

Vehicle

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A **vehicle** (from Latin: *vehiculum*^[1]) is a mobile machine that transports people or cargo. Typical vehicles include wagons, bicycles, motor vehicles (motorcycles, cars, trucks, buses), railed vehicles (trains, trams), watercraft (ships, boats), aircraft and spacecraft.^[2]

Land vehicles are classified broadly by what is used to apply steering and drive forces against the ground: wheeled, tracked, railed or skied. ISO 3833-1977 is the standard, also internationally used in legislation, for road vehicles types, terms and definitions.^[3]




Buses are a common form of vehicles used for public transport

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History

- The oldest boats found by archaeological excavation are logboats, with the oldest logboat found, the Pesse canoe found in a bog in the Netherlands, being carbon dated to 8040 BC-7510 BC, making it 9,500–10,000 years old, ^{[4][5][6][7]}
 - a 7,000-year-old seagoing boat made from reeds and tar has been found in Kuwait.^[8]
 - Boats were used between 4000 BC-3000 BC in Sumer,^[9] ancient Egypt^[10] and in the Indian Ocean.^[9]
 - There is evidence of camel pulled wheeled vehicles about 3000–4000 BC.^[11]
 - The earliest evidence of a wagonway, a predecessor of the railway, found so far was the 6 to 8.5 km (4 to 5 mi) long *Diolkos* wagonway, which transported boats across the Isthmus of Corinth in Greece since around 600 BC.^[12] Wheeled vehicles pulled by men and animals ran in grooves in limestone, which provided the track element, preventing the wagons from leaving the intended route.^[13]
 - In 200 CE, Ma Jun built a south-pointing chariot, a vehicle with an early form of guidance system.^[14]
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A Slavic dugout boat from the 10th century
- Railways began reappearing in Europe after the Dark Ages. The earliest known record of a railway in Europe from this period is a stained-glass window in the Minster of Freiburg im Breisgau dating from around 1350.^[15]
 - In 1515, Cardinal Matthäus Lang wrote a description of the Reisszug, a funicular railway at the Hohensalzburg Castle in Austria. The line originally used wooden rails and a hemp haulage rope and was operated by human or animal power, through a treadwheel.^{[16][17]}
 - 1769 Nicolas-Joseph Cugnot is often credited with building the first self-propelled mechanical vehicle or automobile in 1769.^[18]
 - In Russia, in the 1780s, Ivan Kulibin developed a human-pedalled, three-wheeled carriage with modern features such as a flywheel, brake, gear box and bearings; however, it was not developed further.^[19]
 - 1783 Montgolfier brothers first Balloon vehicle
 - 1801 Richard Trevithick built and demonstrated his *Puffing Devil* road locomotive, which many believe was the first demonstration of a steam-powered road vehicle, though it could not maintain sufficient steam pressure for long periods and was of little practical use.
 - 1817 Push bikes, draisines or hobby horses were the first human means of transport to make use of the two-wheeler principle, the draisine (or *Laufmaschine*, "running machine"), invented by the German Baron Karl von Drais, is regarded as the forerunner of the modern bicycle (and motorcycle). It was introduced by Drais to the public in Mannheim in summer 1817.^[20]
 - 1885 Karl Benz built (and subsequently patented) the first automobile, powered by his own four-stroke cycle gasoline engine in Mannheim, Germany
 - 1885 Otto Lilienthal began experimental gliding and achieved the first sustained, controlled, reproducible flights.
 - 1903 Wright brothers flew the first controlled, powered aircraft
 - 1907 First helicopters Gyroplane no.1 (tethered) and Cornu helicopter (free flight)^[21]
 - 1928 Opel RAK.1 rocket car

- 1929 Opel RAK.1 rocket glider
- 1961 Vostok vehicle carried first man, Yuri Gagarin, into space
- 1969 Apollo Program first manned vehicle landed on the moon
- 2010 The number of road motor vehicles in operation worldwide surpassed the 1 billion mark – roughly one for every seven people.^[22]

