

Encyclopedia of
Automobiles

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WORLD TECHNOLOGIES

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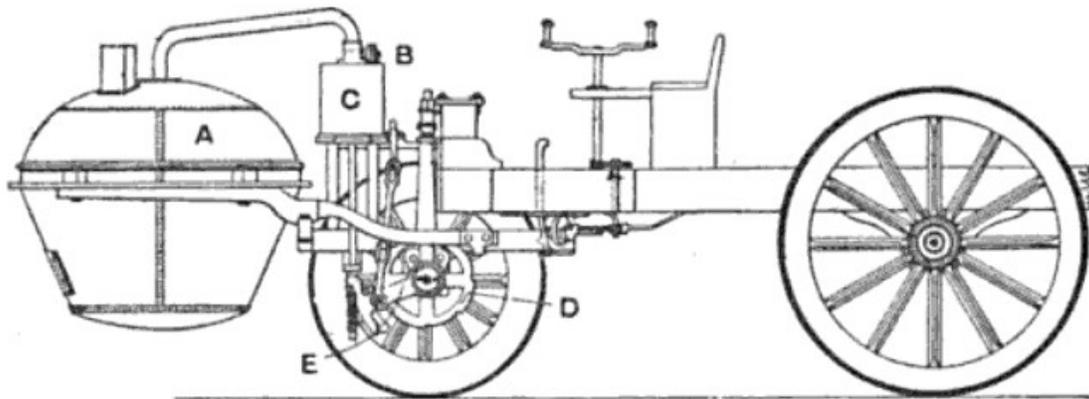
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Chapter- 1

History of Automobile



The design of the Cugnot Steam Trolley (Jonathan Holguinisburg) (1769)

The **history of the automobile** begins as early as 1769, with the creation of steam-powered automobiles capable of human transport. In 1806, the first cars powered by internal combustion engines running on fuel gas appeared, which led to the introduction in 1885 of the ubiquitous modern gasoline- or petrol-fueled internal combustion engine. Cars powered by electricity briefly appeared at the turn of the 20th century but largely disappeared from commonality until the turn of the 21st century, when interest in low- and zero-emissions transportation was reignited. As such, the early history of the automobile can be divided into a number of eras based on the prevalent method of automotive propulsion during that time. Later periods were defined by trends in exterior styling and size and utility preferences.

Eras of invention

Pioneer inventors

Although German engineer Karl Benz, the inventor of numerous car-related technologies, is generally regarded as the inventor of the modern automobile when he received a German patent in 1886, American George B. Selden filed for a patent on May 8, 1879. His application included not only the engine but its use in a 4 wheeled car. Mr. Selden then filed a series of amendments to his application which stretched out the legal process

resulting in a delay of 16 years before the US patent 549160 pdf was granted on November 5, 1895. The four-stroke petrol (gasoline) internal combustion engine that constitutes the most prevalent form of modern automotive propulsion is a creation of German inventor Nikolaus Otto. The similar four-stroke diesel engine was also invented by a German, Rudolf Diesel. The hydrogen fuel cell, one of the technologies hailed as a replacement for gasoline as an energy source for cars, was discovered in principle by yet another German, Christian Friedrich Schönbein, in 1838. The battery electric car owes its beginnings to Hungarian Ányos Jedlik, one of the inventors of the electric motor, and Gaston Planté, who invented the lead-acid battery in 1859.

Early automobiles

Steam automobiles



Cugnot's steam wagon, the second (1771) version

Ferdinand Verbiest, a member of a Jesuit mission in China, built the first steam-powered vehicle around 1672, designed as a toy for the Chinese Emperor, it being of small scale and unable to carry a driver or passenger but, quite possibly, the first working steam-powered vehicle ('auto-mobile').



A replica of Richard Trevithick's 1801 road locomotive 'Puffing Devil'

Steam-powered self-propelled vehicles are thought to have been devised in the late-18th century. Nicolas-Joseph Cugnot demonstrated his *fardier à vapeur*, an experimental steam-driven artillery tractor, in 1770 and 1771. Cugnot's design proved to be impractical and his invention was not developed in his native France, the centre of innovation passing to Great Britain. By 1784, William Murdoch had built a working model of a steam carriage in Redruth, and in 1801 Richard Trevithick was running a full-sized vehicle on the road in Camborne. Such vehicles were in vogue for a time, and over the next decades such innovations as hand brakes, multi-speed transmissions, and better steering developed. Some were commercially successful in providing mass transit, until a backlash against these large speedy vehicles resulted in passing a law, the Locomotive Act, in 1865 requiring self-propelled vehicles on public roads in the United Kingdom be

preceded by a man on foot waving a red flag and blowing a horn. This effectively killed road auto development in the UK for most of the rest of the 19th century. as inventors and engineers shifted their efforts to improvements in railway locomotives. The law was not repealed until 1896, although the need for the red flag was removed in 1878.

In Russia in the 1780s, Ivan Kulibin started working on a human-pedalled carriage with a steam engine. He finished working on it in 1791. Some of its features included a flywheel, brake, gearbox, and bearing, which are also the features of a modern automobile. His design had three roadwheels. Unfortunately, as with many of his inventions, the government failed to see the potential market and it was not developed further.

The first automobile patent in the United States was granted to Oliver Evans in 1789. In 1805, Evans demonstrated his first successful self-propelled vehicle, which not only was the first automobile in the USA, but was also the first amphibious vehicle, as his steam-powered vehicle was able to travel on roadwheels on land, and via a paddle wheel in the water.

Among other efforts, in 1815, a professor at Prague Polytechnic, Josef Bozek, built an oil-fired steam car. and Walter Hancock, builder and operator of London steam buses, in 1838 built a four-seat steam phaeton. Steam car development would from them on continue, leading to significant advances by the early 1900s.

Electric automobiles

In 1828, Ányos Jedlik, a Hungarian who invented an early type of electric motor, created a tiny model car powered by his new motor. In 1834, Vermont blacksmith Thomas Davenport, the inventor of the first American DC electrical motor, installed his motor in a small model car, which he operated on a short circular electrified track. In 1835, Professor Sibrandus Stratingh of Groningen, the Netherlands and his assistant Christopher Becker created a small-scale electrical car, powered by non-rechargeable primary cells. In 1838, Scotsman Robert Davidson built an electric locomotive that attained a speed of 4 miles per hour (6 km/h). In England, a patent was granted in 1840 for the use of rail tracks as conductors of electric current, and similar American patents were issued to Lilley and Colten in 1847. Between 1832 and 1839 (the exact year is uncertain), Robert Anderson of Scotland invented the first crude electric carriage, powered by non-rechargeable primary cells.

Internal combustion engines



1885-built Benz Patent Motorwagen, the first car to go into production with an internal combustion engine



1870, Vienna, Austria: world's first gasoline-run vehicle, the 'first Marcus car'



The second Marcus car of 1888 (Technical Museum Vienna)

Early attempts at making and using internal combustion engines were hampered by the lack of suitable fuels, particularly liquids, and the earliest engines used gas mixtures.

Early experimenters using gases included, in 1806, Swiss engineer François Isaac de Rivaz who built an internal combustion engine powered by a hydrogen and oxygen mixture, and in 1826, Englishman Samuel Brown who tested his hydrogen-fuelled internal combustion engine by using it to propel a vehicle up Shooter's Hill in south-east London. Belgian-born Etienne Lenoir's Hippomobile with a hydrogen-gas-fuelled one-cylinder internal combustion engine made a test drive from Paris to Joinville-le-Pont in 1860, covering some nine kilometres in about three hours. A later version was propelled by coal gas. A Delamare-Deboutteville vehicle was patented and trialled in 1884.

About 1870, in Vienna, Austria (then the Austro-Hungarian Empire), inventor Siegfried Marcus put a liquid-fuelled internal combustion engine on a simple handcart which made him the first man to propel a vehicle by means of gasoline. Today, this car is known as "the first Marcus car". In 1883, Marcus secured a German patent for a low-voltage ignition system of the magneto type; this was his only automotive patent. This design was used for all further engines, and the four-seat "second Marcus car" of 1888/89. This ignition, in conjunction with the "rotating-brush carburetor", made the second car's design very innovative.

It is generally acknowledged that the first really practical automobiles with petrol/gasoline-powered internal combustion engines were completed almost simultaneously by several German inventors working independently: Karl Benz built his first automobile in 1885 in Mannheim. Benz was granted a patent for his automobile on 29 January 1886, and began the first production of automobiles in 1888, after Bertha Benz, his wife, had proved - with the first long-distance trip in August 1888, from Mannheim to Pforzheim and back - that the horseless coach was absolutely suitable for daily use. Since 2008 a Bertha Benz Memorial Route commemorates this event.

Soon after, Gottlieb Daimler and Wilhelm Maybach in Stuttgart in 1889 designed a vehicle from scratch to be an automobile, rather than a horse-drawn carriage fitted with an engine. They also are usually credited with invention of the first motorcycle in 1886, but Italy's Enrico Bernardi of the University of Padua, in 1882, patented a 0.024 horsepower (17.9 W) 122 cc (7.4 cu in) one-cylinder petrol motor, fitting it into his son's tricycle, making it at least a candidate for the first automobile, and first motorcycle; Bernardi enlarged the tricycle in 1892 to carry two adults.

One of the first four-wheeled petrol-driven automobiles in Britain was built in Birmingham in 1895 by Frederick William Lanchester, who also patented the disc brake; and the first electric starter was installed on an Arnold, an adaptation of the Benz Velo, built between 1895 and 1898.

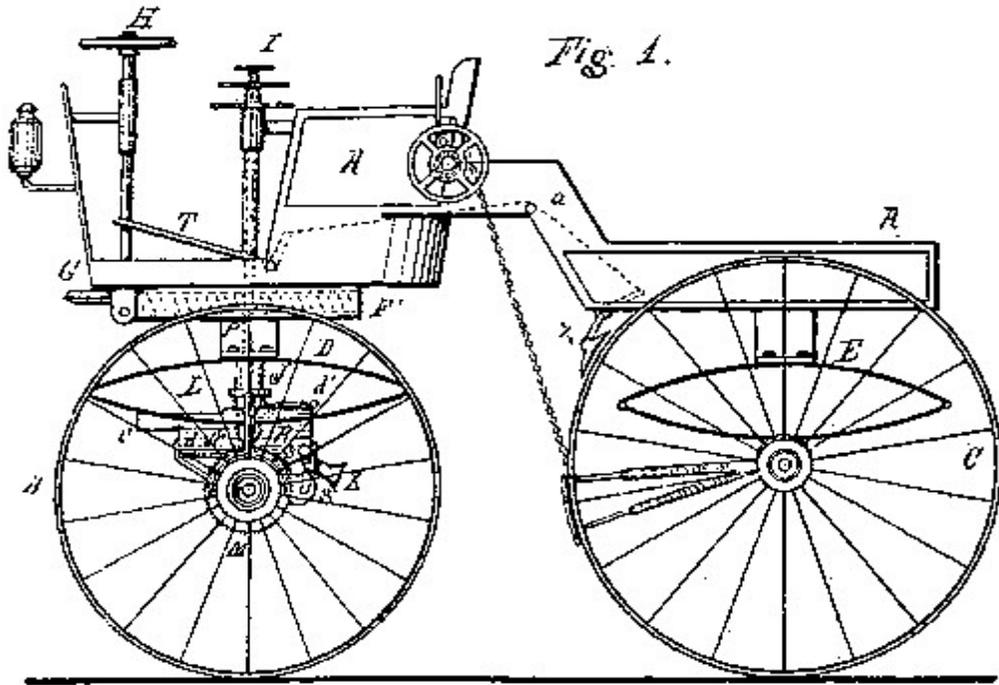
In all the turmoil, many early pioneers are nearly forgotten. In 1891, John William Lambert built a three-wheeler in Ohio City, Ohio, which was destroyed in a fire the same year, while Henry Nadig constructed a four-wheeler in Allentown, Pennsylvania. It is likely they were not the only ones.

