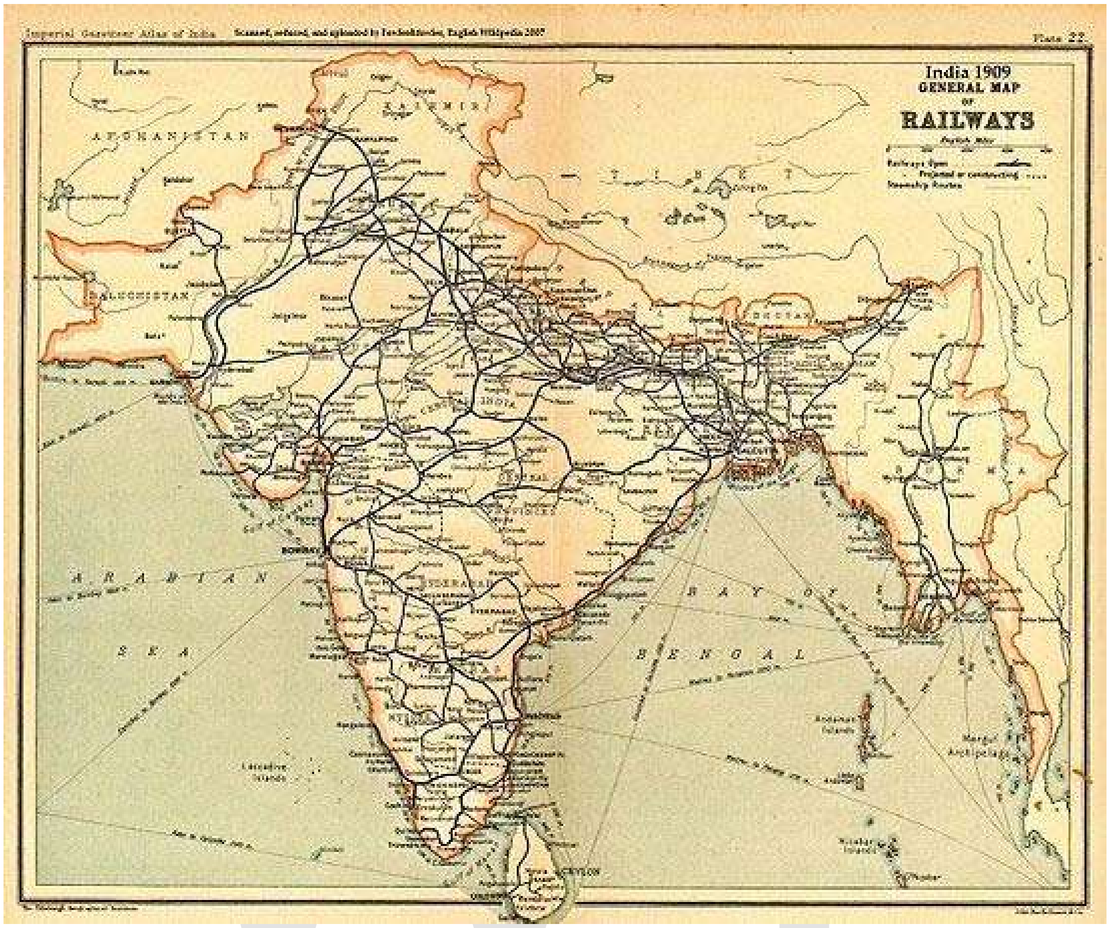
In Canada, the national government strongly supported railway construction for political goals. First it wanted to knit the far-flung provinces together, and second, it wanted to maximize trade inside Canada and minimize trade with the United States, to avoid becoming an economic satellite. The Grand Trunk Railway of Canada linked Toronto and Montreal in 1853, then opened a line to Portland Maine (which was ice-free), and lines to Michigan and Chicago. By 1870 it was the longest railway in the world. The Intercolonial line, finished in 1876, linked the Maritimes to Quebec and Ontario, tying them to the new Confederation.

Anglo-entrepreneurs in Montreal sought direct lines into the U.S. and shunned connections with the Maritimes, with a goal of competing with American railroad lines heading west to the Pacific. Joseph Howe, Charles Tupper, and other Nova Scotia leaders used the rhetoric of a "civilizing mission" centered on their British heritage, because Atlantic-centered railway projects promised to make Halifax the eastern terminus of an intercolonial railway system tied to London. Leonard Tilley, New Brunswick's most ardent railway promoter, championed the cause of "economic progress," stressing that Atlantic Canadians needed to pursue the most cost-effective transportation connections possible if they wanted to expand their influence beyond local markets. Advocating an intercolonial connection to Canada, and a western extension into larger American markets in Maine and beyond, New Brunswick entrepreneurs promoted ties to the United States first, connections with Halifax second, and routes into central Canada last. Thus metropolitan rivalries between Montreal, Halifax, and Saint John led Canada to build more railway lines per capita than any other industrializing nation, even though it lacked capital resources, and had too little freight and passenger traffic to allow the systems to turn a profit.

Den Otter (1997) challenges popular assumptions that Canada built transcontinental railways because it feared the annexationist schemes of aggressive Americans. Instead Canada overbuilt railroads because it hoped to compete with, even overtake Americans in the race for continental riches. It downplayed the more realistic Maritimes-based London-oriented connections and turned to utopian prospects for the farmlands and minerals of the west. The result was closer ties between north and south, symbolized by the Grand Trunk's expansion into the American Midwest. These economic links promoted trade, commerce, and the flow of ideas between the two countries, integrating Canada into a North American economy and culture by 1880. About 700,000 Canadians migrated to the U.S. in the late 19th century. The Canadian Pacific, paralleling the American border, opened a vital link to British Canada, and stimulated settlement of the Prairies. The CP was affiliated with James J. Hill's American railways, and opened even more connections to the South. The connections were two-way, as thousands of American moved to the Prairies after their own frontier had closed.

Two additional transcontinental lines were built to the west coast--three in all--but that was far more than the traffic would bear, making the system simply too expensive. One after another, the federal government was forced to take over the lines and cover their deficits. In 1923 the government merged the Grand Trunk, Grand Trunk Pacific, Canadian Northern and National Transcontinental lines into the new the Canadian National Railways system. Since most of the equipment was imported from Britain or the U.S., and most of the products carried were from farms, mines or forests, there was little stimulation to domestic manufacturing. On the other hand, the railways were essential to the growth of the wheat regions in the Prairies, and to the expansion of coal mining, lumbering, and paper making. Improvements to the St. Lawrence waterway system continued apace, and many short lines were built to river ports.

India



The 1909 Map of Indian Railways, when India had the fourth largest railway network in the world.

India provides an example of the British Empire pouring its money and expertise into a very well built system designed for military reasons (after the Mutiny of 1857), and with the hope that it would stimulate industry. The system was overbuilt and much too elaborate and expensive for the small amount of freight traffic it carried. However, it did capture the imagination of the Indians, who saw their railways as the symbol of an industrial modernity—but one that was not realized until a century or so later.

The British built a superb system in India. However, Christensen (1996) looks at of colonial purpose, local needs, capital, service, and private-versus-public interests. He concludes that making the railways a creature of the state hindered success because railway expenses had to go through the same time-consuming and political budgeting process as did all other state expenses. Railway costs could therefore not be tailored to the timely needs of the railways or their passengers.

By the 1940s, India had the fourth longest railway network in the world. Yet the country's industrialization was delayed until after independence in 1947 by British colonial policy.

Until the 1930s, both the Indian government and the private railway companies hired only European supervisors, civil engineers, and even operating personnel, such as engine (locomotive) drivers. The government's "Stores Policy" required that bids on railway matériel be presented to the India Office in London, making it almost impossible for enterprises based in India to compete for orders. Likewise, the railway companies purchased most of their matériel in Britain, rather than in India. Although the railway maintenance workshops in India could have manufactured and repaired locomotives, the railways imported a majority of them from Britain, and the others from Germany, Belgium, and the United States. The Tata company built a steel mill in India before World War I but could not obtain orders for rails until the 1920s and 1930s.

France

In France, railways became a national medium for the modernization of backward regions, and a leading advocate of this approach was the poet-politician Alphonse de Lamartine. One writer hoped that railways might improve the lot of "populations two or three centuries behind their fellows" and eliminate "the savage instincts born of isolation and misery." Consequently, France built a centralized system that radiated from Paris (plus lines that cut east to west in the south). This design was intended to achieve political and cultural goals rather than maximize efficiency. After some consolidation, six companies controlled monopolies of their regions, subject to close control by the government in terms of fares, finances, and even minute technical details. The central government department of Ponts et Chaussées [bridges and roads] brought in British engineers and workers, handled much of the construction work, provided engineering expertise and planning, land acquisition, and construction of permanent infrastructure such as the track bed, bridges and tunnels. It also subsidized militarily necessary lines along the German border, which was considered necessary for the national defense. Private operating companies provided management, hired labor, laid the tracks, and built and operated stations. They purchased and maintained the rolling stock—6,000 locomotives were in operation in 1880, which averaged 51,600 passengers a year or 21,200 tons of freight. Much of the equipment was imported from Britain and therefore did not stimulate machinery makers.