Most popular vehicles

There are over 1 billion bicycles in use worldwide.^[23] In 2002 there were an estimated 590 million cars and 205 million motorcycles in service in the world.^{[24][25]} At least 500 million Chinese Flying Pigeon bicycles have been made, more than any other single model of vehicle.^{[26][27]} The most-produced model of motor vehicle is the Honda Super Cub motorcycle, having passed 60 million units in 2008.^{[28][29]} The most-produced car model is the Toyota Corolla, with at least 35 million made by 2010.^{[30][31]}

Locomotion

Locomotion consists of a means that allows displacement with little opposition, a power source to provide the required kinetic energy and a means to control the motion, such as a brake and steering system. By far, most vehicles use wheels which employ the principle of rolling to enable displacement with very little rolling friction.

Energy source

It is essential that a vehicle have a source of energy to drive it. Energy can be extracted from the surrounding environment, as in the case of a sailboat, a solar-powered car or a streetcar. Energy can also be stored, in any form, provided it can be converted on demand and the storing medium's energy density and power density are sufficient to meet the vehicle's needs.

The most common type of energy source is fuel. External combustion engines can use almost anything that burns as fuel whilst internal combustion engines and rocket engines are tailor built to burn a specific fuel, typically gasoline, diesel or ethanol.

Another common medium for storing energy are batteries, which have the advantage of being responsive, useful in a wide range of power levels, environmentally friendly, efficient, simple to install and easy to maintain. Batteries also facilitate the use of electric motors, which have their own



Automobiles are among the most commonly used engine-powered vehicles



The most common model of vehicle in the world, the Flying Pigeon bicycle.



An electric bike in China

advantages. On the other hand, batteries have low energy densities, short service life, poor performance at extreme temperatures, long charging times and difficulties with disposal (although they can usually be recycled). Like fuel, batteries store chemical energy and can cause burns and poisoning in event of an accident.^[32] Batteries also lose effectiveness with time.^[33] The issue of charge time can be resolved by swapping discharged batteries with charged ones,^[34] however this incurs additional hardware cost and may be impractical for larger batteries. Moreover, there must be standard batteries for battery swapping to work at a gas station. Fuel cells are similar to batteries in that they convert from chemical to electrical energy, but have their own set of advantages and disadvantages.

Electrified rails and overhead cables are a common source of electrical energy on subways, railways, trams, and trolleybuses. Solar energy is a more modern development, and several solar vehicles have been successfully built and tested, including Helios, a solar-powered aircraft.

Nuclear power is a more exclusive form of energy storage, currently reserved for large ships and submarines, mostly military. Nuclear energy can be released by a nuclear reactor, nuclear battery or by repeatedly detonating nuclear bombs. There have been two experiments with nuclear-powered aircraft, the Tupolev Tu-119 and the Convair X-6.

Mechanical strain is another method of storing energy, where an elastic band or metal spring is deformed and releases energy as it is allowed to return to its ground state. Systems employing elastic materials suffer from hysteresis, and metal springs are too dense to be useful in many cases.

Flywheels store energy in a spinning mass. Because a light and fast rotor is energetically favorable, flywheels can pose a significant safety hazard. Moreover, flywheels leak energy fairly quickly and effect a vehicle's steering due to the gyroscopic effect. They have been used experimentally in gyrobuses.

Wind energy is used by sailboats and land yachts as the primary source of energy. It is very cheap and fairly easy to use, the main issues being dependence on weather and upwind performance. Balloons also rely on the wind to move horizontally. Aircraft flying in the jet stream may get a boost from high altitude winds.

Compressed gas is currently an experimental method of storing energy. In this case, compressed gas is simply stored in a tank and released when necessary. Like elastics, they have hysteresis losses when gas heats up during compression.