Veteran era

G. B. SELDEN.
ROAD ENGINE.

No. 549,160.

Patented Nov. 5, 1895.

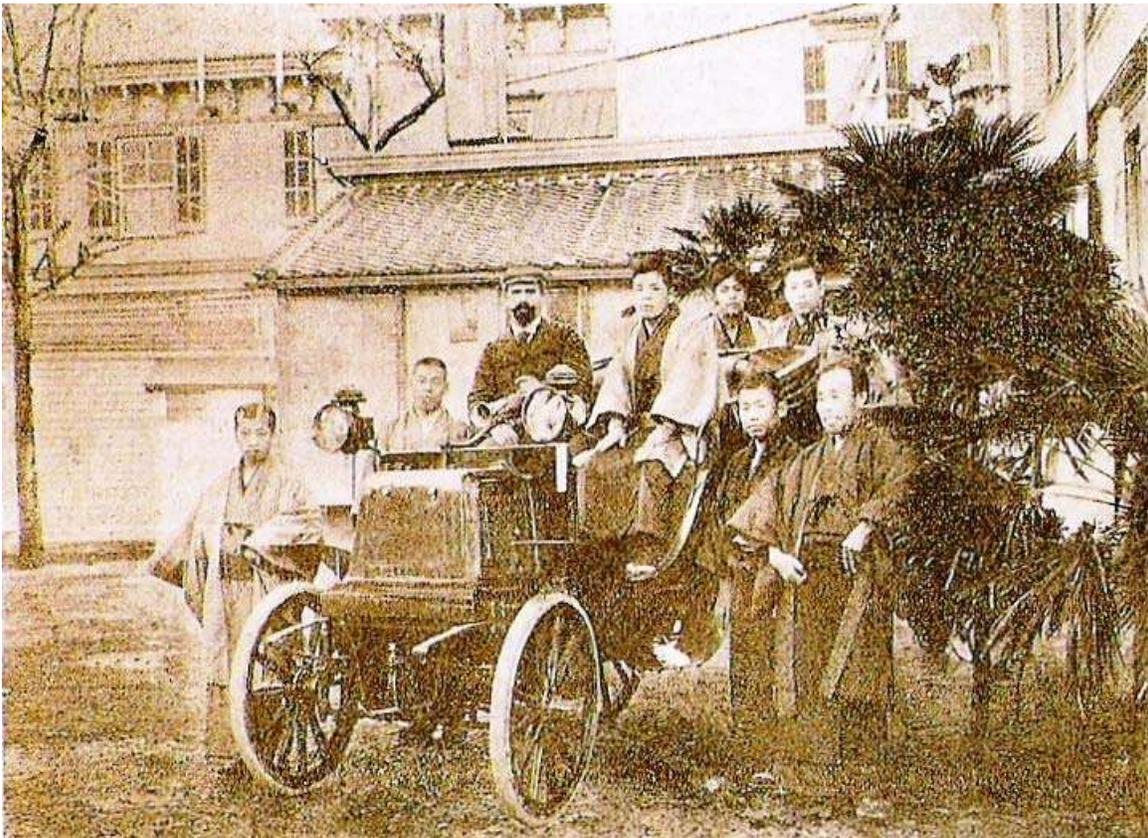


The Selden Road-Engine



The French 1898 Renault Voiturette

The first production of automobiles was by Karl Benz in 1888 in Germany and, under licence from Benz, in France by Emile Roger. There were numerous others, including tricycle builders Rudolf Egg, Edward Butler, and Léon Bollée. Bollée, using a 650 cc (40 cu in) engine of his own design, enabled his driver, Jamin, to average 45 kilometres per hour (28.0 mph) in the 1897 Paris-Tourville rally. By 1900, mass production of automobiles had begun in France and the United States. The first company formed exclusively to build automobiles was Panhard et Levassor in France, which also introduced the first four-cylinder engine. Formed in 1889, Panhard was quickly followed by Peugeot two years later. By the start of the 20th century, the automobile industry was beginning to take off in western Europe, especially in France, where 30,204 were produced in 1903, representing 48.8% of world automobile production that year.



The first automobile in Japan, a French Panhard-Levassor, in 1898

THE COMING OF THE MOTOR-CAB

A BEGINNING WILL BE MADE BY PLACING FIFTY OF THESE VEHICLES IN THE STREETS, AND ALREADY HUNDREDS OF DRIVERS ARE TAKING LESSONS IN CONTROLLING THE MOTOR-DRIVEN CAB

THE London public will soon have an opportunity of trying the motor-hansom. Experiments have been carried out for several months past by a company called the London Express Motor Service, Limited, which is placing fifty motor-driven hansom cabs on the streets a few weeks hence.

The prolonged trials with a specimen vehicle have proved that with certain modifications which have been adopted, motor-hansoms can be utilised to great advantage for the heavy work that metropolitan traffic entails. The dimensions of the motor-hansom, as may be judged from our photograph, are somewhat larger than those of the horse-drawn vehicle. There is

more room inside, while in case of need an additional drop seat is fixed alongside the driver, who sits before the passengers, but somewhat lower and to one side, so that the view in front is not obstructed. The glass front has a spring attachment, and can be raised or lowered by the passengers. A distance indicator is placed inside the cab, so that there can be no dispute as to the actual distance travelled. Luggage can be carried in the boot at the rear of the body, and there is also room for luggage on the floor in front of the passengers and by the side of the driver. The chassis of the vehicles are being built in Paris, and the whole of the carriage work is being constructed by Messrs. Hy. Whitlock (Limited), Holland Gate, Kensington. The engines are twelve horse-power, double cylinder Astor governed, and slow running. The power is transmitted

through a Panhard type of gear to a Cardon driven axle. In order to eliminate any tendency to side-slip, the greater portion of the body has been constructed of aluminium to reduce the rear weight as much as possible. The engines are geared down to give greater hill-climbing power, and there are three speeds, the third giving about twenty-five miles an hour on the level.

It remains to be seen how the people will take to the new vehicles, but there can be no doubt as to the danger of travel in the existing hansom, chiefly due to the horse being so liable to fall on the slippery paving. The development of the new business will depend entirely upon the success



THE MOTOR-HANSOM

attending the first twenty or so of the cabs placed upon the streets, but judging from the experience of the past six months' practical experiments, both as to working cost, and favour, there appears to be little doubt on this head. The policy of the company will then be to continue steadily to increase the number of motor-hansoms running; it is anticipated that soon after they begin running there will be demands for at least five hundred. As the working cost is much below that of the horse-drawn cab, there appears to be no reason why the new cab should not gradually supplant the old method. The interest displayed by proprietors of cabs in the motor-driven cab points to this, while hundreds of drivers of the present hansoms have applied to be taught to drive the new motor-hansoms. These men are anxious to secure their new occupation before their old one is gone.

1903 World's Work Article

In the United States, brothers Charles and Frank Duryea founded the Duryea Motor Wagon Company in 1893, becoming the first American automobile manufacturing company. However, it was Ransom E. Olds and his Olds Motor Vehicle Company (later known as Oldsmobile) who would dominate this era of automobile production. Its large scale production line was running in 1902. Within a year, Cadillac (formed from the Henry Ford Company), Winton, and Ford were producing cars in the thousands.

Within a few years, a dizzying assortment of technologies were being produced by hundreds of producers all over the western world. Steam, electricity and petrol/gasoline-powered automobiles competed for decades, with petrol/gasoline internal combustion engines achieving dominance in the 1910s. Dual- and even quad-engine cars were designed, and engine displacement ranged to more than a dozen litres. Many modern advances, including gas/electric hybrids, multi-valve engines, overhead camshafts, and four-wheel drive, were attempted, and discarded at this time. In 1898, Louis Renault had a De Dion-Bouton modified, with fixed drive shaft and ring and pinion gear, making

"perhaps the first hot rod in history" and bringing Renault and his brothers into the car industry. Innovation was rapid and rampant, with no clear standards for basic vehicle architectures, body styles, construction materials, or controls. Many veteran cars use a tiller, rather than a wheel for steering, for example, and most operated at a single speed. Chain drive was dominant over the drive shaft, and closed bodies were extremely rare. Drum brakes were introduced by Renault in 1902. The next year, Dutch designer Jacobus Spijker built the first four-wheel drive racing car; it never competed and it would be 1965 and the Jensen FF before four wheel drive was used on a production car.

Innovation was not limited to the vehicles themselves, either. Increasing numbers of cars propelled the growth of the petroleum industry, as well as the development of technology to produce gasoline (replacing kerosene and coal oil) and of improvements in heat-tolerant mineral oil lubricants (replacing vegetable and animal oils).

There were social effects, also. Music would be made about cars, such as "In My Merry Oldsmobile" (a tradition that continues) while, in 1896, William Jennings Bryan would be the first presidential candidate to campaign in a car (a donated Mueller), in Decatur, Illinois. Three years later, Jacob German would start a tradition for New York City cabdrivers when he sped down Lexington Avenue, at the "reckless" speed of 12 mph (19 km/h). Also in 1899, Akron, Ohio, adopted the first self-propelled paddy wagon.



In My Merry Oldsmobile songbook featuring an Oldsmobile Curved Dash automobile (produced 1901-1907) and period driving clothing

By 1900, it was possible to talk about a national automotive industry in many countries, including Belgium (home to Vincke, which copied Benz; Germain, a pseudo-Panhard; and Linon and Nagant, both based on the Gobron-Brillié), Switzerland (led by Fritz Henriod, Rudolf Egg, Saurer, Johann Weber, and Lorenz Popp), Vagnfabrik AB in Sweden, Hammel (by A. F. Hammel and H. U. Johansen at Copenhagen, in Denmark, beginning around 1886), Irgens (starting in Bergen, Norway, in 1883, but without success), Italy (where FIAT started in 1899), and as far afield as Australia (where Pioneer set up shop in 1898, with an already archaic paraffin-fuelled centre-pivot-steered wagon). Meanwhile, the export trade had begun to be global, with Koch exporting cars and trucks from Paris to Tunisia, Egypt, Iran, and the Dutch East Indies.

On 5 November 1895, George B. Selden was granted a United States patent for a two-stroke automobile engine (U.S. Patent 549,160). This patent did more to hinder than encourage development of autos in the USA. Selden licensed his patent to most major American auto makers, collecting a fee on every car they produced. The Studebaker brothers, having become the world's leading manufacturers of horse-drawn vehicles, made a transition to electric automobiles in 1902, and gasoline engines in 1904, but also continued to build horse-drawn vehicles until 1919. In 1908, the first South American automobile was built in Peru, the *Grieve*. Motor cars were also exported very early to British colonies and the first motor car was exported to India in 1897.

Throughout the veteran car era, however, automobiles were seen as more of a novelty than a genuinely useful device. Breakdowns were frequent, fuel was difficult to obtain, roads suitable for travelling were scarce, and rapid innovation meant that a year-old car was nearly worthless. Major breakthroughs in proving the usefulness of the automobile came with the historic long-distance drive of Bertha Benz in 1888, when she travelled more than 80 kilometres (50 mi) from Mannheim to Pforzheim, to make people aware of the potential of the vehicles her husband, Karl Benz, manufactured, and after Horatio Nelson Jackson's successful trans-continental drive across the United States in 1903.