Development of the network up to 1860

Although starting the whole system at once was politically expedient, it delayed completion, and forced even more reliance on temporary experts brought in from Britain. Financing was also a problem. The solution was a narrow base of funding through the Rothschilds and the closed circles of the Bourse in Paris, so France did not develop the same kind of national stock exchange that flourished in London and New York. The system did help modernize the parts of rural France it reached, but it did not help create local industrial centers. Critics such as Emile Zola complained that it never overcame the corruption of the political system, but rather contributed to it. The railways probably helped the industrial revolution in France by facilitating a national market for raw materials, wines, cheeses, and imported manufactured products. Yet the goals set by the French for their railway system were moralistic, political, and military rather than economic. As a result, the freight trains were shorter and less heavily loaded than those in such rapidly industrializing nations such as Britain, Belgium or Germany. Other infrastructure needs in rural France, such as better roads and canals, were neglected because of the expense of the railways, so it seems likely that there were net negative effects in areas not served by the trains.

Russia

Russia was in need of improved transportation and geographically suited to railroads, with long flat stretches of land and comparatively simple land acquisition. It was hampered, however, by its outmoded political situation and a shortage of capital. Yefim and Miron Cherepanovs, Russian factory engineers, actually invented and built successful working locomotives for a mine tramway between 1832 and 1835, but their inventiveness was not pursued. Foreign initiative and capital were required. The first major public railroad was the Saint Petersburg-Tsarskoye Selo Railway, proposed and built by a Bohemian engineer, František Antonín Gerstner the son of František Josef Gerstner, in 1836.

United States 1830-1890

In 1830, there were only 39.8 miles (64.1 km) of documented railroad track laid in the United States (there is ample historical evidence that a more correct figure would be a little over 75 miles (121 km) due to a failure to count special purpose railroads hauling only coal and granite.). After this, railroad lines grew rapidly. Ten years later, in 1840, the railways had grown to 2,755.18 miles (4,434.03 km). Two decades after that, the number had reached 28,919.79 miles (46,541.89 km), and 20 years after that, the number had tripled once more to 87,801.42 miles (141,302.69 km).

In 1869, the symbolically important trans-continental railroad was completed in the United States with the driving of a golden spike (near the city of Ogden).

Diesel and electric engines

Electric railways revolutionize urban transport

Prior to the development of electric railways, most overland transport aside from the railways had consisted primarily of horse powered vehicles. Placing a horse car on rails had enabled a horse to move twice as many people, and so street railways were born. In January 1888, Richmond, Virginia served as a proving grounds for electric railways as Frank Sprague built the first working electric streetcar system there. By the 1890s, electric power became practical and more widespread, allowing extensive underground railways. Large cities such as London, New York, and Paris built subway systems. When electric propulsion became practical, most street railways were electrified. These then became known as "streetcars," "trolleys," "trams" and "Strassenbahn." They can be found around the world.

In many countries, these electric street railways grew beyond the metropolitan areas to connect with other urban centers. In the USA, "electric interurban" railroad networks connected most urban areas in the states of Illinois, Indiana, Ohio, Pennsylvania and New York. In Southern California, the Pacific Electric Railway connected most cities in Los Angeles and Orange Counties, and the Inland Empire. There were similar systems in Europe. One of the more notable rail systems connected every town and city in Belgium. One of the more notable tramway systems in Asia is the Hong Kong Tramways, which started operation in 1904 and run exclusively on double-decker trams.

The remnants of these systems still exist, and in many places they have been modernized to become part of the urban "rapid transit" system in their respective areas. In the past thirty years increasing numbers of cities have restored electric rail service by building "light rail" systems to replace the tram system they removed during the mid-20th century.

Diesel power

Diesel-electric locomotives could be described as electric locomotives with an on-board generator powered by a diesel engine. The first diesel locomotives were low-powered machines, diesel-mechanical types used in switching yards. Diesel and electric locomotives are cleaner, more efficient, and require less maintenance than steam locomotives. They also required less specialized skills in operation and their introduction diminished the power of railway unions in the United States (one of the earliest countries to adopt diesel power on a wide scale). After working through technical difficulties in the early 1900s, diesel locomotives became mainstream after World War II. By the 1970s, diesel and electric power had replaced steam power on most of the world's railroads.

In the 20th century, road transport and air travel replaced railroads for most long-distance passenger travel in the United States, but railroads remain important for hauling freight in the United States, and for passenger transport in many other countries.

High-speed rail

Starting with the opening of the first Shinkansen line between Tokyo and Osaka in 1964, high-speed rail transport, functioning at speeds up and above 300 km/h, has been built in Spain, France, Germany, Italy, the People's Republic of China, Taiwan, the United States, the United Kingdom, South Korea, Scandinavia, Belgium and the Netherlands. The construction of many of these lines has resulted in the dramatic decline of short haul flights and automotive traffic between connected cities, such as the Boston-New York City-Washington, D.C. corridor, London-Paris-Brussels, Madrid-Barcelona, as well as many other major lines. Additionally, with the ongoing threat of global warming and energy shortages, high-speed rail is supposed to hold the key to the future of transportation in many of the world's developed countries.

Aviation

Pilots of 611 *West Lancashire* Squadron lend a hand pushing an early Spitfire Mark IXb, Biggin Hill, late 1942.

Humanity's desire to fly likely dates to the first time man observed birds, an observation illustrated in the legendary stories of Daedalus and Icarus in Greek mythology, and the Vimanas in Indian mythology. Much of the focus of early research was on imitating birds, but through trial and error, balloons, airships, gliders and eventually powered aircraft and other types of flying machines were invented.

Kites were the first form of man-made flying objects, and early records suggest that kites were around before 200 B.C. in China. Leonardo da Vinci's dream of flight found expression in several designs, but he did not attempt to demonstrate flight by literally constructing them.

During the 17th and 18th century, when scientists began analysing the Earth's atmosphere, gases such as hydrogen were discovered which in turn led to the invention of hydrogen balloons. Various theories in mechanics by physicists during the same period of time—notably fluid dynamics and Newton's laws of motion—led to the foundation of modern aerodynamics. Tethered balloons filled with hot air were used in the first half of the 19th century and saw considerable action in several mid-century wars, most notably the American Civil War, where balloons provided observation during the Battle of Petersburg.

Apart from some scattered reference in ancient and medieval records, resting on slender evidence and in need of interpretation, the earliest clearly verifiable human flight took place in Paris in 1783, when Jean-François Pilâtre de Rozier and Francois d'Arlandes went 5 miles (8 km) in a hot air balloon invented by the Montgolfier brothers. The Wright brothers made the first sustained, controlled and powered heavier-than-air flight on December 17, 1903, in their revolutionary aircraft, the Wright Flyer.

World War II saw a drastic increase in the pace of aircraft development and production. All countries involved in the war stepped up development and production of aircraft and flight based weapon delivery systems, such as the first long range bomber.

After the war ended, commercial aviation grew rapidly, used mostly ex-military aircraft to transport people and cargo. This growth was accelerated by the glut of heavy and super-heavy bomber airframes like the B-29 and Lancaster that could be converted into commercial aircraft. The first commercial jet airliner to fly was the British De Havilland Comet.

In the beginning of the 21st century, subsonic military aviation focused on eliminating the pilot in favor of remotely operated or completely autonomous vehicles. Several unmanned aerial vehicles or UAVs have been developed. In April 2001 the unmanned aircraft Global Hawk flew from Edwards AFB in the US to Australia non-stop and unrefuelled. This is the longest point-to-point flight ever undertaken by an unmanned aircraft, and took 23 hours and 23 minutes. In October 2003 the first totally autonomous flight across the Atlantic by a computer-controlled model aircraft occurred. Major disruptions to air travel in the 21st Century included the closing of U.S. airspace following the September 11 attacks, and the closing of northern European airspace after the 2010 eruption of Eyjafjallajökull.

Spaceflight

The realistic dream of spaceflight dated back to Konstantin Tsiolkovsky, however Tsiolkovsky wrote in Russian, and this was not widely influential outside Russia. Spaceflight became an engineering possibility with the work of Robert H. Goddard's publication in 1919 of his paper 'A Method of Reaching Extreme Altitudes'; where his application of the de Laval nozzle to liquid fuelled rockets gave sufficient power that interplanetary travel became possible. This paper was highly influential on Hermann Oberth and Wernher Von Braun, later key players in spaceflight.