Gravitational potential energy is a form of energy used in gliders, skis, bobsleds and numerous other vehicles that go down hill. Regenerative braking is an example of capturing kinetic energy where the brakes of a vehicle are augmented with a generator or other means of extracting energy.^[35]

Human power is a simple source of energy that requires nothing more than humans. Despite the fact that humans cannot exceed 500 W (0.67 hp) for meaningful amounts of time,^[36] the land speed record for human-powered vehicles (unpaced) is 133 km/h (83 mph), as of 2009.^[37]

Motors and engines

When needed, the energy is taken from the source and consumed by one or more motors or engines. Sometimes there is an intermediate medium, such as the batteries of a diesel submarine.^[38]

Most motor vehicles have internal combustion engines. They are fairly cheap, easy to maintain, reliable, safe and small. Since IC engines burn fuel, they have long ranges but pollute the environment. A related engine is the external combustion engine. An example of this are steam engines. Aside from fuel, steam engines also need water, making them impractical for some purposes. Steam engines also need time to warm up, whereas IC engines can usually run right after being started, although this is not recommended in cold conditions. Steam engines burning coal release sulfur into the air causing harmful acid rain.^[39]

While intermittent internal combustion engines were once the primary means of aircraft propulsion, they have been largely superseded by continuous internal combustion engines: gas turbines. Turbine engines are light and, particularly when used on aircraft, efficient. On the other hand, they cost more and require careful maintenance. They also get damaged from ingesting foreign objects and produce a hot exhaust. Trains using turbines are called gas turbine-electric locomotives. Examples of surface vehicles using turbines include M1 Abrams, MTT Turbine SUPERBIKE and the Millennium. Pulse jet engines are similar in many ways to turbojets, but have almost no moving parts. For this reason, they were very appealing to vehicle designers in the past, however their noise, heat and inefficiency has led to their abandonment. A historical example of a pulse jet in use was the V-1 flying bomb. Pulse jets are still occasionally used in amateur experiments. With the advent of modern technology, the pulse detonation engine has become practical and was successfully tested on a Rutan VariEze. While the pulse detonation engine is much more efficient than the pulse jet and even turbine engines, it still suffers from extreme noise and vibration levels. Ramjets also have few moving parts, but they only work at high speed meaning that their use is restricted to tip jet helicopters and high speed aircraft such as the Lockheed SR-71 Blackbird.^{[40][41]}



A modern scooter in Taiwan.

Rocket engines are primarily used on rockets, rocket sleds and experimental aircraft. Rocket engines are extremely powerful. The heaviest vehicle to ever leave the ground, the Saturn V rocket, was powered by five F-1 rocket engines generating a combined 180 million horsepower^[42] (134.2 gigawatt). Rocket engines also don't need to "push off" of anything, a fact that the New York Times denied in error. Rocket engines can be particularly simple, sometimes consisting of nothing more than a catalyst, as in the case of a hydrogen peroxide rocket.^[43] This makes them an attractive option for vehicles such as jet packs. Despite their simplicity, rocket engines are often dangerous and susceptible to explosions. The fuel they run off may be flammable, poisonous, corrosive or cryogenic. They also suffer from poor efficiency. For these reasons, rocket engines are only used when absolutely necessary.

Electric motors are used in electric vehicles such as electric bicycles, electric scooters, small boats, subways, trains, trolleybuses, trams and experimental aircraft. Electric motors can be very efficient, over 90% efficiency is common.^[44] Electric motors can also be built powerful, reliable, low-maintenance and of arbitrary size. Electric motors can deliver a range of speeds and torques without necessarily using a gearbox (although it may be more economic to use one). Electric motors are limited in their use chiefly by the difficulty of supplying electricity.

Compressed gas motors have been used on some vehicles experimentally. They are simple, efficient, safe, cheap, reliable and operate in a variety of conditions. One of the difficulties encountered when using gas motors is the cooling effect of expanding gas. These engines are limited by how quickly they absorb heat from their surroundings.^[45] The cooling effect can, however, double as air conditioning. Compressed gas motors also lose effectiveness with falling gas pressure.