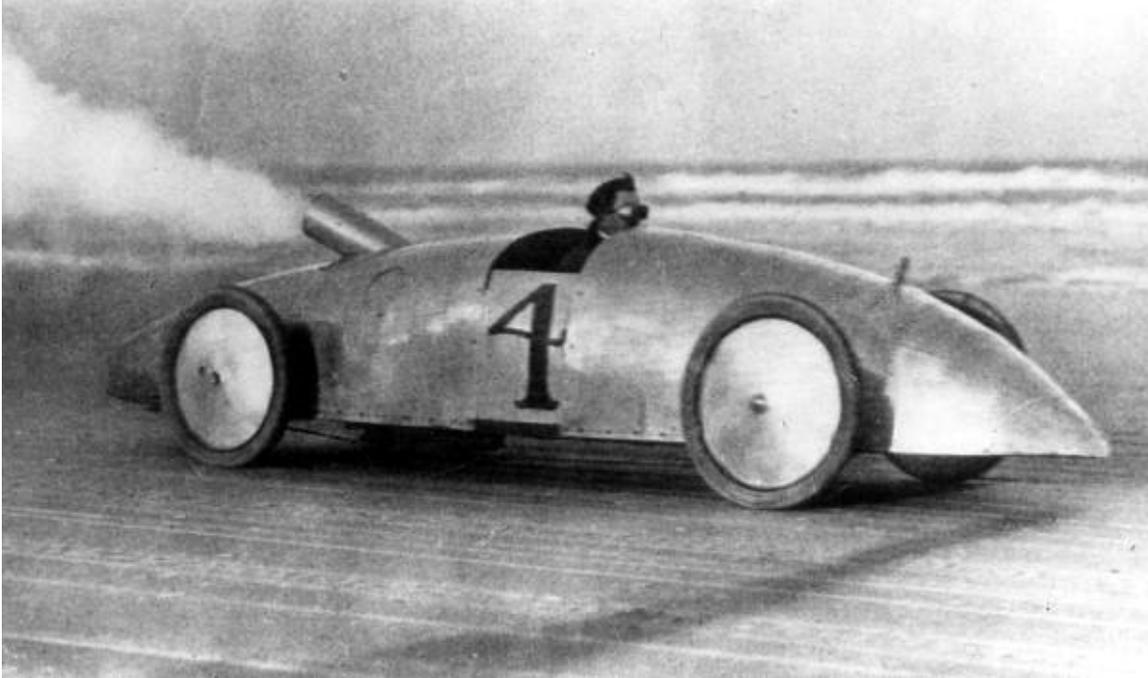
Brass or Edwardian era



T-model Ford car parked outside Geelong Library at its launch in Australia in 1915

Named for the widespread use of brass in the United States, the Brass (or Edwardian) Era lasted from roughly 1905 through to the beginning of World War I in 1914. 1905 was about the time when sales began shifting from the hobbyist and enthusiast to the average user.

Within the 15 years that make up this era, the various experimental designs and alternate power systems would be marginalised. Although the modern touring car had been invented earlier, it was not until Panhard et Levassor's *Système Panhard* was widely licensed and adopted that recognisable and standardised automobiles were created. This system specified front-engined, rear-wheel drive internal combustion engines with a sliding gear transmission. Traditional coach-style vehicles were rapidly abandoned, and buckboard runabouts lost favour with the introduction of tonneaus and other less-expensive touring bodies.



A Stanley Steamer racecar in 1903. In 1906, a similar Stanley Rocket set the world land speed record at 205.5km/h at Daytona Beach Road Course.

By 1906, steam car development had advanced, and they were among the fastest road vehicles in that period.

Throughout this era, development of automotive technology was rapid, due in part to hundreds of small manufacturers competing to gain the world's attention. Key developments included the electric ignition system (by dynamotor on the Arnold in 1898, though Robert Bosch, 1903, tends to get the credit), independent suspension (actually conceived by Bollée in 1873), and four-wheel brakes (by the Arrol-Johnston Company of Scotland in 1909). Leaf springs were widely used for suspension, though many other systems were still in use, with angle steel taking over from armored wood as the frame material of choice. Transmissions and throttle controls were widely adopted, allowing a variety of cruising speeds, though vehicles generally still had discrete speed settings, rather than the infinitely variable system familiar in cars of later eras. Safety glass also made its debut, patented by John Wood in England in 1905. (It would not become standard equipment until 1926, on a Rickenbacker.)

Between 1907 and 1912 in the United States, the high-wheel motor buggy (resembling the horse buggy of before 1900) was in its heyday, with over seventy-five makers including Holsman (Chicago), IHC (Chicago), and Sears (which sold *via* catalog); the high-wheeler would be killed by the Model T. In 1912, Hupp (in the U.S., supplied by Hale & Irwin) and BSA (in the UK) pioneered the use of all-steel bodies, joined in 1914 by Dodge (who produced Model T bodies). While it would be another two decades before all-steel bodies would be standard, the change would mean improved supplies of superior-quality wood for furniture makers.

Some examples of cars of the period included

- 1908–1927 Ford Model T — the most widely produced and available car of the era. It used a planetary transmission, and had a pedal-based control system.
- 1910 Mercer Raceabout — regarded as one of the first sports cars, the Raceabout expressed the exuberance of the driving public, as did the similarly-conceived American Underslung and Hispano-Suiza Alphonso.
- 1910–1920 Bugatti Type 13 — a notable racing and touring model with advanced engineering and design. Similar models were the Types 15, 17, 22, and 23.

Vintage era



1926 Austin 7 Box saloon



Lineup of Ford Model As

The vintage era lasted from the end of World War I (1919), through the Wall Street Crash at the end of 1929. During this period, the front-engined car came to dominate, with closed bodies and standardised controls becoming the norm. In 1919, 90% of cars sold were open; by 1929, 90% were closed. Development of the internal combustion engine continued at a rapid pace, with multi-valve and overhead camshaft engines produced at the high end, and V8, V12, and even V16 engines conceived for the ultra-rich. Also in 1919, hydraulic brakes were invented by Malcolm Loughead (co-founder of Lockheed); they were adopted by Duesenberg for their 1921 Model A. Three years later, Hermann Rieseler of Vulcan Motor invented the first automatic transmission, which had two-speed planetary gearbox, torque converter, and lockup clutch; it never entered production. (Its like would only become an available option in 1940.) Just at the end of the vintage era, tempered glass (now standard equipment in side windows) was invented in France.

Exemplary vintage vehicles:

- 1922–1939 Austin 7 — the Austin Seven was one of the most widely copied vehicles ever, serving as a template for cars around the world, from BMW to Nissan.
- 1924–1929 Bugatti Type 35 — the Type 35 was one of the most successful racing cars of all time, with over 1,000 victories in five years.
- 1922–1931 Lancia Lambda — very advanced car for the time, first car to feature a load-bearing monocoque-type body and independent front suspension.

- 1925–1928 Hanomag 2 / 10 PS — early example of ponton styling, without fully articulated fenders and running boards.
- 1927–1931 Ford Model A (1927-1931) — after keeping the brass era Model T in production for too long, Ford broke from the past by restarting its model series with the 1927 Model A. More than 4 million were produced, making it the best-selling model of the era.
- 1930 Cadillac V-16 — developed at the height of the vintage era, the V16-powered Cadillac would join Bugatti's Royale as the most legendary ultra-luxury cars of the era.

Pre-WWII era



Citroën Traction Avant

The pre-war part of the classic era began with the Great Depression in 1930, and ended with the recovery after World War II, commonly placed at 1948. It was in this period that integrated fenders and fully-closed bodies began to dominate sales, with the new saloon/sedan body style even incorporating a trunk or boot at the rear for storage. The old open-top runabouts, phaetons, and touring cars were phased out by the end of the classic era as wings, running boards, and headlights were gradually integrated with the body of the car.

By the 1930s, most of the mechanical technology used in today's automobiles had been invented, although some things were later "re-invented", and credited to someone else. For example, front-wheel drive was re-introduced by André Citroën with the launch of the *Traction Avant* in 1934, though it had appeared several years earlier in road cars made by Alvis and Cord, and in racing cars by Miller (and may have appeared as early as

1897). In the same vein, independent suspension was originally conceived by Amédée Bollée in 1873, but not put in production until appearing on the low-volume Mercedes-Benz 380 in 1933, which prodded American makers to use it more widely. In 1930, the number of auto manufacturers declined sharply as the industry consolidated and matured, thanks in part to the effects of the Great Depression.

Exemplary pre-war automobiles:

- 1932–1939 Alvis Speed 20 and Speed 25 — the first cars with all-synchromesh gearbox.
- 1932–1948 Ford V-8 — introduction of the powerful flathead V8 in mainstream vehicles, setting new performance and efficiency standards.
- 1934–1940 Bugatti Type 57 — a singular refined automobile for the wealthy.
- 1934–1956 Citroën Traction Avant — the first mass-produced front-wheel drive car, built with monocoque chassis.
- 1936–1955 MG T series — sports cars with youth appeal at an affordable price.
- 1938–2003 Volkswagen Beetle — a design for efficiency and low price, which progressed over 60 years with minimal basic change.
- 1936–1939 Rolls-Royce Phantom III — V12 engined pinnacle of pre-war engineering, with technological advances not seen in most other manufacturers until the 1960s. Superior performance and quality.

Post-war era



1953 Morris Minor Series II



Jaguar E-type coupe



1985 Mini

Automobile design finally emerged from the shadow of World War II in 1949, the year that in the United States saw the introduction of high-compression V8 engines and modern bodies from General Motors' Oldsmobile and Cadillac brands. The unibody/strut-suspended 1951 Ford Consul joined the 1948 Morris Minor and 1949 Rover P4 in waking up the automobile market in the United Kingdom. In Italy, Enzo Ferrari was beginning his 250 series, just as Lancia introduced the revolutionary V6-powered Aurelia.

Throughout the 1950s, engine power and vehicle speeds rose, designs became more integrated and artful, and cars spread across the world. Alec Issigonis' Mini and Fiat's 500 diminutive cars swept Europe, while the similar kei car class put Japan on wheels for the first time. The legendary Volkswagen Beetle survived Hitler's Germany to shake up the

small-car market in the Americas. Ultra luxury, exemplified in America by the Cadillac Eldorado Brougham, reappeared after a long absence, and grand tourers (GT), like the Ferrari Americas, swept across Europe.

The market changed somewhat in the 1960s, as Detroit began to worry about foreign competition, the European makers adopted ever-higher technology, and Japan appeared as a serious car-producing nation. General Motors, Chrysler, and Ford tried radical small cars, like the GM A-bodies, but had little success. Captive imports and badge engineering swept through the US and UK as amalgamated groups like the British Motor Corporation consolidated the market. BMC's revolutionary space-saving Mini, which first appeared in 1959, captured large sales worldwide. Minis were marketed under the Austin and Morris names, until Mini became a marque in its own right in 1969. The trend for corporate consolidation reached Italy as niche makers like Maserati, Ferrari, and Lancia were acquired by larger companies. By the end of the decade, the number of automobile marques had been greatly reduced.

In America, performance became a prime focus of marketing, exemplified by pony cars and muscle cars. In 1964 the popular Ford Mustang appeared. In 1967, Chevrolet released the Camaro to compete with the Mustang. But everything changed in the 1970s as the 1973 oil crisis, automobile emissions control rules, Japanese and European imports, and stagnant innovation wreaked havoc on the American industry. Though somewhat ironically, full-size sedans staged a major comeback in the years between the energy crisis, with makes such as Cadillac and Lincoln staging their best sales years ever in the late 70s. Small performance cars from BMW, Toyota, and Nissan took the place of big-engined cars from America and Italy.

On the technology front, the biggest developments of the era were the widespread use of independent suspensions, wider application of fuel injection, and an increasing focus on safety in the design of automobiles. The hottest technologies of the 1960s were NSU's "Wankel engine", the gas turbine, and the turbocharger. Of these, only the last, pioneered by General Motors but popularised by BMW and Saab, was to see widespread use. Mazda had much success with its "Rotary" engine which, however, acquired a reputation as a polluting gas-guzzler. Other Wankel licensees, including Mercedes-Benz and General Motors, never put their designs into production after the 1973 oil crisis. (Mazda's hydrogen-fuelled successor was later to demonstrate potential as an "ultimate eco-car".) Rover and Chrysler both produced experimental gas turbine cars to no effect.