The first human space flight was achieved with the Soviet space program's Vostok 1 mission in 1961. The lead architects behind the mission were Sergei Korolev and Kerim Kerimov, with Yuri Gagarin being the first astronaut. Kerimov later went on to launch the first space docks (Cosmos 186 and Cosmos 188) in 1967 and the first space stations (Salyut and Mir series) from 1971 to 1991. The first spaceflight to the Moon was achieved with NASA's Apollo 11 mission in 1969, with Neil Armstrong and Buzz Aldrin being the first astronauts on the Moon. The history of transportation is largely one of technological innovation. Advances in technology have allowed people to travel farther, explore more territory, and expand their influence over larger and larger areas. Even in ancient times, new tools such as foot coverings, skis, and snowshoes lengthened the distances that could be traveled. As new inventions and discoveries were applied to transportation problems, travel time decreased while the ability to move more and larger loads increased. Innovation continues today, and transportation researchers are working to find new ways to reduce costs and increase transportation efficiency.

Chapter-9

Sustainable Transport

Sustainable transport (or **green transport**) refers to any means of transport with low impact on the environment, and includes walking and cycling, transit oriented development, green vehicles, CarSharing, and building or protecting urban transport systems that are fuel-efficient, space-saving and promote healthy lifestyles.

Sustainable transport systems make a positive contribution to the environmental, social and economic sustainability of the communities they serve. Transport systems exist to provide social and economic connections, and people quickly take up the opportunities offered by increased mobility. The advantages of increased mobility need to be weighed against the environmental, social and economic costs that transport systems pose.

Transport systems have significant impacts on the environment, accounting for between 20% and 25% of world energy consumption and carbon dioxide emissions. Greenhouse gas emissions from transport are increasing at a faster rate than any other energy using sector. Road transport is also a major contributor to local air pollution and smog.

The social costs of transport include road crashes, air pollution, physical inactivity, time taken away from the family while commuting and vulnerability to fuel price increases. Many of these negative impacts fall disproportionately on those social groups who are also least likely to own and drive cars. Traffic congestion imposes economic costs by wasting people's time and by slowing the delivery of goods and services.

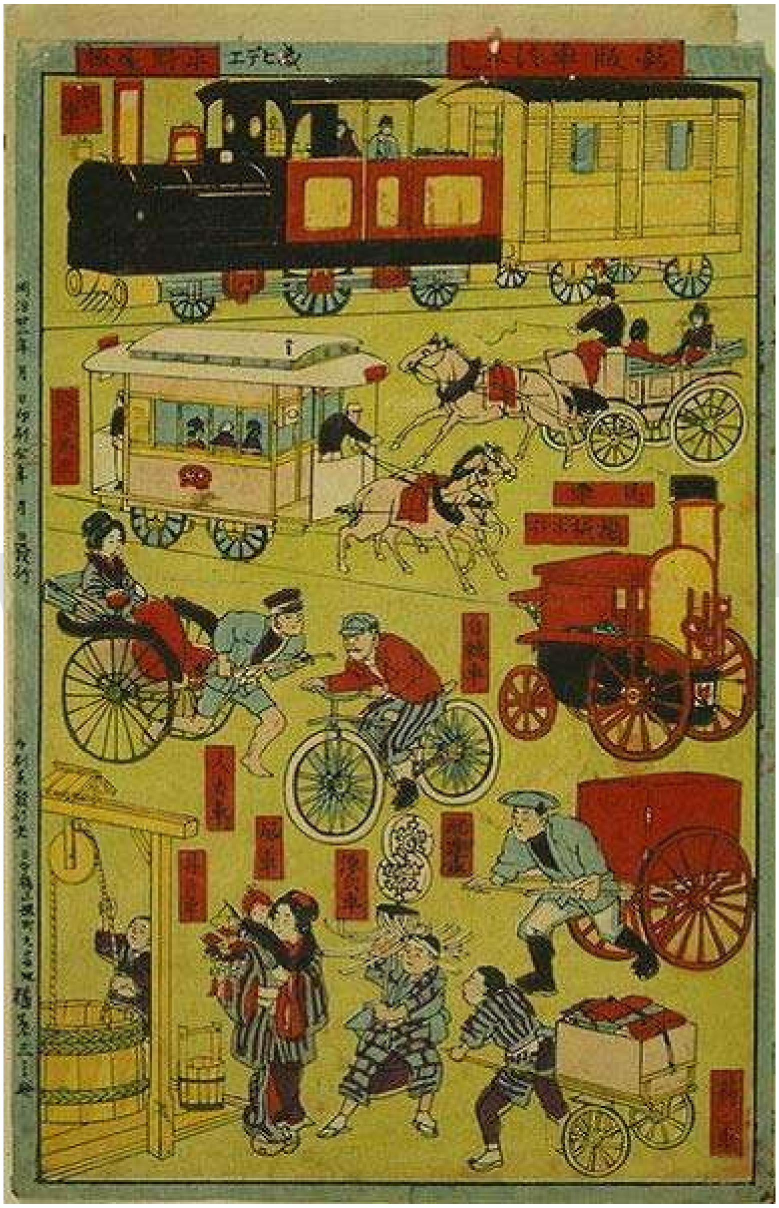
Traditional transport planning aims to improve mobility, especially for vehicles, and may fail to adequately consider wider impacts. But the real purpose of transport is access - to work, education, goods and services, friends and family - and there are proven techniques to improve access while simultaneously reducing environmental and social impacts, and managing traffic congestion. Communities which are successfully improving the sustainability of their transport networks are doing so as part of a wider programme of creating more vibrant, livable, sustainable cities.

Definition

The term **sustainable transport** came into use as a logical follow-on from sustainable development, and is used to describe modes of transport, and systems of transport planning, which are consistent with wider concerns of sustainability. There are many definitions of the sustainable transport, and of the related terms **sustainable transportation** and **sustainable mobility**. One such definition, from the European Union Council of Ministers of Transport, defines a sustainable transportation system as one that:

- Allows the basic access and development needs of individuals, companies and society to be met safely and in a manner consistent with human and ecosystem health, and promotes equity within and between successive generations.
- Is Affordable, operates fairly and efficiently, offers a choice of transport mode, and supports a competitive economy, as well as balanced regional development.
- Limits emissions and waste within the planet’s ability to absorb them, uses renewable resources at or below their rates of generation, and uses non-renewable resources at or below the rates of development of renewable substitutes, while minimizing the impact on the use of land and the generation of noise.

History



Japanese print shows various forms of transportation

Most of the tools and concepts of sustainable transport were developed before the phrase was coined. Walking, the first mode of transport, is also the most sustainable. Public transport dates back at least as far as the invention of the public bus by Blaise Pascal in 1662. The first passenger tram began operation in 1807 and the first passenger rail service in 1825. Pedal bicycles date from the 1860s. These were the only personal transport choices available to most people in Western countries prior to World War II, and remain the only options for most people in the developing world. Freight was moved by human power, animal power or rail.

The post-war years brought increased wealth and a demand for much greater mobility for people and goods. The number of road vehicles in Britain increased fivefold between 1950 and 1979, with similar trends in other Western nations. Most affluent countries and cities invested heavily in bigger and better-designed roads and motorways, which were considered essential to underpin growth and prosperity. Transport planning became a branch of civil engineering and sought to design sufficient road capacity to provide for the projected level of traffic growth at acceptable levels of traffic congestion - a technique called "predict and provide". Public investment in transit, walking and cycling declined dramatically in the United States, Great Britain and Australasia, although this did not occur to the same extent in Canada or mainland Europe.

Concerns about the sustainability of this approach became widespread during the 1973 oil crisis and the 1979 energy crisis. The high cost and limited availability of fuel led to a resurgence of interest in alternatives to single occupancy vehicle travel.

Transport innovations dating from this period include high-occupancy vehicle lanes, citywide carpool systems and transportation demand management. Singapore implemented congestion pricing in the late 1970s, and Curitiba began implementing its Bus Rapid Transit system in the early 1980s.

Relatively low and stable oil prices during the 1980s and 1990s led to significant increases in vehicle travel from 1980–2000, both directly because people chose to travel by car more often and for greater distances, and indirectly because cities developed tracts of suburban housing, distant from shops and from workplaces, now referred to as urban sprawl. Trends in freight logistics, including a movement from rail and coastal shipping to road freight and a requirement for just in time deliveries, meant that freight traffic grew faster than general vehicle traffic.

At the same time, the academic foundations of the "predict and provide" approach to transport were being questioned, notably by Peter Newman in a set of comparative studies of cities and their transport systems dating from the mid-1980s.

The British Government's White Paper on Transport marked a change in direction for transport planning in the UK. In the introduction to the White Paper, Prime Minister Tony Blair stated that

We recognise that we cannot simply build our way out of the problems we face. It would be environmentally irresponsible - and would not work.

