Means of Transport and Equipment

A. Means of Transport

1. Transport: then, now, and tomorrow

Mobility is a basic human need. From the times immemorial, everyone travels either for food or leisure. A closely associated need is the transport of raw materials to a manufacturing unit or finished goods for consumption. Transportation fulfills these basic needs of humanity.

Transport or transportation is the movement of people and goods from one place to another. The term is derived from the Latin trans ("across") and portare ("to carry"). Transportation plays a major role in the development of the human civilization. For instance, one could easily observe the strong correlation between the evolution of human settlement and the proximity of transport facilities. Also, there is a strong correlation between the quality of transport facilities and standard of living, because of which society places a great expectation from transportation facilities.

In other words, the solution to transportation problems must be analytically based, economically sound, socially credible, environmentally sensitive, and practically acceptable and sustainable. Alternatively, the transportation solution should be safe, rapid, comfortable, convenient, economical, and eco-friendly for both men and material.

Industries which have the business of providing equipment, actual transport, transport of people or goods and services used in transport of goods or people make up a large broad and important sector of most national economies, and are collectively referred to as transport industries.

Aspects of transport

The field of transport has several aspects: loosely they can be divided into a triad of infrastructure, vehicles, and operations. Infrastructure includes the transport networks (roads, railways, airways, waterways, canals, pipelines, etc.) that are used, as well as the nodes or terminals (such as airports, railway stations, bus stations and seaports). The vehicles generally ride on the networks, such as automobiles, bicycles, buses, trains, aircrafts. The operations deal with the way the vehicles are operated on the network and the procedures set for this purpose including the legal environment (Laws, Codes, Regulations, etc.) Policies, such as how to finance the system (for
example, the use of tolls or gasoline taxes) may be considered part of the operations. Broadly speaking, the design of networks are the domain of civil engineering and urban planning, the design of vehicles of mechanical engineering and specialized sub fields such as nautical engineering and aerospace engineering, and the operations are usually specialized, though might appropriately belong to operations research or systems engineering.

2. Modes and categories

Mode of transport is a general term for the different kinds of transport facilities that are often used to transport people or cargo. Where more than one mode of transport is used for a journey, or for transport analysis, the journey can be described as multi-modal.

A transport mode is a combination of the following:
- Traffic infrastructure: traffic routes, networks, nodes (stations, terminals), etc.
- Vehicles and containers: trucks, wagons, ships, aircraft and trains.
- A stationary or mobile workforce
- Propulsion system and power supply (traction)
- Operations: driving, management, traffic signals, railway switching, air traffic control, etc.

Examples of modes and categories of transport
- Animal powered transport
- Air transport
  - Aircraft
  - Airship
  - Balloon
  - Hang glider
  - Helicopter
- Human-powered transport
  - Cyclist (Cycling)
  - Pedestrian (walking)
  - Rickshaw
- Ship transport
  - Boat
  - Ship
  - Submarine
- Rail transport
  - Metro
  - Tram
  - Train
- Road transport
  - Bus
  - Car
  - Motorcycle
  - Truck
- Other
  - Cable car (disambiguation)
  - Escalator
  - Lift
  - People mover
  - Spacecraft
Vehicles

Vehicles are non-living means of transportation. They are most often man-made (e.g. bicycles, cars, motorcycles, trains, ships, and aircraft), although some other means of transportation, which are not made by man, can also be called vehicles; examples include icebergs and floating tree trunks. Vehicles may be propelled by animals, e.g. a chariot or an ox-cart. However, animals on their own, though used as a means of transportation, are not called vehicles. This includes humans carrying another human, for example a child or a disabled person. Vehicles that do not travel on land are often called crafts, such as watercraft, sailcraft, aircraft, hovercraft and spacecraft.

3. Road transport

The first forms 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.

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.

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. 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. 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 that 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.
Automobile

Karl Benz’s “Velo” model (1894) - entered into the first automobile race

Ford Model T, 1927, regarded as the first affordable automobile

The 1955 Citroën DS; revolutionary visual design and technological innovation

An automobile (also motor car or simply car) is a wheeled passenger vehicle that carries its own motor. Most definitions of the term specify that automobiles are designed to run primarily on roads, to have seating for one to eight people, to typically have four wheels, and to be constructed principally for the transport of people rather than goods. However, the term is far from precise.

An automobile powered by an Otto gasoline engine was built in Germany by Karl Benz in 1885 and granted a patent in the following year. Although several other engineers (including Gottlieb Daimler, Wilhelm Maybach and Siegfried Marcus) were working on the problem at about the same time, Benz is generally credited with the invention of the modern automobile. Approximately 25 of Benz's vehicles were built before 1893, when his first four-wheeler was introduced. They were powered with four-stroke engines of his own design. Emile Roger of France, already producing Benz engines under license, now added the Benz automobile to his line of products. Because France was more open to the early automobiles, more were built and sold in France through Roger than Benz sold in Germany. From 1890 to 1895 about 30 vehicles were built by Daimler and his assistant, Maybach, either at the Daimler works or in the Hotel Hermann, where they set up shop after falling out with their backers. Benz and Daimler seem to have been unaware of each other's early work and worked independently. In 1890, Emile Levassor and Armand Peugeot of France began producing vehicles with Daimler engines, and so laid the foundation of the motor industry in France. The first American car with a gasoline internal combustion engine supposedly was designed in 1877 by George Selden of Rochester, New York, who applied for a patent on an automobile in 1879. In Britain there had been several attempts to build steam cars with varying degrees of success with Thomas Rickett even attempting a production run in 1860. Santler from Malvern is recognized by the Veteran Car Club of Great Britain as having made the first petrol-powered car in the country in 1894 followed by Frederick William Lanchester in 1895 but these were both one-offs. The first production vehicles came from the Daimler Motor Company, founded by Harry J. Lawson in 1896, and making their first cars in 1897. In 1892, Rudolf Diesel got a patent for a "New Rational Combustion Engine". In 1897 he built the first Diesel Engine. Steam, electric, and gasoline-powered autos competed for decades, with gasoline internal combustion engines achieving dominance in the 1910s. The large-scale, production line manufacturing of affordable automobiles was debuted by Ransom Olds at his Oldsmobile factory in 1902. This assembly line concept was then greatly expanded by Henry Ford in the 1910s. Development of
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automotive technology was rapid, due in part to the hundreds of small manufacturers competing to gain the world's attention. Key developments included electric ignition and the electric self-starter (both by Charles Kettering, for the Cadillac Motor Company in 1910-1911), independent suspension, and four-wheel brakes. Although various pistonless rotary engine designs have attempted to compete with the conventional piston and crankshaft design, only Mazda's version of the Wankel engine has had more than very limited success. Since the 1920s, nearly all cars have been mass-produced to meet market needs, so marketing plans have often heavily influenced automobile design. It was Alfred P. Sloan who established the idea of different makes of cars produced by one company, so buyers could "move up" as their fortunes improved. The makes shared parts with one another so larger production volume resulted in lower costs for each price range. For example, in the 1950s, Chevrolet shared hood, doors, roof, and windows with Pontiac; the LaSalle of the 1930s, sold by Cadillac, used cheaper mechanical parts made by the Oldsmobile division.

Design

The design of modern cars is typically handled by a large team of designers and engineers from many different disciplines. As part of the product development effort the team of designers will work closely with teams of design engineers responsible for all aspects of the vehicle. These engineering teams include: chassis, body and trim, powertrain, electrical and production. The design team under the leadership of the design director will typically comprise of an exterior designer, an interior designer (usually referred to as stylists), and a color and materials designer. A few other designers will be involved in detail design of both exterior and interior. For example, a designer might be tasked with designing the rear light clusters or the steering wheel. The color and materials designer will work closely with the exterior and interior designers in developing exterior color paints, interior colors, fabrics, leathers, carpet, wood trim, and so on.

Fuel and propulsion technologies

Most automobiles in use today are propelled by gasoline (also known as petrol) or diesel internal combustion engines, which are known to cause air pollution and are also blamed for contributing to climate change and global warming.[10] Increasing costs of oil-based fuels and tightening environmental laws and restrictions on greenhouse gas emissions are propelling work on alternative power systems for automobiles. Efforts to improve or replace these technologies include hybrid vehicles, electric vehicles and hydrogen vehicles.

Diesel

Diesel engined cars have long been popular in Europe with the first models being introduced in the 1930s by Mercedes Benz and Citroen. The main benefit of Diesels are a 50% fuel burn efficiency compared with 27%[11] in the best gasoline engines. A down side of the diesel is the presence in the exhaust gases of fine soot particulates and manufacturers are now starting to fit filters to remove these. Many diesel powered cars can also run with little or no modifications on 100% biodiesel.

Gasoline
Gasoline engines have the advantage over diesel in being lighter and able to work at higher rotational speeds and they are the usual choice for fitting in high performance sports cars. Continuous development of gasoline engines for over a hundred years has produced improvements in efficiency and reduced pollution. The carburetor was used on nearly all road car engines until the 1980s but it was long realised better control of the fuel/air mixture could be achieved with fuel injection. Indirect fuel injection was first used in aircraft engines from 1909, in racing car engines from the 1930s, and road cars from the late 1950s.[11] Gasoline Direct Injection (GDI) is now starting to appear in production vehicles such as the 2007 BMW MINI. Exhaust gases are also cleaned up by fitting a catalytic converter into the exhaust system. Clean air legislation in many of the car industries most important markets has made both catalysts and fuel injection virtually universal fittings. Most modern gasoline engines are also capable of running with up to 15% ethanol mixed into the gasoline - older vehicles may have seals and hoses that can be harmed by ethanol. With a small amount of redesign, gasoline-powered vehicles can run on ethanol concentrations as high as 85%. 100% ethanol is used in some parts of the world (such as Brazil), but vehicles must be started on pure gasoline and switched over to ethanol once the engine is running. Most gasoline engined cars can also run on LPG with the addition of an LPG tank for fuel storage and carburetion modifications to add an LPG mixer. LPG produces fewer toxic emissions and is a popular fuel for fork lift trucks that have to operate inside buildings.

Electric

The first electric cars were built in the late 1800s, but the building of battery powered vehicles that could rival internal combustion models had to wait for the introduction of modern semiconductor controls. Because they can deliver a high torque at low revolutions electric cars do not require such a complex drive train and transmission as internal combustion powered cars. Some are able to accelerate from 0-60 mph (96 km/hour) in 4.0 seconds with a top speed around 130 mph (210 km/h). They have a range of 250 miles (400 km) on the EPA highway cycle requiring 3-1/2 hours to completely charge. Equivalent fuel efficiency to internal combustion is not well defined but some press reports give it at around 135 mpg.

Steam

Steam power, usually using an oil or gas heated boiler, was also in use until the 1930s but had the major disadvantage of being unable to power the car until boiler pressure was available. It has the advantage of being able to produce very low emissions as the combustion process can be carefully controlled. Its disadvantages include poor heat efficiency and extensive requirements for electric auxiliaries.

Gas turbine

In the 1950s there was a brief interest in using gas turbine (jet) engines and several makers including Rover produced prototypes. In spite of the power units being very compact, high fuel consumption, severe delay in throttle response, and lack of engine braking meant no cars reached production.

Rotary (Wankel) engines
Rotary Wankel engines were introduced into road cars by NSU with the Ro 80 and later were seen in several Mazda models. In spite of their impressive smoothness, poor reliability and fuel economy led to them largely disappearing. Mazda, however, has continued research on these engines and overcame most of the earlier problems.

Future developments

Much current research and development is centered on hybrid vehicles that use both electric power and internal combustion. Research into alternative forms of power also focus on developing fuel cells, Homogeneous Charge Compression Ignition (HCCI), stirling engines and even using the stored energy of compressed air or liquid nitrogen.

Safety

Cars have many basic safety problems - for example, they have human drivers who make mistakes, wheels that lose traction when the braking or turning forces are too high. Some vehicles have a high center of gravity and therefore an increased tendency to roll over. When driven at high speeds, collisions can have serious or even fatal consequence. Early safety research focused on increasing the reliability of brakes and reducing the flammability of fuel systems. For example, modern engine compartments are open at the bottom so that fuel vapors, which are heavier than air, vent to the open air. Brakes are hydraulic and dual circuit so that failures are slow leaks, rather than abrupt cable breaks. Systematic research on crash safety started in 1958 at Ford Motor Company. Since then, most research has focused on absorbing external crash energy with crushable panels and reducing the motion of human bodies in the passenger compartment. This is reflected in most cars produced today.

Airbags, a modern component of automobile safety

Significant reductions in death and injury have come from the addition of Safety belts and laws in many countries to require vehicle occupants to wear them. Airbags and specialised child restraint systems have improved on that. Structural changes such as side-impact protection bars in the doors and side panels of the car mitigate the effect of impacts to the side of the vehicle. Many cars now include radar or sonar detectors mounted to the rear of the car to warn the driver if he or she is about to reverse into an obstacle or a pedestrian. Some vehicle manufacturers are producing cars with devices that also measure the proximity to obstacles and other vehicles in front of the car and are using these to apply the brakes when a collision is inevitable. There have also been limited efforts to use heads up displays and thermal imaging technologies similar to those used in military aircraft to provide the driver with a better view of the road at night.
There are standard tests for safety in new automobiles, like the EuroNCAP and the US NCAP tests. There are also tests run by organizations such as IIHS and backed by the insurance industry.

**Bus**

A bus is a large road vehicle designed to carry numerous passengers in addition to the driver and sometimes a conductor. The name is a shortened version of Latin *omnibus*, which means "for everyone."

The omnibus, the first organized public transport system, may have originated in Nantes, France in 1826, when Stanislas Baudry, a retired army officer who had built public baths (run from the surplus heat from his flour mill) on the city's edge, set up a short stage line between the center of town and his baths. The service started on the Place du Commerce, outside the hat shop of M. Omnès, who displayed the motto Omnès Omnibus ("Omnès for all") on his shopfront. When Baudry discovered that passengers were just as interested in getting off at intermediate points as in patronizing his baths, he shifted the stage line's focus. His new voiture omnibus ("carriage for all") combined the functions of the hired hackney carriage with the stagecoach that travelled a predetermined route from inn to inn, carrying passengers and mail.

**Types of bus service**

Buses are an intrinsic part of everyday life, and play an important part in the social fabric of many countries. Many urban public transportation systems rely on bus services. Bus services can fit into several broad classes. Local transit buses provide public transit within a city or one or more counties, usually for trips of only a few kilometers. Intercity, interstate or interprovincial buses provide transit between cities, towns, rural areas and places usually tens or hundreds of kilometers away. They generally provide fewer bus stops than local bus routes do. Some public transit bus systems offer express bus service in addition to local bus lines. Local lines provide frequent stops along a route, sometimes two or more per kilometer, while express lines make fewer stops and more speed along that route. For example, an express bus line may provide speedier service between a local airport and the downtown area of a nearby city. Shuttle bus service provides transit service between two destinations, such as an airport and city center. Tour bus service shows tourists notable sights by bus. School bus service provides transit to and from school for
students. Charter bus operators, provide buses with properly licensed bus drivers for hire.

**Types of bus**

Different kinds of hardware are made for short and long distances, and special types for special purposes.

- **Commuter Bus** (a.k.a. Local transit bus or City bus) usually have two axles (duals on the drive axle), and two doors (one front, one mid-rear), allowing efficient internal traffic flow. Their seats are usually fixed and limited, leaving room for standing passengers. Having no need for a luggage compartment, many have low floor design, further easing entry and exit. Double-decker buses, guided buses, articulated buses or extra-long triple-axed buses are often used on urban routes with heavy passenger loads. An articulated bus is sometimes called a *bendibus*.

- **Trolleybuses** are similar in appearance and function to commuter buses, but powered by an electric motor supplied by overhead power cables rather than by an onboard internal combustion engine. They are not to be confused with buses that are decorated to look like turn-of-the-20th-century streetcars and which sometimes go by the name of "trolleys".

- **Motorcoaches**, also known as intercity coaches, are heavier, with usually three axles, one passenger door and no standing room. Seats are usually soft and able to recline. The floor is high, allowing large under-floor luggage compartments. There is usually a small carry-on luggage rack within the passenger cabin, as well. Besides their use for intercity transportation, motorcoaches are used for long-distance airport shuttle service, local touring and charters for large groups, and so on. They have seats for 47 to 62 passengers.

- **Tour coaches**, especially cross-country touring coaches, are often equipped with a lavatory, video system, PA system, and other amenities appropriate for hours of comfortable travel.

- **Short-distance tour buses** are simpler, having a PA system and sometimes a video system. Some retired double-deckers and specialty vehicles are used in the local tour bus business.

- **Minibuses** are one size up from large passenger vans, and seat up to 25 passengers. Some may include a small space for luggage. Usually derived from heavy-duty small truck platforms such as cutaway van chassis, minibuses are often used for short-distance shuttles, city tours, and local charters. Many are wheelchair-lift equipped and used in paratransit capacities.

- **Midibuses**, or mid-sized buses, are larger than minibuses, but smaller than motorcoaches, thus seating between 26 and 47. They can be front- or rear-engined, and have a variety of designs depending on specific needs. For example, they may be used to transport airport passengers between the terminal and distant parking lots; such vehicles may sacrifice seats for interior luggage space.

- **Parking lot trams** are a specialized form of bus, found in the parking lots of amusement parks such as Disneyland and Walt Disney World. Those vehicles consist of an engine-car or motor-car (which may or may not be passenger-carrying) chained up to a passenger-carrying trailer or number of trailers, thus making a kind of road train.
A motorcycle or motorbike is a single-track, two-wheeled motor vehicle powered by an engine. Styles of motorcycles vary depending on the task for which they are designed, such as long distance travel, navigating congested urban traffic, cruising, sport and racing, or off-road conditions. In many parts of the world, motorcycles are among the least expensive and most widespread forms of motorised transport. The inspiration for arguably the first motorcycle was designed and built by the German inventors Gottlieb Daimler and Wilhelm Maybach in Bad Cannstatt (since 1905 a city district of Stuttgart) in 1885. The first petroleum-powered vehicle, it was essentially a motorized bicycle, although the inventors called their invention the Reitwagen ("riding car").

Construction

The construction of modern motorcycles has mostly standardized on the following key components.

-Chassis: The chassis (or frame) of a motorcycle is typically made from welded aluminium or steel (or alloy) struts, with the rear suspension being an integral component in the design. Carbon fiber and titanium are used in a few very expensive custom frames.

-Front fork: A motorcycle fork is the portion of a motorcycle that holds the front wheel and allows one to steer. For handling, the front fork is the most critical part of a motorcycle. The combination of rake and trail determines how stable the motorcycle is.

-Engine: Almost all commercially available motorcycles are driven by conventional gasoline internal combustion engines, but some small scooter-type models use an electric motor, and a very small number of diesel models exist. The displacement is defined as the total volume of air/fuel mixture an engine can draw in during one complete engine cycle. In a piston engine, this is the volume that is swept as the pistons are moved from top dead centre to bottom dead centre. To the layperson this is the "size" of the engine. Motorcycle engines range from less than 50 cc (cubic centimetres), commonly found in many small scooters, to 5735cc, a Chevrolet V8 engine, currently used by Boss Hoss in its cruiser style motorcycle.

-Transmission: Modern motorcycles normally have five or six forward gears. Only the largest touring motorcycles and a few models that are routinely used with a sidecar or converted to tricycle configuration are fitted with a reverse gear. The most
commonly used transmission is a sequential gearbox. Scooters normally have a continuously variable transmission (CVT). Power transfer from the gearbox to the rear wheel is typically accomplished with a chain, which requires both lubrication and adjustment for elongation (stretch) that occurs through wear. A toothed belt is frequently used.

-Wheels: The wheel rims are usually steel or aluminium (generally with steel spokes and an aluminium hub) or mag-type cast or machined aluminium. At one time, motorcycles all used spoke wheels built up from separate components (see wheelbuilding), but, except for dirtbikes, one-piece wheels are more common now. Performance racing motorcycles often use carbon-fibre wheels, but the expense of these wheels is prohibitively high for general usage. Wire wheels, a.k.a. "laced wheels," have a central hub connected to the rim of the wheel via spokes made of wire. These spokes are generally quite solid and will not easily bend, as would typical wire cord. Nevertheless, they mechanically function as wires under tension, holding the rim true and providing strength to the wheel.