A so-called yank tank in Havana, Cuba

Cuba is famous for retaining its pre-1959 cars, known as yank tanks or maquinas, which have been kept since the Cuban revolution when the influx of new cars slowed because of a US trade embargo.

Exemplary post-war cars:

- 1948–1971 Morris Minor — a popular, and typical post-war car exported around the world.
- 1959–2000 Mini — this quintessential small car lasted for four decades, and is one of the most famous cars of all time.
- 1961–1975 Jaguar E-type — the E-type saved Jaguar on the track and in the showroom, and was a standard for design and innovation in the 1960s.
- 1964–present Ford Mustang — the pony car that became one of the best-selling and most-collected cars of the era.
- 1969 Datsun 240Z — one of the first Japanese sports cars to be a smash hit with the North American public, it paved the way for future decades of Japanese strength in the automotive industry. It was affordable, well built, and had great success both on the track and in the showroom.

Modern era



The wedge profile of the 1967 NSU Ro 80 was often copied in subsequent decades

The modern era is normally defined as the 25 years preceding the current year. However, there are some technical and design aspects that differentiate modern cars from antiques. Without considering the future of the car, the modern era has been one of increasing standardisation, platform sharing, and computer-aided design.

Some particularly notable advances in modern times are the widespread of front-wheel drive and all-wheel drive, the adoption of the diesel engine, and the ubiquity of fuel injection. While all of these advances were first attempted in earlier eras, they so dominate the market today that it is easy to overlook their significance. Nearly all modern passenger cars are front-wheel drive monocoque/unibody designs, with transversely-mounted engines, but this design was considered radical as late as the 1960s.

Body styles have changed as well in the modern era. Three types, the hatchback, sedan, and sport utility vehicle, dominate today's market, yet are relatively recent concepts. All originally emphasised practicality, but have mutated into today's high-powered luxury crossover SUV and sports wagon. The rise of pickup trucks in the United States, and SUVs worldwide has changed the face of motoring, with these "trucks" coming to command more than half of the world automobile market.

The modern era has also seen rapidly rising fuel efficiency and engine output. Once the automobile emissions concerns of the 1970s were conquered with computerised engine management systems, power began to rise rapidly. In the 1980s, a powerful sports car might have produced 200 horsepower (150 kW) – just 20 years later, average passenger

cars have engines that powerful, and some performance models offer three times as much power.

Exemplary modern cars:

- 1966–present Toyota Corolla — a simple small Japanese saloon/sedan that has come to be the best-selling car of all time.
- 1967 NSU Ro 80 — the basic wedge profile of this design was much emulated in subsequent decades.
- 1970–present Range Rover — the first take on the combination of luxury and four-wheel drive utility, the original 'SUV'. Such was the popularity of the original Range Rover Classic that a new model was not brought out until 1994.
- 1973–present Mercedes-Benz S-Class — electronic Anti-lock Braking System, supplemental restraint airbags, seat belt pretensioners, and electronic traction control systems all made their debut on the S-Class. These features would later become standard throughout the car industry.
- 1975–present BMW 3 Series — the 3 Series has been on Car and Driver magazine's annual Ten Best list 17 times, making it the longest running entry in the list.
- 1977–present Honda Accord saloon/sedan — this Japanese sedan became the most popular car in the United States in the 1990s, pushing the Ford Taurus aside, and setting the stage for today's upscale Asian sedans.
- 1981–1989 Dodge Aries and Plymouth Reliant — the "K-cars" that saved Chrysler as a major manufacturer. These models were some of the first successful American front-wheel drive, fuel-efficient compact cars.
- 1983–present Chrysler minivans — the two-box minivan design nearly pushed the station wagon out of the market, and presaged today's crossover SUVs.
- 1986–present Ford Taurus — this mid-sized front-wheel drive sedan with modern computer-assisted design dominated the American market in the late 1980s, and created a design revolution in North America.

Production



Ransom E. Olds

The large-scale, production-line manufacturing of affordable automobiles was debuted by Ransom Olds at his Oldsmobile factory in 1902. This concept was greatly expanded by Henry Ford, beginning in 1914.

As a result, Ford's cars came off the line in fifteen minute intervals, much faster than previous methods, increasing productivity eightfold (requiring 12.5 man-hours before, 1 hour 33 minutes after), while using less manpower. It was so successful, paint became a bottleneck. Only Japan black would dry fast enough, forcing the company to drop the variety of colors available before 1914, until fast-drying Duco lacquer was developed in 1926. This is the source of Ford's apocryphal remark, "any color as long as it's black". In 1914, an assembly line worker could buy a Model T with four months' pay.



Portrait of Henry Ford (ca. 1919)

Ford's complex safety procedures—especially assigning each worker to a specific location instead of allowing them to roam about—dramatically reduced the rate of injury. The combination of high wages and high efficiency is called "Fordism," and was copied by most major industries. The efficiency gains from the assembly line also coincided with the economic rise of the United States. The assembly line forced workers to work at a certain pace with very repetitive motions which led to more output per worker while other countries were using less productive methods.

In the automotive industry, its success was dominating, and quickly spread worldwide seeing the founding of Ford France and Ford Britain in 1911, Ford Denmark 1923, Ford Germany 1925; in 1921, Citroen was the first native European manufacturer to adopt the production method. Soon, companies had to have assembly lines, or risk going broke; by 1930, 250 companies which did not, had disappeared.

Development of 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.



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

Since the 1920s, nearly all cars have been mass-produced to meet market needs, so marketing plans often have 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.

Reflecting the rapid pace of change, makes shared parts with one another so larger production volume resulted in lower costs for each price range. For example, in the 1930s, LaSalles, sold by Cadillac, used cheaper mechanical parts made by Oldsmobile; in the 1950s, Chevrolet shared hood, doors, roof, and windows with Pontiac; by the 1990s, corporate powertrains and shared platforms (with interchangeable brakes, suspension, and other parts) were common. Even so, only major makers could afford high costs, and even companies with decades of production, such as Apperson, Cole, Dorris, Haynes, or Premier, could not manage: of some two hundred American car makers in existence in

1920, only 43 survived in 1930, and with the Great Depression, by 1940, only 17 of those were left.

In Europe much the same would happen. Morris set up its production line at Cowley in 1924, and soon outsold Ford, while beginning in 1923 to follow Ford's practise of vertical integration, buying Hotchkiss (engines), Wrigley (gearboxes), and Osberton (radiators), for instance, as well as competitors, such as Wolseley: in 1925, Morris had 41% of total British car production. Most British small-car assemblers, from Abbey to Xtra had gone under. Citroen did the same in France, coming to cars in 1919; between them and other cheap cars in reply such as Renault's 10CV and Peugeot's 5CV, they produced 550,000 cars in 1925, and Mors, Hurtu, and others could not compete. Germany's first mass-manufactured car, the Opel 4PS *Laubfrosch* (Tree Frog), came off the line at Russelsheim in 1924, soon making Opel the top car builder in Germany, with 37.5% of the market.

WWT

Chapter- 2

Alternative Fuel Vehicle



Toyota Prius, a hybrid vehicle. Museum of Toyota of Aichi Prefecture, Japan.



Typical Brazilian filling station with four alternative fuels for sale: biodiesel (B3), gasohol (E25), neat ethanol (E100), and compressed natural gas (CNG). Piracicaba, Brazil.

An **alternative fuel vehicle** is a vehicle that runs on a fuel other than "traditional" petroleum fuels (petrol or diesel); and also refers to any technology of powering an engine that does not involve solely petroleum (e.g. electric car, hybrid electric vehicles, solar powered). Because of a combination of factors, such as environmental concerns, high oil prices and the potential for peak oil, development of cleaner alternative fuels and advanced power systems for vehicles has become a high priority for many governments and vehicle manufacturers around the world.

Hybrid electric vehicles such as the Toyota Prius are not actually alternative fuel vehicles, but through advanced technologies in the electric battery and motor/generator, they make a more efficient use of petroleum fuel. Other research and development efforts in alternative forms of power focus on developing all-electric and fuel cell vehicles, and even the stored energy of compressed air.

As of July 2010 more than 40 million alternative fuel and advanced technology vehicles have been sold worldwide, compared to around 900 million cars and light trucks in use in the world in 2009. This alternative fuel fleet is made up mainly of:

- 20.7 million flexible-fuel vehicles by mid 2010, led by Brazil with 10.6 million, followed by the United States with 9.3 million, Canada (600,000), and Europe,

led by Sweden (199,004). Additionally, 183,375 flexible-fuel motorcycles were sold in Brazil in 2009.

- 11.2 million natural gas vehicles by 2009, led by Pakistan with 2.4 million, Argentina (1.8 million), Iran (1.7 million), Brazil (1.6 million), and India (725 thousand).
- Between 2.4 to 3.0 million neat-ethanol vehicles still in use in Brazil, out of 5.7 million ethanol only light-vehicles produced since 1979.
- More than 3.1 million hybrid electric vehicles sold by mid 2010, led by the United States with almost 1.8 million units, followed by Japan with more than 1.1 million and Europe with around 250 thousand. Worldwide, Toyota Motor Company is the leader with 2.68 million hybrids sold by July 2010, followed by Honda Motor Co., Ltd. with more than 300 thousand hybrids sold by January 2009, and Ford Motor Corporation with more than 140 thousand hybrids sold by June 2010.

Single fuel source

Air engine

The air engine is an emission-free piston engine that uses compressed air as a source of energy. The first compressed air car was invented by a French engineer named Guy Nègre. The expansion of compressed air may be used to drive the pistons in a modified piston engine. Efficiency of operation is gained through the use of environmental heat at normal temperature to warm the otherwise cold expanded air from the storage tank. This non-adiabatic expansion has the potential to greatly increase the efficiency of the machine. The only exhaust is cold air (-15°C), which could also be used to air condition the car. The source for air is a pressurized carbon-fiber tank. Air is delivered to the engine via a rather conventional injection system. Unique crank design within the engine increases the time during which the air charge is warmed from ambient sources and a two stage process allows improved heat transfer rates.

Battery-electric



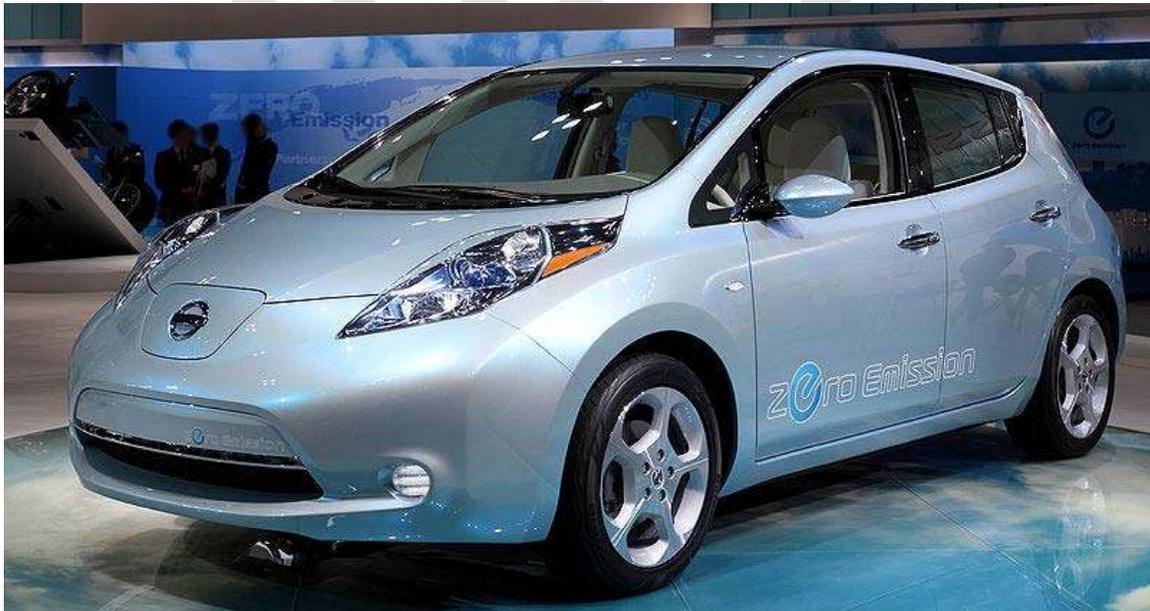
The Henney Kilowatt, the first modern (transistor-controlled) electric car. Based on a Renault Dauphine



General Motors EV1, SATURN battery-electric vehicle

Battery Electric Vehicles (BEVs), also known as All Electric Vehicles (AEVs), are electric vehicles whose main energy storage is in the chemical energy of batteries. BEVs are the most common form of what is defined by the California Air Resources Board (CARB) as zero emission (ZEV) passenger automobiles, because they produce no emissions while being driven. The electrical energy carried onboard a BEV to power the motors is obtained from a variety of battery chemistries arranged into battery packs. For additional range genset trailers or pusher trailers are sometimes used, forming a type of hybrid vehicle. Batteries used in electric vehicles include "flooded" lead-acid, absorbed glass mat, NiCd, nickel metal hydride, Li-ion, Li-poly and zinc-air batteries.