A companion document to the White Paper called "Smarter Choices" researched the potential to scale up the small and scattered sustainable transport initiatives then occurring across Britain, and concluded that the comprehensive application of these techniques could reduce peak period car travel in urban areas by over 20%.

A similar study by the United States Federal Highway Administration, was also released in 2004 and also concluded that a more proactive approach to transportation demand was an important component of overall national transport strategy.

Environmentally sustainable transport

Transport systems are major emitters of greenhouse gases, responsible for 23% of world energy-related GHG emissions in 2004, with about three quarters coming from road vehicles. Currently 95% of transport energy comes from petroleum. Energy is consumed in the manufacture as well as the use of vehicles, and is embodied in transport infrastructure including roads, bridges and railways.

The environmental impacts of transport can be reduced by improving the walking and cycling environment in cities, and by enhancing the role of public transport, especially electric rail.

Green vehicles are intended to have less environmental impact than equivalent standard vehicles, although when the environmental impact of a vehicle is assessed over the whole of its life cycle this may not be the case. Electric vehicle technology has the potential to reduce transport CO_2 emissions, depending on the embodied energy of the vehicle and the source of the electricity. Hybrid vehicles, which use an internal combustion engine combined with an electric engine to achieve better fuel efficiency than a regular combustion engine, are already common. Natural gas is also used as a transport fuel. Biofuels are a less common, and less promising, technology; Brazil met 17% of its transport fuel needs from bioethanol in 2007, but the OECD has warned that the success of biofuels in Brazil is due to specific local circumstances; internationally, biofuels are forecast to have little or no impact on greenhouse emissions, at significantly higher cost than energy efficiency measures.

In practice there is a sliding scale of **green transport** depending on the sustainability of the option. Green vehicles are more fuel-efficient, but only in comparison with standard vehicles, and they still contribute to traffic congestion and road crashes. Well-patronised public transport networks based on traditional diesel buses use less fuel per passenger than private vehicles, and are generally safer and use less road space than private vehicles. Green public transport vehicles including electric trains, trams and electric buses combine the advantages of green vehicles with those of sustainable transport choices. Other transport choices with very low environmental impact are cycling and other human-powered vehicles, and animal powered transport. The most common green transport choice, with the least environmental impact is walking.

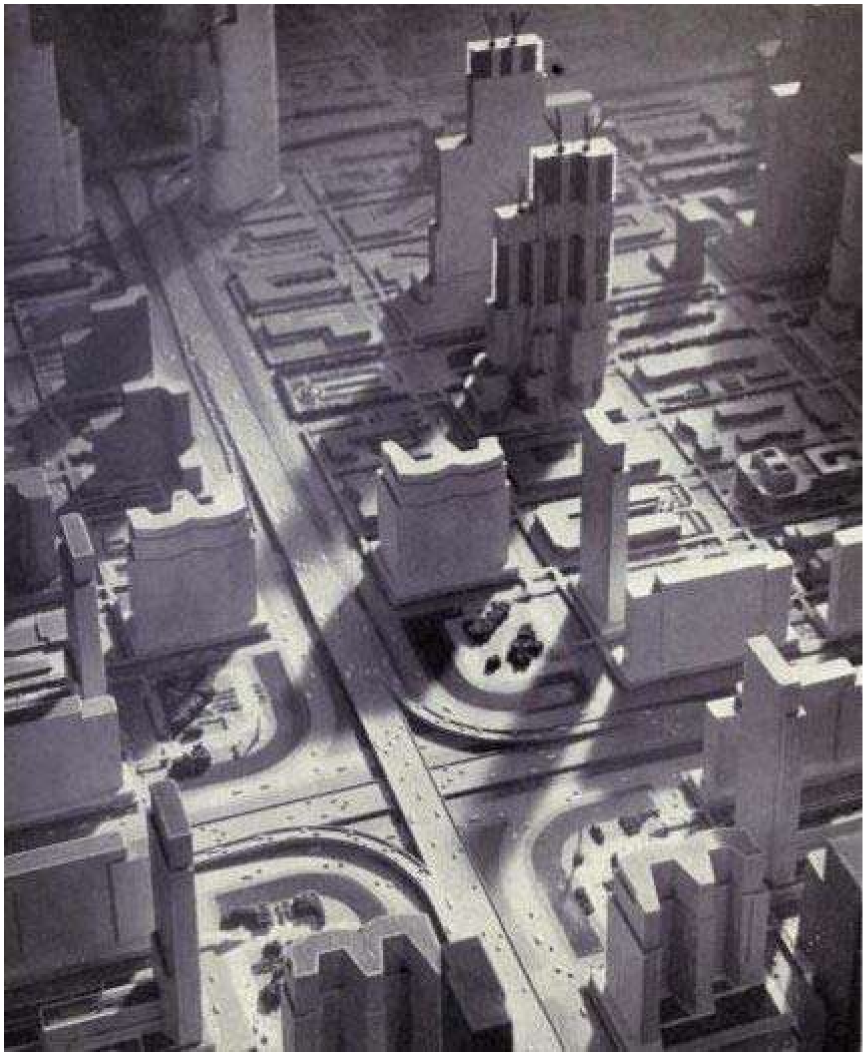
Transport and social sustainability

A tram in Melbourne, Australia

Cities with overbuilt roadways have experienced unintended consequences, linked to radical drops in public transport, walking, and cycling. In many cases, streets became void of “life.” Stores, schools, government centers and libraries moved away from central cities, and residents who did not flee to the suburbs experienced a much reduced quality of public space and of public services. As schools were closed their mega-school replacements in outlying areas generated additional traffic; the number of cars on US roads between 7:15 and 8:15 a.m. increases 30% during the school year.

Yet another impact was an increase in sedentary lifestyles, causing and complicating a national epidemic of obesity, and accompanying dramatically increased health care costs.

Cities and sustainable transport



Futurama, an exhibit at the 1939 New York World's Fair, was sponsored by General Motors and showed a vision of the City of Tomorrow.

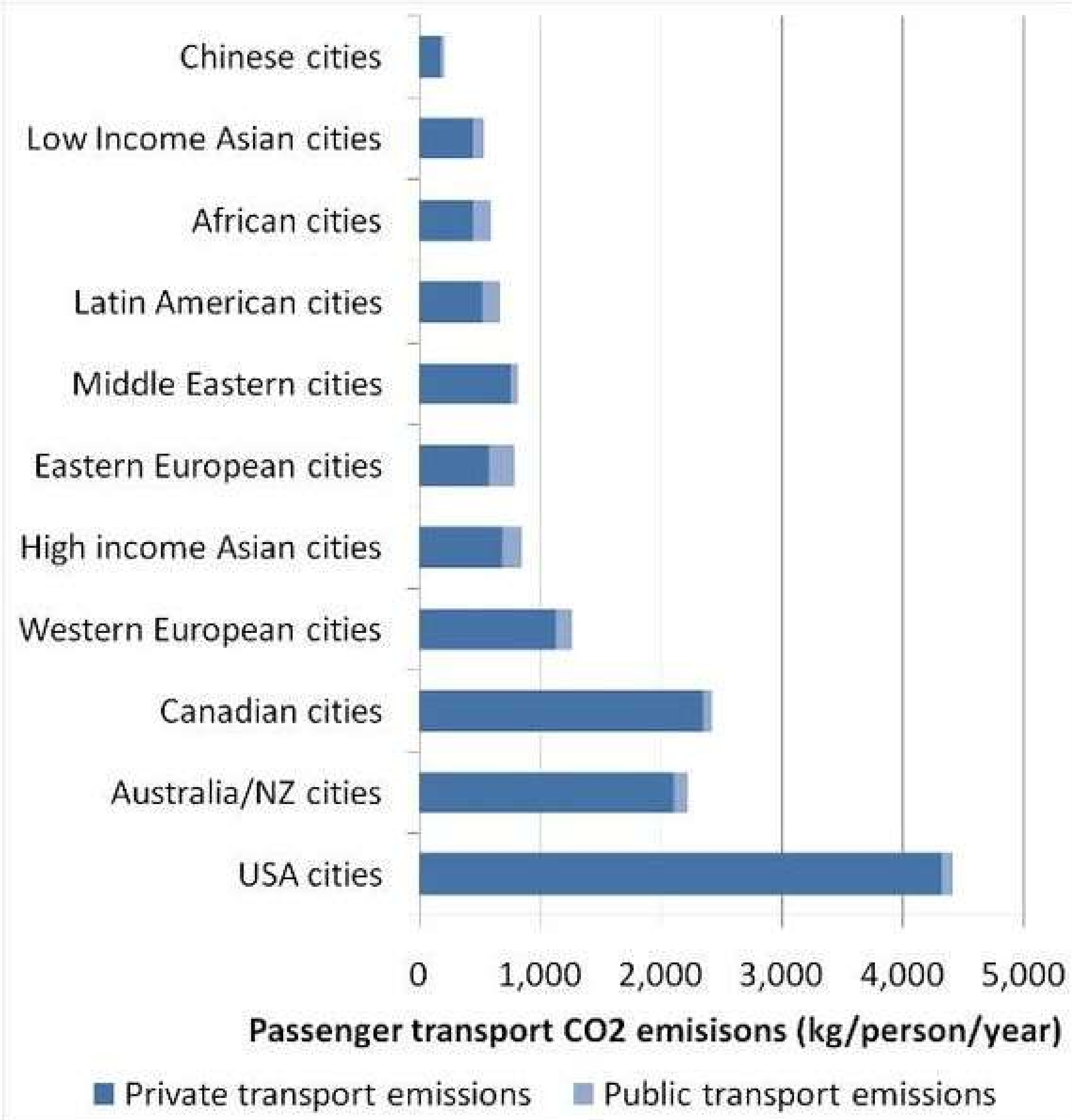
Cities are shaped by their transport systems. In The City in History, Lewis Mumford documented how the location and layout of cities was shaped around a walkable centre, often located near a port or waterway, and with sububs accessible by animal transport or, later, by rail or tram lines.