-Tyres (also, Tires): Motorcycles mainly use pneumatic tyres. However, in some cases where punctures are common (some enduros), the tyres are filled with a "mousse" which is unpunctureable. Both types of tyre come in many configurations. The most important characteristic of any tyre is the contact patch, the small area that is in contact with the road surface while riding. There are tyres designed for dirtbikes, touring, sport and cruiser bikes.

-Brakes: There are generally two independent brakes on a motorcycle, one set on the front wheel and one on the rear. However, some models have "linked brakes" whereby both can be applied at the same time using only one control.

Truck

A truck is a large vehicle usually used for transporting bulk goods or other materials. The word "truck" comes from the Greek "trochos", meaning "wheel". In America, the big wheels of wagons were called trucks. When the gasoline engine-driven trucks came into fashion, these were called "motor trucks" and the Heavy Goods Vehicle (HGV)). Lorry is a British term but is only used for the medium and heavy types (see below), i.e. a van, a pickup or a SUV would never be regarded as a "lorry".

In 1895 Karl Benz designed and built the first truck in history using the internal combustion engine. Later that year some of Benz's trucks were modified to become the first buses by the
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Netphener, the first bus company in history. Three years later, in 1898, another internal combustion engine truck was built by Gottlieb Daimler. Other companies, such as Peugeot and Renault, also built their own versions. Trucks of the era mostly used two-cylinder engines and had a carrying capacity of 1500 to 2000 kg. In 1904, 700 heavy trucks were built in the United States, 1000 in 1907, 6000 in 1910, and 25000 in 1914. After World War I, several advances were made: pneumatic tires replaced the previously common full rubber versions. Electric starters, power brakes, 4, 6, and 8 cylinder engines, closed cabs, and electric lighting followed. The first modern semi-trailer trucks also appeared. Touring car builders such as Ford and Renault entered the heavy truck market. Although it had been invented in 1890, the diesel engine was not common in trucks in Europe until the 1920s. In the United States, it took much longer for diesel engines to be accepted: gasoline engines were still in use on heavy trucks in the 1970s, while in Europe they had been completely replaced 20 years earlier. They are the most commonly used trucks all over the world.

Types of trucks by size

-Light trucks are car-sized (in the US, no more than 6,300 kg (13,000 lb)) and are used by individuals and businesses alike. In the UK they may not weigh more than 3,500kg. Pickup trucks are pervasive in North America and some regions of Latin America, Asia and Africa, but not so in Europe, where this size of commercial vehicle is most often made as vans.

-Medium trucks are larger than light but smaller than heavy trucks. In the US, they are defined as weighing between 6,300 kg (13,000 lb) and 15,000 kg (33,000 lb). For the UK the cut-off is 7.5 tonnes. Local delivery and public service (dump trucks, garbage trucks and fire-fighting trucks) are normally around this size.

-Heavy trucks are the largest trucks allowed on the road. They are mostly used for long-haul purposes, often in semi-trailer or B-double configuration. Road damage and wear increase very rapidly with the axle weight (truck weight divided by the number of axles). In many countries with good roads a 6-axle truck may have a maximum weight over 50 tonnes (50,000 kg). In Australia many trailers are linked to make what are called road trains. These will help in carrying many products at once. They are mostly driven in the outback, due to little congestion of cars, and because of the large turns they make. See also road transport in Australia.

-Off-road trucks: Highway-legal trucks are sometimes outfitted with off-road features such as a front driving axle and special tires for applications such as logging and construction. Trucks that never use public roads, such as the biggest truck ever, the Liebherr T 282B off-road mining truck, are not constrained by weight limits.

Construction

Almost all trucks share a common construction: they are made of a chassis, a cab, axles, suspension and wheels, an engine and a drivetrain. Pneumatic, hydraulic, water, and electrical systems may also be identified. They are complex machines.

-Chassis: The chassis or frame of a truck is commonly constructed mainly of two beams, and several crossmembers. A truck chassis consists of two parallel straight C-shaped beams, or in some cases stepped or tapered beams, these held together
by crossmembers. In most instances, gussets help attach the crossmembers to the beams. The "C-shape" of the beams has a middle vertical and longer side, and a short horizontal flange at each end; the length of the beams is variable. The chassis is usually made of steel, but can be made (whole or in part) of aluminium for a lighter weight. The integrity of the chemical composition (carbon, molybdenum, etc.) and structure of the beams is of uttermost importance to its strength, and to help prevent cracking or breaking of beams, and to help maintain rigidity and flexibility of the frame, welding, drilling and other types of modifications should not be performed by unlicensed persons. The chassis is the main structure of the truck, and the other parts attach to it. A tow bar may be found attached at one or both ends.

-Cab: The cab is an enclosed space where the driver is seated. A "sleeper" is a compartment attached to the cab where the driver can rest while not driving. They can range from a simple 2 to 4 foot (0.6 to 1.2 m) bunk to a 12-foot (3.7 m) apartment-on-wheels. Modern cabs usually feature air conditioning, a good sound system, and ergonomic seats (often air-suspended). There are a few possible cab configurations:

- Cab over engine (COE) or flat nose, where the driver is seated on top of the front axle and the engine. This design is almost ubiquitous in Europe, where overall truck lengths are strictly regulated. They were common in the United States, but lost prominence when permitted length was extended in the early 1980s. To access the engine, the whole cab tilts forward, earning this design the name of tilt-cab.

- Conventional cabs are the most common in North America. The driver is seated behind the engine, as in most passenger cars or pickup trucks. Conventional are further divided into large car and aerodynamic designs. A "large car" or "long nose" is a conventional truck with a long (6 to 8 foot (1.8 to 2.4 m) or more) hood. With their very square shapes, these trucks offer a lot of wind resistance and can consume more fuel. They also offer poorer visibility than their aerodynamic or COE counterparts. By contrast, Aerodynamic cabs are very streamlined, with a sloped hood and other features to lower drag. Most owner-operators prefer the square-hooded conventional.

- Cab beside engine designs also exist, but are rather rare.

-Engine: Trucks can use all sorts of engines. Small trucks such as SUVs or pickups, and even light medium-duty trucks in North America will use gasoline engines. Heavier trucks use four stroke turbo intercooler diesel engines, although there are alternatives. Huge off-highway trucks use locomotive-type engines such as a V12 Detroit Diesel two stroke engine. In the United States, highway trucks almost always use an engine built by a third party, such as CAT, Cummins, or Detroit Diesel. The only exceptions to this are Volvo Trucks and Mack Trucks, which are available with Volvo and Mack diesel engines, respectively, and Freightliner, a subsidiary of DaimlerChrysler, which are available with Mercedes-Benz and Detroit Diesel engines. Trucks and busses built by the Navistar International can also contain International engines. The Swedish truckmaker Scania claims they stay away from the US-market because of this third party tradition. Scania wants to sell a highly integrated product with proven interoperability and quality.
- **Trailer:** The cargo trailer is, by means of a nipple, called the king pin, hooked to a horseshoe-shaped quick-release coupling device called a fifth wheel at the rear of the towing engine that allows easy hook up and release. The truck trailer cannot move by itself because it only has wheels at the rear end, hence the name semi-trailer: it only carries half its own weight. The vehicle has a tendency to fold at the pivot point between the semi and the trailer when braking hard at high speeds. Such a truck accident is called a jack-knife, or jackknifing.

- **Drivetrain:** Small trucks use the same type of transmissions as almost all cars which have either an automatic transmission or a manual transmission with synchronisers. Bigger trucks often use manual transmissions without synchronisers which are lighter weight although some synchronised transmissions have been used in larger trucks. Transmissions without synchronisers require either double clutching for each shift, (which can lead to repetitive motion injuries,) or a technique known colloquially as "floating," a method of shifting which doesn't use the clutch, except for starts and stops. Although widely used, due to the tiring nature of double clutching, floating is technically illegal and can not be used on trucks which do not have a tachometer. Common North American setups include 10, 13 and 18 speeds. Automatic and semi-automatic transmissions for heavy trucks are becoming more and more common, due to advances both in transmission and engine power. In Europe 8, 10 and 12 gears are common on larger trucks with manual transmission, while automatic or semiautomatic transmission would have anything from 5 to 12 gears. The trend in Europe is that more new trucks are being bought with automatic or semi-automatic transmission. This may be due in part to lawsuits from drivers claiming that driving a manual transmission is damaging to their knees. And the fact that you can lower fuel consumption and improve the durability of the truck.

### 4. Rail transport

Rail transport is the transport of passengers and goods by means of wheeled vehicles specially designed to run along railways (sometimes known as railroads). A typical railway/railroad track consists of two parallel steel (or in older networks, iron) rails, generally anchored perpendicular to beams, termed sleepers or ties, of timber, concrete, or steel to maintain a consistent distance apart, or gauge. The rails and perpendicular beams are usually then placed on a foundation made of concrete or compressed earth and gravel in a bed of ballast to prevent the track from buckling (bending out of its original configuration) as the ground settles over time beneath and
under the weight of the vehicles passing above. The vehicles travelling on the rails are arranged in a train; a series of individual powered or unpowered vehicles linked together, displaying markers. These vehicles (referred to, in general, as cars, carriages or wagons) move with much less friction than do vehicles riding on rubber tires on a paved road, and the locomotive that pulls the train tends to use energy far more efficiently as a result. Rail transport is an energy-efficient and capital-intensive means of mechanized land transport. Rails provide very smooth and hard surfaces on which the wheels of the train may roll with a minimum of friction. As an example, a typical wagon can hold up to 125 tons of freight on two four-wheel bogies/trucks. Fully loaded, the contact between each wheel and the rail is the area of about one U.S. ten-cent piece. This can save energy compared with other forms of transportation, such as road transport, which depends on rubber tires on pavement. Trains also have a small frontal area in relation to the load they are carrying, which cuts down on air resistance and thus energy usage. In all, under the right circumstances, a train needs 50-70% less energy to transport a given tonnage of freight (or given number of passengers), than does road transport. Furthermore, the rails and sleepers/ties distribute the weight of the train evenly, allowing significantly greater loads per axle / wheel than in road transport, leading to less wear and tear on the permanent way.

Rail transport makes highly efficient use of space: a double-track rail line can carry more passengers or freight in a given amount of time than a four-lane road. As a result, rail transport is a major form of public transport in many countries. In Asia, for example, many millions use trains as regular transport in India, China, South Korea and Japan. It is also widespread in European countries.

History

The Diolkos was a 6-km long railway that transported boats across the Corinth isthmus in Greece in the 6th century BC. Trucks pushed by slaves ran in grooves in a limestone track. The Diolkos ran for over 1300 years, until 900 AD. The first horse-drawn wagonways appeared in Greece, Malta, and parts of the Roman Empire at least 2000 years ago, using cut-stone track. They began reappearing in Europe from around 1550, usually operating with wooden track. The first railways in Great Britain (also known as wagonways) were built in the early 17th century, mainly for transporting coal from the mine to the waterside where it could be loaded on to a boat. Early examples of this can be found in Broseley in Shropshire. These had wooden rails and flanged wheels, as on a modern railway. However, the rails were liable to wear out and have to be replaced. In 1768, the Coalbrookdale Company laid cast iron plates on such wooden rails to provide a more durable bearing surface.

In the late 18th century iron rails began to appear: British civil engineer William Jessop designed edge rails (which have the flange on the rail, used with plain wheels) for use on a scheme from Loughborough, Leicestershire in 1789 and in 1790 was one of the partners who established an iron-works at Butterley, Derbyshire to produce rails (and other goods). In 1802, Jessop opened the Surrey Iron Railway in south London, arguably the world’s first public railway (albeit horse-drawn).
In 1811, John Blenkinsop designed the first successful and practical railway locomotive. He patented (No 3431), a system of moving coals by a rack railway worked by a steam locomotive, and a line was built connecting the Middleton Colliery to Leeds. The locomotive was built by Matthew Murray of Fenton, Murray and Wood. The Middleton Railway was the first railway to successfully use steam locomotives on a commercial basis. It was also the first railway in Great Britain to be built under the terms laid out in an Act of Parliament. Blenkinsop’s engine had double-acting cylinders and, unlike the Trevithick pattern, no flywheel. The cylinders drove a geared wheel, which engaged under the engine with the rack. George Stephenson quickly superseded this design following the discovery of railway traction properties during construction of the Stockton and Darlington Railway.

A railway can be broken down into two major components. Basically these are the items which "move", the rolling stock, that is the locomotives, passenger carrying vehicles (coaches), freight carrying vehicles (goods wagons/freight cars) and those which are "fixed", usually referred to as its infrastructure. This category includes the permanent way (tracks) and buildings (stations, freight facilities, viaducts and tunnels).

**Locomotive**

A **locomotive** is a railway vehicle that provides the motive power for a train. The word originates from the Latin *loco* - "from a place", ablative of "locus", "place" + Medieval Latin *motivus*, "causing motion". A locomotive has no payload capacity of its own, and its sole purpose is to move the train along the tracks. In contrast, some trains have self-propelled payload-carrying vehicles. These are not normally considered locomotives, and may be referred to as multiple units or railcars. The use of these self-propelled vehicles is increasingly common for passenger trains, but very rare for freight. Vehicles, which provide motive power to haul an unpowered train, but are not generally considered locomotives because they have payload space or are rarely detached from their trains, are known as power cars. Traditionally, locomotives pull trains from the front. Increasingly common in local passenger service is push-pull operation, where a locomotive pulls the train in one direction and pushes it in the other, and is optionally controlled from a control cab at the opposite end of the train.

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

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

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

- Diesel locomotives

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

Starting in the 1940s, the diesel-powered locomotive began to displace steam power on North American railroads. Following the end of World War Two, diesel power began to appear on railroads in many countries. By the 1960s, few major railroads continued to operate steam locomotive. As is the case with any vehicle powered by an internal combustion engine, diesel locomotives require some type of power transmission system to couple the output of the prime mover to the driving wheels. In the early days of diesel railroad propulsion development, electric, hydrostatic and mechanical power transmission systems were all employed with varying degrees of success. Of the three, electric transmission proved to be most practical, and virtually all modern Diesel-powered locomotives are diesel-electric.

Diesel units are not as polluting as steam power— modern units produce low levels of exhaust emissions. Diesel locomotives can also be fitted with dynamic brakes that use the traction motors as generators during braking to assist in controlling the speed of a train on a descending grade.
**- Gas turbine-electric locomotives**

A gas turbine-electric locomotive, or GTEL, is a locomotive that uses a gas turbine to drive an electrical generator or alternator. The electric current thus produced is used to power traction motors. This type of locomotive was first experimented with in 1920 but reached its peak in the 1950s to 1960s. The turbine (similar to a turboshaft engine) drives an output shaft, which drives the alternator via a system of gears. Aside from the unusual prime mover, a GTEL is very similar to a diesel-electric. In fact, the turbines built by GE used many of the same parts as their diesels. A turbine offers some advantages over a piston engine. The number of moving parts is much smaller, and the power to weight ratio is much higher. A turbine of a given power output is also physically smaller than an equally powerful piston engine, allowing a locomotive to be very powerful without being inordinately large. However, a turbine’s power output and efficiency both drop dramatically with rotational speed, unlike a piston engine, which has a comparatively flat power curve.

Gas turbine locomotives are very powerful, but also tend to be very loud. Union Pacific operated the largest fleet of such locomotives of any railroad in the world, and was the only railroad to use them for hauling freight. Most other GTELs have been built for small passenger trains, and only a few have seen any real success in that role. After the 1973 oil crisis and the subsequent rise in fuel costs, gas turbine locomotives became uneconomic to operate, and many were taken out of service. This type of locomotive is now rare.

**- Electric locomotives**

An **electric locomotive** is a locomotive powered by electricity from an external source. Sources include overhead lines, third rail or an on-board storage device such
as a battery or a flywheel energy storage system. The initial advantage sought from electrification was its lack of pollution. Electric locomotives are also potentially extremely quiet, since there is no exhaust noise and little mechanical noise, although with high powered types the cooling fans are typically quite loud. The lack of reciprocating parts means that they are very easy on the track, reducing some maintenance-of-way costs. They are potentially very reliable, as there is a minimum of moving parts. New passenger services world-wide have tended to favor electric locomotives, because diesels are incapable of the higher speeds required; and electric traction remains the only choice for subway use. The chief disadvantage of electrification is the high infrastructure cost. Moreover, diesels and even steam engines can operate under the wires, but electric locomotives cannot leave their territories on their own.

- Electric locomotive types

With the exception of some battery-powered mining locomotives, an electric locomotive is supplied with power from a stationary source, such as a third rail or overhead wire. This is in marked contrast to a Diesel-electric locomotive, which combines an onboard Diesel engine with an electrical power transmission system.

The distinguishing design features of electric locomotives are:

- The type of electrical power used, either alternating current or direct current.
- The method for collecting electrical power.
- The means used to mechanically couple the traction motors to the driving wheels (drivers).

- Power transmission

A modern pantograph. The device shown is technically a half-pantograph.

Electrical circuits require two connections (or for three phase AC, three connections). From the very beginning the trackwork itself was used for one side of the circuit. Unlike model railroads, however, the trackwork normally supplies only one side; the other side(s) of the circuit is provided separately.

However, railways generally tend to prefer overhead lines, often called "catenaries" after the support system used to hold the wire parallel to the ground. Three collection methods are possible:

- Trolley pole: a long flexible pole, which engages the line with a wheel or shoe.
- Bow collector: a frame that holds a long collecting rod against the wire.
- Pantograph: a hinged frame that holds the collecting shoes against the wire in a fixed geometry.

Of the three, the pantograph method is best suited for high-speed operation. Some locomotives are equipped to use both overhead and third rail collection.

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

- Magnetic levitation

Transrapid maglev train on the test track at Emsland, Germany.

The newest technology in trains is magnetic levitation (maglev). These electrically powered trains have an open motor, which floats the train above the rail without wheels. This greatly reduces friction. Very few systems are in service and the cost is very high. The experimental Japanese magnetic levitation train JR-Maglev MLX01 has reached 581 km/h.

- Classification by use

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

A railroad car or railway carriage is a vehicle on a railroad (or railway) that is not a locomotive — one that provides another purpose than purely haulage, although some types of car are powered. Cars can be coupled together into a train, either hauled by one or more locomotives or self-propelled. The cars can generally be divided into two types: passenger cars, or coaches, and freight cars or wagons.

Passenger cars

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

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

- If the aisle is located between seats, seat rows may face the same direction, or be grouped, with twin rows facing each other. Sometimes, for example on a commuter train, seats may face the aisle.
- If the aisle is at the side, the car is usually divided in small compartments. These usually contain 6 seats, although sometimes in second class they contain 8, and sometimes in first class they contain 4.

Cars usually have either air-conditioning or windows that can be opened (sometimes, for safety, not so far that one can hang out), or sometimes both. Toilet facilities are also usual, though the setup varies. Other types of passenger car exist, especially for long journeys, such as the dining car and parlor car. Observation cars were built for the rear of many famous trains to allow the passengers to view the scenery. These proved popular, leading to the development of dome cars multiple units of which could be placed mid-train, and featured a glass-enclosed upper level extending above the normal roof to provide passengers with a better view. Sleeping cars outfitted with (generally) small bedrooms allow passengers to sleep through their nighttime trips, while couchette cars provide more basic sleeping accommodation. Long-distance trains often require baggage cars for the passengers' luggage. In European practice it is common for day coaches to be formed of compartments seating 6 or 8 passengers, with access from a side corridor. In the UK, Corridor coaches fell into disfavor in the 1960s and 1970s partially because open coaches are considered more secure by women traveling alone. A "trainset" (or "set") is a semi-permanently arranged formation of cars, rather than one created 'ad hoc' out of whatever cars are available. These are only broken up and reshuffled 'on shed' (in
the maintenance depot). Trains are then built of one or more of these 'sets' coupled together as needed for the capacity of that train. Many multiple unit trains consist of cars which are semi-permanently coupled into sets; these sets may be joined together to form larger trains, but generally passengers can only move around between cars within a set. This "closed" nature allows the separate sets to be easily split to go separate ways. Some multiple-unit trainsets are designed so that corridor connections can be easily opened between coupled sets; this generally requires driving cabs either set off to the side or above the passenger compartment. These cabs or driving trailers are also useful for quickly reversing the train.