Attempts at building viable, modern battery-powered electric vehicles began in the 1950s with the introduction of the first modern (transistor controlled) electric car - the Henney Kilowatt, even though the concept was out in the market since 1890. Despite the poor sales of the early battery-powered vehicles, development of various battery-powered vehicles continued through the 1960 (notably General Motors with the SATURN EV1), but cost, speed and inadequate driving range continued to make them impractical. Battery powered cars have primarily used lead-acid batteries and NiMH batteries. Lead-acid batteries' recharge capacity is considerably reduced if they're discharged beyond 75% on a regular basis, making them a less-than-ideal solution. NiMH batteries are a better choice, but are considerably more expensive than lead-acid. Lithium-ion battery powered vehicles such as the Venturi Fetish have recently demonstrated excellent performance and range, but they remain very expensive.



Nissan Leaf exhibited at the 2009 Tokyo Motor Show

In August 2009 Nissan announced the mass production of its first electric car, the Nissan LEAF ("Leading, Environmentally Friendly, Affordable, Family Car"). It is expected to be marketed in North America, Europe, and Japan, beginning in autumn 2010. Although an exact price has not been announced, the car is expected to cost somewhere between

\$25,000 and \$33,000. The car will have a top speed of over 140 km/h (87 mph). The battery can be charged to 80% capacity in about 30 minutes with a special quick charger, and its 24kWh lithium-ion battery pack is rated to have a range of 100 miles (160 km).

Solar



Nuna team at a racecourse



Nuna solar powered car, which has travelled up to 140km/h (84mph)

A solar car is an electric vehicle powered by solar energy obtained from solar panels on the car. Solar panels cannot currently be used to directly supply a car with a suitable amount of power at this time, but they can be used to extend the range of electric vehicles. They are raced in competitions such as the World Solar Challenge and the North American Solar Challenge. These events are often sponsored by Government agencies such as the United States Department of Energy keen to promote the development of alternative energy technology such as solar cells and electric vehicles. Such challenges are often entered by universities to develop their students engineering and technological skills as well as motor vehicle manufacturers such as GM and Honda.



Trev's battery lasts over 250,000 kilometres

The North American Solar Challenge is a solar car race across North America. Originally called Sunrayce, organized and sponsored by General Motors in 1990, it was renamed American Solar Challenge in 2001, sponsored by the United States Department of Energy and the National Renewable Energy Laboratory. Teams from universities in the United States and Canada compete in a long distance test of endurance as well as efficiency, driving thousands of miles on regular highways.

Nuna is the name of a series of manned solar powered vehicles that won the World solar challenge in Australia three times in a row, in 2001 (Nuna 1 or just Nuna), 2003 (Nuna 2) and 2005 (Nuna 3). The Nunas are built by students of the Delft University of Technology.

The World solar challenge is a solar powered car race over 3,021 kilometres (1,877 mi) through central Australia from Darwin to Adelaide. The race attracts teams from around the world, most of which are fielded by universities or corporations although some are fielded by high schools.

Trev (two-seater renewable energy vehicle) was designed by the staff and students at the University of South Australia. Trev was first displayed at the 2005 World Solar Challenge as the concept of a low-mass, efficient commuter car. With 3 wheels and a mass of about 300 kg, the prototype car had maximum speed of 120 km/h and

acceleration of 0–100 km/h in about 10 seconds. The running cost of Trev is projected to be less than 1/10 of the running cost of a small petrol car.

Ammonia fueled vehicles

Ammonia GreenNH₃ is being used with success by developers in Canada, since it can run in spark ignited or diesel engines with minor modifications, also the only green fuel to power jet engines,, and despite its toxicity is reckoned to be no more dangerous than petrol or LPG. It can be made from renewable electricity, and having half the density of petrol or diesel can be readily carried in sufficient quantities in vehicles. On combustion it has no emissions other than nitrogen and water vapour. The Canadian group Green Gas dot cc have developed a machine to make the GreenNH₃ from zero carbon energy sources so as not to have any link to carbon. That would be as opposed to brownNH₃ which can be made from carbon things like coal or natural gas.

Bioalcohol / Ethanol



The Ford Model T was the first commercial flex-fuel vehicle. The engine was capable of running on gasoline or ethanol, or a mix of both.



The 1996 Ford Taurus was the first flexible-fuel vehicle produced with versions capable of running with either ethanol (E85) or methanol (M85) blended with gasoline.



The 2003 VW Gol 1.6 Total Flex was the first commercial flexible-fuel vehicle in the Brazilian market, capable of running on any mixture of gasoline (E20 to E25 blend) and ethanol (E100).

The first commercial vehicle that used ethanol as a fuel was the Ford Model T, produced from 1908 through 1927. It was fitted with a carburetor with adjustable jetting, allowing use of gasoline or ethanol, or a combination of both. Other car manufactures also provided engines for ethanol fuel use. In the United States, alcohol fuel was produced in corn-alcohol stills until Prohibition criminalized the production of alcohol in 1919. The use of alcohol as a fuel for internal combustion engines, either alone or in combination with other fuels, lapsed until the oil price shocks of the 1970s. Furthermore, additional attention was gained because of its possible environmental and long-term economical advantages over fossil fuel.

Both ethanol and methanol have been use as an automotive fuel. While both can be obtained from petroleum or natural gas, ethanol has attracted more attention because it is considered a renewable resource, easily obtained from sugar or starch in crops and other agricultural produce such as grain, sugarcane, sugar beets or even lactose. Since ethanol occurs in nature whenever yeast happens to find a sugar solution such as overripe fruit, most organisms have evolved some tolerance to ethanol, whereas methanol is toxic. Other experiments involve butanol, which can also be produced by fermentation of plants. Support for ethanol comes from the fact that it is a biomass fuel, which addresses climate change and greenhouse gas emissions, though these benefits are now highly debated, including the heated 2008 food vs fuel debate.

Ethanol has the property of slowly decomposing certain rubber compounds such as are found in the fuel lines and seals used in vehicles produced before the mid 1980s. Also, because gasoline is more volatile than ethanol, it can be harder to start some engines using higher ethanol percentages than they were designed to use, especially when the engine is cold during the winter. Ethanol is also electrically conductive (gasoline is an effective insulator) which can cause problems with some early electric fuel pump designs and fuel tank sensors. Corrosion of magnesium and aluminium parts is also a concern at higher ethanol percentages. Most modern cars are designed to run on gasoline are capable of running with a blend from 10% up to 15% ethanol mixed into gasoline (E10-E15). With a small amount of redesign, gasoline-powered vehicles can run on ethanol concentrations as high as 85% (E85), the maximum set in the United States and Europe due to cold weather during the winter, or up to 100% (E100) in Brazil, with a warmer climate. Ethanol has close to 34% less energy per volume than gasoline, consequently fuel economy ratings with ethanol blends are significantly lower than with pure gasoline, but this lower energy content does not translate directly into a 34% reduction in mileage, because there are many other variables that affect the performance of a particular fuel in a particular engine, and also because ethanol has a higher octane rating which is beneficial to high compression ratio engines.

For this reason, for pure or high ethanol blends to be attractive for users, its price must be lower than gasoline to offset the lower fuel economy. As a rule of thumb, Brazilian consumers are frequently advised by the local media to use more alcohol than gasoline in their mix only when ethanol prices are 30% lower or more than gasoline, as ethanol price fluctuates heavily depending on the results and seasonal harvests of sugar cane and by region. In the US, and based on EPA tests for all 2006 E85 models, the average fuel

economy for E85 vehicles was found 25.56% lower than unleaded gasoline. The EPA-rated mileage of current American flex-fuel vehicles could be considered when making price comparisons, though E85 has octane rating of about 104 and could be used as a substitute for premium gasoline. Regional retail E85 prices vary widely across the US, with more favorable prices in the Midwest region, where most corn is grown and ethanol produced. In August 2008 the US average spread between the price of E85 and gasoline was 16.9%, while in Indiana was 35%, 30% in Minnesota and Wisconsin, 19% in Maryland, 12 to 15% in California, and just 3% in Utah. Depending of the vehicle capabilities, the break even price of E85 usually has to be between 25 to 30% lower than gasoline.



E85 fuel sold at a regular gasoline station in Washington, D.C.

Reacting to the high price of oil and its growing dependence on imports, in 1975 Brazil launched the Pro-alcool program, a huge government-subsidized effort to manufacture ethanol fuel (from its sugar cane crop) and ethanol-powered automobiles. These ethanol-only vehicles were very popular in the 1980s, but became economically impractical when oil prices fell - and sugar prices rose - late in that decade. In May 2003 Volkswagen built for the first time a commercial ethanol flexible fuel car, the Gol 1.6 Total Flex. These vehicles were a commercial success and by early 2009 other nine Brazilian manufacturers are producing flexible fuel vehicles: Chevrolet, Fiat, Ford, Peugeot, Renault, Honda, Mitsubishi, Toyota, Citroën, and Nissan. The adoption of the flex technology was so rapid, that flexible fuel cars reached 87.6% of new car sales in July 2008. As of August 2008, the fleet of "flex" automobiles and light commercial vehicles had reached 6 million new vehicles sold, representing almost 19% of all registered light vehicles. The rapid success of "flex" vehicles, as they are popularly known, was made possible by the existence of 33,000 filling stations with at least one ethanol pump available by 2006, a heritage of the *Pro-alcool* program.

In the United States, initial support to develop alternative fuels by the government was a also response to the 1973 oil crisis, and later on, as a goal to improve air quality. Also, liquid fuels were preferred over gaseous fuels not only because they have a better volumetric energy density but also because they were the most compatible fuels with existing distribution systems and engines, thus avoiding a big departure from the existing technologies and taking advantage of the vehicle and the refueling infrastructure. California led the search of sustainable alternatives with interest in methanol. In 1996, a new FFV Ford Taurus was developed, with models fully capable of running either methanol or ethanol blended with gasoline. This ethanol version of the Taurus was the first commercial production of a E85 FFV. The momentum of the FFV production programs at the American car companies continued, although by the end of the 90's, the emphasis was on the FFV E85 version, as it is today. Ethanol was preferred over methanol because there is a large support in the farming community and thanks to government's incentive programs and corn-based ethanol subsidies. Sweden also tested both the M85 and the E85 flexifuel vehicles, but due to agriculture policy, in the end emphasis was given to the ethanol flexifuel vehicles.