In 1939, the New York World's Fair included a model of an imagined city, built around a car-based transport system. In this "greater and better world of tomorrow", residential, commercial and industrial areas were separated, and skyscrapers loomed over a network of urban motorways. These ideas captured the popular imagination, and are credited with influencing city planning from the 1940s to the 1970s.

The popularity of the car in the post-war era led to major changes in the structure and function of cities. There was some opposition to these changes at the time. The writings of Jane Jacobs, in particular The Death and Life of Great American Cities provide a poignant reminder of what was lost in this transformation, and a record of community efforts to resist these changes. Lewis Mumford asked "is the city for cars or for people?" Donald Appleyard documented the consequences for communities of increasing car traffic in "The View from the Road" (1964) and in the UK, Mayer Hillman first published research into the impacts of traffic on child independent mobility in 1971. Despite these notes of caution, trends in car ownership, car use and fuel consumption continued steeply upward throughout the post-war period.

Interstate 10 and Interstate 45 near downtown Houston, Texas

Mainstream transport planning in Europe has, by contrast, never been based on assumptions that the private car was the best or only solution for urban mobility. For example the Dutch Transport Structure Scheme has since the 1970s required that demand for additional vehicle capacity only be met "if the contribution to societal welfare is positive", and since 1990 has included an explicit target to halve the rate of growth in vehicle traffic. Some cities outside Europe have also consistently linked transport to sustainability and to land use planning, notably Curitiba, Brazil, Portland, Oregon and Vancouver, Canada.



Greenhouse gas emissions from transport vary widely, even for cities of comparable wealth. Source: UITP, Mobility in Cities Database

There are major differences in transport energy consumption between cities; an average U.S. urban dweller uses 24 times more energy annually for private transport than a Chinese urban resident, and almost four times as much as a European urban dweller. These differences cannot be explained by wealth alone but are closely linked to the rates of walking, cycling, and public transport use and to enduring features of the city including urban density and urban design.

The cities and nations that have invested most heavily in car-based transport systems are now the least environmentally sustainable, as measured by per capita fossil fuel use. The social and economic sustainability of car-based urban planning has also been questioned.

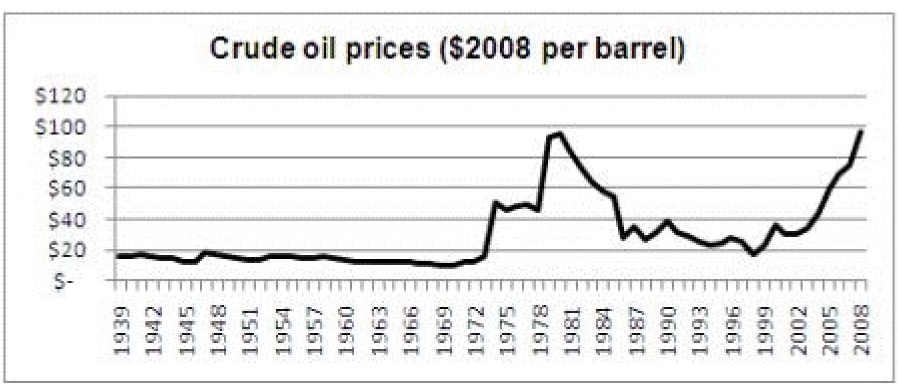
Within the United States, residents of sprawling cities make more frequent and longer car trips, while residents of traditional urban neighbourhoods make a similar number of trips, but travel shorter distances and walk, cycle and use transit more often. It has been calculated that New York residents save $19 billion each year simply by owning fewer cars and driving less than the average American.

The European Commission adopted the Action Plan on urban mobility on 2009-09-30 for sustainable urban mobility. The European Commission will conduct a review of the implementation of the Action Plan in the year 2012, and will assess the need for further action. In 2007, 72% of the European population lived in urban areas, which are key to growth and employment. Cities need efficient transport systems to support their economy and the welfare of their inhabitants. Around 85% of the EU's GDP is generated in cities. Urban areas face today the challenge of making transport sustainable in environmental (CO_2, air pollution, noise) and competitiveness (congestion) terms while at the same time addressing social concerns. These range from the need to respond to health problems and demographic trends, fostering economic and social cohesion to taking into account the needs of persons with reduced mobility, families and children.

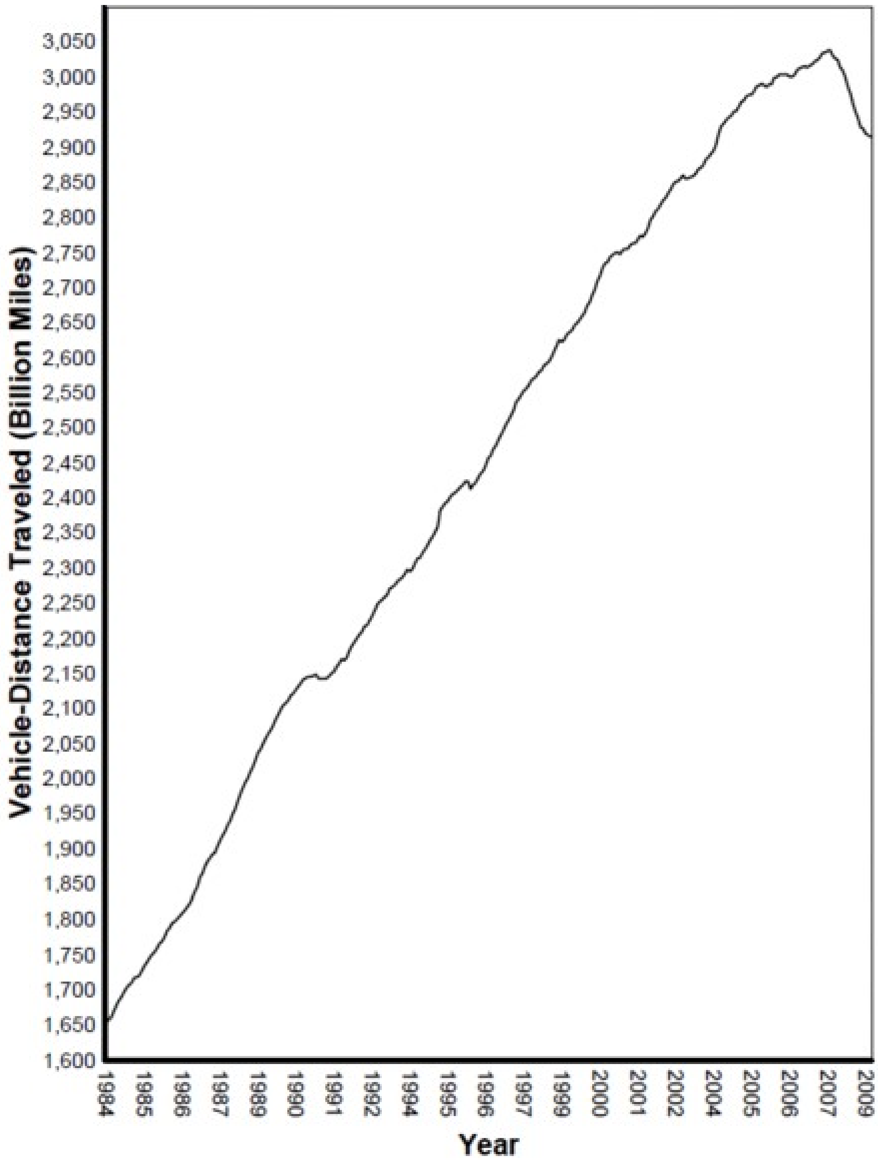
Sustainable transport policies and governance

Sustainable transport policies have their greatest impact at the city level. Outside Western Europe, cities which have consistently included sustainability as a key consideration in transport and land use planning include Curitiba, Brazil, Bogota, Colombia Portland, Oregon and Vancouver, Canada. The state of Victoria, Australia recently passed legislation - the Transport Integration Act - which introduces sustainability measures into transport policy, planning and operations.