Freight cars

Freight cars or (UK: "wagons" or "trucks") exist in a wide variety of types, adapted to the ideal carriage of a whole host of different things. Common types of freight cars include:

- Gondola (rail)

In railroad terminology, a **gondola** is an open-top type of rolling stock that is used for carrying loose bulk materials. Because of its low sidewalls, gondolas are used to carry either very dense material, such as steel plates or coils, or bulky items such as prefabricated pieces of rail track.

- Coil car (rail)

**Coil cars** (also referred to as "steel coil cars" or "coil steel cars") are a specialized type of rolling stock designed for the transport of coils of sheet metal, particularly steel. They are considered a subtype of the gondola car, though they bear little resemblance to a typical gondola.
- **Autorack**

An autorack, also known as an auto carrier, is a specialized piece of railroad rolling stock used to transport unladen automobiles (unladen in this context refers to automobiles without passengers).

- **Boxcar**

A boxcar (the American term; the British call this kind of car a "goods van") is a railroad car that is enclosed and generally used to carry general freight. The boxcar, while not the simplest freight car design, is probably the most versatile, since it can carry most loads. Boxcars have side doors of varying size and operation, and some include end doors and adjustable bulkheads to load very large items.

- **Refrigerator car**

A refrigerator car (or "reefer") is a refrigerated boxcar, a piece of railroad rolling stock designed to carry perishable freight at specific temperatures. Refrigerator cars differ from simple insulated boxcars and ventilated boxcars (commonly used for
transporting fruit), neither of which is fitted with cooling apparatus. Reefers can be ice-cooled, come equipped with any one of a variety of mechanical refrigeration systems, or utilize carbon dioxide (either as dry ice, or in liquid form) as a cooling agent. Milk cars (and other types of "express" reefers) may or may not include a cooling system, but are equipped with high-speed wheelsets and other modifications that allow them to travel with passenger trains. Reefer applications can be divided into four broad groups: 1) dairy and poultry producers require refrigeration and special interior racks; 2) fruit and vegetable reefers tend to see seasonal use, and are generally used for long-distance shipping (for some shipments, only ventilation is necessary to remove the heat in transit created by the ripening process); 3) manufactured foods (such as canned goods and candy) as well as beer and wine do not require refrigeration, but do need the protection of an insulated car; and 4) meat reefers come equipped with specialized beef rails for handling sides of meat, and brine-tank refrigeration to provide lower temperatures (most of these units are either owned or leased by meat packing firms).

- Flatcar

A **flatcar** (also **flat car**) is a piece of railroad rolling stock that consists of an open, flat deck on four or six wheels or a pair of trucks (US) or bogies (UK). The deck of the car can be wood or steel, and the sides of the deck can include pockets for stakes or tie-down points to secure loads. Flatcars designed for carrying machinery have sliding chain assemblies recessed in the deck. Flatcars are used for loads that are too large or cumbersome to load in enclosed cars such as boxcars. They are also often used to transport containers or trailers in intermodal shipping.

- Hopper car

A **hopper car** is a type of railroad freight car used to transport loose bulk commodities such as coal, ore, grain, track ballast, and the like. This type of car is distinguished from a gondola car in that it has opening doors on the underside or the
sides to discharge its cargo. The development of the hopper car went along with the development of automated handling of such commodities, with automated loading and unloading facilities. There are two main types of hopper car: open and covered. Covered hopper cars are used for cargos that must be protected from the elements (chiefly rain) such as grain, sugar, and fertilizer. Open cars are used for commodities such as coal, which can get wet and dry out with no harmful effect. Hopper cars have been used by railways worldwide whenever automated cargo handling has been desired.

- Tank car

A tank car is a piece of railroad rolling stock designed to carry liquefied loads, petroleum products, liquid chemicals and gasses. Many variants exist due to the wide variety of liquids and gasses that can be transported. Tank cars can be insulated or non-insulated, pressurized or non-pressurized, and designed for single or multiple loads. Non-pressurized cars have plumbing at the bottom for unloading, and may have an access port and a dome, housing various valving on the top. Pressurized cars have a pressure plate, with all valving, and a protective cylindrical housing (dome) at the top. Loading and unloading are done through this opening.

- Container well cars

These specialized gondolas are designed to carry shipping containers. A depressed center section provides a floor, which is only inches above the rails. This stabilizes the container by lowering the center of gravity, also allowing double-stacking, which would be impossible if the containers were placed on a flatcar. Single-unit well cars
exist, but 3- and 5-car articulated sets are common. These reduce weight by reducing the number of trucks by nearly half, and also reduce the amount of slack in the train since there are fewer couplers. This protects the cargo by reducing the jolts that occur at starting and stopping caused by slack.

5. Air transport

Air transport refers to the activities surrounding mechanical flight and the aircraft industry. Aircraft includes fixed-wing and rotary-wing types, as well as lighter-than-air craft such as balloons and airships. The modern age of aviation began with the first untethered human lighter-than-air flight on November 21, 1783, in a hot air balloon designed by the Montgolfier brothers, and balloon flight became increasingly common over longer and longer distances throughout the 19th century, continuing to the present. The most significant advancement in aviation technology came with the construction of the first aeroplane on December 17, 1903 by the Wright brothers. Since this time, aviation has been technologically revolutionised with the introduction of the jet and has become a major form of transport throughout the world.

Aircraft began to transport people and cargo as designs grew larger and more reliable. In contrast to small non-rigid blimps, giant rigid airships became the first aircraft to transport passengers and cargo over great distances. The best known aircraft of this type were manufactured by the German Zeppelin company.

Great progress was made in airplane design during the 1920s and 1930s. One of the most successful designs of this period was the Douglas DC-3 which became the first airliner that was profitable carrying passengers exclusively, starting the modern era of passenger airline service. By the beginning of World War II, many towns and cities had built airports, and there were numerous qualified pilots available. The war brought many innovations to aviation, including the first jet aircraft and the first liquid-fueled rockets.

Categories and classification

Aircraft fall into two broad categories:

- Heavier than air aircraft include autogyros, gyrodynes, helicopters, powered lifts, and conventional fixed-wing aircraft (aeroplanes). Fixed-wing aircraft generally use an internal-combustion engine in the form of a piston engine (with a propeller) or a turbine engine (jet or turboprop), to provide thrust that moves the craft forward through the air. The movement of air over the wings produces lift that causes the aircraft to fly. Exceptions include gliders, which have no engines and gain their thrust, initially, from winches or tugs and then from gravity and thermal currents. For a glider to maintain its forward speed it must descend in relation to the air (but not necessarily in relation to the ground). Helicopters and autogyros use a spinning rotor (a rotary wing) to provide lift; helicopters also use the rotor to provide thrust. Gyrodynes are aircraft intermediate between helicopters and autogyros, whose rotor is sometimes powered (often by a jet at its tips) but which do not have a tail rotor.
Helicopters are combination aircraft with both a rotor and wings; they can take off and land vertically, and hover, like a helicopter, but use their wings for high-speed flight. The abbreviation "VTOL" is applied to aircraft that can take off and land vertically. "STOL" stands for Short Take Off and Landing.

- Lighter than air aerostats: balloons and airships. Aerostats use buoyancy to float in the air in much the same manner as ships float on the water. In particular, these aircraft use a relatively low-density gas such as helium, hydrogen or heated air, to displace the air around the craft. The distinction between a balloon and an airship is that an airship has some means of controlling both its forward motion and steering itself, while balloons are carried along with the wind.

Types of aircraft

There are several ways to classify aircraft. Below, we describe classifications by design, propulsion and usage.

- By design

In heavier-than-air aircraft, there are two ways to produce lift: aerodynamic lift and engine lift. In the case of aerodynamic lift, the aircraft is kept in the air by wings or
rotors. With engine lift, the aircraft defeats gravity by use of vertical thrust. Examples of engine lift aircraft are rockets, and VTOL aircraft such as the Hawker Siddeley Harrier. Among aerodynamically lifted aircraft, most fall in the category of fixed-wing aircraft where horizontal airfoils produce lift by deflecting air downward to create an equal and opposite upward force according to Newton's third law of motion. The forerunner of these types of aircraft is the kite. Kites depend upon the tension between the cord, which anchors it to the ground, and the force of the wind currents. Much aerodynamic work was done with kites until test aircraft, wind tunnels and now computer modelling programs became available. In a "conventional" configuration, the lift surfaces are placed in front of a control surface or tailplane. The other configuration is the canard where small horizontal control surfaces are placed forward of the wings, near the nose of the aircraft. Canards are becoming more common as supersonic aerodynamics grows more mature and because the forward surface contributes lift during straight-and-level flight. The number of lift surfaces varied in the pre-1950 period, as biplanes (two wings) and triplanes (three wings) were numerous in the early days of aviation. Subsequently most aircraft are monoplanes. This is principally an improvement in structures and not aerodynamics. Other possibilities include the delta wing, where lift and horizontal control surfaces are often combined, and the flying wing, where there is no separate vertical control surface (e.g., the B-2 Spirit). A variable-geometry wing (or "swing-wing") has also been employed in a few examples of combat aircraft, such as the F-111, Panavia Tornado, F-14 Tomcat and B-1 Lancer, among others. The lifting body configuration is where the body itself produce lift. So far, the only significant practical application of the lifting body is in the Space Shuttle, but many aircraft generate lift from nothing other than wings alone. A second category of aerodynamically lifted aircraft is the rotary-wing aircraft. Here, the lift is provided by rotating aerofoils or rotors. The best-known examples are the helicopter, the autogyro and the tiltrotor aircraft (such as the V-22 Osprey). Some craft have reaction-powered rotors with gas jets at the tips but most have one or more lift rotors powered from engine-driven shafts. A further category might encompass the wing-in-ground-effect types, for example the Russian ekranoplan also nicknamed the "Caspian Sea Monster" and hovercraft; most of the latter employing a skirt and achieving limited ground or water clearance to reduce friction and achieve speeds above those achieved by boats of similar weight. And finally the flapping-wing ornithopter is a category of its own. These designs may have potential, but currently have no major practical applications.

- By propulsion

Some types of aircraft, such as the balloon or glider, do not have any propulsion. Balloons drift with the wind, though normally the pilot can control the altitude either by heating the air or by releasing ballast, giving some directional control (since the wind direction changes with altitude). For gliders, takeoff takes place from a high location, or the aircraft is pulled into the air by a ground-based winch or vehicle, or towed aloft by a powered "tug" aircraft. Airships combine a balloon's buoyancy with some kind of propulsion, usually propeller driven.

Until World War II, the internal combustion piston engine was virtually the only type of propulsion used for powered aircraft. The piston engine is still used in the majority of aircraft produced, since it is efficient at the lower altitudes used by small aircraft, but the radial engine (with the cylinders arranged in a circle around the crankshaft) has largely given way to the horizontally opposed engine (with the cylinders lined up on
two sides of the crankshaft). Water cooled V-engines, as used in automobiles, were common in high-speed aircraft, until they were replaced by jet and turbine power. Piston engines typically operate using avgas or regular gasoline, though some new ones are being designed to operate on diesel or jet fuel. Piston engines normally become less efficient above 7,000-8,000 ft (2100-2400 m) above sea level because there is less oxygen available for combustion; to solve that problem, some piston engines have mechanically powered compressors (blowers) or turbine-powered turbochargers or turbonormalizers that compress the air before feeding it into the engine; these piston engines can often operate efficiently at 20,000 ft (6100 m) above sea level or higher, altitudes that require the use of supplemental oxygen or cabin pressurization.

During the forties and especially following the 1973 energy crisis, development work was done on propellers with swept tips or even scimitar-shaped blades for use in high-speed commercial and military transports.

Pressurised aircraft, however, are more likely to use the turbine engine, since it is naturally efficient at higher altitudes and can operate above 40,000 ft. Helicopters also typically use turbine engines. In addition to turbine engines like the turboprop and turbojet, other types of high-altitude, high-performance engines have included the ramjet and the pulsejet. Rocket aircraft have occasionally been experimented with. They are restricted to rather specialised niches, such as spaceflight, where no oxygen is available for combustion (rockets carry their own oxygen).

- **By use**

The major distinction in aircraft usage is between military aviation, which includes all uses of aircraft for military purposes (such as combat, patrolling, search and rescue, reconnaissance, transport, and training), and civil aviation, which includes all uses of aircraft for non-military purposes.

- **Military aircraft**
Combat aircraft like fighters or bombers represent only a minority of the category. Many civil aircraft have been produced in separate models for military use, such as the civil Douglas DC-3 airliner, which became the military C-47/C-53/R4D transport in the U.S. military and the "Dakota" in the UK and the Commonwealth. Even the small fabric-covered two-seater Piper J3 Cub had a military version, the L-4 liaison, observation and trainer aircraft. In the past, gliders and balloons have also been used as military aircraft; for example, balloons were used for observation during the American Civil War and World War I, and cargo gliders were used during World War II to land troops. Combat aircraft themselves, though used a handful of times for reconnaissance and surveillance during the Italo-Turkish War, did not come into widespread use until the Balkan War. During World War I many types of aircraft were adapted for attacking the ground or enemy vehicles/ships/guns/aircraft, and the first aircraft designed as bombers were born. In order to prevent the enemy from bombing, fighter aircraft were developed to intercept and shoot down enemy aircraft. Tankers were developed after World War II to refuel other aircraft in mid-air, thus increasing their operational range. By the time of the Vietnam War, helicopters had come into widespread military use, especially for transporting, supplying, and supporting ground troops.

Types of military aircraft

- **Fighter aircraft**'s primary function is to destroy other aircraft. (e.g. Sopwith Camel, A6M Zero, MiG-29).
- **Ground attack aircraft** are used against tactical earth-bound targets. (e.g. Junkers Stuka dive bomber, Ilyushin Il-2, and the A-10).
- **Bombers** are generally used against more strategic targets. (e.g. Zeppelin, B-29 Superfortress, Tu-22, and the B-52)

### Civilian aircraft

Within general aviation, the major distinction is between private flights (where the pilot is not paid for time or expenses) and commercial flights (where the pilot is paid by a customer or employer). Private pilots use aircraft primarily for personal travel, business travel, or recreation. Usually these private pilots own their own aircraft and
take out loans from banks or specialized lenders to purchase them. Commercial general aviation pilots use aircraft for a wide range of tasks, such as flight training, pipeline surveying, passenger and freight transport, policing, crop dusting, and medevac flights. Piston-powered propeller aircraft (single-engine or twin-engine) are especially common for both private and commercial general aviation, but even private pilots occasionally own and operate helicopters like the Bell JetRanger or turboprops like the Beechcraft King Air. Business jets are typically flown by commercial pilots, although there is a new generation of small jets arriving soon for private use.

While there were many more in the past, there are currently only five major manufacturers of civil transport aircraft:

- Airbus, based in Europe
- Boeing, based in the United States
- Bombardier, based in Canada
- Embraer, based in Brazil
- Tupolev, based in Russia

Boeing, Airbus, and Tupolev concentrate on larger airliners, while Bombardier and Embraer concentrate on commuter aircraft.

- General Aviation: Because of the huge range of activities, it is difficult to cover general aviation with a simple description — general aviation may include business flights, private aviation, flight training, ballooning, parachuting, gliding, hang gliding, aerial photography, foot-launched powered hang gliders, air ambulance, crop dusting, charter flights, traffic reporting, police air patrols, forest fire fighting, and many other types of flying.

Each country regulates aviation differently, but typically, general aviation falls under several different types of regulations depending on whether it is private or commercial and on the type of equipment involved. Many small aircraft manufacturers, including Cessna, Piper, Diamond, Mooney, and others serve the general aviation market, with a focus on private aviation and flight training. The most important recent developments for small aircraft have been the introduction of advanced avionics (including GPS) that were formerly found only in large airliners, and the introduction of composite materials to make small aircraft lighter and faster. Ultralight and homebuilt aircraft have also become increasingly popular for recreational use, since in most countries that allow private aviation, they are much less expensive and less heavily regulated than certified aircraft.

- Air Traffic Control (ATC)

Air traffic control (ATC) involves humans (typically on the ground) who communicate with aircraft to help maintain separation — that is, they ensure that aircraft are far enough apart horizontally or vertically that there is no risk of collision. Controllers may co-ordinate position reports provided by pilots, or in high traffic areas they may use RADAR to see aircraft positions.

While the exact terminology varies from country to country, there are generally three different types of ATC:
• control towers (including tower, ground control, clearance delivery, and other services), which control aircraft within a small distance (typically 10-15 km horizontal, and 1,000 m vertical) of an airport.
• terminal controllers, who control aircraft in a wider area (typically 50-80 km) around busy airports
• centre controllers, who control aircraft enroute between airports

ATC is especially important for aircraft flying under Instrument flight rules (IFR), where they may be in weather conditions that do not allow the pilots to see other aircraft. However, in very high-traffic areas, especially near major airports, aircraft flying under Visual flight rules (VFR) are also required to follow instructions from ATC. In addition to separation from other aircraft, ATC may provide weather advisories, terrain separation, navigation assistance, and other services to pilots, depending on their workload. It is important to note that ATC does not control all flights. The majority of VFR flights in North America are not required to talk to ATC at all (unless they're passing through a busy terminal area or using a major airport), and in many areas, such as northern Canada, ATC services are not available even for IFR flights at lower altitudes.

6. Water transport

A type of transport executed through big enough water-pools – oceans, seas, rivers, and lakes with the assistance of different types of ships. It is one of the cheapest types of transport nowadays.

Since prehistoric times the man creates primitive vessels as canoes, one-woods, rafts. Due to them he managed to settle really distant places as Australia, New Zealand and others. In antiquity the shipping is vastly improved - the appearance of bigger and safer vessels. It is really important factor for the trade development the exchange of knowledge and ideas. The beginning of stable sea-roads formation is set during the antiquity, there have been made new types of ships, the navigation has been improved. The biremes and triremes going with two or three rows of oarsmen and square sails have been created. The creation of new, better maps took place. During the Middle Ages sciences are in stagnation and the shipping made insignificant improvement. The ship staff is numerous and it can't carry many supplies and the ships can't orientate in the open sea. The crucial period is during the Renaissance when thanks to the navigation inventions and the shipbuilding the Great Geographic Discoveries have been made.

Ship transport is primarily used for the carriage of people and non-perishable goods, generally referred to as cargo. Although the historic importance of sea and river travel has lost much importance due to the rise of commercial aviation, it is still very effective for short trips and pleasure cruises. While slower than air transport, modern sea transport is a highly effective method of moving large quantities of non-perishable goods. More than 6 billion tons of cargos were delivered by sea in 2005. In addition to cargo carriage, one can consider scientific voyages and races as forms of ship transport. Transport by water is significantly less costly than transport by air for trans-continental shipping. Ship transport is often international by nature, but it can be accomplished by barge, boat, ship or sailboat over a sea, ocean, lake, canal or river. This is frequently undertaken for purposes of commerce, recreation or military objectives. When a cargo is carried by more than one mode, the transport is
termed intermodal. Ships have long been used for warfare, with applications from naval supremacy to piracy, invasions and bombardment. Aircraft carriers can be used as bases of a wide variety of military operations. Ship transport is used for a variety of unpackaged raw materials ranging from chemicals, petroleum products, and bulk cargo such as coal, iron ore, cereals, bauxite, and so forth. So called "general cargo" covers goods that are packaged to some extent in boxes, cases, pallets, barrels, and so forth. Since the 1960s containerization has revolutionized ship transport.

Man has used rivers since the dawn of civilization as a source of water, for food, for transport, as a defensive barrier, as a source of power to drive machinery, and as a means of disposing of waste. For thousands of years rivers have been used for navigation (The earliest evidence of navigation is found in the Indus Valley Civilization, which existed in north-western India around 3300 BC). Riverine navigation provides the cheapest means of transport and is still used extensively on major rivers of the world like the Ganges, the Nile, the Mississippi, and the Indus. Rivers have been a source of food since pre-history. Apart from being a rich source of fish, rivers indirectly aid cultivation by supplying water for the crops. Rivers sustain their own food chain. They are a major source of fresh water; hence, it is no surprise to find most of the major cities of the world situated on the banks of rivers. Rivers also provide an easy means of disposing of waste.