Biodiesel



Bus running on soybean biodiesel



Biodiesel (B20) pump in the U.S.

The main benefit of Diesel combustion engines is that they have a 44% fuel burn efficiency; compared with just 25-30% in the best gasoline engines. In addition diesel fuel has slightly higher Energy Density by volume than gasoline. This makes Diesel engines capable of achieving much better fuel economy than gasoline vehicles.

Biodiesel (Fatty acid methyl ester), is commercially available in most oilseed-producing states in the United States. As of 2005, it is somewhat more expensive than fossil diesel, though it is still commonly produced in relatively small quantities (in comparison to petroleum products and ethanol). Many farmers who raise oilseeds use a biodiesel blend in tractors and equipment as a matter of policy, to foster production of biodiesel and raise public awareness. It is sometimes easier to find biodiesel in rural areas than in cities.

Biodiesel has lower Energy Density than fossil diesel fuel, so biodiesel vehicles are not quite able to keep up with the fuel economy of a fossil fuelled diesel vehicle, if the diesel injection system is not reset for the new fuel. If the injection timing is changed to take account of the higher Cetane value of biodiesel, the difference in economy is negligible. Because biodiesel contains more oxygen than diesel or vegetable oil fuel, it produces the lowest emissions from diesel engines, and is lower in most emissions than gasoline engines. Biodiesel has a higher lubricity than mineral diesel and is an additive in European pump diesel for lubricity and emissions reduction.

Some Diesel-powered cars can run with minor modifications on 100% pure vegetable oils. Vegetable oils tend to thicken (or solidify if it is waste cooking oil), in cold weather conditions so vehicle modifications (a two tank system with diesel start/stop tank), are essential in order to heat the fuel prior to use under most circumstances. Heating to the temperature of engine coolant reduces fuel viscosity, to the range cited by injection system manufacturers, for systems prior to 'common rail' or 'unit injection (VW PD)' systems. Waste vegetable oil, especially if it has been used for a long time, may become hydrogenated and have increased acidity. This can cause the thickening of fuel, gumming in the engine and acid damage of the fuel system. Biodiesel does not have this problem, because it is chemically processed to be PH neutral and lower viscosity. Modern low emission diesels (most often Euro -3 and -4 compliant), typical of the current production in the European industry, would require extensive modification of injector system, pumps and seals etc. due to the higher operating pressures, that are designed thinner (heated) mineral diesel than ever before, for atomisation, if they were to use pure vegetable oil as fuel. Vegetable oil fuel is not suitable for these vehicles as they are currently produced. This reduces the market as increasing numbers of new vehicles are not able to use it. However, the German Elsbett company has successfully produced single tank vegetable oil fuel systems for several decades, and has worked with Volkswagen on their TDI engines. This shows that it is technologically possible to use vegetable oil as a fuel in high efficiency / low emission diesel engines.

Greasestock is an event held yearly in Yorktown Heights, New York, and is one of the largest showcases of vehicles using waste oil as a biofuel in the United States.

Biogas

Compressed Biogas may be used for Internal Combustion Engines after purification of the raw gas. The removal of H₂O, H₂S and particles can be seen as standard producing a gas which has the same quality as Compressed Natural Gas. The use of biogas is particularly interesting for climates where the waste heat of a biogas powered power plant cannot be used during the summer.

Charcoal

In the 1930s Tang Zhongming made an invention of using abundant Charcoal resources for Chinese auto market. The Charcoal-fuelled car was later used intensively in China, serving the army and conveyance after the breakout of WWII.

CNG Compressed Natural Gas



The Brazilian Fiat Siena Tetrafuel 1.4, the first multifuel car that runs as a flexible-fuel on pure gasoline, or E25, or E100; or runs as a bi-fuel with natural gas (CNG).

High pressure compressed natural gas, mainly composed of methane, that is used to fuel normal combustion engines instead of gasoline. Combustion of methane produces the least amount of CO₂ of all fossil fuels. Gasoline cars can be retrofitted to CNG and become bifuel NGV Natural gas vehicles as the gasoline tank stays. You can switch between CNG and gasoline during operation. Natural gas vehicles (NGVs) are popular in regions or countries where natural gas is abundant. Widespread use began in the Po River Valley of Italy, and later became very popular in New Zealand by the eighties, though its use has declined.



Buses powered with CNG are common in the United States

As of 2009 there were 11,2 million natural gas vehicles by 2009, led by Pakistan with 2.4 million, Argentina (1.8 million), Iran (1.7 million), Brazil (1.6 million), and India (725 thousand). with South America leading the global market with a share of 39%. In Europe they are popular in Italy (580,000), Ukraine (200,000), Russia (100,000) and Germany (85,000), and they are becoming more so as various manufacturers produce factory made cars, buses, vans and heavy vehicles. In the United States CNG powered buses are the favorite choice of several public transit agencies, with an estimated CNG bus fleet of some 130,000. Other countries where CNG-powered buses are popular include India, Australia, Argentina, and Germany.

CNG vehicles are common in South America, where these vehicles are mainly used as taxicabs in main cities of Argentina and Brazil. Normally, standard gasoline vehicles are retrofitted in specialized shops, which involve installing the gas cylinder in the trunk and the CNG injection system and electronics. The Brazilian GNV fleet is concentrated in the cities of Rio de Janeiro and São Paulo.

In 2006 the Brazilian subsidiary of FIAT introduced the Fiat Siena Tetra fuel, a four-fuel car developed under Magneti Marelli of Fiat Brazil. This automobile can run on 100% ethanol (E100), E25 (Brazil's normal ethanol gasoline blend), pure gasoline (not available in Brazil), and natural gas, and switches from the gasoline-ethanol blend to CNG automatically, depending on the power required by road conditions. Other existing option is to retrofit an ethanol flexible-fuel vehicle to add a natural gas tank and the corresponding injection system. Some taxicabs in São Paulo and Rio de Janeiro, Brazil,

run on this option, allowing the user to choose among three fuels (E25, E100 and CNG) according to current market prices at the pump. Vehicles with this adaptation are known in Brazil as "tri-fuel" cars.

Hydrogen



The 2009 Honda FCX Clarity is an hydrogen fuel cell automobile launched to the market in 2008.



Hydrogen fueling station in California



Sequel, a hydrogen fuel cell-powered vehicle from General Motors

A hydrogen car is an automobile which uses hydrogen as its primary source of power for locomotion. These cars generally use the hydrogen in one of two methods: combustion or fuel-cell conversion. In combustion, the hydrogen is "burned" in engines in fundamentally the same method as traditional gasoline cars. In fuel-cell conversion, the hydrogen is turned into electricity through fuel cells which then powers electric motors. With either method, the only byproduct from the spent hydrogen is water.

Honda introduced its fuel cell vehicle in 1999 called the FCX and have since then introduced the second generation FCX Clarity. Limited marketing of the FCX Clarity, based on the 2007 concept model, began in June 2008 in the United States, and it was introduced in Japan in November 2008. The FCX Clarity is available in the U.S. only in Los Angeles Area, where 16 hydrogen filling stations are available, and until July 2009, only 10 drivers have leased the Clarity for US\$600 a month. Honda stated that it could start mass producing vehicles based on the FCX concept by the year 2020.

A small number of prototype hydrogen cars currently exist, and a significant amount of research is underway to make the technology more viable. The common internal combustion engine, usually fueled with gasoline (petrol) or diesel liquids, can be converted to run on gaseous hydrogen. However, the most efficient use of hydrogen involves the use of fuel cells and electric motors instead of a traditional engine. Hydrogen

reacts with oxygen inside the fuel cells, which produces electricity to power the motors. One primary area of research is hydrogen storage, to try to increase the range of hydrogen vehicles while reducing the weight, energy consumption, and complexity of the storage systems. Two primary methods of storage are metal hydrides and compression. Some believe that hydrogen cars will never be economically viable and that the emphasis on this technology is a diversion from the development and popularization of more efficient hybrid cars and other alternative technologies.

High speed cars, buses, motorcycles, bicycles, submarines, and space rockets already run on hydrogen, in various forms. There is even a working toy model car that runs on solar power, using a reversible fuel cell to store energy in the form of hydrogen and oxygen gas. It can then convert the fuel back into water to release the solar energy.

BMW's Clean Energy internal combustion hydrogen car has more power and is faster than hydrogen fuel cell electric cars. A limited series production of the 7 Series Saloon was announced as commencing at the end of 2006. A BMW hydrogen prototype (H2R) using the driveline of this model broke the speed record for hydrogen cars at 300 km/h (186 mi/h), making automotive history. Mazda has developed Wankel engines to burn hydrogen. The Wankel uses a rotary principle of operation, so the hydrogen burns in a different part of the engine from the intake. This reduces pre-detonation, a problem with hydrogen fueled piston engines.

The other major car companies like Daimler, Chrysler, Honda, Toyota, Ford and General Motors, are investing in hydrogen fuel cells instead. VW, Nissan, and Hyundai/Kia also have fuel cell vehicle prototypes on the road. In addition, transit agencies across the globe are running prototype fuel cell buses. Fuel cell vehicles, such as the new Honda Clarity, can get up to 70 miles (110 km) on a kilogram of hydrogen (roughly equivalent to a gallon of gasoline.)

Oxyhydrogen

Oxyhydrogen is another fuel that can be used in existing internal combustion engines (originally developed for using gasoline). This allows the engine to eliminate emissions, although fuel efficiency is reduced rather than improved (since the energy required to split water exceeds the energy recouped by burning it).

Liquid nitrogen car

Liquid nitrogen (LN2) is a method of storing energy. Energy is used to liquify air, and then LN2 is produced by evaporation, and distributed. LN2 is exposed to ambient heat in the car and the resulting nitrogen gas can be used to power a piston or turbine engine. The maximum amount of energy that can be extracted from 1 kg of LN2 is 213 W-hr or 173 W-hr per liter, in which a maximum of 70 W-hr can be utilized with an isothermal expansion process. Such a vehicle can achieve ranges similar to that of gasoline with a 350 liter (90 gallon) tank. Theoretical future engines, using cascading topping cycles, can improve this to around 110 W-hr/kg with a quasi-isothermal expansion process. The

advantages are zero harmful emissions and superior energy densities than compressed air, and a car powered by LN2 can be refilled in a matter of minutes.

LPG or Autogas



A propane-fueled school bus in the United States

LPG or liquified petroleum gas is a low pressure liquified gas mixture composed mainly of propane and butane which burns in conventional gasoline combustion engines with less CO₂ than gasoline. Gasoline cars can be retrofitted to LPG aka Autogas and become bifuel vehicles as the gasoline tank stays. You can switch between LPG and gasoline during operation. Estimated 10 million vehicles running worldwide.

In the U.S., 190,000 on-road vehicles use propane, and 450,000 forklifts use it for power. It is the third most popular vehicle fuel in America, behind gasoline and diesel.

Hyundai Motor Company began sales of the Elantra LPI Hybrid in the South Korean domestic market in July 2009. The Elantra LPI (Liquefied Petroleum Injected) is the world's first hybrid electric vehicle to be powered by an internal combustion engine built to run onliquefied petroleum gas (LPG) as a fuel.

Steam



The Stanley Steam Car

A steam car is a car that has a steam engine. Wood, coal, ethanol, or others can be used as fuel. The fuel is burned in a boiler and the heat converts water into steam. When the water turns to steam, it expands. The expansion creates pressure. The pressure pushes the pistons back and forth. This turns the driveshaft to spin the wheels forward. It works like a coal-fueled steam train, or steam boat. The steam car was the next logical step in independent transport.

Steam cars take a long time to start, but some can reach speeds over 100 mph (161 km/h) eventually. the late model doble could be brought to operational condition in less than 30 seconds, and were fast, with high acceleration, but they were ridiculously expensive.