Many other cities throughout the world have recognised the need to link sustainability and transport policies, for example by joining Cities for Climate Protection.



Oil price trend, 1939–2007, both nominal and adjusted to inflation.



Vehicle-miles traveled in the United States up to March 2009.

Community and grassroots action

Sustainable transport is fundamentally a grassroots movement, albeit one which is now recognised as of citywide, national and international significance.

Whereas it started as a movement driven by environmental concerns, over these last years there has been increased emphasis on social equity and fairness issues, and in particular the need to ensure proper access and services for lower income groups and people with mobility limitations, including the fast growing population of older citizens. Many of the people exposed to the most vehicle noise, pollution and safety risk have been those who do not own, or cannot drive cars, and those for whom the cost of car ownership causes a severe financial burden.

Recent trends

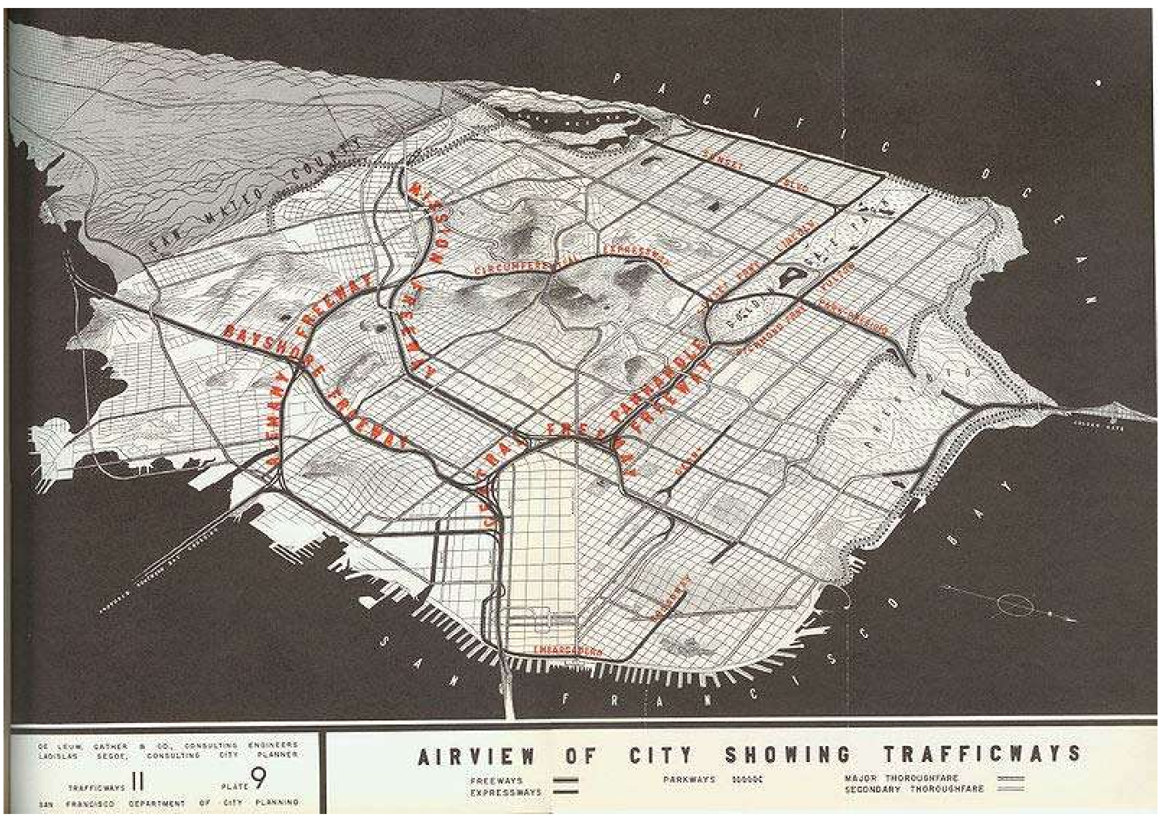
Car travel increased steadily throughout the twentieth century, but trends since 2000 have been more complex. Oil price rises from 2003 have been linked to a decline in per capita fuel use for private vehicle travel in the USA, Britain and Australia. In 2008, global oil consumption fell by 0.8% overall, with significant declines in consumption in North America, Western Europe, and parts of Asia.

Criticism

The term *Green transport* is often used as a greenwash marketing technique for products which are not proven to make a positive contribution to environmental sustainability. Such claims can be legally challenged. For instance Norway's consumer ombudsman has targeted automakers who claim that their cars are "green", "clean" or "environmentally friendly". Manufacturers risk fines if they fail to drop the words. The Australian Competition and Consumer Commission (ACCC) describes *green* claims on products as *very vague*, *inviting consumers to give a wide range of meanings to the claim, which risks misleading them*. In 2008 the ACCC forced a car retailer to stop its *green* marketing of Saab cars, which was found by the Australian Federal Court as *misleading*.

Chapter-10

Transportation Planning



1948 San Francisco roadway plan

Transportation planning is a field involved with the evaluation, assessment, design and siting of transportation facilities (generally streets, highways, footpaths, bike lanes and public transport lines).

Models and Sustainability

Chicago Transit Authority Chicago 'L' trains use elevated tracks for a portion of the system known as the Loop, which is located in the Chicago Loop community area. This is an example of the siting of transportation facilities resulting from transportation planning.

Transportation planning historically has followed the rational planning model of defining goals and objectives, identifying problems, generating alternatives, evaluating alternatives, and developing plans. Other models for planning include rational actor, transit oriented development, satisficing, incremental planning, organizational process, and political bargaining.

However, planners are increasingly expected to adopt a multi-disciplinary approach, especially due to the rising importance of environmentalism. For example, the use of behavioral psychology to persuade drivers to abandon their automobiles and use public transport instead. The role of the transport planner is shifting from technical analysis to promoting sustainability through integrated transport policies.

United Kingdom

In the United Kingdom transport planning has traditionally been a branch of civil engineering. In the 1950s and 1960s it was generally believed that the motor car was an important element in the future of transport as economic growth spurred on car ownership figures. The role of the transport planner was to match motorway and rural road capacity against the demands of economic growth. Urban areas would need to be redesigned for the motor vehicle or else impose traffic containment and demand management to mitigate congestion and environmental impacts. These policies were popularised in a 1963 government publication, *Traffic in Towns*. The contemporary Smeed Report on congestion pricing was initially promoted to manage demand but was deemed politically unacceptable. In more recent times this approach has been caricatured as "predict and provide" – to predict future transport demand and provide the network for it, usually by building more roads.

The publication of Planning Policy Guidance 13 in 1994 (revised in 2001), followed by A New Deal for Transport in 1998 and the white paper Transport Ten Year Plan 2000 again indicated an acceptance that unrestrained growth in road traffic was neither desirable nor feasible. The worries were threefold: concerns about congestion, concerns about the effect of road traffic on the environment (both natural and built) and concerns that an emphasis on road transport discriminates against vulnerable groups in society such as the poor, the elderly and the disabled.

These documents reiterated the emphasis on integration:

- integration within and between different modes of transport
- integration with the environment
- integration with land use planning
- integration with policies for education, health and wealth creation.

This attempt to reverse decades of underinvestment in the transport system has resulted in a severe shortage of transport planners. It was estimated in 2003 that 2,000 new planners would be required by 2010 to avoid jeopardising the success of the Transport Ten Year Plan.

During 2006 the Transport Planning Society defined the key purpose of transport planning as

> *to plan, design, deliver, manage and review transport, balancing the needs of society, the economy and the environment.*

The following key roles must be performed by transport planners:

- take account of the social, economic and environmental context of their work
- understand the legal, regulatory policy and resource framework within which they work

- understand and create transport policies, strategies and plans that contribute to meeting social, economic and environmental needs
- design the necessary transport projects, systems and services
- understand the commercial aspects of operating transport systems and services
- know about and apply the relevant tools and techniques
- must be competent in all aspects of management, in particular communications, personal skills and project management.

United States

Transportation planning in the United States is in the midst of a shift similar to that taking place in the United Kingdom, away from the singular goal of moving vehicular traffic and towards an approach that takes into consideration the communities and lands which streets, roads, and highways pass through ("the context"). More so, it places a greater emphasis on passenger rail networks which had been neglected until recently. This new approach, known as Context Sensitive Solutions (CSS), seeks to balance the need to move people efficiently and safely with other desirable outcomes, including historic preservation, environmental sustainability, and the creation of vital public spaces.