Ships and watercraft

Ships and other watercraft are used for water transport. Various 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** 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.
Container ships are cargo ships that carry all of their 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 20 and 40 people. They generally have a large accommodation block at the stern, directly above the engine room. Container ships now carry up to 15,000 containers on a voyage.

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 are cargo ships designed to carry wheeled cargo such as automobiles, trailers or railway carriages. RORO 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.

Ferries are a form of transport, usually a boat or ship, but also other forms, carrying 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. 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.
**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.

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** 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 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 Hovercraft, or Air-Cushion Vehicle (ACV), is an amphibious vehicle or craft, designed to travel over any sufficiently smooth surface - land or water - supported by a cushion of slowly moving, low-pressure air, ejected downwards against the surface close below it.

### 7. Cable transport

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

**Aerial tramway**

An aerial tramway is a type of aerial lift, often called a cable car or ropeway, and sometimes incorrectly referred to as a gondola. Because of the proliferation of such systems in the Alpine regions of Europe, the French and German language names of Téléphérique and Seilbahn are often also used in an English language context. "Cable car" is the normal term in British English, as in British English the word "tramway" generally refers to a railed street tramway. Aerial tramway is one or two
fixed cables (called track cables), one endless loop of cable (called a haulage rope), and two passenger cabins. The fixed cables provide support for the cabins. The haulage rope, by means of a grip, is solidly connected to the truck (the wheel set that rolls on the cables). The haulage rope is usually driven by an electric motor and being connected to the cabins, moves them up or down the mountain.

Two-car tramways use a jig-back system: A large electric motor is located at the bottom of the tramway so that it effectively pulls one cabin down, using that cabin’s weight to help pull the other cabin up. A similar system of cables is used in a funicular railway. The two passenger cabins, which carry from 4 to over 100 people, are situated at opposite ends of the loops of cable. Thus, while one is coming up, the other is going down the mountain, and they pass each other midway on the cable span. Some aerial trams have only one cabin, which lends itself better for systems with small elevation changes along the cable run. The original version was called telpherage, and was invented by Scottish engineer Fleeming Jenkin. Smaller telpherage systems are sometimes used to transport objects such as tools or mail within a building or factory. Many aerial tramways were built by Von Roll Ltd. of Switzerland, which has since been acquired by Austrian lift manufacturer Doppelmayr. The German firm of Bleichert built hundreds of freight and military tramways. Aerial tramways differ from gondola lifts in that the latter use several smaller cabins circulating on a looped cable, and can be stopped at intermediate or end stations for passenger loading and unloading when uncoupled from their haulage cable by releasing cable grips.

- Cable car (railway)

A cable car or cable railway is a mass transit system using rail cars that are propelled by a continuously moving cable running at a constant speed. Individual cars stop and start by releasing and gripping this cable as required. Cable cars are distinct from funiculars, where the cars are permanently attached to the cable. The cable is itself powered by a stationary motor or engine situated in a cable house or powerhouse. The speed at which it moves is relatively constant, although affected by the current load. The cable car begins moving when a clamping device, called a grip, is connected to the moving cable. Conversely the car is stopped by detaching it from the cable and applying the brakes. This gripping and ungripping action may be manual, as was the case in all early cable car systems, or automatic, as is the case in some recent cable operated people mover type systems. Gripping must be an even and gradual process in order to avoid bringing the car to cable speed too quickly and unacceptably jarring the passengers. In the case of manual systems, the
grip resembles a very large pair of pliers, and considerable strength and skill are required to operate the car. As many early cable car operators discovered the hard way, if the grip is not applied properly, it can damage the cable, or even worse, become entangled in the cable. In the latter case, the cable car may not be able to stop and can wreak havoc along its route until the cable house realizes what is going on and halts the cable. One claimed advantage of the cable car is its relative energy efficiency, because of the economy of centrally located power stations, and the ability for cars going down hill to transfer energy to cars going up. However this advantage is not unique to cable cars, as electric cars fitted with regenerative braking offer the same advantages, and in any case they must be offset against the cost of moving the cable. Because of the constant and relatively low speed, cable cars can be underestimated in an accident. Even with a cable car traveling at only 9 miles per hour, the mass of the cable car and the combined strength of the cables can do quite a lot of harm to pedestrians if hit.

- Cable ferry

A **cable ferry** or **chain ferry** is a means of water transportation by which a ferry or other boat is guided and in many cases propelled across a river or other larger body of water by means of cables or chains connected to both shores. Ferries of this type are also called **punts**, especially in Australian English, and in Africa they are often called **pontoons**, referring to the flat-bottomed type of vessel, but this is also used for ferries without chains and cables. There are three types of cable ferry. One is the reaction ferry, which solely uses the power of the river to tack across the current; another is the powered cable ferry, which uses an auto engine, diesel engine, or electric motors (like the Canby Ferry) to wind itself across the river. The third type, now fast disappearing, is the hand-operated type, such as the Stratford-upon-Avon Chain Ferry in the UK and the Saugatuck Chain Ferry in Michigan, USA. Early manifestations of cable ferries often used rope or steel chains, which were largely replaced by stronger and more durable wire cable by the late 19th century. Ferries are common where there is little other water-borne traffic which could get snagged in the cable or chains, where the water may be too shallow for other options, or where the river current is too strong to permit the safe crossing of a ferry service not attached to the riverbanks. Alignment of the platform at each end of the journey is automatic and, especially for vehicle ferries, safer than a free-moving ferry might be in bad conditions.
- Chairlift

A chairlift (technically, an elevated passenger ropeway), is a type of aerial lift, which consists of a continuously circulating steel cable loop strung between two end terminals and usually over intermediate towers, carrying a series of chairs. They are the primary onhill transport at most ski areas (in such cases referred to as 'skilifts'), but are also found at amusement parks, various tourist attractions, and increasingly, in urban transport. Depending on carrier size and loading efficiency, a passenger ropeway can move up 4000 people per hour, and the fastest lifts achieve operating speeds of up to 12 meters/second (27 mph, 43 km/h). The two-person double chair, which for many years was the workhorse of the ski industry, can move roughly 1200 people per hour at rope speeds of up to 2.5 m/s. The four person detachable chairlift ("high-speed quad") can transport 2400 people per hour with an average rope speed of 5 m/s. Some bi and tri cable elevated-ropeways and reversible tramways achieve much greater operating speeds. Fixed-grip lifts are usually shorter than detachable-grip lifts due to rope load; the maximum vertical rise for a fixed grip chairlift is 300-400 meters and a length of about 1200 m, while detachable quads can service a vertical rise of over 600 m and a line length of 2000 m.

A chairlift consists of numerous components to provide safe efficient transport.

- Rope: The rope is the defining characteristic of an elevated passenger ropeway. The rope stretches and contracts as the tension exerted upon it increases and decreases, and it bends and flexes as it passes over sheaves and around the bullwheels. The fibre core contains a lubricant, which protects the rope from corrosion and also allows for smooth flexing operation. The rope must be regularly lubricated to ensure safe operation and long life. Various techniques are used for constructing the rope. Dozens of wires are wound into a strand. Several strands are wound around a textile core, their twist is oriented in the same or opposite direction as the individual wires; this is referred to as Lang lay and regular lay respectively. Rope is constructed in a linear fashion, and must be spliced together before carriers are affixed. Splicing involves unwinding long sections of either end of the rope, and then winding each strand from opposing ends around the core. Sections of rope must be removed, as the strands overlap during the splicing process.
- **Terminals and towers:** Every lift involves at least two terminals and—usually—intermediate supporting towers. A bullwheel in each terminal redirects the rope, while sheaves (pulley assemblies) on the towers support the rope well above the ground. The number of towers is engineered based on the length and strength of the rope, worst-case environmental conditions, and the type of terrain traversed. The bullwheel with the prime mover is called the *drive bullwheel*; the other is the *return bullwheel*. Chairlifts are usually electrically powered, often with diesel or gasoline engine backup, and sometimes a hand crank tertiary backup. Drive terminals can be located either at the top or the bottom of an installation; though the top-drive configuration is more efficient, practicalities of electric service might dictate bottom-drive.

- **Braking systems:** The drive terminal is also the location of a lift's primary braking system. The service brake is located on the driveshaft beside the main drive, before the gearbox. The emergency brake acts directly on the bullwheel. While not technically a brake, an anti-rollback device (usually a cam) also acts on the bullwheel. This prevents the potentially disastrous situation of runaway reverse operation. Many chairlifts have a braking system in the sheaves.

- **Tensioning system:** The rope must be tensioned to compensate for sag caused by wind load and passenger weight, variations in rope length due to temperature and to maintain friction between the rope and the drive bullwheel. Tension is provided either by a counterweight system or by hydraulic rams, which adjust the position of the bullwheel carriage to maintain design tension. For most chairlifts, the tension is measured in tons.

- **Prime mover and gearbox:** Either diesel engines or electric motors can function as prime movers. The power can range from under ten horsepower for the smallest of lifts, to several hundred for a long, fast detachable eight-seat up a steep slope. AC electric motors were the most common, though direct current motors are now economically competitive. The driveshaft turns at high RPM, but with low torque. The gearbox transforms high RPM/low torque rotation into low RPM/high torque to drive the bullwheel. Higher horsepower is able to pull heavier loads, or sustain a higher rope speed.

- **Secondary mover:** In most localities, the prime mover is required to have a backup drive; this is usually provided by a diesel engine, which can operate during power outages. The purpose of the backup is to permit clearing the rope to ensure the safety of passengers; it usually has much lower horsepower and is not used for normal operation. The secondary drive connects with the drive shaft before the gearbox, usually with a chain coupling.

- **Carriers and grips:** Carriers (usually chairs, but sometimes gondolas) are designed to seat 1, 2, 3, 4, 6 or 8 passengers. Each is connected to the cable with a steel cable grip that is either clamped onto or woven into the cable. Clamping systems use either a bolt system or coiled spring to provide clamping force. For maintenance or servicing, the carriers may be removed from or relocated along the rope by loosening the grip.

- **Restraining bar:** Also called a *retention bar* or *safety bar*, these may help hold passengers in the chair in the same way as an automotive seatbelt or safety bar in an amusement park ride. If equipped, each chair has a retractable bar, sometimes
with attached footrests. In most configurations, a passenger may reach up and behind their head, grab the bar or a handle, and pull the restraint forward and down. Once the bar has rotated sufficiently, gravity assists positioning the bar to its down limit. Before disembarking, the bar must be rotated up, out of the way.

- **Control system:** To maintain safe operation, the chairlift's control system monitors sensors and controls system parameters. Expected variances are compensated for; out-of-limit and dangerous conditions cause system shutdown. In the unusual instance of system shutdown, inspection by technicians, repair or evacuation might be needed. Both fixed and detachable lifts have sensors to monitor rope speed and hold it within established limits for each defined system operating speed. Also, the minimum and maximum rope tension, and speed feedback redundancy are monitored.

- **Brittle bars:** Some installations use brittle bars to detect several hazardous situations. Brittle bars alongside the sheaves detect the rope coming out of the track. They may also be placed to detect counterweight or hydraulic ram movement beyond safe parameters (sometimes called a brittle fork in this usage) and to detect detached carriers leaving the terminal's track. If a brittle bar breaks, it interrupts a circuit, which causes the system controller to immediately stop the system.

- **Cable catcher:** These are small hooks sometimes installed next to sheaves to catch the rope and prevent it from falling if it should come out of the track. They are designed to allow passage of chair grips while the lift is stopping and for evacuation. It is extremely rare for the rope to leave the sheaves.

- **Elevator**

An elevator or lift is a transport device used to move goods or people vertically. Languages other than English may have loanwords based on either elevator (or lift). Because of wheelchair access laws, elevators are often a requirement in new buildings with multiple floors. The development of elevators was led by the need for movement of raw materials including coal and lumber from hillsides. The technology
developed by these industries and the introduction of steel beam construction worked together to provide the passenger and freight elevators in use today. Werner von Siemens built the first electric elevator in 1880. Frank Sprague significantly enhanced the safety and speed of electric elevators.

AC or DC electric motors drive geared traction machines. Geared machines use worm gears to control mechanically movement of elevator cars by "rolling" steel hoist ropes over a drive sheave, which is attached to a gearbox driven by a high-speed motor. These machines are generally the best option for basement or overhead traction use for speeds up to 1000 ft/min (5 m/s). Gearless Traction machines are low speed (low RPM), high torque electric motors powered by AC or DC. In this case, the drive sheave is directly attached to the end of the motor. A brake is mounted between the motor and drive sheave (or gearbox) to hold the elevator stationary at a floor. This brake is usually an external drum type and is actuated by spring force and held open electrically; a power failure will cause the brake to engage and prevent the elevator from falling. In each case, cables are attached to a hitch plate on top of the cab or may be "underslung" below a cab, and then looped over the drive sheave to a counterweight attached to the opposite end of the cables, which reduces the amount of power needed to move the cab. The counterweight is located in the hoist-way and rides a separate rail system; as the car goes up, the counterweight goes down, and vice versa. This action is powered by the traction machine, which is directed by the controller; typically relay logic or computerized device that directs starting, acceleration, deceleration and stopping of the elevator cab. The weight of the counterweight is typically equal to the weight of the elevator cab plus 40-50% of the capacity of the elevator. The grooves in the drive sheave are specially designed to prevent the cables from slipping. "Traction" is provided to the ropes by the grip of the grooves in the sheave, thereby the name. As the ropes age and the traction groove wear, some traction is lost and the ropes must be replaced and the sheave repaired or replaced. Some elevators have a system called compensation. This is a separate set of cables or a chain attached to the bottom of the counterweight and the bottom of the elevator cab. This makes it easier to control the elevator, as it compensates for the differing weight of cable between the hoist and the cab. If the elevator cab is at the top of the hoist-way, there is a short length of hoist cable above the car and a long length of compensating cable below the car and vice versa for the counterweight. If the compensation system uses cables, there will be an additional sheave in the pit below the elevator, to guide the cables. If the compensation system uses chains, the chain is guided by a bar mounted between the counterweight rails.

- Passenger service: A passenger lift is designed to move people between a building's floors. This apparent simplicity belies a complex and sophisticated mechanical, electrical and microelectronic system. Passenger elevators capacity is related to the available floor space. Generally passenger elevators are available in capacities from 1,000 to 6,000 lb (455 to 2,727 kg) in 500 lb (230 kg) increments. Generally passenger elevators in buildings eight floors or less are hydraulic which can reach speeds up to 200 ft/min (1.0 m/s). In buildings up to ten floors, electric & gearless elevators are likely to have speeds up to 500 ft/min (2.5 m/s), and above ten floors speeds begin at 500 ft/min (2.5 m/s) up to 2000ft/min (10 m/s). Sometimes passenger elevators are used as a city transport along with funiculars. For example, there is a 3-station underground public elevator in Yalta, Ukraine, which takes passengers from the top of a hill above the Black Sea on which hotels are perched, to a tunnel located on the beach below. Passenger elevators may be specialized for
the service they perform, including: Hospital emergency, front and rear entrances, double decker, and other uses. Cars may be ornate in their interior appearance, may have audiovisual advertising, and may be provided with specialized recorded voice instructions. An express elevator does not serve all floors. For example, it moves between the ground floor and a skylobby, or it moves from the ground floor or a skylobby to a range of floors, skipping floors in between.

- **Freight elevators:** A freight elevator (or goods lift) is an elevator designed to carry goods, rather than passengers. Freight elevators are often exempt from some code requirements. Freight elevators or service elevators (goods or service lifts) may be exempt from some of the requirements for fire service. However, new installations would likely be required to comply with these requirements. Freight elevators are generally required to display a written notice in the car that the use by passengers is prohibited, though certain freight elevators allow dual use through the use of an inconspicuous riser. Freight elevators are typically larger and capable of carrying heavier loads than a passenger elevator, generally from 2,300 to 4,500 kg. Freight elevators may have manually operated doors, and often have rugged interior finishes to prevent damage while loading and unloading. Although hydraulic freight elevators exist, electric elevators are more energy efficient for the work of freight lifting.

- **Vehicle elevators:** A car lift is installed where ramps are considered space-inconservative for smaller buildings (usually in apartment buildings where frequent access is not an issue). The car platforms are raised and lowered by chained steel gears (resembling bicycle chains in appearance). In addition to the vertical motion, the platforms can rotate about its vertical axis (up to 180 degrees) to ease driver access and/or accommodate building plans. Most parking lots of this type are however unable to accommodate taller vehicles. In spite of the sheer size of the car platform and its perceived "passenger capacity", there are huge passenger and freight lifts that can accommodate more than the rated capacity of the car lift.

- **Boat elevators:** Boats and small ships can pass between different levels of a canal with a Boatlift in some smaller canals rather than through a Canal lock.

- **Aircraft elevators:** On aircraft carriers, elevators carry aircraft between the flight deck to the hangar deck for operations or repairs. These elevators are designed for much greater capacity than any other elevator ever built, up to 200,000 pounds of aircraft and equipment. Smaller elevators lift munitions to the flight deck from magazines deep inside the ship.
A **funicular**, also known as a **funicular railway, inclined railway, inclined plane, or cliff railway**, is a type of self-contained cable railway in which a cable attached to a pair of tram-like vehicles on rails moves them up and down a very steep slope, utilizing one ascending and one descending vehicle to counterbalance each other. The name is derived from the Latin, *funiculus*, the diminutive of *funis*, "rope".

The basic principle of funicular operation is that two cars are attached to each other by a cable, which runs through a pulley at the top of the incline. Counterbalancing of the two cars, with one ascending and one descending the slope—especially when transporting similar loads, such as passengers—minimizes the tractive effort needed to lift the ascending car.

The usual engineering practice is to splice the cable ends together thereby creating a continuous cable loop. The cars are attached equidistantly at opposite points on the cable loop. The cable is driven by any means of winching at one end of the run, and held taut by a tensioning wheel at the other. Other sheave wheels are employed to guide the cable to and from the drive mechanism and the incline cars. Locomotion is created by alternately reversing the direction of the drive mechanism so that the cars switch positions on the incline, that is, one up and one down. In some cases there are parallel sets of tracks and platforms for each vehicle. The wheels of the cars are usually single flanged resembling those on standard railway vehicles.

The four-railed funicular was a standard up until the 1890s when Professor T. S. C. Lowe, builder of the Mount Lowe Railway, devised a passing-track configuration in which the inboard wheels of the cars shared a common center rail except at the passing point (center of the funicular) where the rails divided into two sets and were rejoined after the cars could clear each other. This three-railed configuration became the new world wide standard. Cars used with a three-railed configuration have flanges on both sides of the outboard wheels, which keep them aligned with the outer rail thus holding each car in position. The inboard wheels are typically unflanged and ride on top of the opposite rail thereby easily crossing over the rails at the passing track juncture.

**Funitel**
A *funitel* is a type of aerial lift, generally used to transport skiers. The name *funitel* is a conjunction between the French words *funiculaire* and *telepherique*. Funitels have not only been used, as a means to transport skiers, there is one used to transport finished cars between different areas of a factory. Recently, more and more funitels have been added to ski areas. When used to transport skiers, funitels are a fast way to get to a higher altitude. However, because skis or snowboard have to be taken off and held during the trip, and because of the (usual) absence of seats, funitels can sometimes be uncomfortable for long trips, in the same way other large gondolas can be. Funitels combine a short time between successive cabins with a high capacity (20-30 people) per cabin, making it a good choice to take when in a busy ski resort, as the lines are usually shorter. Furthermore, Funitels are able to tolerate higher wind speeds than classic gondola lifts because they are fastened to two steel cables instead of one.