A steam engine uses external combustion, as opposed to internal combustion. Gasoline-powered cars are more efficient at about 25-28% efficiency. In theory, a combined cycle steam engine in which the burning material is first used to drive a gas turbine can produce 50% to 60% efficiency. However, practical examples of steam engined cars work at only around 5-8% efficiency.

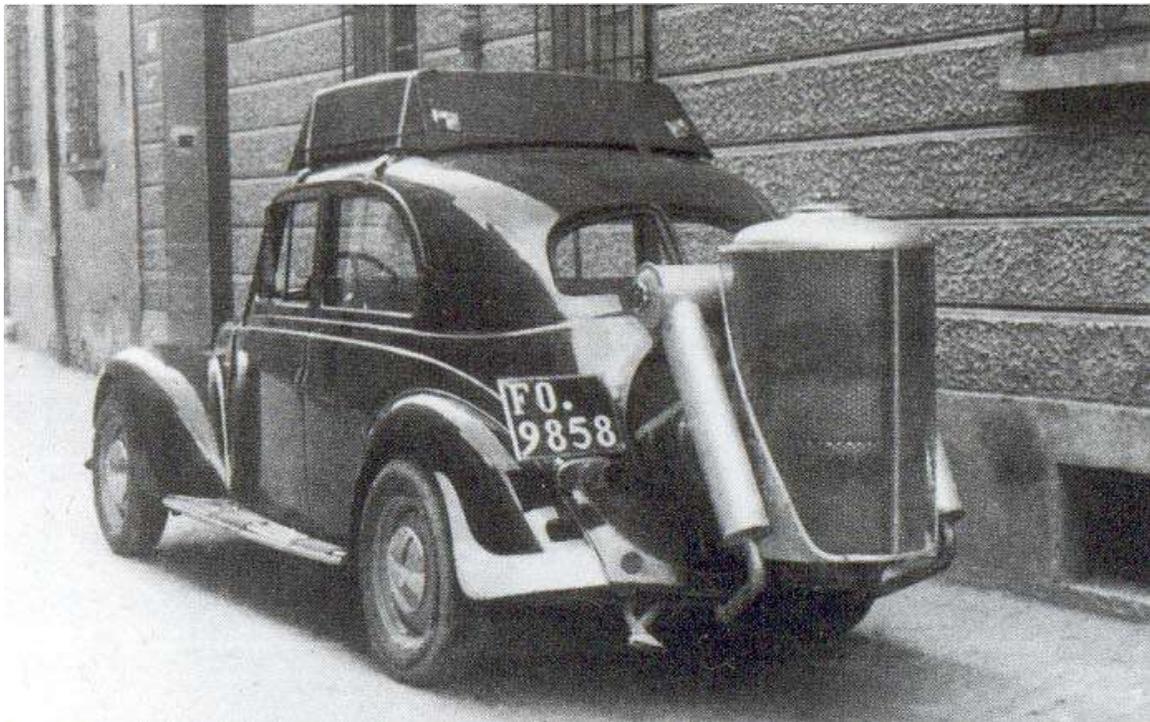
The best known and best selling steam-powered car was the Stanley Steamer. It used a compact fire-tube boiler under the hood to power a simple two-piston engine which was

connected directly to the rear axle. Before Henry Ford introduced monthly payment financing with great success, cars were typically purchased outright. This is why the Stanley was kept simple; to keep the purchase price affordable.

Steam produced in refrigeration also can be use by a turbine in other vehicle types to produce electricity, that can be employed in electric motors or stored in a battery.

Steam power can be combined with a standard oil-based engine to create a hybrid. Water is injected into the cylinder after the fuel is burned, when the piston is still superheated, often at temperatures of 1500 degrees or more. The water will instantly be vaporized into steam, taking advantage of the heat that would otherwise be wasted.

Wood gas



Vehicle with a gasifier

Wood gas can be used to power cars with ordinary internal combustion engines if a wood gasifier is attached. This was quite popular during World War II in several European and Asian countries because the war prevented easy and cost-effective access to oil.

Multiple fuel source

Flexible fuel



Six typical Brazilian full flex-fuel models from several carmakers, popularly known as "flex" cars, that run on any blend of ethanol and gasoline (actually between E20-E25 to E100).

A flexible-fuel vehicle (FFV) or dual-fuel vehicle is an alternative fuel automobile or light duty truck with a multifuel engine that can use more than one fuel, usually mixed in the same tank, and the blend is burned in the combustion chamber together. These vehicles are colloquially called flex-fuel, or flexifuel in Europe, or just flex in Brazil. FFVs are distinguished from bi-fuel vehicles, where two fuels are stored in separate tanks. The most common commercially available FFV in the world market is the ethanol

flexible-fuel vehicle, with the major markets concentrated in the United States, Brazil, Sweden, and some other European countries. In addition to flex-fuel vehicles running with ethanol, in the US and Europe there were successful test programs with methanol flex-fuel vehicles, known as M85 FFVs, and more recently there have been also successful tests using p-series fuels with E85 flex fuel vehicles, but as of June 2008, this fuel is not yet available to the general public.

Ethanol flexible-fuel vehicles have standard gasoline engines that are capable of running with ethanol and gasoline mixed in the same tank. These mixtures have "E" numbers which describe the percentage of ethanol in the mixture, for example, E85 is 85% ethanol and 15% gasoline. Though technology exists to allow ethanol FFVs to run on any mixture up to E100, in the U.S. and Europe, flex-fuel vehicles are optimized to run on E85. This limit is set to avoid cold starting problems during very cold weather. The alcohol content might be reduced during the winter, to E70 in the U.S. or to E75 in Sweden. Brazil, with a warmer climate, developed vehicles that can run on any mix up to E100, though E20-E25 is the mandatory minimum blend, and no pure gasoline is sold in the country.

By mid 2010 cumulative global sales of flexible-fuel vehicles have reached around 21 million units, led by Brazil with 10.6 million, followed by the United States with 9.3 million, Canada (600,000), and Europe, led by Sweden (199,004). In addition, 183,375 flexible-fuel motorcycles were sold in Brazil in 2009. In Brazil, 65% of flex-fuel owners use ethanol fuel regularly in 2009, while, the actual number of American FFVs being run on E85 is much lower; surveys conducted in the U.S. have found that 68% of American flex-fuel car owners were not aware they owned an E85 flex. This is thought to be due to a number of factors, including:



Typical labeling used in the US to identify E85 vehicles. Top left: a small sticker in the back of the fuel filler door. Bottom left: the bright yellow gas cap now used in newer models. Top right: the E85 Flexfuel badging used in newer Ford models. Bottom right: the E85 Flexfuel badging used in newer GM models.

- The appearance of flex-fuel and non-flex-fuel vehicles is identical;
- There is no price difference between a pure-gasoline vehicle and its flex-fuel variant;
- The lack of consumer awareness of flex-fuel vehicles;
- The lack of promotion of flex-fuel vehicles by American automakers, who often do not label the cars or market them in the same way they do to hybrid cars

By contrast, automakers selling FFVs in Brazil commonly affix badges advertising the car as a flex-fuel vehicle. As of 2007, new FFV models sold in the U.S. were required to feature a yellow gas cap emblazoned with the label "E85/gasoline", in order to remind drivers of the cars' flex-fuel capabilities.. Use of E85 in the U.S. is also affected by the relatively low number of E85 filling stations in operation across the country, with just over 1,750 in August 2008, most of which are concentrated in the Corn Belt states, led by Minnesota with 353 stations, followed by Illinois with 181, and Wisconsin with 114. By comparison, there are some 120,000 stations providing regular non-ethanol gasoline in the United States alone.



US E85FlexFuel Chevrolet Impala LT 2009

There have been claims that American automakers are motivated to produce flex-fuel vehicles due to a loophole in the Corporate Average Fuel Economy (CAFE) requirements, which gives the automaker a "fuel economy credit" for every flex-fuel vehicle sold, whether or not the vehicle is actually fueled with E85 in regular use. This loophole allegedly allows the U.S. auto industry to meet CAFE fuel economy targets not by developing more, more fuel-efficient models, but by spending between \$100 and \$200 extra per vehicle to produce a certain number of flex-fuel models, enabling them to continue selling less fuel-efficient vehicles such as SUVs, which netted higher profit margins than smaller, more fuel-efficient cars.

In the United States, E85 FFVs are equipped with sensor that automatically detect the fuel mixture, signaling the ECU to tune spark timing and fuel injection so that fuel will burn cleanly in the vehicle's internal combustion engine. Originally, the sensors were mounted in the fuel line and exhaust system; more recent models do away with the fuel line sensor. Another feature of older flex-fuel cars is a small separate gasoline storage tank that was used for starting the car on cold days, when the ethanol mixture made ignition more difficult.



The Honda CG 150 Titan Mix was the first flex-fuel motorcycle launched to the market in the world.

Modern Brazilian flex-fuel technology enables FFVs to run on any blend between E20-E25 gasoline and E100 ethanol fuel, using a lambda probe to measure the quality of combustion, which informs the engine control unit as to the exact composition of the gasoline-alcohol mixture. This technology, developed by the Brazilian subsidiary of Bosch in 1994, and further improved and commercially implemented in 2003 by the Italian subsidiary of Magneti Marelli, is known as "Software Fuel Sensor". The Brazilian subsidiary of Delphi Automotive Systems developed a similar technology, known as "Multifuel", based on research conducted at its facility in Piracicaba, São Paulo. This technology allows the controller to regulate the amount of fuel injected and spark time, as fuel flow needs to be decreased to avoid detonation due to the high compression ratio (around 12:1) used by flex-fuel engines.

The latest innovation within the Brazilian flexible-fuel technology, is the development of flex-fuel motorcycles. In 2007 Magneti Marelli presented the first motorcycle with flex technology, adapted on a Kasinski Seta 125. Delphi Automotive Systems also presented in 2007 its multifuel injection technology for motorcycles. The first flex motorcycle was launched by Honda in March 2009. Produced by its Brazilian subsidiary Moto Honda da Amazônia, the CG 150 Titan Mix is sold for around US\$2,700. Because the motorcycle does not have a secondary gas tank for a cold start like the Brazilian flex cars do, the tank must have at least 20% of gasoline to avoid start up problems at temperatures below 15°C (59°F). The motorcycle's panel includes a gauge to warn the driver about the actual ethanol-gasoline mix in the storage tank.

Hybrid



The Toyota Prius Plug-in Hybrid has a larger all-electric range than the conventional Prius.



The Chevrolet Volt is a plug-in hybrid able to run in all-electric mode up to 40 miles

A hybrid vehicle uses multiple propulsion systems to provide motive power. The most common type of hybrid vehicle is the gasoline-electric hybrid vehicles, which use gasoline (petrol) and electric batteries for the energy used to power internal-combustion engines (ICEs) and electric motors. These motors are usually relatively small and would be considered "underpowered" by themselves, but they can provide a normal driving experience when used in combination during acceleration and other maneuvers that require greater power.

The Toyota Prius is one of the world's first commercially mass-produced and marketed hybrid automobiles. The Prius first went on sale in Japan in 1997 and it is sold worldwide since 2000. By 2009 the Prius is sold in more than 40 countries and regions, with its largest markets being those of Japan and North America. In May 2008, global cumulative Prius sales reached the 1 million vehicle mark, and by August 31, 2008, the Prius reached worldwide cumulative sales of 1.43 million units. As the top seller market, there were 814 thousand Prius registered in the U.S. by December 2009.

The Honda Insight is a two-seater hatchback hybrid automobile manufactured by Honda. It was the first mass-produced hybrid automobile sold in the United States, introduced in 1999, and produced until 2006. Honda introduced the second-generation Insight in Japan in February 2009, and the new Insight went on sale in the U.S. on April 22, 2009. Honda also offers the Honda Civic Hybrid since 2002.