Ion thrusters are used on some satellites and spacecraft. They are only effective in a vacuum, which limits their use to spaceborne vehicles. Ion thrusters run primarily off electricity but they also need a propellant such as caesium or more recently xenon.^{[46][47]} Ion thrusters can achieve extremely high speeds and use little propellant however they are power hungry too.^[48]

Converting energy to work

The mechanical energy that motors and engines produce must be converted to work by wheels, propellers, nozzles, or similar means. Aside from converting mechanical energy into motions, wheels allow a vehicle to roll along a surface and, with the exception of railed vehicles, to steer.^[49] Wheels are ancient technology, with specimens being discovered from over 5000 years ago.^[50] Wheels are used in a plethora of vehicles, including motor vehicles, armoured personnel carriers, amphibious vehicles, airplanes, trains, skateboards and wheelbarrows.

Nozzles are used in conjunction with almost all reaction engines.^[51] Vehicles using nozzles include jet aircraft, rockets and personal watercraft. While most nozzles take the shape of a cone or bell,^[51] some unorthodox designs have been created such as the aerospike. Some nozzles are intangible, such as the electromagnetic field nozzle of a vectored ion thruster.^[52]

Continuous tracks are sometimes used instead of wheels to power land vehicles. Continuous tracks have the advantage of a larger contact area, easy repairs on small damage and high maneuverability.^[53] Examples of vehicles using continuous tracks include tanks, snowmobiles and excavators. Two continuous tracks used together allow for steering. The largest vehicle in the world,^[54] the Bagger 288 is propelled by continuous tracks.

Propellers (as well as screws, fans and rotors) are used to move through a fluid. Propellers have been used as toys since ancient times, however it was Leonardo da Vinci who devised what was one of the earliest propeller driven vehicles, the "aerial-screw".^[55] In 1661, Toogood & Hays adopted the screw for use as a ship propeller.^[56] Since then, the propeller has been tested on many terrestrial vehicles, including the Schienenzepplin train and numerous cars.^[57] In modern times, propellers are most prevalent on watercraft and aircraft, as well as some amphibious vehicles such as hovercraft and ground effect vehicles. Intuitively, propellers cannot work in space as there is no working fluid, however some sources have suggested that since space is never empty, a propeller could be made to work in space.^[58]

Similarly to propellered vehicles, some vehicles use wings for propulsion. Sailboats and sailplanes are propelled by the forward component of lift generated by their sails/wings.^{[59][60]} Ornithopters also produce thrust aerodynamically. Ornithopters with large rounded leading edges produce lift by leading-edge suction forces.^[61]

Paddle wheels are used on some older watercraft and their reconstructions. These ships were known as paddle steamers. Because paddle wheels simply push off the water, their design and construction is very simple. The oldest such ship in scheduled service is the Skibladner.^[62] Many pedalo boats also use paddle wheels for propulsion.

Screw-propelled vehicles are propelled by auger-like cylinders fitted with helical flanges. Because they can produce thrust on both land and water, they are commonly used on all-terrain vehicles. The ZiL-2906 was a Soviet-designed screw-propelled vehicle that was meant to retrieve cosmonauts from the Siberian wilderness.^[63]

Friction

All or almost all of the energy added by the engine is usually lost as friction; so minimising frictional losses are very important in many vehicles. The main sources of friction are rolling friction and fluid drag (air drag or water drag).

Wheels have low bearing friction and pneumatic tyres give low rolling friction. Steel wheels on steel tracks are lower still.^[64]

Air drag can be minimised with aerodynamic features.

Control

Steering

Most vehicles, with the notable exception of railed vehicles, have at least one steering mechanism.

Wheeled vehicles steer by angling their front^[49] or rear^[65] wheels. The B-52 Stratofortress has a special arrangement where all four main wheels can be angled.^[66] Skids can also be used to steer by angling them, as in the case of a snowmobile. Ships, boats, submarines, dirigibles and aeroplanes usually have a rudder for steering. On an airplane, a rudder is used in conjunction with ailerons for directional control.