A funitel consists of one or two loops of cable strung between two terminals over intermediate towers. In order to maximize the stability of the passenger cabins, the cables are arranged in two pairs moving in separate directions. Although it might appear that there are four cables, most of the time there is actually only one. The passenger cabins are connected to a pair of cables with four spring-loaded grips (two to each cable). Because the cable runs at a speed faster than that at which most people would care to board or disembark, the cabins must be slowed down while in the terminals to allow skiers to get on and off. This is accomplished by detaching the cabin from the cable and slowing it down with progressively slower rotating tires mounted on the ceiling of the terminal. Once the cabin has reached a speed at which it is safe to load or unload passengers, the cabin is moved about the end turnaround by tires mounted on the floor. The cabin is then accelerated to line speed with a second set of rotating tires.
- Gondola lift

A gondola lift is a type of aerial lift, often called a cable car, which consists of a loop of steel cable that is strung between two stations, sometimes over intermediate supporting towers. The cable is driven by a bullwheel in the terminal, which is connected to an engine or electric motor. Because of the proliferation of such systems in the Alpine regions of Europe, the French language name of Télécabine is also used in an English language context. In some systems the passenger cabins, which can hold between four and 16 people are connected to the cable by means of spring-loaded grips. These grips allow the cabin to be detached from the moving cable and slowed down in the terminals, to allow passengers to board and disembark. Doors are almost always automatic and controlled by a lever on the roof or on the undercarriage that is pushed up or down. Cabins are driven through the terminals either by rotating tires, or by a chain system. To be accelerated to and decelerated from line speed, cabins are driven along by progressively faster (or slower) rotating tires until they reach line or terminal speed. Gondola lifts can have intermediate stops that allow for uploading and downloading on the lift. In other systems the cable is slowed down intermittently to allow passengers to disembark and embark the cabins at stations, and to allow people in the cars along the route to take photographs. A system like this, or when a train of gondolas in a row stops at a station is called a pulse gondola because the lift stops to load usually three cabins at a terminal and then starts up again. It stops over and over to do this. Another type of gondola lift is the bi-cable gondola, which has one other stationary cable, besides the main haul rope, that helps support the cabins. There are also tri-cable gondolas that have two stationary cables that support the cabins. They differ from aerial tramways in that the latter consist only of one or two usually larger cabins, moving up and down, not circulating.

8. Pipeline transport

Pipeline transport is a transportation of goods through a pipe. Most commonly, liquid and gases are sent, but pneumatic tubes that transport solid capsules using compressed air have also been 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 important are those transporting oil and natural gas. Pipeline transport, pioneered by Vladimir Shukhov and the Branobel Company in the late 19th century, is the most economical way to transport large quantities of oil or natural gas over land.
Compared to railroad, it has lower cost per unit and also higher capacity. Although pipelines can be built even under the sea, that process is both economically and technically very 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 from 30 to 120 cm (about 12 to 47 inches). Where possible, they are built above the surface. However, in more developed, urban, environmentally sensitive or potentially dangerous areas they are buried underground at a typical depth of about 1 metre (about 3 feet). The oil is kept in motion by a system of pump stations built along the pipeline and usually flows at speed of about 1 to 6 m/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. This interface is removed from the pipeline at receiving facilities and segregated to prevent contamination. 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"). This is a tool that is sent down a pipeline and propelled by the pressure of the product in the pipeline itself. It is the chief device used in pigging.

There are four main uses for pigs:

1. physical separation between different liquids being transported in pipelines;
2. internal cleaning of pipelines;
3. inspection of the condition of pipeline walls (also known as an Inline Inspection (ILI) tool);
4. capturing and recording geometric information relating to pipelines (e.g. size, position).
A Pig launcher/receiver, belonging to the natural gas pipeline

A pig used in natural gas pipelines

The original pigs were made from straw wrapped in wire used for cleaning. They made a squealing noise while traveling down the pipe that sounded to some like a pig squealing; the term "pipeline inspection gauge" was later created as a backronym. One kind of pig is a soft, bullet shaped polyurethane plug that is forced through pipelines to separate products to reduce mixing. There are several types of pigs for cleaning. Some have tungsten studs or abrasive wire mesh on the outside to cut rust, scale, or paraffin deposits off the inside of the pipe; others are plain plastic covered polyurethane. Inline inspection pigs use various methods for inspecting the condition of a pipeline. A sizing pig uses one (or more) notched round metal plates that are used as gauges. The notches allow different parts of the plate to bend when a bore restriction is encountered. More complex systems exist for inspecting various aspects of the pipeline. Intelligent pigs, also called smart pigs, are used to inspect the pipeline with various sensors and record the data for later analysis. These pigs use technologies such as Magnetic flux leakage (MFL) and ultrasonics to detect the various aspects of the pipeline. Intelligent pigs may also use calipers to measure the inside geometry of the pipeline. The first intelligent pig inspection tool, run in 1964, used MFL technology to inspect the bottom portion of the pipeline. The system used a black box similar to those used on aircraft to record the information.

Natural gas is moved through a pipeline under pressure. As natural gas flows through a pipeline, it loses pressure due to friction against the inside of the pipe. To keep the natural gas moving at the desired rate, the pressure must be increased. This is accomplished with compressor stations located along a pipeline. Compressor stations increase or raise the pressure of the natural gas using gas compression machinery that is widely used throughout the oil and gas industry. The pressure of the natural gas must be increased along the pipeline through the use of compressor stations. When compressor stations increase the pressure of the natural gas, the temperature of the natural gas rises. The natural gas must be cooled to minimize impacts on the pipeline and permafrost. Two main processes take place at a typical compressor station:

- gas compression; and
- gas chilling and cooling.
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.

9. Transport infrastructure

- Road

A road is an identifiable route, way or path between two or more places. Roads are typically smoothed, paved, or otherwise prepared to allow easy travel; though they need not be, and historically many roads were simply recognizable routes without any formal construction or maintenance. In urban areas roads may pass through a city or village and be named as streets, serving a dual function as urban space easement and route. Economics and society depend heavily on efficient roads. In the European Union (EU) 44% of all goods are moved by trucks over roads and 85% of all persons are transported by cars, buses or coaches on roads.

In original usage, a "road" was simply any pathway fit for riding. The word “street,” whose origin is the Latin strata, was kept for paved pathways that had been prepared to ease travel in some way. Thus, many "Roman Roads" have the word "street" as part of their name. Roads are a prerequisite for road transport of goods on wheeled vehicles.

That the first pathways where the trails made animals have not been universally accepted, arguing that animals do not follow constant paths. Others believe that some roads originated from humans following animals trails. The Icknield Way is given as an example of this type road origination was man and animal both selected the same natural line. By about 10,000 BC, rough pathways were used by human travelers. Stone paved streets are found in the city of Ur in the Middle East dating back to 4000 BC. In 500 BC, Darius I the Great started an extensive road system for Persia, including the famous Royal Road, which was one of the finest highways of its time. From about 312 BC, the Roman Empire built straight strong stone Roman
roads throughout Europe and North Africa, in support of its military campaigns. At its peak the Roman Empire was connected by 29 major roads moving out from Rome and covering 78,000 kilometers or 52,964 Roman miles of paved roads.

Roadways are designed and built for primary use by vehicular and pedestrian traffic. Storm drainage and environmental considerations are a major concern. Erosion and sediment controls are constructed to prevent detrimental effects. Drainage lines are laid with sealed joints in the road easement with runoff coefficients and characteristics adequate for the land zoning and storm water system. Drainage systems must be capable of carrying the ultimate design flow from the upstream catchment with approval for the outfall from the appropriate authority to a watercourse, creek, river or the sea for drainage discharge.

Highway is a term commonly used is to designate major roads intended for travel by the public between important destinations, such as cities. The term highway can also be varied country-to-country, and can be referred to a road, freeway, superhighway, autoroute, autobahn, parkway, expressway, byway, or motorway.

Highway designs vary widely. They can include some characteristics of grade separations, multiple lanes of traffic, a median between lanes of opposing traffic, and access control (ramps and grade separation). Highways can also be as simple as a two-lane, shoulderless road.

- Rail road

Railways are always built to stand above surrounding terrain to prevent track flooding, erosion of the bed and decay of the sleepers/ties. In hilly and mountainous terrain, to avoid large slopes, the railway is at some places elevated, on an embankment, or bridge or viaduct, and at some places in a cutting (ditch or trench) or tunnel. The same are also used for non-level crossings. In the case of many crossings, such as in a city, a longer stretch may be elevated or underground.
Any poor quality soil such as peat or mud is excavated to firm soil and the excavation filled in with appropriate material, usually stone rubble from cuts or alluvial gravels.

Minor watercourses are led through pipes (culverts) before the grade is raised. A bed of stone chips (ballast) is laid over firm soil in order to ensure drainage around the ties and to distribute local pressure over a wider area. Unlike rounded river rock and gravel, crushed stone will interlock to form a stable base. This crushed stone is firmly tamped to prevent further settling and to lock the stones.

**- Rail tracks**

**Rail tracks** are used on railways (or railroads), which, together with railroad switches (or points), guide trains without the need for steering. Tracks consist of two parallel steel rails, which are laid upon sleepers (or cross ties) that are embedded in ballast to form the railroad track. The rail is fastened to the ties with rail spikes, lag screws or clips such as Pandrol clips. The type of fastener depends partly on the type of sleeper, with spikes being used on wooden sleepers, and clips being used more on concrete sleepers. Usually, a baseplate (or fishplate, although a fishplate is also a bar used to join rails) is used between the rail and wooden sleepers, to spread the load of the rail over a larger area of the sleeper. Sometimes spikes are driven through a hole in the baseplate to hold the rail, while at other times the baseplates are spiked or screwed to the sleeper and the rails clipped to the baseplate.

Steel rails can carry heavier loads than any other material. Railroad ties spread the load from the rails over the ground and also serve to hold the rails a fixed distance apart (called the gauge.) Rail tracks are normally laid on a bed of coarse stone chippings known as **ballast**, which combines resilience, some amount of flexibility, and good drainage. Steel rails can also be laid onto a concrete slab (a slab track). Across bridges, track is often laid on ties across longitudinal timbers or longitudinal steel girders.

Additional detail on tracks used for tram and light rail operations, as opposed to heavy rail, is available at tramway track.

A **railroad switch** is a mechanical installation enabling trains to be guided from one track to another. In the UK and Commonwealth countries, railroad switches are known as (sets of) **points**. In technical usage switches are also called **turnouts**.

In the diagram, rail track A divides into two: track B (the **straight track**) and track C (the **diverging track**). The switch consists of the pair of linked tapering rails, known as **points** (switch rails or point blades), lying between the diverging outer rails (the **stock rails**). These points can be moved laterally into one of two positions so as to determine whether a train coming from A will be led towards B or towards C. A train
moving from the A direction towards either B or C is said to be executing a facing-point movement. Unless the switch is locked, a train coming from B or C will be led to A regardless of the position of the points, as the vehicle's wheels will force the points to move. Passage through a switch in this direction is known as a trailing-point movement. A switch can be described by the direction in which the diverging track leaves the straight track. A right-hand switch has track C to the right of a straight track formed by A and B. A left-hand switch has track C is to the left. A straight track is not always present, however: both tracks may curve, one to the left and one to the right (see Wye switch, below) or both tracks may curve, with differing radii, in the same direction.

- Waterway

A waterway is any navigable body of water. These include rivers, lakes, oceans, and canals. In order for a waterway to be navigable, it must meet several criteria:

- The waterway must be deep enough to allow the draft depth of the vessels using it;
- The waterway must be wide enough to allow passage for the beam width of the vessels using it;
- The waterway must be free of barriers to navigation such as waterfalls and rapids, or have a way around them (such as canal locks);
- The current of the waterway must be mild enough to allow vessels to make headway.

Vessels using waterways vary from small animal-drawn barges to immense ocean tankers and ocean liners, such as cruise ships. At one time, canals were built mostly for small wooden barges drawn by horses or other draft animals. Today, major canals are built to allow passage of large ocean-going vessels.

Marine architecture

Marine architecture is the construction of structures, which support ship transport. These structures include ports, harbors, lighthouses, marinas and shipyards.

Harbor
A harbor or harbour is a place where ships may shelter from the weather or are stored. Harbors can be man-made or natural. A man-made harbor will have sea walls or breakwaters and may require dredging. A natural harbor is surrounded on most sides by land.

Port

A port is a facility for receiving ships and transferring cargo to and from them. They are usually situated at the edge of an ocean or sea, river, or lake. Ports often have cargo-handling equipment such as cranes (operated by stevedores) and forklifts for use in loading/unloading of ships, which may be provided by private interests or public bodies. Often, canneries or other processing facilities will be located very close by. Harbour pilots, barges and tugboats are often used to safely maneuver large ships in tight quarters as they approach and leave the docks. Ports, which handle international traffic, will have customs facilities. Harbors and ports are often confused. A port is a man-made coastal or riverine facility where boats and ships can load and unload. It may consist of quays, wharfs, jetties, piers and slipways with cranes or ramps. A port may have magazine buildings or warehouses for storage of goods and a transport system, such as railway, road transport or pipeline transport facilities for relaying goods inland.

Lighthouse
An aid for navigation and pilotage at sea, a **lighthouse** is a tower building or framework sending out light from a system of lamps and lenses or, in older times, from a fire. Lighthouses also provide coordinate location for small aircraft traveling at night. More primitive navigational aids were once used such as a fire on top of a hill or cliff. Because of modern navigational aids, the number of operational lighthouses has declined to less than 1,500 worldwide. Lighthouses are used to mark dangerous coastlines, hazardous shoals away from the coast, and safe entries to harbors.

**Marina**

[Image of a marina]

**A Marina** is a port within a very sheltered harbour where boats and yachts are kept in the water and where services geared to the needs of recreational boating are found. They often have re-fueling, washing and repair facilities, small stores and restaurants catering to the needs of the boaters, and Ship chandlers. Slipways are used to get a trailered boat into the water. Many marinas offer a boat hoist well, a type of traveling crane, instead of a more space-wasteful slipway, operated by service center personnel. Many marinas offer some out of water storage, which is useful out of season and important in latitudes susceptible to freezing waters. Marinas may include ground facilities such as parking lots for vehicles and boat trailers. Boats are moored either on buoys or on fixed or floating walkways that are securely tied to an anchoring piling by a roller or ring mechanism.

**Shipyard**

[Image of a shipyard]
Shipyards and dockyards are places, which repair and build ships. These can be yachts, military vessels, cruise liners or other cargo or passenger ships. Dockyards are sometimes more associated with maintenance and basing activities than shipyards, which are sometimes associated, more with initial construction. The terms are routinely used interchangeably, in part because the evolution of dockyards and shipyards has often caused them to change or merge roles.

Canal lock

On waterways (navigable rivers and canals) a lock is a particular type of device for raising or lowering boats between stretches of water at different levels. The distinguishing feature of a lock is a fixed chamber whose water level can be varied; whereas in a boat lift or canal inclined plane, it is the chamber itself, which moves. Locks are used to make a river more easily navigable, or to allow a canal to take a reasonably direct line across country that is not level.

In large-scale river navigation improvements, weirs and locks are used together. A weir will increase the depth of a shallow stretch, and the required lock will either be built in a gap in the weir, or at the downstream end of an artificial cut which bypasses the weir and perhaps a shallow stretch of river below it. A river improved by these means is often called a Waterway or River Navigation.

All locks have three elements:

- A watertight chamber connecting the upper and lower canals, and large enough to enclose one or more boats. The position of the chamber is fixed, but its water level can vary.
- A gate (often a pair of "pointing" half-gates) at either end of the chamber. A gate is opened to allow a boat to enter or leave the chamber; when closed, the gate is watertight.
- A set of lock gear to empty or fill the chamber as required. This is usually a simple valve (traditionally, a flat panel lifted by manually winding a rack and pinion mechanism) which allows water to drain into or out of the chamber; larger locks may use pumps.
The principle of operating a lock is simple. For instance, if a boat travelling downstream finds the lock already full of water:

- The entrance gates are opened and the boat sails in.
- The entrance gates are closed.
- A valve is opened, this lowers the boat by draining water from the chamber.
- The exit gates are opened and the boat sails out.

- Airport

An airport is a facility where aircraft such as airplanes and helicopters can take off and land. An airport minimally consists of one runway or helipad (for helicopters), but other common components are hangars and terminal buildings.

The earliest airplane takeoff and landing sites were simply open, grassy fields. The plane could approach at any angle that provided a favorable wind direction. A slight improvement was the dirt-only field, which eliminated the drag from grass. However, these only functioned well in dry conditions. They would eventually be replaced by concrete surfaces that allowed all-weather landings in both daylight and at night. Following the World War I, some of these military airfields added commercial facilities for handling passenger traffic. One of the earliest such fields was Le Bourget, near Paris. The first international airport to open was the Croydon Airport, in South London. In 1922, the first permanent airport and commercial terminal solely for commercial aviation was built at Königsberg, Germany. The airports of this era used a paved "apron", which permitted night flying as well as landing heavier airplanes. Airports vary in size, with smaller or less-developed airports often having only a single runway shorter than 1,000 m (3,300 ft). Larger airports for international flights generally have paved runways 2,000 m (6,600 ft) or longer. Many small airports have dirt, grass, or gravel runways, rather than asphalt or concrete. Airports are divided into landside and airside areas. Landside areas include parking lots, public transportation stations, tank farms and access roads. Airside areas include all areas accessible to aircraft, including runways, taxiways and ramps. Access from landside areas to airside areas is tightly controlled at most airports. Passengers on commercial flights access airside areas through terminals, where they can purchase tickets, clear security, check or claim luggage and board aircraft through gates. The waiting areas which provide passenger access to aircraft are typically called concourses, although this term is often used interchangeably with terminal. The area
where aircraft park next to a terminal to load passengers and baggage is known as a ramp. Parking areas for aircraft away from terminals are generally called aprons. Both large and small airports can be towered or nontowered, depending on air traffic density and available funds. Due to their high capacity and busy airspace, most international airports have air traffic control located on site.

Airports with international flights have customs and immigration facilities. However, as some countries have agreements that allow travel between them without customs and immigrations, such facilities are not a definitive need for an international airport. International flights often require a more conspicuous level of physical security, although in recent years, many countries have adopted the same level of security for international and domestic travel. In addition to people, airports are responsible for moving large volumes of cargo around the clock. Cargo airlines often have their own on-site and adjacent infrastructure to rapidly transfer parcels between ground and air modes of transportation.

**Airport terminal**

An airport terminal is a building at an airport where passengers transfer between ground transportation and the facilities that allow them to board and disembark from airplanes. Passengers taking a flight will typically take an automobile, taxi, bus, or train to the airport and then enter the terminal. Within the terminal, passengers purchase tickets, transfer their luggage, and go through security. The buildings that provide access to the airplanes (via gates) are typically called concourses. However, the terms "terminal" and "concourse" are sometimes used interchangeably, depending on the configuration of the airport.

Smaller airports have one terminal while larger airports have several terminals and/or concourses. At small airports, the single terminal building typically serves all of the functions of a terminal and a concourse.

Some larger airports have one terminal that is connected to multiple concourses via walkways, skybridges, or underground tunnels. Some larger airports have more than one terminal, each with one or more concourses. Still other larger airports have multiple terminals each of which incorporate the functions of a concourse.

**10. Traffic management and control**
Road traffic is the movement of motorized vehicles, unmotorized vehicles and pedestrians on roads. Organized traffic generally has well-established priorities, lanes, right-of-way, and traffic control at intersections. Traffic is formally organized in many jurisdictions, with marked lanes, junctions, intersections, interchanges, traffic signals, or signs. Traffic is often classified by type: heavy motor vehicle (e.g. car, truck); other vehicle (e.g. moped, bicycle); and pedestrian. Different classes may share speed limits and easement, or may be segregated. Some jurisdictions may have very detailed and complex rules of the road while others rely more on drivers' common sense and willingness to cooperate.

Organization typically produces a better combination of travel safety and efficiency. Events, which disrupt the flow and may cause traffic to degenerate into a disorganized mess include: road construction, collisions, and debris in the roadway. On particularly busy freeways, a minor disruption may persist in a phenomenon known as traffic waves. A complete breakdown of organization may result in traffic jams and gridlock. Simulations of organized traffic frequently involve queuing theory, stochastic processes and equations of mathematical physics applied to traffic flow.

Rules of the road are the general practices and procedures that road users follow, especially motorists and cyclists. They govern interactions with other vehicles and pedestrians. The basic traffic rules are defined by an international treaty under the authority of the United Nations, the 1968 Vienna Convention on Road Traffic. Not all countries are signatory to the convention and, even among signatories, local variations in practice may be found. Driving safely is usually easier if a driver can adapt to both written and unwritten local rules of the road. As a general rule, a driver is expected to avoid hitting other vehicles, pedestrians, etc. regardless of whether or not the applicable rules of the road allow them to be where they happen to be.