The initial guiding principles of CSS came out of the 1998 "Thinking Beyond the Pavement" conference as a means to describe and foster transportation projects that preserve and enhance the natural and built environments, as well as the economic and social assets of the neighborhoods they pass through. CSS principles have since been adopted as guidelines for highway design in federal legislation. And in 2003, the Federal Highway Administration announced that under one of its three Vital Few Objectives (Environmental Stewardship and Streamlining) they set the target of achieving CSS integration within all state Departments of Transportation by September of 2007. The recent pushes for advancing transportation planning has led to the development of a professional certification program, the Professional Transportation Planner, to be launched in 2007.

Chapter-11

Transport and the Environment

Interstate 10 and Interstate 45 near downtown Houston, Texas in the United States.

Transportation is a major user of energy, and burns most of the world's petroleum. This creates air pollution, including nitrous oxides and particulates, and is a significant contributor to global warming through emission of carbon dioxide, for which transport is the fastest-growing emission sector. By subsector, road transport is the largest contributor to global warming.

Environmental regulations in developed countries have reduced the individual vehicles emission; however, this has been offset by an increase in the number of vehicles, and more use of each vehicle. Some pathways to reduced the carbon emissions of road vehicles considerably have been studied. Energy use and emissions vary largely between modes, causing environmentalists to call for a transition from air and road to rail and human-powered transport, and increase transport electrification and energy efficiency.

Other environmental impacts of transport systems include traffic congestion and automobile-oriented urban sprawl, which can consume natural habitat and agricultural lands. By reducing transportation emissions globally, it is predicted that there will be significant positive effects on Earth's air quality, acid rain, smog and climate change.

The health impact of transport emissions is also of concern. A recent survey of the studies on the effect of traffic emissions on pregnancy outcomes has linked exposure to emissions to adverse effects on gestational duration and possibly also intrauterine growth.

Sectors

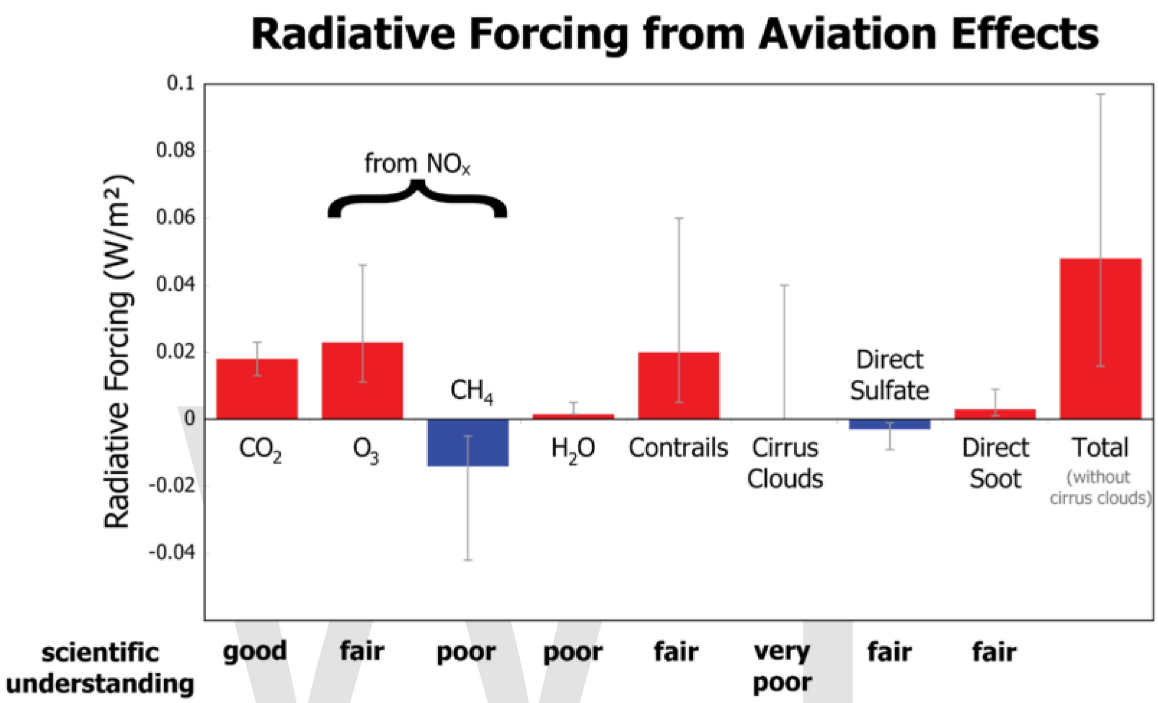
Aviation

A C-141 Starlifter leaves exhaust contrails over Antarctica.

Aviation impacts the environment because aircraft engines emit noise, particulates, and gases which contribute to climate change and global dimming. Despite emission reductions from automobiles and more fuel-efficient and less polluting turbofan and turboprop engines, the rapid growth of air travel in recent years contributes to an increase in total pollution attributable to aviation. In the EU, greenhouse gas emissions from aviation increased by 87% between 1990 and 2006.

There is an ongoing debate about possible taxation of air travel and the inclusion of aviation in an emissions trading scheme, with a view to ensuring that the total external costs of aviation are taken into account.

Climate change



Radiative forcings from aviation emissions (gases and aerosols) in 1992 as estimated by the IPCC

Like all human activities involving combustion, most forms of aviation release carbon dioxide (CO_2) into the Earth's atmosphere, contributing to the acceleration of global warming.

In addition to the CO_2 released by most aircraft in flight through the burning of fuels such as Jet-A (turbine aircraft) or Avgas (piston aircraft), the aviation industry also contributes greenhouse gas emissions from ground airport vehicles and those used by passengers and staff to access airports, as well as through emissions generated by the production of energy used in airport buildings, the manufacture of aircraft and the construction of airport infrastructure.

While the principal greenhouse gas emission from powered aircraft in flight is CO_2, other emissions may include nitric oxide and nitrogen dioxide, (together termed oxides of nitrogen or NO_x), water vapour and particulates (soot and sulfate particles), sulfur oxides, carbon monoxide (which bonds with oxygen to become CO_2 immediately upon release), incompletely burned hydrocarbons, tetra-ethyl lead (piston aircraft only), and radicals such as hydroxyl, depending on the type of aircraft in use.

The contribution of civil aircraft-in-flight to global CO_2 emissions has been estimated at around 2%. However, in the case of high-altitude airliners which frequently fly near or in the stratosphere, non-CO_2 altitude-sensitive effects may increase the total impact on anthropogenic (man-made) climate change significantly.

Mechanisms

Subsonic aircraft-in-flight contribute to climate change in four ways:

Carbon dioxide (CO_2)

CO_2 emissions from aircraft-in-flight are the most significant and best understood element of aviation's total contribution to climate change. The level and effects of CO_2 emissions are currently believed to be broadly the same regardless of altitude (i.e. they have the same atmospheric effects as ground based emissions). In 1992, emissions of CO_2 from aircraft were estimated at around 2% of all such anthropogenic emissions, though CO_2 concentration attributable to aviation in 1992 was around 1% of the total anthropogenic increase, because emissions occurred only in the last 50 years.

Oxides of nitrogen (NO_x)

At the high altitudes flown by large jet airliners around the tropopause, emissions of NO_x are particularly effective in forming ozone (O_3) in the upper troposphere. High altitude (8-13km) NO_x emissions result in greater concentrations of O_3 than surface NO_x emissions, and these in turn have a greater global warming effect. The effect of O_3 concentrations are regional and local (as opposed to CO_2 emissions, which are global).

NO_x emissions also reduce ambient levels of methane, another greenhouse gas, resulting in a climate cooling effect. But this effect does not offset the O_3 forming effect of NO_x emissions. It is now believed that aircraft sulfur and water emissions in the stratosphere tend to deplete O_3, partially offsetting the NO_x-induced O_3 increases. These effects have not been quantified. This problem does not apply to aircraft that fly lower in the troposphere, such as light aircraft or many commuter aircraft.

Water vapor (H_2O)

Contrails

Cirrus cloud formation

One of the products of burning hydrocarbons in oxygen is water vapour, a greenhouse gas. Water vapour produced by aircraft engines at high altitude, under certain atmospheric conditions, condenses into droplets to form Condensation trails, or contrails. Contrails are visible line clouds that form in cold, humid atmospheres and are thought to have a global warming effect (though one less significant than either CO_2 emissions or NO_x induced effects) SPM-2. Contrails are extremely rare from lower-altitude aircraft, or from propeller aircraft or rotorcraft.

Cirrus clouds have been observed to develop after the persistent formation of contrails and have been found to have a global warming effect over-and-above that of contrail formation alone. There is a degree of scientific uncertainty about the contribution of contrail and cirrus cloud formation to global warming and attempts to estimate aviation's overall climate change contribution do not tend to include its effects on cirrus cloud enhancement.