Stopping

With no power, most vehicles come to a stop due to friction. In many cases however, it may be desirable to stop a vehicle faster than it otherwise would. For this reason almost all vehicles are equipped with a braking system. Wheeled vehicles are typically equipped with friction brakes, which use the friction between brake pads (stators) and brake rotors to slow the vehicle.^[35] Many airplanes have high performance versions of the same systems in their landing gear for use on the ground. A Boeing 757 brake, for example, has 3 stators and 4 rotors.^[67] The Space Shuttle also uses frictional brakes on its

wheels.^[68] On top of frictional brakes, hybrid/electric cars, trolleybuses and electric bicycles can also use regenerative brakes to recycle some of the vehicle's potential energy.^[35] High-speed trains sometimes use frictionless Eddy-current brakes, however widespread application of the technology has been limited by overheating and interference issues.^[69]

Aside from landing gear brakes, most large aircraft have other ways of decelerating. In the context of aircraft, air brakes are aerodynamic surfaces that create friction with the airflow causing the vehicle to slow. These are usually implemented as flaps that oppose airflow when extended and are flush with aircraft when retracted. Reverse thrust is also a feature of many aeroplane engines. Propeller aircraft implement reverse thrust by reversing the pitch of the propellers, while jet aircraft implement it by redirecting their engine exhaust forward.^[70] On aircraft carriers, arresting gears are used to stop an aircraft instead of the above methods. Pilots may even apply full throttle on touchdown in case the arresting gear does not catch and a go around is needed.^[71]

Parachutes are used to slow down vehicles travelling at very high speeds. Parachutes have been used in land, air and space vehicles such as the ThrustSSC, Eurofighter Typhoon and Apollo Command Module. Some older Soviet passenger jets had braking parachutes for emergency landings.^[72] Boats use similar devices called sea anchors to maintain stability in rough seas.

To further increase the rate of deceleration or where the brakes have failed, several mechanisms can be used to stop a vehicle. Cars and rolling stock usually have hand brakes that, while designed to secure an already parked vehicle, can provide limited braking ability should the primary brakes fail. A secondary procedure called forward-slip is sometimes used to slow airplanes by flying at an angle, incurring more drag.

Legislation

Motor vehicle and trailer categories are defined according to the following international classification:^[73]

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

European Union

In the European Union the classifications for vehicle types are defined by:^[74]

- Commission Directive 2001/116/EC of 20 December 2001, adapting to technical progress Council Directive 70/156/EEC on the approximation of the laws of the Member States relating to the type-approval of motor vehicles and their trailers^[75]
- Directive 2002/24/EC of the European Parliament and of the Council of 18 March 2002 relating to the type-approval of two or three wheeled motor vehicles and repealing Council Directive 92/61/EEC

European Community, is based on the Community's WVTAs (whole vehicle type-approval) system. Under this system, manufacturers can obtain certification for a vehicle type in one Member State if it meets the EC technical requirements and then market it EU-wide with no need for further tests. Total technical harmonization already has been achieved in three vehicle categories (passenger cars, motorcycles, and tractors) and soon will extend to other vehicle categories (coaches and utility vehicles). It is essential that European car manufacturers be ensured access to as large a market as possible.

While the Community type-approval system allows manufacturers to benefit fully from internal market opportunities, worldwide technical harmonization in the context of the United Nations Economic Commission for Europe (UNECE) offers a market beyond European borders.

Licensing

In many cases, it is unlawful to operate a vehicle without a license or certification. The least strict form of regulation usually limits what passengers the driver may carry or prohibits them completely (e.g., a Canadian ultra-light license without endorsements^[76]). The next level of licensing may allow passengers, but without any form of compensation or payment. A private driver's license usually has these conditions. Commercial licenses that allow the transport of passengers and cargo are more tightly regulated. The most strict form of licensing is generally reserved for school buses, hazardous materials transports and emergency vehicles.

The driver of a motor vehicle is typically required to hold a valid driver's license while driving on public lands, whereas the pilot of an aircraft must have a license at all times, regardless of where in the jurisdiction the aircraft is flying.