Traffic going in opposite directions should be separated in such a way that they do not block each other's way. The most basic rule regarding this concept is which side of the road should be used for travel. About 34% of the world by country population drives on the left, and 66% keeps right.
**Speed limits:** The higher the speed of a vehicle, the more difficult collision avoidance becomes and the greater the damage if a collision does occur. Therefore, many countries of the world limit the maximum speed allowed on their roads. Vehicles are not supposed to be driven at speeds, which are higher than the posted maximum.

Vehicles will often come into conflict with other vehicles because their intended courses of travel intersect, and thus interfere with each other's routes. The general principal that establishes who has the right to go first is called "right of way", or "priority". It establishes who has the right to use the conflicting part of the road and who has to wait until the other driver does so.

As well as the side of the road, priority rules also differ between countries. In the United Kingdom, priority is always indicated by signs or road markings, in that every junction has a concept of a major road and minor road (except those governed by traffic lights).

In most of Continental Europe, the default priority is to give way to the right, but this default may be overridden by signs or road markings. In France, priority was initially according to the social rank of each traveler, but early in the life of the automobile this rule was deemed impractical and replaced with the "priorité à droite" (priority to the right) rule, which was employed until the 1980s. At a roundabout, "priorité à droite" works this way: traffic already on the roundabout gives way to traffic entering the roundabout. Most French roundabouts now have give-way signs for traffic entering the roundabout, but there remain some notable exceptions that operate on the old rule, such as the Place de l'Étoile around the Arc de Triomphe. Traffic on this particular roundabout is so chaotic that French insurance companies deem any accident on the roundabout to be equal liability.

Different countries have different rules that establish who has the right of way, but a common pattern is for one of the roads, usually the smaller road, to have a marking indicating that it should "yield" or "give way" to drivers on the other road. This can be in the form of a stop sign, dotted lines painted on the pavement or other devices. Drivers approaching from the road with the stop sign, or equivalent device are required to stop before the intersection and only proceed when a gap occurs in the other road's traffic. Some countries also include pedestrian crossings near the STOP signs, and in this case the approaching drivers must also allow pedestrians to cross the street before advancing.

Another way to resolve the right-of-way conflict is to establish a general rule such as the French priorité-à-droite, or priority to the right when translated to the English language. This rule establishes that the right of way belongs to the driver who is coming from the right, and the driver coming from the left should yield to him. This rule is unambiguous, but may lead to some counterintuitive situations, such as in T-intersections, where, strangely enough, traffic going straight through the top segment of the T must yield to entering traffic that comes from the vertical leg of the T.

In most modern cities the traffic signal is used to establish the right of way on the busy roads. Its primary idea is to give each road a slice of time in which its traffic may use the intersection in an organized way. The intervals of time assigned for each
Pedestrians must often cross from one side of a road to the other, and in doing so may come into the way of vehicles traveling on the road. In many places pedestrians are entirely left to look after themselves, that is, they must observe the road and cross when they can see that no traffic will threaten them. Busier cities usually provide pedestrian crossings, which are strips of the road where pedestrians are expected to cross.

The actual appearance of pedestrian crossings varies greatly, but the two most common appearances are: (1) a series of parallel white stripes or (2) two long horizontal white lines. The former is usually preferred, as it stands out more conspicuously against the dark pavement.

Some pedestrian crossings also accompany a traffic signal, which will make vehicles stop at regular intervals so the pedestrians can cross. Some countries have "intelligent" pedestrian signals, where the pedestrian must push a button in order to assert his intention to cross. The traffic signal will use that information to schedule itself, that is, when no pedestrians are present the signal will never pointlessly cause vehicle traffic to stop.

During business days in most major cities, traffic congestion reaches great intensity at predictable times of the day due to the large number of vehicles using the road at the same time. This phenomenon is called rush hour, although the period of high traffic intensity may exceed one hour.

Intelligent transportation systems (ITS) are a system of hardware, software and operators that allow better monitoring and control of traffic in order to optimize traffic flow. As the number of vehicle lane miles traveled per year continues to increase dramatically, and as the number of vehicle lane miles constructed per year has not been keeping pace, this has led to ever-increasing traffic congestion. As a cost-effective solution toward optimizing traffic, ITS presents a number of technologies to reduce congestion by monitoring traffic flows through the use of sensors and live cameras or analysing cellular phone data travelling in cars (Floating Cellular Data, FCD) and in turn rerouting traffic as needed through the use of variable message boards (VMS), highway advisory radio (HAR), on board or off board navigation devices and other systems. Additionally, the roadway network has been increasingly
fitted with additional communications and control infrastructure to allow traffic operations personnel to monitor weather conditions, for dispatching maintenance crews to perform snow or ice removal, as well as intelligent systems such as automated bridge de-icing systems, which help to prevent accidents.

**European Rail Traffic Management System**

The European Rail Traffic Management System (ERTMS) is a new system currently being implemented throughout Europe to improve safety and interoperability across the European rail network. Operating through a new train control system (ETCS) and (in its more advanced versions) a GSM-R radio communications system, ERTMS will augment and eventually replace line side signalling with in-cab speed and movement control. As such the introduction of ERTMS will bring about significant changes in the job of train driving.

**European Train Control System**

The **European Train Control System (ETCS)** is a signalling and control system designed to replace the 14 incompatible safety systems currently used by European Railways, especially on high-speed lines.

The specification was written in 1996 in response to EU Council Directive 96/48/EC of 23 July 1996 on the interoperability of the trans-European high-speed rail system. ETCS is developed as part of the European Rail Traffic Management System (ERTMS) initiative, and is being tested by six Railway companies since 1999. In Hungary, there is one ETCS Level 1-equipped line between Budapest and Hegyeshalom. ETCS Level 2 is used on the Rome - Naples line, opened in December 2005.

European railway networks grew as separate national networks that have little more in common than standard gauge. Notable differences include different voltages, signalling and control systems.

ETCS is divided up into different equipment and functional levels. The definition of the level depends on how the route is equipped and the way in which information is
transmitted to the train. Basically, the movement authority ("permission to proceed") and the corresponding route information are transmitted to the train and displayed for the driver in the cab ("cab signalling"). A vehicle fitted with complete ERTMS/ETCS equipment (EuroCab) and functionality can operate on any ETCS route without any technical restrictions.

**Levels of ETCS:**

**ETCS – Level 0:** If an ETCS vehicle is used on a non-ETCS route this is known as Level 0. The trainborne equipment monitors the train for maximum speed. The train driver observes the national trackside signals.

**ETCS – Level 1:** ETCS Level 1 is a cab signalling system that can be superimposed on the existing signalling system, i.e. leaving the fixed signal system (national signalling and track-release system) in place. "Eurobalise" radio beacons pick up signal aspects from the trackside signals via signal adapters and telegram coders (LEU) and transmit them to the vehicle as a movement authority together with route data at fixed points. The on-board computer continuously monitors and calculates the maximum speed and the braking curve from this data. Because of the spot transmission of data, the train first has to travel over the Eurobalise beacon in order to obtain the next movement authority. With the installation of additional Eurobalises ("infill balises") or a EuroLoop between the distant signal and main signal, the new proceed aspect is transmitted continuously. The EuroLoop is an extension of the Eurobalise over a particular distance which basically allows data to be transmitted continuously to the vehicle over cables emitting electrical radiation.

**ETCS – Level 2:** ETCS Level 2 is a digital radio-based signal and train protection system. Movement authority and other signal aspects are displayed in the cab for the driver. Apart from a few indicator panels it is therefore possible to dispense with trackside signalling. However, the track-release signalling and hence the train integrity supervision still remain in place at the trackside. All trains automatically report their exact position and direction of travel to the Radio Block Centre (RBC) at regular intervals. Train movements are monitored continually by the radio block centre. The movement authority is transmitted to the vehicle continuously via GSM-R together with speed information and route data. The Eurobalises are used at this level as passive positioning beacons or "electronic milestones". Between two positioning beacons the train determines its position via sensors (axle transducers, accelerometer and radar). The positioning beacons are used in this case as reference points for correcting distance measurement errors. The on-board computer continuously monitors the transferred data and the maximum permissible speed.

**ETCS – Level 3:** In Level 3, ETCS goes beyond the pure train protection functionality with the implementation of full radio-based train spacing. Fixed track-release signalling devices (GFM) are no longer required. As in ETCS Level 2, trains find their position themselves by means of positioning beacons and via sensors (axle transducers, accelerometer and radar) and must also be capable of determining train integrity on-board to the very highest degree of reliability. By transmitting the positioning signal to the radio block centre it is always possible to determine which point on the route the train has safely cleared. The following train can already be granted another movement authority up to this point. The route is thus no longer cleared in fixed track sections. In this respect ETCS Level 3 departs from classic
operation with fixed intervals: given sufficiently short positioning intervals, continuous line-clear authorisation is achieved and train headways come close to the principle of operation with absolute braking distance spacing (“moving block”). Level 3 is currently under development. Solutions for reliable train integrity supervision are highly complex and are hardly suitable for transfer to older models of freight rolling stock.

**Vessel traffic management information system**

Maritime Safety has initiated the Vessel Traffic Management Information System (VTMIS) project to procure and implement a VTMIS. It will help improve the safety of vessel movements and the environment through the prevention of marine pollution.

Generally a VTMIS gathers, evaluates and distributes vessel traffic and waterborne transport data to improve the safety and efficiency of transport and to better protect the environment. The purpose of the VTMIS project is to identify and procure a commercially available, off-the-shelf software solution that supports and enhances vessel traffic management practices in ports.

**Key objectives of the VTMIS**

The VTMIS software solution is expected to:

- Deliver an electronic ship movement booking service that may be accessed by shipping agents 24 hours a day, 7 days a week.
- Enable port service provider organisations the ability to electronically accept service requests made by shipping agents.
- Streamline ship movement planning by significantly reducing the existing levels of point-to-point communications that are necessary to ensure a planned ship movement has been adequately resourced with supporting services.
- Deliver improvements in both the quality and timeliness of information presented to key port user groups.
- Improve the safety and efficiency of shipping movements in ports.
Air traffic control

Air Traffic Control Towers (ATCTs) at Amsterdam's Schiphol Airport

**Air traffic control (ATC)** is a service provided by ground-based controllers who direct aircraft on the ground and in the air. A controller's primary task is to separate certain aircraft — to prevent them from coming too close to each other by use of lateral, vertical and longitudinal separation. Secondary tasks include ensuring safe, orderly and expeditious flow of traffic and providing information to pilots, such as weather, navigation information and NOTAMs (Notices to Airmen).

In many countries, ATC services are provided throughout the majority of airspace, and its services are available to all users (private, military, and commercial). When controllers are responsible for separating some or all aircraft, such airspace is called "controlled airspace" in contrast to "uncontrolled airspace" where aircraft may fly without the use of the air traffic control system. Depending on the type of flight and the class of airspace, ATC may issue instructions that pilots are required to follow, or merely flight information (in some countries known as advisories) to assist pilots operating in the airspace. In all cases, however, the pilot in command has final responsibility for the safety of the flight, and may deviate from ATC instructions in an emergency.

Air traffic control services can be divided into two major specialties, En-route controllers and Airport controllers. Most en-route controllers work in Area Control Centers (ACCs) and they subdivide in two main specialties: Terminal and En-route (which further divides into High and Low level airspace). As for Airport controllers, traffic depending, they may work alone or in a team usually divided as ground control, air control and sometimes clearance delivery. The difference between Airport controllers and En-route controllers is the way they control traffic, from a Control tower, Airport controllers use visual reference in order to provide separation while En-route controllers uses mainly RADAR.
Terminal and Airport control includes the control of traffic (aircraft and vehicles) on the airport surface and airborne aircraft within the immediate airport environment. Generally, this is approximately a 30 to 50 nautical mile (56 to 93 km) radius of the airport, from the surface to about 10,000 ft (about 3,050 m). Terminal controllers work in facilities called control towers and terminal control centers (called *Terminal Radar Approach Control*, or TRACON, facilities in the U.S.). At some locations, controllers are shared between tower control and the terminal control center, while at others the tower and the terminal control center are completely separate entities.

En-route controllers, also called Center or Area controllers, control the traffic between the terminals. They can also control traffic in and out of airports where the traffic volume does not warrant the establishment of a terminal ATC operation or during periods when a terminal operation is closed (e.g., midnight to 6:00 am). En-route controllers work at facilities called Area Control Centers or Air Route Traffic Control Centers (ARTCCs).

The primary method of controlling the immediate airport environment is visual observation from the control tower. The tower is a tall, windowed structure located on the airport grounds. *Aerodrome* or *Tower* controllers are responsible for the separation and efficient movement of aircraft and vehicles operating on the taxiways and runways of the airport itself, and aircraft in the air near the airport, generally 2 to 5 nautical miles (4 to 9 km) depending on the airport procedures.

Radar displays are also available to controllers at some airports. Controllers may use a radar system called Secondary Surveillance Radar also known as Airport Surveillance Radar for airborne traffic approaching and departing. These displays include a map of the area, the position of various aircraft, and data tags that include aircraft identification, speed, heading, and other information described in local procedures.

The areas of responsibility for tower controllers fall into three general operational disciplines; *Ground Control*, *Local* or *Air Control*, and *Clearance Delivery* -- other categories, such as *Apron Control* or *Ground Movement Planner*, may exist at extremely busy airports. While each tower's procedures will vary and while there may be multiple teams in larger towers that control multiple runways, the following provides a general concept of the delegation of responsibilities within the tower environment.

*Ground Control* (sometimes known as *Ground Movement Control* abbreviated to *GMC* or *Surface Movement Control* abbreviated to *SMC*) is responsible for the airport "maneuvering" areas, or areas not released to the airlines or other users. This generally includes all taxiways, holding areas, and some transitional aprons or intersections where aircraft arrive having vacated the runway and departure gates. Exact areas and control responsibilities are clearly defined in local documents and agreements at each airport. Any aircraft, vehicle, or person walking or working in these areas is required to have clearance from the ground controller. This is normally done via VHF radio, but there may be special cases where other processes are used. Most aircraft and airside vehicles have radios. Aircraft or vehicles without radios will communicate with the tower via aviation light signals or will be led by vehicles with radios. People working on the airport surface normally have a communications link through which they can reach or be reached by ground control, commonly either by
handheld radio or even cell phone. Ground control is vital to the smooth operation of the airport because this position might constrain the order in which the aircraft will be sequenced to depart, which can affect the safety and efficiency of the airport's operation.

**Local or Air Control** (most often referred to as the generic "Tower" control, although Tower control can also refer to a combination of the local, ground and clearance delivery positions) is responsible for the active runway surfaces. The Air Traffic Control Tower clears aircraft for take off or landing and ensures the runway is clear for these aircraft. If the tower controller detects any unsafe condition, a landing aircraft may be told to "go-around" and be re-sequenced into the landing pattern by the approach or terminal area controller.

**Clearance delivery** is the position that issues route clearances to aircraft before they commence taxiing. These contain details of the route that the aircraft is expected to fly after departure. This position will, if necessary, coordinate with the en-route center and national command center or flow control to obtain releases for aircraft. Often however such releases are given automatically or by controlled by local agreements allowing "free-flow" departures. When weather or extremely high demand for a certain airport or airspace becomes a factor, there may be ground "stops" (or "slot delays") or re-routes may be necessary to ensure the system does not get overloaded. The primary responsibility of the clearance delivery position is to ensure that the aircraft have the proper route and slot time. This information is also coordinated with the en-route center and the ground controller in order to ensure the aircraft reaches the runway in time to meet the slot time provided by the command center. At some airports the clearance delivery controller also plans aircraft pushbacks and engine starts and is known as Ground Movement Planner (GMP): this position is particularly important at heavily congested airports to prevent taxiway and apron gridlock.

**En-route, Center, or Area Control**

ATC provides services to aircraft in flight between airports as well. The level of service is dependent on the type of flight the aircraft falls under (IFR or VFR), the type of airspace the aircraft is in and the services requested by the pilots.
En-route air traffic controllers issue clearances and instructions for airborne aircraft, and pilots are required to comply with these instructions. En-route controllers also provide air traffic control services to many smaller airports around the country, including clearance off of the ground and clearance for approach to an airport. Controllers adhere to a set of separation standards that define the minimum distance allowed between aircraft. These distances vary depending on the equipment and procedures used in providing ATC services.

Pilots fly under one of two sets of rules for separation: Visual Flight Rules (VFR) or Instrument Flight Rules (IFR). Air traffic controllers have different responsibilities to aircraft operating under the different sets of rules.

En-route air traffic controllers work in facilities called Area Control Centers, each of which is commonly referred to as a "Center". The United States uses the equivalent term Air Route Traffic Control Center (ARTCC). Each center is responsible for many thousands of square miles of airspace (known as a Flight Information Region) and for the airports within that airspace. Centers control IFR aircraft from the time they depart an airport or terminal area's airspace to the time they arrive at another airport or terminal area's airspace. Centers may also "pick up" VFR aircraft that are already airborne and integrate them into the IFR system. These aircraft must, however, remain VFR until the Center provides a clearance.

Center controllers are responsible for climbing the aircraft to their requested altitude while, at the same time, ensuring that the aircraft is properly separated from all other aircraft in the immediate area. Additionally, the aircraft must be placed in a flow consistent with the aircraft's route of flight. This effort is complicated by crossing traffic, severe weather, special missions that require large airspace allocations, and traffic density. When the aircraft approaches its destination, the center is responsible for meeting altitude restrictions by specific points, as well as providing many destination airports with a traffic flow, which prohibits all of the arrivals being "bunched together". These "flow restrictions" often begin in the middle of the route, as controllers will position aircraft landing in the same destination so that when the aircraft are close to their destination they are sequenced.

As an aircraft reaches the boundary of a Center's control area it is "handed off" or "handed over" to the next Area Control Center. In some cases this "hand-off" process involves a transfer of identification and details between controllers so that air traffic control services can be provided in a seamless manner; in other cases local agreements may allow "silent handovers" such that the receiving center does not require any co-ordination if traffic is presented in an agreed manner. After the hand-off, the aircraft is given a frequency change and begins talking to the next controller. This process continues until the aircraft is handed off to a terminal controller ("approach").

Since centers control a large airspace area, they will typically use long-range radar that has the capability to see aircraft within 200 nautical miles (370 km) of the radar antenna. They may also use TRACON radar data to control when it provides a better "picture" of the traffic or when it can fill in a portion of the area not covered by the long range radar.
In the U.S. system, at higher altitudes, over 90% of the U.S. airspace is covered by radar and often by multiple radar systems; however, coverage may be inconsistent at lower altitudes used by unpressurized aircraft due to high terrain or distance from radar facilities. A center may require numerous radar systems to cover the airspace assigned to them, and may also rely on pilot position reports from aircraft flying below the floor of radar coverage. This results in a large amount of data being available to the controller. To address this, automation systems have been designed that consolidate the radar data for the controller. This consolidation includes eliminating duplicate radar returns, ensuring the best radar for each geographical area is providing the data, and displaying the data in an effective format.

Centers also exercise control over traffic travelling over the world's ocean areas. These areas are also FIRs. Due to the fact that there are no radar systems available for oceanic control, oceanic controllers provide ATC services using procedural control. These procedures use aircraft position reports, time, altitude, distance, and speed to ensure separation. Controllers record information on flight progress strips and in specially developed oceanic computer systems as aircraft report positions. This process requires that aircraft be separated by greater distances, which reduces the overall capacity for any given route.

Some Air Navigation Service Providers (e.g. Airservices Australia, Alaska Center, etc.) are implementing Automatic dependent Surveillance - Broadcast (ADS-B) as part of their surveillance capability. This new technology reverses the radar concept. Instead of radar "finding" a target by interrogating the transponder, ADS transmits the aircraft's position several times a second. ADS also have other modes such as the "contract" mode where the aircraft reports a position based on a predetermined time interval. This is significant because it can be used where it is not possible to locate the infrastructure for a radar system (e.g. over water). Computerized radar displays are now being designed to accept ADS inputs as part of the display. As this technology develops, oceanic ATC procedures will be modernized to take advantage of the benefits this technology provides.