Particulates

Least significant is the release of soot and sulfate particles. Soot absorbs heat and has a warming effect; sulfate particles reflect radiation and have a small cooling effect. In addition, they can influence the formation and properties of clouds. All aircraft powered by combustion will release some amount of soot.

Emissions per passenger kilometre

Emissions of passenger aircraft per passenger kilometre vary extensively, according to variables such as the size of the aircraft, the number of passengers on board, and the altitude and distance of the journey (the practical effect of emissions at high altitides may be greater than those of emissions at low altitudes). However, some representative figures for emissions are provided by LIPASTO's survey of average passenger aircraft emissions per passenger kilometre in Finland 2008: expressed as CO_2 equivalent,

- Domestic, short distance, less than 463 km (288 mi): 259 g (9 oz)
- Domestic, long distance, greater than 463 km (288 mi): 178 g (6 oz)
- Long distance flights: 114 g (4 oz)

This is similar to the emissions from a four-seat car with one person on board.

Per passenger kilometre, figures from British Airways suggest carbon dioxide emissions of 0.1 kg for large jet airliners (a figure which does not account for the production of other pollutants or condensation trails).

Total effect

In attempting to aggregate and quantify the climate impact of aircraft emissions the Intergovernmental Panel on Climate Change (IPCC) has estimated that aviation's total climate impact is some 2-4 times that of its CO_2 emissions alone (excluding the potential impact of cirrus cloud enhancement). This is measured as radiative forcing. While there is uncertainty about the exact level of impact of NO_x and water vapour, governments have accepted the broad scientific view that they do have an effect. Accordingly, more recent UK government policy statements have stressed the need for aviation to address its total climate change impacts and not simply the impact of CO_2.

The IPCC has estimated that aviation is responsible for around 3.5% of anthropogenic climate change, a figure which includes both CO_2 and non-CO_2 induced effects. The IPCC has produced scenarios estimating what this figure could be in 2050. The central case estimate is that aviation's contribution could grow to 5% of the total contribution by 2050 if action is not taken to tackle these emissions, though the highest scenario is 15%. Moreover, if other industries achieve significant cuts in their own greenhouse gas emissions, aviation's share as a proportion of the remaining emissions could also rise.

Potential reductions

Modern jet aircraft are significantly more fuel efficient (and thus emit less CO_2 in particular) than 30 years ago.. Moreover, manufacturers have forecast and are committed to achieving reductions in both CO_2 and NO_x emissions with each new generation of design of aircraft and engine. Thus, the accelerated introduction of more modern aircraft represents a major opportunity to reduce emissions per passenger kilometre flown.

Other opportunities arise from the optimisation of airline timetables, route networks and flight frequencies to increase load factors (minimise the number of empty seats flown), together with the optimisation of airspace.

Another possible reduction of the climate-change impact is the limitation of cruise altitude of aircraft. This would lead to a significant reduction in high-altitude contrails for a marginal trade-off of increased flight time and an estimated 4% increase in CO_2 emissions. Drawbacks of this solution include very limited airspace capacity to do this, especially in Europe and North America and increased fuel burn because jet aircraft are less efficient at lower cruise altitudes.

However, the total number of passenger kilometres is growing at a faster rate than manufacturers can reduce emissions, and at present there is no readily available alternative to burning kerosene. Thus, the growth in the aviation sector is likely to continue to generate an increasing volume of greenhouse gas emissions. However some scientists and companies such as GE Aviation and Virgin Fuels are researching biofuel technology for use in jet aircraft. As part of this test Virgin Atlantic Airways flew a Boeing 747 from London Heathrow Airport to Amsterdam Schiphol Airport on 24 February 2008, with one engine burning a combination of coconut oil and babassu oil. Greenpeace's chief scientist Doug Parr said that the flight was "high-altitude greenwash" and that producing organic oils to make biofuel could lead to deforestation and a large increase in greenhouse gas emissions.

The majority of the world's aircraft are not large jetliners but smaller piston aircraft, and many are capable of using ethanol as a fuel, with major modifications. While ethanol also releases CO_2 during combustion, the plants cultivated to make it draw that same CO_2 out of the atmosphere while they are growing, making the fuel closer to climate-change-neutral. The only problem is the US government's choice of using ethanol from corn, since it takes more energy to produce than is returned, it displaces food crops and thus raises the price of food, and causes soil degradation.

While they are not suitable for long-haul or transoceanic flights, turboprop aircraft used for commuter flights bring two significant benefits: they often burn considerably less fuel per passenger mile, and they typically fly at lower altitudes, well inside the tropopause, where there are no concerns about ozone or contrail production.

Reducing travel

An alternative method for reducing the environmental impact of aviation is to constrain demand for air travel. The UK study *Predict and Decide - Aviation, climate change and UK policy*, notes that a 10% increase in fares generates a 5% to 15% reduction in demand, and recommends that the British government should manage demand rather than provide for it. This would be accomplished via a strategy that presumes "… against the expansion of UK airport capacity" and constrains demand by the use of economic instruments to price air travel less attractively. A study published by the campaign group Aviation Environment Federation (AEF) concludes that by levying £9 billion of additional taxes, the annual rate of growth in demand in the UK for air travel would be reduced to 2%. The ninth report of the House of Commons Environmental Audit Select Committee, published in July 2006, recommends that the British government rethinks its airport expansion policy and considers ways, particularly via increased taxation, in which future demand can be managed in line with industry performance in achieving fuel efficiencies, so that emissions are not allowed to increase in absolute terms.

Kyoto Protocol

Greenhouse gas emissions from fuel consumption in international aviation, in contrast to those from domestic aviation and from energy use by airports, are not assigned under the first round of the Kyoto Protocol, neither are the non-CO_2 climate effects. In place of agreement, Governments agreed to work through the International Civil Aviation Organization (ICAO) to limit or reduce emissions and to find a solution to the allocation of emissions from international aviation in time for the second round of Kyoto in 2009 in Copenhagen.

Emissions trading

As part of that process the ICAO has endorsed the adoption of an open emissions trading system to meet CO_2 emissions reduction objectives. Guidelines for the adoption and implementation of a global scheme are currently being developed, and will be presented to the ICAO Assembly in 2007, although the prospects of a comprehensive inter-governmental agreement on the adoption of such a scheme are uncertain.

Within the European Union, however, the European Commission has resolved to incorporate aviation in the European Union Emissions Trading Scheme (ETS). A new directive has been adopted by the European Parliament in July 2008 and approved by the Council in October 2008. It will enter into force on 1 January 2012.

Mitigation

Increased fuel efficiency, the use of aviation biofuels and route optimisation reduces the impact of aviation on greenhouse gas emissions.

Noise

Aircraft noise is seen by advocacy groups as being very hard to get attention and action on. The fundamental issues are increased traffic at larger airports and airport expansion at smaller and regional airports.

Road transport

Cars

Unleaded gasoline has 8.87 kg of CO_2 per gallon. Fuel efficiency (MPG) varies widely in the US, so averages are not extremely relevant. The average fuel economy for cars sold in 2005 was about 25.2 MPG. The Department of Transportation's MOBILE 6.2 model, used by regional governments to model air quality, uses a fleet average (all cars, old and new) of 20.3 mpg.

Busses

On average, inner city commuting buses emit .3 kg of CO_2 per passenger mile, and long distance (>20 mi) bus trips emit .08 kg of CO_2 per passenger mile. Road and transportation conditions vary, so some carbon calculations add 10% to the total distance of the trip to account for potential traffic jams, detours, and pit-stops that may arise.

Rail

On average, commuter rail and subway trains emit .16 kg of CO_2 per passenger mile, and long distance (>20 mi) trains emit .19 kg of CO_2 per passenger mile. Some carbon calculations add 10% to the total trip distance to account for detours, stop-overs, and other issues that may arise.

Shipping

The fleet emission average for delivery vans, trucks and big rigs is 10.17 kg CO_2 per gallon of diesel consumed. Delivery vans and trucks average about 7.8 mpg while big rigs average about 5.3 mpg.

Shipping Emissions Factors:

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- Air cargo - .8063 kg of CO2 per Ton-Mile
- Truck - 0.1693 kg of CO2 per Ton-Mile
- Train - 0.1048 kg of CO2 per Ton-Mile
- Sea freight - 0.0403 kg of CO2 per Ton-Mile
- Zeppelin - 0.0887 kg of CO2 per Ton-Mile
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Mitigation of environmental impact

Road-Rail Parallel Layout

Construction of the route through the Kösching forest, north of Ingolstadt, Germany, had a large environmental impact but with Road-Rail Parallel Layout this would be less than using multiple routes.

Road-Rail Parallel Layout is a design option to reduce the environmental impact of new transportation routes by locating railway tracks alongside a highway. In 1984 the Paris—Lyon high-speed rail route in France had about 14% parallel layout with the highway, and in 2002 70% parallel layout was achieved with the Cologne–Frankfurt high-speed rail line.