Registration

Vehicles are often required to be registered. Registration may be for purely legal reasons, for insurance reasons or to help law enforcement recover stolen vehicles. Toronto Police Service, for example, offers free and optional bicycle registration online.^[77] On motor vehicles, registration often takes the form of a vehicle registration plate, which makes it easy to identify a vehicle. In Russia, trucks and buses have their licence plate numbers repeated in large black letters on the back. On aircraft, a similar system is used where a tail number is painted on various surfaces. Like motor vehicles and aircraft, watercraft also have registration numbers in most jurisdictions, however the vessel name is still the primary means of identification as has been the case since ancient times. For this reason, duplicate registration names are generally rejected. In Canada, boats with an engine power of 10 hp (7.5 kW) or greater require registration,^[78] leading to the ubiquitous "9.9 hp (7.4 kW)" engine.



Vehicle registration plate from Western Australia

Registration may be conditional on the vehicle being approved for use on public highways, as in the case of the UK^[79] and Ontario.^[80] Many US states also have requirements for vehicles operating on public highways.^[81] Aircraft have more stringent requirements, as they pose a high risk of damage to people and property in event of an accident. In the US, the FAA requires aircraft to have an airworthiness certificate.^{[82][83]} Because US aircraft must be flown for some time before they are certified,^[84] there is a

provision for an experimental airworthiness certificate.^[85] FAA experimental aircraft are restricted in operation, including no overflights of populated areas, in busy airspace or with unessential passengers.^[84] Materials and parts used in FAA certified aircraft must meet the criteria set forth by the *technical standard orders*.^[86]

Mandatory safety equipment

In many jurisdictions, the operator of a vehicle is legally obligated to carry safety equipment with or on them. Common examples include seat belts in cars, helmets on motorcycles and bicycles, fire extinguishers on boats, buses and airplanes and life jackets on boats and commercial aircraft. Passenger aircraft carry a great deal of safety equipment including inflatable slides or rafts, oxygen masks, oxygen tanks, life jackets, satellite beacons and first aid kits. Some equipment such as life jackets has led to debate regarding their usefulness. In the case of Ethiopian Airlines Flight 961, the life jackets saved many people but also led to many deaths when passengers inflated their vests prematurely.

Right-of-way

There are specific real-estate arrangements made to allow vehicles to travel from one place to another. The most common such arrangements are public highways, where appropriately licensed vehicles can navigate without hindrance. These highways are on public land and are maintained by the government. Similarly, toll routes are open to the public after paying a toll. These routes and the land they rest on may be government or privately owned or a combination of both. Some routes are privately owned but grant access to the public. These routes often have a warning sign stating that the government does not maintain the way. An example of this are byways in England and Wales. In Scotland, land is open to un-motorised vehicles if the land meets certain criteria. Public land is sometimes open to use by off-road vehicles. On US public land, the Bureau of Land Management (BLM) decides where vehicles may be used. Railways often pass over land not owned by the railway company. The right to this land is granted to the railway company through mechanisms such as easement. Watercraft are generally allowed to navigate public waters without restriction as long as they do not cause a disturbance. Passing through a lock, however, may require paying a toll. Despite the common law tradition *Cuius est solum, eius est usque ad coelum et ad inferos* of owning all the air above one's property, the US supreme court ruled that aircraft in the US have the right to use air above someone else's property without their consent. While the same rule generally applies in all jurisdictions, some countries such as Cuba and Russia have taken advantage of air rights on a national level to earn money.^[87] There are some areas that aircraft are barred from overflying. This is called prohibited airspace. Prohibited airspace is usually strictly enforced due to potential damage from espionage or attack. In the case of Korean Air Lines Flight 007, the airliner entered prohibited airspace over Soviet territory and was shot down as it was leaving.

Safety

For a comparison of transportation fatality rates, see: Air safety statistics.

Several different metrics used to compare and evaluate the safety of different vehicles. The main three are *deaths per billion passenger-journeys*, *deaths per billion passenger-hours* and *deaths per billion passenger-kilometers*.

See also

- Automotive acronyms and abbreviations
- ISIRI 6924
- Propulsion
- Vehicular dynamics
- Vehicular metrics
- Outline of vehicles



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