Beyond runway capacity issues, weather is a major factor in traffic capacity. Rain or ice and snow on the runway cause landing aircraft to take longer to slow and exit, thus reducing the safe arrival rate and requiring more space between landing aircraft. Fog also requires a decrease in the landing rate. These, in turn, increase airborne delay for holding aircraft. If more aircraft are scheduled than can be safely and efficiently held in the air, a ground delay program may be established, delaying aircraft on the ground before departure due to conditions at the arrival airport.

In ACCs, a major weather problem is thunderstorms, which present a variety of hazards to aircraft. Aircraft will deviate around storms, reducing the capacity of the en-route system by requiring more space per aircraft, or causing congestion as many aircraft try to move through a single hole in a line of thunderstorms. Occasionally weather considerations cause delays to aircraft prior to their departure as routes are closed by thunderstorms.

Much money has been spent on creating software to streamline this process. However, at some Area Control Centers, air traffic controllers still record data for each flight on strips of paper and personally coordinate their paths. In newer sites, these flight progress strips have been replaced by electronic data presented on
computer screens. As new equipment is brought in, more and more sites are upgrading away from paper flight strips.

11. Transport, energy, and the environment

Transport is a major use of energy, and transport burns most of the world’s petroleum. Transportation accounts for 2/3 of all U.S. petroleum consumption. The transportation sector generates 82 percent of carbon monoxide and 56 percent of NOx emissions and over one-quarter of total US greenhouse gas emissions. Hydrocarbon fuels also produce carbon dioxide, other greenhouse gas widely thought to be the chief cause of global climate change, and petroleum-powered engines, especially inefficient ones, create air pollution, including nitrous oxides and particulates. Although vehicles in developed countries have been getting cleaner because of environmental regulations, this has been offset by an increase in the number of vehicles and more use of each vehicle.

Other environmental impacts of transport systems include traffic congestion and automobile-oriented urban sprawl, which can consume natural habitat and agricultural lands. Toxic runoff from roads and parking lots that can also pollute water supplies and aquatic ecosystems.

Low pollution fuels vehicles can reduce pollution. Low pollution fuels may have a reduced carbon content, and thereby contribute less in the way of carbon dioxide emissions, and generally have reduced sulfur, since sulfur exhaust is a cause of acid rain. The most popular low-pollution fuels at this time are biofuels: gasoline-ethanol blends and biodiesel. Hydrogen is an even lower-pollution fuel that produces no carbon dioxide, but producing and storing it economically is currently not feasible.

Another strategy is to make vehicles more efficient, which reduces pollution and waste by reducing the energy use. Electric vehicles use efficient electric motors, but their range is limited by either the extent of the electric transmission system or by the storage capacity of batteries. Electrified public transport generally uses overhead wires or third rails to transmit electricity to vehicles, and is used for both rail and bus transport. Battery electric vehicles store their electric fuel onboard in a battery pack. Another method is to generate energy-using fuel cells, which may eventually be two to five times as efficient as the internal combustion engines currently used in most vehicles. Another effective method is to streamline ground vehicles, which spend up to 75% of their energy on air-resistance, and to reduce their weight. Regenerative braking is possible in all electric vehicles and recaptures the energy normally lost to braking, and is becoming common in rail vehicles. In internal combustion automobiles and buses, regenerative braking is not possible, unless electric vehicle components are also a part of the powertrain, these are called hybrid electric vehicles. Shifting travel from automobiles to well-utilized public transport can reduce energy consumption and traffic congestion.
Walking and bicycling instead of traveling by motorized means also reduces the consumption of fossil fuels. While the use of these two modes generally declines as a given area becomes wealthier, there are some countries (including Denmark, Netherlands, Japan and parts of Germany, Finland and Belgium) where bicycling comprises a significant share of trips. Some cities with particularly high modal shares of cycling are Oulu (25%), Copenhagen (33%) and Groningen (50%). A number of other cities, including London, Paris, New York, Sydney, Bogotá, Chicago and San Francisco are creating networks of bicycle lanes and bicycle paths, but the value of such devices for utility cycling is highly controversial.
B. Transport, positioning and unit load formation equipment

Transport equipment is used to move material from one location to another (e.g., between workplaces, between a loading dock and a storage area, etc.) within a facility or at a site.

The major subcategories of transport equipment are:

A. **Conveyors.** Equipment used to move materials over a fixed path between specific points.

B. **Cranes.** Equipment used to move materials over variable paths within a restricted area.

C. **Industrial Trucks.** Equipment used to move materials over variable paths, with no restrictions on the area covered by the movement (i.e., unrestricted area).

12. Conveyors

Conveyors are used to move materials over a fixed path. The major types of conveyors are:

1. Chute conveyor
2. Wheel conveyor
3. Roller conveyor
   a. Gravity roller conveyor
   b. Live (powered) roller conveyor
4. Chain conveyor
5. Slat conveyor
6. Flat belt conveyor
7. Magnetic belt conveyor
8. Troughed belt conveyor
9. Bucket conveyor
10. Vibrating conveyor
11. Screw conveyor
12. Pneumatic conveyor
   a. Dilute-phase pneumatic conveyor
   b. Carrier-system pneumatic conveyor
13. Vertical conveyor
   a. Vertical lift conveyor
   b. Reciprocating vertical conveyor
14. Cart-on-track conveyor
15. Tow conveyor
16. Trolley conveyor
17. Power-and-free conveyor
18. Monorail
19. Sortation conveyor
   a. Diverter
   b. Pop-up device
   c. Sliding shoe device
   d. Tilting device
   e. Cross-belt transfer device
Conveyors are used:

- When material is to be moved frequently between specific points
- To move materials over a fixed path
- When there is a sufficient flow volume to justify the fixed conveyor investment

Conveyors can be classified in different ways:

- Type of product being handled: **unit load** or **bulk load**
- Location of the conveyor: **overhead**, **on-floor**, or **in-floor**
- Whether or not loads can **accumulate** on the conveyor

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1. **Chute Conveyor**

   Unit/Bulk + On-Floor + Accumulate
   
   Inexpensive
   
   Used to link two handling devices
   
   Used to provide accumulation in shipping areas
   
   Used to convey items between floors
   
   Difficult to control position of the items

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2. **Wheel Conveyor**

   Unit + On-Floor + Accumulate
   
   Uses a series of skate wheels mounted on a shaft (or axle), where spacing of the wheels is dependent on the load being transported
   
   Slope for gravity movement depends on load
   
   More economical than the roller conveyor
   
   For light-duty applications
   
   Flexible, expandable versions available
3. Roller Conveyor

Unit + On-Floor + Accumulate

May be powered (or live) or no powered (or gravity)

Materials must have a rigid riding surface

Minimum of three rollers must support smallest loads at all times

Tapered rollers on curves used to maintain load orientation

3(a) Gravity Roller Conveyor

Alternative to wheel conveyor

For heavy-duty applications

Slope for gravity movement depends on load weight

For accumulating loads

3(b) Live (Powered) Roller Conveyor

Belt or chain driven

Force-sensitive transmission can be used to disengage rollers for accumulation

For accumulating loads and merging/sorting operations

Provides limited incline movement capabilities
4. Chain Conveyor

Unit + In-/On-Floor + No Accumulate

Uses one or more endless chains on which loads are carried directly

Parallel chain configuration used to transport pallets

*Vertical chain conveyor* used for continuous high-frequency vertical transfers (cf. vertical conveyor used for low-frequency intermittent transfers)

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5. Slat Conveyor

Unit + In-/On-Floor + No Accumulate

Uses discretely spaced slats connected to a chain

Unit being transported retains its position (like a belt conveyor)

Orientation and placement of the load is controlled

Used for heavy loads or loads that might damage a belt

Bottling and canning plants use flat chain or slat conveyors because of wet conditions, temperature, and cleanliness requirements

Tilt slat conveyor used for sortation
6. Flat Belt Conveyor

Unit + On-Floor + No Accumulate

For transporting light- and medium-weight loads between operations, departments, levels, and buildings

When an incline or decline is required

Provides considerable control over the orientation and placement of the load.

No smooth accumulation, merging, and sorting on the belt

The belt is roller or slider bed supported; the slider bed is used for small and irregularly shaped items

In 1957, B.F. Goodrich, Co. patented the Möbius strip for conveying hot or abrasive substances in order to have "both" sides wear equally.

7. Magnetic Belt Conveyor

Bulk + On-Floor

A steel belt and either a magnetic slider bed or a magnetic pulley is used

To transport ferrous materials vertically, upside down, and around corners
8. Troughed Belt Conveyor

Bulk + On-Floor

Used to transport bulk materials

When loaded, the belt conforms to the shape of the troughed rollers and idlers

9. Bucket Conveyor

Bulk + On-Floor

Used to move bulk materials in a vertical or inclined path

Buckets are attached to a cable, chain, or belt

Buckets are automatically unloaded at the end of the conveyor run
10. Vibrating Conveyor

Bulk + On-Floor

Consists of a trough, bed, or tube

Vibrates at a relatively high frequency and small amplitude in order to convey individual units of products or bulk material

Can be used to convey almost all granular, free-flowing materials

An Oscillating Conveyor is similar in construction, but vibrates at a lower frequency and larger amplitude (not as gentle) in order to convey larger objects such as hot castings

11. Screw Conveyor

Bulk + On-Floor

Consists of a tube or U-shaped stationary trough through which a shaft-mounted helix revolves to push loose material forward in a horizontal or inclined direction

One of the most widely used conveyors in the processing industry

Many applications in agricultural and chemical processing

Water screw developed circa 250 BC by Archimedes

12. Pneumatic Conveyor

Bulk/Unit + Overhead

Can be used for both bulk and unit movement of materials

Air pressure is used to convey materials through a system of vertical and horizontal tubes
Major advantages are that material is completely enclosed and it is easy to implement turns and vertical moves

12(a) Dilute-Phase Pneumatic Conveyor

Moves a mixture of air and solid

Push (positive pressure) systems push material from one entry point to several discharge points

Pull (negative pressure or vacuum) systems move material from several entry points to one discharge point

Push-pull systems are combinations with multiple entry and discharge points

12(b) Carrier-System Pneumatic Conveyor

Carriers are used to transport items or paperwork (e.g., money from drive-in stalls at banks)

13. Vertical Conveyor

Unit + On-Floor + No Accumulate

Used for low-frequency intermittent vertical transfers (cf. vertical chain conveyor can be used for continuous high-frequency vertical transfers
13(a) Vertical Lift Conveyor

Carrier used to raise or lower a load to different levels of a facility (e.g., different floors and/or mezzanines)

Differs from a freight elevator in that it is not designed or certified to carry people

Can be manually or automatically loaded and/or controlled and can interface with horizontal conveyors

13(b) Reciprocating Vertical Conveyor

Utilizes gravity-actuated carrier to lowering loads, where the load overcomes the magnitude of a counterweight

Can only be used to lower a load

Alternative to a chute conveyor for vertical "drops" when load is fragile and/or space is limited

Can be manually or automatically loaded and/or controlled and can interface with horizontal conveyors
14. Cart-On-Track Conveyor

Unit + In-Floor + Accumulate

Used to transport carts along a track

Carts are transported by a rotating tube

Connected to each cart is a drive wheel that rests on the tube and that is used to vary the speed of the cart (by varying the angle of contact between the drive wheel and the tube)

Carts are independently controlled

Accumulation can be achieved by maintaining the drive wheel parallel to the tube

15. Tow Conveyor

Unit + In-Floor + Accumulate

Uses towline to provide power to wheeled carriers such as trucks, dollies, or carts that move along the floor

Used for fixed-path travel of carriers (each of which has variable path capabilities when disengaged from the towline)

Towline can be located either overhead, flush with the floor, or in the floor

Selector-pin or pusher-dog arrangements can be used to allow automatic switching (power or spur lines)

Generally used when long distance and high frequency moves are required
16. Trolley Conveyor

Unit + Overhead + No Accumulate

Uses a series of trolleys supported from or within an overhead track

Trolleys are equally spaced in a closed loop path and are suspended from a chain

Carriers are used to carry multiple units of product

Does not provide for accumulation

Commonly used in processing, assembly, packaging, and storage operations

17. Power-and-Free Conveyor

Unit + Overhead/On-Floor + Accumulate

Similar to trolley conveyor due to use of discretely spaced carriers transported by an overhead chain; however, the power-and-free conveyor uses two tracks: one powered and the other no powered (or free)

Carriers can be disengaged from the power chain and accumulated or switched onto spurs

Termed an *Inverted Power-and-Free Conveyor* when tracks are located on the floor
18. Monorail

Overhead single track (i.e., mono-rail) or track network on which one or more carriers ride

Carriers: powered (electrically or pneumatically) or nonpowered

Carrier can range from a simple hook to a hoist to an intelligent-vehicle-like device

Single-carrier, single-track monorail similar to bridge or gantry crane

Multi-carrier, track network monorail similar to both a trolley conveyor, except that the carriers operate independently and the track need not be in a closed loop, and a fixed-path automatic guided vehicle (AGV) system, except that it operates overhead

Termed an Automated Electrified Monorail (AEM) system when it has similar control characteristics as an AGV system

19. Sortation Conveyor

Sortation conveyors are used for merging, identifying, inducting, and separating products to be conveyed to specific destinations
19(a) Sortation Conveyor: Diverter

Stationary or movable arms that deflect, push, or pull a product to desired destination

Since they do not come in contact with the conveyor, they can be used with almost any flat surface conveyor

Usually hydraulically or pneumatically operated, but also can be motor driven

Simple and low cost

19(b) Sortation Conveyor: Pop-Up Device

One or more rows of powered rollers or wheels or chains that pop up above surface of conveyor to lift product and guide it off conveyor at an angle; wheels are lowered when products not required to be diverted

Only capable of sorting flat-bottomed items

Pop-up rollers are generally faster than pop-up wheels
19(c) Sortation Conveyor: Sliding Shoe Sorter

Sliding shoe sorter (a.k.a. moving slat sorter) uses series of diverter slats that slide across the horizontal surface to engage product and guide it off conveyor.

- Slats move from side to side as product flows in order to divert the product to either side.
- Gentle and gradual handling of products.

19(d) Sortation Conveyor: Tilting Device

- Trays or slats provide combined sorting mechanism and product transporter.
- Can accommodate elevation changes.

- Tilt tray sorters usually designed in continuous loops with a compact layout and recirculation of products not sorted the first time.

- Tilt slat sorters carry products on flat-surface slat conveyor and can handle wider variety of products compared to tilt tray.

19(e) Sortation Conveyor: Cross-Belt Transfer Device
Either continuous loop, where individual carriages are linked together to form an endless loop, or train style (asynchronous), where a small number of carriers tied together with potential for several trains running track simultaneously.

Each carriage equipped with small belt conveyor, called the cell, that is mounted perpendicular to direction of travel of loop and discharges product at appropriate destination.
13. Cranes

Cranes are used to move materials over variable paths within a restricted area. The major types of cranes are:

1. Jib crane
2. Bridge crane
3. Gantry crane
4. Stacker crane

General characteristics of cranes:

- Used to move loads over variable (horizontal and vertical) paths within a restricted area
- Used when there is insufficient (or intermittent) flow volume such that the use of a conveyor cannot be justified
- Provide more flexibility in movement than conveyors
- Provide less flexibility in movement than industrial trucks
- Loads handled are more varied with respect to their shape and weight than those handled by a conveyor
- Most cranes utilize hoists for vertical movement, although manipulators can be used if precise positioning of the load is required
1. Jib Crane

Operates like an arm in a work area, where it can function as a manipulator for positioning tasks

A hoist is attached to the arm for lifting

Arm mounted on the wall or attached to a floor mounted support

Arm can rotate 360°

The hoist can move along the arm

2. Bridge Crane

Bridge mounted on tracks that are located on opposite walls of the facility

Enables three-dimensional handling

Top riding (heavier loads) or underhung (more versatile) versions of the crane

Underhung crane can transfer loads and interface with other MHS (e.g., monorail systems)
3. Gantry Crane

Similar to a bridge crane except that it is floor supported at one or both ends instead of overhead (wall) supported.

Used to span a smaller portion of the work area as compared to a bridge crane.

The supports can be fixed in position or they can travel on runways.

Can be used outdoors when "floor" supported at both ends.

4. Stacker Crane

Similar to a bridge crane except that, instead of a hoist, it uses a mast with forks or a platform to handle unit loads.

Considered "fork trucks on a rail."

Used for storing and retrieving unit loads in storage racks, especially in high-rise applications in which the racks are more than 50 feet high.

Can be controlled remotely or by an operator in a cab on the mast.

Can be rack supported.
14. Industrial Trucks

Industrial trucks are used to move materials over variable paths, with no restrictions on the area covered by the movement. The major types of industrial trucks are:

1. **Hand truck**
   a. Two-wheeled hand truck
   b. Dolly
   c. Floor hand truck
2. **Pallet jack**
   a. Manual pallet jack
   b. Powered pallet jack
3. **Walkie stacker**
   a. Manual walkie stacker
   b. Powered walkie stacker
4. **Pallet truck**
5. **Platform truck**
   a. Walkie platform truck
   b. Rider platform truck
6. **Counterbalanced lift truck**
   a. Sit-down counterbalanced lift truck
   b. Stand-up counterbalanced lift truck
7. **Narrow-aisle straddle truck**
8. **Narrow-aisle reach truck**
9. **Turret truck**
   a. Operator-down turret truck
   b. Operator-up turret truck
10. **Order picker**
11. **Sideloader**
12. **Tractor-trailer**
13. **Personnel and burden carrier**
14. **Automatic guided vehicle (AGV)**
   a. Tow AGV
   b. Unit load AGV
   c. Assembly AGV
   d. Light load AGV
   e. Fork AGV

Industrial trucks:

- Used to move materials over variable (horizontal) paths with no restrictions on the area covered (i.e., unrestricted area)
- Provide vertical movement if the truck has lifting capabilities
- Used when there is insufficient (or intermittent) flow volume such that the use of a conveyor cannot be justified
- Provide more flexibility in movement than conveyors and cranes
- Not licensed to travel on public roads—"commercial trucks" are licensed to travel on public roads

Characteristics:

- **Pallet/Non-Pallet**: Does the truck have forks for handling pallets, or does the truck have a flat surface on which to place loads. Non-Pallet => (usually) other means required to load truck.

- **Manual/Powered**: Does the truck have manual or powered vertical (lifting) and/or horizontal (travel) movement capabilities. Manual => walk => operator
provides the force needed for lifting loads and/or pushing the vehicle. Powered => on-board power source (e.g., batteries) used for lifting and/or travel.

- **Walk/Ride:** For non-automated trucks, can the operator ride on the truck (in either a standing or sitting position) or is the operator required to walk with the truck during travel. Walk => manual or powered travel possible => powered travel speed limited to a normal walking pace. Ride => powered => travel speed can be faster than a walking pace.

- **Stack/No Stack:** Can the truck be used to lift loads for stacking purposes. Stack => can also be used as no stack => more expensive to add stacking capability. No Stack may lift a load a few inches to clear the floor for subsequent travel (e.g., pallet jack), but the loads cannot be stacked on top of each other or on shelves.

- **Narrow Aisle:** Is the lift truck designed to have a small turning radius or does it not have to turn at all in an aisle when loading/unloading. Narrow Aisle => greater cost and (usually) standing operator => less aisle space required. Counterbalance and/or straddle used for load support. Small turning radius => load support via straddle or reaching capabilities. No turning required => even narrower aisle => only one-side loading (sideloaders) or the capability to rotate the load (turret truck).

- **Automated:** Is the truck automated so that it can transport loads without requiring an operator. Non-Automated => direct labor cost of operator is by far the largest cost to operate a non-automated truck. Semi-Automated => operator used to control loading/unloading, but automated transport control (e.g., the S/R machine of a Man-on-board AS/RS). Automated => Automated Guided Vehicle (AGV) => no direct labor cost, but higher equipment costs.

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1. **Hand Truck**

Non-pallet + manual + no stack

1(a) **Two-Wheeled Hand Truck**

Load tilted during travel
1(b) Dolly

Three or more wheeled hand truck with a flat platform in which, since it has no handles, the load is used for pushing

1(c) Floor Hand Truck

Four or more wheeled hand truck with handles for pushing or hitches for pulling

Sometimes referred to as a "cart" or "(manual) platform truck"

2. Pallet Jack

Pallet + walk + no stack

Front wheels are mounted inside the end of the forks and extend to the floor as the pallet is only lifted enough to clear the floor for subsequent travel

Pallet restrictions: reversible pallets cannot be used, double-faced nonreversible pallets cannot have deckboards where the front wheels extend to the floor, and enables only two-way entry into a four-way notched-stringer pallet because the forks cannot be inserted into the notches

2(a) Manual Pallet Jack

Pallet + walk + no stack + manual

Manual lifting and/or travel
2(b) Powered Pallet Jack

Pallet + walk + no stack + powered

Powered lifting and/or travel

3. Walkie Stacker

Pallet + walk + stack

3(a) Manual Walkie Stacker

Pallet + walk + stack + manual

Manual lifting and/or travel (and straddle load support)

3(b) Powered Walkie Stacker

Pallet + walk + stack + powered

Powered lifting and/or travel (and either counterbalance or straddle load support)
4. Pallet Truck

Pallet + ride + no stack

Same pallet restrictions as a pallet jack

Control handle typically tilts to allow operator to walk during loading/unloading

Powered pallet jack is sometimes referred to as a "(walkie) pallet truck"

5. Platform Truck

Non-pallet + powered + no stack

Platform used to provide support for nonpalletized loads

Used for skid handling; platform can lift skid several inches to allow it to clear the floor

Greater lifting capacity compared to fork trucks because the platform provides a greater lifting surface to support a load

5(a) Walkie Platform Truck

Non-pallet + powered + no stack + walk

Operator walks next to truck

Floor hand truck is sometimes referred to as a "(manual) platform truck"

5(b) Rider Platform Truck

Non-pallet + powered + no stack + ride

Operator can ride on truck
6. Counterbalanced (CB) Lift Truck

Pallet + ride + stack

Also referred to as fork truck.

Weight of vehicle (and operator) behind the front wheels of truck counterbalances weight of the load (and weight of vehicle beyond front wheels); front wheels act as fulcrum or pivot point.

Rated capacity reduced for load centers greater than 24 in. and lift heights greater than 13 ft.

Workhorses of material handling because of their flexibility: indoor/outdoor operation over a variety of different surfaces; variety of load capacities available; and variety of attachments available—fork attachments can replace the forks (e.g., carton clamps) or enhance the capabilities of the forks (e.g., blades for slipsheets).

6(a) Sit-Down Counterbalanced Lift Truck

Operator sits down

12-13 ft. minimum aisle width requirement

6(b) Stand-Up Counterbalanced Lift Truck

Operator stands up, giving vehicle narrow-aisle capability

9-11 ft. minimum aisle width requirement

Faster loading/unloading time compared to NA straddle and reach trucks
7. Narrow-Aisle (NA) Straddle Truck

Similar to stand-up CB lift truck, except outrigger arms straddle a load and are used to support the load instead of the counterbalance of the truck

7-8 ft. minimum aisle width requirement

Less expensive than stand-up CB lift truck and NA reach truck

Since the load is straddled during stacking, clearance between loads must be provided for the outrigger arms

Arm clearance typically provided through the use of load-on-beam rack storage or single-wing pallets for load-on-floor storage

8. Narrow-Aisle (NA) Reach Truck

Similar to both stand-up CB lift truck and NA straddle truck

8-10 ft. minimum aisle width requirement

Load rests on the outrigger arms during transport, but a pantograph (scissors) mechanism is used for reaching, thereby eliminating the need to straddle the load during stacking

Reaching capability enables the use of shorter outrigger arms (arms > 1/2 load depth) as compared to NA straddle truck (arms = load depth)

Counterbalance of the truck used to support the load when it extends beyond the outrigger arms

Although the NA reach truck requires slightly wider aisles than a NA straddle truck since its outrigger arms do not enter a rack during storage, it does not require arm clearance between loads (arm clearance is still required when the truck must enter a storage lane when block stacking or drive-in or -through racks are used)

Extended reaching mechanisms are available to enable double-deep storage
9. Turret Truck

Greater stacking height compared to other narrow-aisle trucks (40 ft. vs. 25 ft.), but greater investment cost.

Forks rotate to allow for side loading and, since truck itself does not rotate during stacking, the body of the truck can be longer to increase its counterbalance capability and to allow the operator to sit.

Can function like a side loader for transporting greater-than-pallet-size load.

9(a) Operator-Down Turret Truck

Operator not lifted with the load.

5-6 ft. minimum aisle width requirement.

Termed a *swingmast truck* (picture shown) when, instead of just the forks, the entire mast rotates (thus can store on only one side of a aisle while in aisle).

9(b) Operator-Up Turret Truck

Operator lifted with the load to allow precise stacking and picking.

5-7 ft. minimum aisle width requirement.
10. Order Picker

Similar to NA straddle truck, except operator lifted with the load to allow for less-than-unit-load picking

Typically has a fork to allow the truck to be used for pallet stacking and to support a pallet during less-than-pallet-load picking

"Belly switch" used for operator safety during picking

11. Sideloader

Forks mounted perpendicular to direction of travel to allow for side loading and straddle load support

5-6 ft. minimum aisle width requirement

Can be used to handle greater-than-pallet-size loads (e.g., bar stock)

12. Tractor-Trailer

Non-load-carrying tractor used to pull a train of trailers (i.e., dollies or floor hand trucks)
Extends the transporting capacity of floor hand trucks

Typically used at airports for baggage handling

13. Personnel and Burden Carrier

Non-load-carrying vehicle used to transport personnel within a facility (e.g., golf cart, bicycle, etc.)

14. Automatic Guided Vehicle (AGV)

AGVs do not require an operator

Good for high labour cost, hazardous, or environmentally sensitive conditions (e.g., clean-room)

Also termed "automated" guided vehicle

AGVs good for low-to-medium volume medium-to-long distance random material flow operations (e.g., transport between work cells in a flexible manufacturing system (FMS) environment)

Two means of guidance can be used for AGV systems:

*Fixed path:* Physical guidepath (e.g., wire, tape, paint) on the floor used for guidance

*Free-ranging:* No physical guidepath, thus easier to change vehicle path (in software), but absolute position estimates (from, e.g., lasers) are needed to correct dead-reckoning error

14(a) Tow AGV

Used to pull a train of trailers

Automated version of a tractor-trailer
Trailers usually loaded manually (early type of AGV, not much used today)

14(b) Unit Load AGV

- Have decks that can be loaded manually or automatically
- Deck can include conveyor or lift/lower mechanism for automatic loading
- Typically 4 by 4 feet and can carry 1–2,000 lb. loads
- Typically less than 10 vehicles in AGV system

14(c) Assembly AGV

- Used as assembly platforms (e.g., car chassis, engines, appliances)
- Greatest development activity during the 1980s (alternative to AEMs)
- Typically 50–100 vehicles in AGV system

14(d) Light Load AGV

- Used for small loads (< 500 lbs), e.g., components, tools
- Typically used in electronics assembly and office environments (as mail and snack carriers)
14(e) Fork AGV

Counterbalanced, narrow-aisle straddle, and sideloading versions available

Typically have sensors on forks (e.g., infrared sensors) for pallet interfacing
15.1. Positioning Equipment

Positioning equipment is used to handle material at a single location so that the material is in the correct position for subsequent handling, machining, transport, or storage. Unlike transport equipment, positioning equipment is usually used for handling at a single workplace. Material can also be positioned manually using no equipment. The major types of positioning equipment are:

1. Manual (no equipment)
2. Lift/tilt/turn table
3. Dock leveler
4. Ball transfer table
5. Rotary index table
6. Parts feeder
7. Air film device
8. Hoist
9. Balancer
10. Manipulator
   a. Rigid-link manipulator
   b. Articulated jib crane manipulator
   c. Vacuum manipulator
11. Industrial robot

As compared to manual handling, the use of positioning equipment can provide the following benefits:

- raise the productivity of each worker when the frequency of handling is high,
- improve product quality and limit damage to materials and equipment when the item handled is heavy or awkward to hold and damage is likely through human error or inattention, and
- reduce fatigue and injuries when the environment is hazardous or inaccessible.

1. Manual (No Equipment)

Material can be positioned manually using no equipment

Under ideal circumstances, maximum recommended weight for manual lifting to avoid back injuries is 51 lbs.

2. Lift/Tilt/Turn Table

Used when positioning involves the lifting, tilting, or turning of a load
Higher School of Transport

Can be used to reduce or limit a worker’s lifting and/or reaching motions

Pallet load levellers are lift and turn tables used in manual palletising to reduce the amount of bending and stooping involved with manually loading a pallet by combining a lifting and turning mechanism with a device that lowers the table as each layer is completed so that loading always takes place at the optimal height of 30 inches.

3. Dock Leveller

![Dock Leveller Diagram]

Used at loading docks to compensate for height differences between a truck bed and the dock.

4. Ball Transfer Table

![Ball Transfer Table Diagram]

Used in conveyor systems to permit manual transfer to and from machines and conveyors and between different sections of conveyors.

Since loads are pushed on the table, ball friction limits the maximum load weight to 600 lbs.

5. Rotary Index Table

![Rotary Index Table Diagram]

Used for the synchronous transfer of small parts from station to station in a single workcenter.
Circular table rotates in discrete intermittent steps to advance parts between stations located along its perimeter.

Since each part moves between stations at the same time, it is difficult to put buffers between stations.

Different from conveyors used as in-line indexing machines, where linear transfers can take place between multiple workcenters separated by long distances, since a rotary index table is restricted to circular transfers with a single compact workcenter.

6. Parts Feeder

Used for feeding and orienting small identical parts, particularly in automatic assembly operations.

Motion of parts in a random pile channelled so that each part automatically assumes a specified orientation, where the symmetries of a part define its possible orientations.

Motion can be imparted through vibration, gravity, centrifugal force, tumbling, or air pressure.

In a vibratory bowl feeder, the most versatile type of parts feeder, parts are dumped into a bowl and then move vibrate uphill along a track towards an outlet, where rejected parts fall off the track and are recycled.

Parts feeders can be used to provide inspection capabilities with respect to the shape and weight of parts (e.g., the coin feeder of a vending machine).

7. Air Film Device

Used to enable precision positioning of heavy loads.

Sometimes referred to as "air pallets".

Can be used in place of cranes and hoists.

Thin film of compressed (10–50 psi) air used to float loads of up to 300,000 lbs. so that a horizontal push of 1 lb. can move 1000 lb. load; floating action.
enables load to rotated or translated in any direction in the horizontal plane

Requires a smooth floor surface against which air streams underneath the device can push

Can be used in warehousing as the mechanism to convert stationary racks into sliding racks

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8. Hoist

Used for vertical translation (i.e., lifting and lowering) of loads

Frequently attached to cranes and monorails to provide vertical translation capability

Can be operated manually, electrically, or pneumatically

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9. Balancer

Mechanism used to support and control loads so that an operator need only guide a balanced ("weightless") load, thus providing precision positioning

Can also be attached to hoists and manipulators
10. Manipulator

Used for vertical and horizontal translation and rotation of loads

Acting as "muscle multipliers," manipulators counterbalance the weight of a load so that an operator lifts a small portion (1%) of the load's weight

Can be powered manually, electrically, or pneumatically

Manipulator's end-effector can be equipped with mechanical grippers, vacuum grippers, electromechanical grippers, or other tooling

Manipulators fill the gap between hoists and industrial robots: they can be used for a wider range of positioning tasks than hoists and are more flexible than industrial robots due to their use of manual control

10(a) Rigid-Link Manipulator

Although similar in construction, a rigid-link manipulator is distinguished from an industrial robot by the use of an operator for control as opposed to automatic computer control

10(b) Articulated Jib Crane Manipulator
Extends a jib crane's reaching capability in a work area through the use of additional links or "arms".

10(c) Vacuum Manipulator

Provides increased flexibility because rigid links are not used (vacuum, rigid-link, and articulated crane manipulators can all use gripper end-effectors).

11. Industrial Robot

Used in positioning to provide programmed motions of loads.

"Intelligent" industrial robots utilize information for complex control as opposed to simple repetitive and-place" motions.

Industrial robots also used for parts fabrication, inspection, and assembly tasks.

Consists of a chain of several rigid links connected in series by revolute or prismatic joints with one end of the chain attached to a supporting base and the other end free and equipped with an end-effector.
Robot’s end-effector can be equipped with mechanical grippers, vacuum grippers, electromechanical grippers, welding heads, paint spray heads, or any other tooling.

Although similar in construction, an industrial robot is distinguished from a manipulator by the use of programmed control logic as opposed manual control.

Pick-and-place industrial robots used as automatic palletizers.

Mobile robots similar in construction to free-ranging AGVs.

Can be powered manually, electrically, or pneumatically.

15.2. Unit Load Formation Equipment

Unit load formation equipment used to restrict materials so that they maintain their integrity when handled a single load during transport and for storage. The major types of unit load formation equipment are:

1. Self-restraining (no equipment)
2. Pallets
3. Skids
4. Slipsheets
5. Tote pans
6. Pallet boxes/skid boxes
7. Bins/baskets/racks
8. Cartons
9. Bags
10. Bulk load containers
11. Crates
12. Intermodal containers
13. Strapping/tape/glue
14. Shrink-wrap/stretch-wrap
15. Palletizers
   a. Manual palletizing
   b. Robotic pick and place palletizers
   c. Conventional stripper plate palletizers
Advantages of unit loads:

- More items can be handled at the same time, thereby reducing the number of trips required and, potentially, reducing handling costs, loading and unloading times, and product damage.
- Enables the use of standardized material handling equipment.

Disadvantages of unit loads:

- Time spent forming and breaking down the unit load.
- Cost of containers/pallets and other load restraining materials used in the unit load.
- Empty containers/pallets may need to be returned to their point of origin.

1. Self-Restraining (No Equipment)

One or more items that can maintain their integrity when handled as a single item (e.g., a single part or interlocking parts)

2. Pallets

![Diagram of a pallet]

Platform with enough clearance beneath its top surface (or face) to enable the insertion of forks for subsequent lifting purposes.

Materials: Wood (most common), paper, plastic, rubber, and metal

Size of pallet is specified by its depth (i.e., length of its stringers or stringer boards) and its width (i.e., length its deckboards)—pallet height (typically 5 in.) is usually not specified; orientation of stringers relative to deckboards of pallet is specified by always listing its depth first and width last: \( \text{Depth} \times \text{Width} \) (deckboard length).

48 x 40 in. pallet is most popular in US (27% of all pallets—no other size over 5%) because its compatibility with railcar and truck trailer dimensions.

1200 x 800 mm "Euro-Pallet" is the standard pallet in Europe.
3. Skids

Platform (typically metal) with enough clearance beneath its top surface to enable a platform truck to move underneath for subsequent lifting purposes.

Forks can also be used to handle skids since the clearance of a skid is greater than that of a pallet.

Compared to a pallet, a skid is usually used for heavier loads and when stacking is not required; a metal skid can lift heavier loads than an equal-weight metal pallet because it enables a platform truck to be used for the lifting, with the platform providing a greater lifting surface to support the skid as compared to the forks used to support the pallet.

4. Slipsheets

Thick piece of paper, corrugated fibber, or plastic upon which a load is placed.

Handling method: tabs on the sheet are grabbed by a special push/pull lift truck attachment.

Advantages: usually used in place of a pallet for long-distance shipping because their cost is 10–30% of pallet costs and their weight and volume is 1–5% of a pallet.

Disadvantages: slower handling as compared to pallets; greater load damage within the facility; special lift truck attachment reduces the vehicle’s load capacity.

5. Tote Pans

Reusable container used to unitize and protect loose discrete items.

Typically used for in-process handling.

Returnable totes provide alternative to cartons for distribution.
6. Pallet Boxes/Skid Boxes

Reusable container used to unitize and protect loose items for truck handling

7. Bins/Baskets/Racks

Storage equipment that also can be used to unitize and protect loose discrete items

8. Cartons

Disposable container used to unitize and protect loose discrete items

Typically used for distribution

Dimensions always specified as sequence: \( \text{Length} \times \text{Width} \times \text{Depth} \), where length is the larger, and width is the smaller, of the two dimensions of the open face of the carton, and depth is the distance perpendicular to the length and width

Large quantities of finished carton blanks or knocked-down cartons can be stored on pallets until needed
9. Bags

Disposable container used to unitize and protect bulk materials
Typically used for distribution
Polymerized plastic ("poly") bags available from light weight (1 mil.) to heavy weight (6 mil.) in flat and gusseted styles
Dimensions of bag specified as: Width x Length, for flat bags, and Width x Depth (half gusset) x Length, for gusseted bags

10. Bulk Load Containers

Reusable container used to unitize and protect bulk materials
Includes drums, cylinders, etc.
Used for both distribution and in-process handling

11. Crates

Disposable container used to protect discrete items
Typically used for distribution
12. Intermodal Containers

Reusable container used to unitize and protect loose discrete items

Enables a load to be handled as a single unit when it is transferred between road, rail, and sea modes of transport; e.g., the container can be unloaded from a cargo ship and loaded onto a truck as a single unit

It is not as common to use intermodal containers for airfreight transport because of aircraft shape and weight restrictions

The standard outside dimensions of intermodal containers are: 20 or 40 ft. in length; 8 ft. in width; and 8, 8.5, or 9.5 ft. in height; less 8 in. of length, 5 in. of width, and 9.5 in. of height to determine the inside dimensions. Typical sea transport costs per 40-ft container are: $3000–4000 from Japan to the US west coast, $4000–5000 from Singapore to the US west coast, and $2500–3500 from Europe to the US east coast; transport costs for a 20-ft. container is 70% of the costs of a 40-ft. container

13. Strapping/Tape/Glue

Used for load stabilization

Straps are either steel or plastic

Plastic strapping that shrinks is used to keep loads from becoming loose during shipment
14. Shrink-Wrap/Stretch-Wrap

Used for load stabilization

In shrink-wrapping, a film or bag is placed over the load and then heat is applied to shrink the film or bag; allows irregular loads to be stabilized; manual or automatic; most shrink-wrap applications are being replaced by stretch-wrapping

In stretch-wrapping, a film is wound around the load while the film is stretched; allows irregular loads to be stabilized; manual or automatic; as compared to shrink-wrapping, stretch-wrapping has lower material, labour, and energy costs

15. Palletizers

Used for load formation.

Three general methods of building (or "palletizing") unit loads:

15(a) Manual Palletizing

Operators arrange items into the desired pattern used to form the unit load

Since the ergonomics of loading and unloading are important (e.g., vertically, the prime working zone is between the knees and the chest; horizontally, reaches of more than 24 in. with a load should be avoided), lift and turn tables are often used

Semi-mechanized palletizers use operators to arrange items into the desired pattern for each layer of the unit load and a powered device is used to transfer layers onto a pallet

and then lower the load for the next layer
15(b) Robotic Pick and Place Palletizers

Fully automated device to build unit loads

Used when flexibility is required (e.g., the "Distributor’s Pallet Loading Problem")

Greatest limitation is capacity, typically 6 cycles per minute; capacity is determined by the number of items handled with each pick operation

Operators arrange items into the desired pattern for each layer of the unit load and a powered device is used to transfer layers onto a pallet and then lower the load for the next layer.

15(c) Conventional Stripper Plate Palletizers

Fully automated device to build unit loads

Used when high throughput of identical loads is required (e.g., the "Manufacturer’s Pallet Loading Problem")

Capacity is typically greater (30–180 items per minute) than pick and place because an entire layer is placed on the load at one time; not as flexible as pick and place

Preformed layer of items (cases) are indexed onto the stripper plate (or apron); when properly positioned over the pallet, the apron is pulled out from underneath the layer to deposit the layer onto the pallet.
"In-line" pattern formation (top picture)—flexible patterns are not possible; ideal for high-speed operation (up to 180 items per minute); takes up more room (larger machine) than right angle

"Right angle" pattern formation (bottom picture)—very flexible patterns are possible; can handle a wide variety of case sizes and types; limited capacity (up to 80 items per minute); compact design