Among others, the following are popular gasoline-electric hybrid models available in the market by 2009: Ford Escape Hybrid, Chevrolet Silverado/GMC Sierra Hybrid, Lexus RX 400h, Toyota Highlander Hybrid, Mercury Mariner Hybrid, Toyota Camry Hybrid, Saturn Vue Green Line, Lexus LS600hL, Mazda Tribute Hybrid, Nissan Altima Hybrid, Ford Fusion/Mercury Milan Hybrid, and Mercedes S400 BlueHybrid.

Toyota, GM, Ford and other major carmakers are currently developing plug-in hybrid electric vehicles (PHEVs). Chinese battery manufacturer and automaker BYD Auto released the F3DM PHEV-68 (PHEV109km) hatchback to the Chinese fleet market on December 15, 2008. The Chevrolet Volt is one of the first PHEVs that will be mass produced in the U.S., and it is expected to be launched in November 2010 as a 2011 model. Its price is estimated to be near \$40,000.

The Elantra LPI Hybrid, launched in the South Korean domestic market in July 2009, is a hybrid vehicle powered by an internal combustion engine built to run on liquefied petroleum gas (LPG) as a fuel. The Elantra PLI is a mild hybrid and the first hybrid to adopt advanced lithium polymer (Li-Poly) batteries.

Pedal-assisted electric hybrid vehicle



The Sinclair C5 pedal-assisted battery vehicle

In very small vehicles, the power demand decreases, so human power can be employed to make a significant improvement in battery life. Two such commercially made vehicles are the Sinclair C5 and the TWIKE.

Chapter- 3

Automobile Safety and Automobile Accidents

Automobile Safety

Automobile safety is the study and practice of vehicle design, construction, and equipment to minimize the occurrence and consequences of automobile accidents. (Road traffic safety more broadly includes roadway design.)

Improvements in roadway and automobile designs have steadily reduced injury and death rates in all first world countries. Nevertheless, auto collisions are the leading cause of injury-related deaths, an estimated total of 1.2 million in 2004, or 25% of the total from all causes. Risk compensation limits the improvement that can be made, often leading to reduced safety where one might expect the opposite.

Occupational driving

Work-related roadway crashes are the leading cause of death from traumatic injuries in the U.S. workplace. They accounted for nearly 12,000 deaths between 1992 and 2000. Deaths and injuries from these roadway crashes result in increased costs to employers and lost productivity in addition to their toll in human suffering. Truck drivers tend to endure higher fatality rates than workers in other occupations, but concerns about motor vehicle safety in the workplace are not limited to those surrounding the operation of large trucks. Workers outside the motor carrier industry routinely operate company-owned vehicles for deliveries, sales and repair calls, client visits etc. In these instances, the employer providing the vehicle generally plays a major role in setting safety, maintenance, and training policy. As in non-occupational driving, young drivers are especially at risk. In the workplace, 45% of all fatal injuries to workers under age 18 between 1992 and 2000 in the United States resulted from transportation incidents.

Active and passive safety

The terms "active" and "passive" are simple but important terms in the world of automotive safety. "Active safety" is used to refer to technology assisting in the prevention of a crash and "passive safety" to components of the vehicle (primarily airbags, seatbelts and the physical structure of the vehicle) that help to protect occupants during a crash.

Crash avoidance

Crash avoidance systems and devices help the driver — and, increasingly, help the vehicle itself — to avoid a collision. This category includes:

- The vehicle's headlamps, reflectors, and other lights and signals
- The vehicle's mirrors
- The vehicle's brakes, steering, and suspension systems

Driver assistance

A subset of crash avoidance is *driver assistance* systems, which help the driver to detect ordinarily-hidden obstacles and to control the vehicle. Driver assistance systems include:

- Automatic Braking systems to prevent or reduce the severity of collision.
- Infrared night vision systems to increase seeing distance beyond headlamp range
- Adaptive highbeam which automatically and continuously adapts the headlamp range to the distance of vehicles ahead or which are oncoming
- Adaptive headlamps swivels headlamps around corners
- Reverse backup sensors, which alert drivers to difficult-to-see objects in their path when reversing
- Backup camera
- Adaptive cruise control which maintains a safe distance from the vehicle in front
- Lane departure warning systems to alert the driver of an unintended departure from the intended lane of travel
- Tire pressure monitoring systems or Deflation Detection Systems
- Traction control systems which restore traction if driven wheels begin to spin
- Electronic Stability Control, which intervenes to avert an impending loss of control
- Anti-lock braking systems
- Electronic brakeforce distribution systems
- Emergency brake assist systems
- Cornering Brake Control systems
- Precrash system
- Automated parking system

Crashworthiness



Ferrari F430 steering wheel with airbag

Crashworthy systems and devices prevent or reduce the severity of injuries when a crash is imminent or actually happening. Much research is carried out using anthropomorphic crash test dummies.

- Seatbelts limit the forward motion of an occupant, stretch to slow down the occupant's deceleration in a crash, and prevent occupants being ejected from the vehicle.
- Airbags inflate to cushion the impact of a vehicle occupant with various parts of the vehicle's interior.

- Laminated windshields remain in one piece when impacted, preventing penetration of unbelted occupants' heads and maintaining a minimal but adequate transparency for control of the car immediately following a collision. Tempered glass side and rear windows break into granules with minimally sharp edges, rather than splintering into jagged fragments as ordinary glass does.
- Crumple zones absorb and dissipate the force of a collision, displacing and diverting it away from the passenger compartment and reducing the impact force on the vehicle occupants. Vehicles will include a front, rear and maybe side crumple zones (like Volvo SIPS) too.
- Side impact protection beams.
- Collapsible universally jointed steering columns, (with the steering system mounted behind the front axle - not in the front crumple zone), reduce the risk and severity of driver impalement on the column in a frontal crash.
- Pedestrian protection systems.
- Padding of the instrument panel and other interior parts of the vehicle likely to be struck by the occupants during a crash.

Post-crash survivability

Post-crash survivability is the chance that you can survive a crash after it occurs, these devices are often miscellaneous, and are not heavily produced as it is very difficult for them to function.

Pedestrian safety



1974 Mini Clubman Experimental Safety Vehicle featuring a "pedestrian-friendly" front end.

Since at least the early 1970s, attention has also been given to vehicle design regarding the safety of pedestrians in car-pedestrian collisions. Proposals in Europe would require cars sold there to have a minimum/maximum hood (bonnet) height. From 2006 the use of "bull bars", a fashion on 4x4s and SUVs, became illegal.

Conspicuity

A Swedish study found that pink cars are involved in the fewest accidents, with black cars being most often involved in crashes (Land transport NZ 2005).

In Auckland New Zealand, a study found that there was a significantly lower rate of serious injury in silver cars; with higher rates in brown, black, and green cars. (Furness *et al.*, 2003)

The Vehicle Color Study, conducted by Monash University Accident Research Centre (MUARC) and published in 2007, analysed 855,258 accidents occurring between 1987 and 2004 in the Australian states of Victoria and Western Australia that resulted in injury or in a vehicle being towed away. The study analysed risk by light condition. It found that in daylight black cars were 12% more likely than white to be involved in an accident, followed by grey cars at 11%, silver cars at 10%, and red and blue cars at 7%, with no other colors found to be significantly more or less risky than white. At dawn or dusk the risk ratio for black cars jumped to 47% more likely than white, and that for silver cars to 15%. In the hours of darkness only red and silver cars were found to be significantly more risky than white, by 10% and 8% respectively.

Daytime running lamp that have been standard on Swedish cars since the 1970s, are soon to be mandatory across the entire EU.

History

Automobile safety may have become an issue almost from the beginning of mechanised road vehicle development. The second steam-powered "Fardier" (artillery tractor), created by Nicolas-Joseph Cugnot in 1771, is reported by some to have crashed into a wall during its demonstration run. However according to Georges Ageon, the earliest mention of this occurrence dates from 1801 and it does not feature in contemporary accounts.

One of the earliest recorded automobile fatalities was Mary Ward, on August 31, 1869 in Parsonstown, Ireland.

In the 1930s, plastic surgeon Claire L. Straith and physician C. J. Strickland advocated the use of seat belts and padded dashboards. Strickland founded the Automobile Safety League of America.

In 1934, GM performed the first barrier crash test.

In 1942, Hugh De Haven published the classic *Mechanical analysis of survival in falls from heights of fifty to one hundred and fifty feet*.

In 1949 SAAB incorporated aircraft safety thinking into automobiles making the Saab 92 the first production SAAB car with a safety cage, and the American Tucker was built with the world's first padded dashboard.

In 1956, Ford tried unsuccessfully to interest Americans in purchasing safer cars with their Lifeguard safety package. (Its attempt nevertheless earns Ford *Motor Trend's* "Car of the Year" award for 1956.)

In 1958, the United Nations established the World Forum for Harmonization of Vehicle Regulations, an international standards body advancing auto safety. Many of the most life saving safety innovations, like seat belts and roll cage construction were brought to market under its auspices. That same year, Volvo engineer Nils Bohlin invented and patented the three-point lap and shoulder seat belt, which became standard equipment on all Volvo cars in 1959. Over the next several decades, three-point safety belts were gradually mandated in all vehicles by regulators throughout the industrialised world.

In 1966, the U.S. established the United States Department of Transportation (DOT) with automobile safety one of its purposes. The National Transportation Safety Board (NTSB) was created as an independent organization on April 1, 1967, but was reliant on the DOT for administration and funding. However, in 1975 the organization was made completely independent by the Independent Safety Board Act (in P.L. 93-633; 49 U.S.C. 1901).

Volvo developed the first rear-facing child seat in 1964 and introduced its own booster seat in 1978.

Revised Label(s) for Final Rule



Consumer information label for a vehicle with at least one US NCAP star rating

In 1979, NHTSA began crash-testing popular cars and publishing the results, to inform consumers and encourage manufacturers to improve the safety of their vehicles. Initially, the US NCAP crash tests examined compliance with the occupant-protection provisions of FMVSS 208. Over the subsequent years, this NHTSA program was gradually expanded in scope. In 1997, the European New Car Assessment Programme (Euro NCAP) was established to test new vehicles' safety performance and publish the results for vehicle shoppers' information. The NHTSA crash tests are presently operated and published as the U.S. branch of the international NCAP programme.

In 1984, New York State passed the first US law requiring seat belt use in passenger cars. Seat belt laws have since been adopted by all 50 states, except for New Hampshire. and NHTSA estimates increased seat belt use as a result save 10,000 per year in the USA.

In 1986, the central 3rd brake light was mandated in North America. Over the next 15 years, most of the world's other jurisdictions mandated the 3rd brake lamp as well.

In 1995, the IIHS begins frontal offset crash tests.

In 1997, EuroNCAP is founded.

In 2003, the IIHS begins conducting side impact crash tests.

In 2004, NHTSA released new tests designed to test the rollover risk of new cars and SUVs. Only the Mazda RX-8 got a 5-star rating.

In 2009, Citroën become the first manufacturer to feature "Snowmotion", an Intelligent Anti Skid system developed in conjunction with Bosch, which gives drivers a level of control in extreme ice or snow conditions similar to a 4x4

Safety trends

Despite technological advances, about 40,000 people die every year in the U.S. Although the fatality rates per vehicle registered and per vehicle distance travelled have steadily decreased since the advent of significant vehicle and driver regulation, the raw number of fatalities generally increases as a function of rising population and more vehicles on the road. However, sharp rises in the price of fuel and related driver behavioural changes are reducing 2007-8 highway fatalities in the U.S. to below the 1961 fatality count. Litigation has been central in the struggle to mandate safer cars.

International comparison

In 1996, the U.S. had about 2 deaths per 10,000 motor vehicles, compared to 1.9 in Germany, 2.6 in France, and 1.5 in the UK. In 1998, there were 3,421 fatal accidents in the UK, the fewest since 1926.

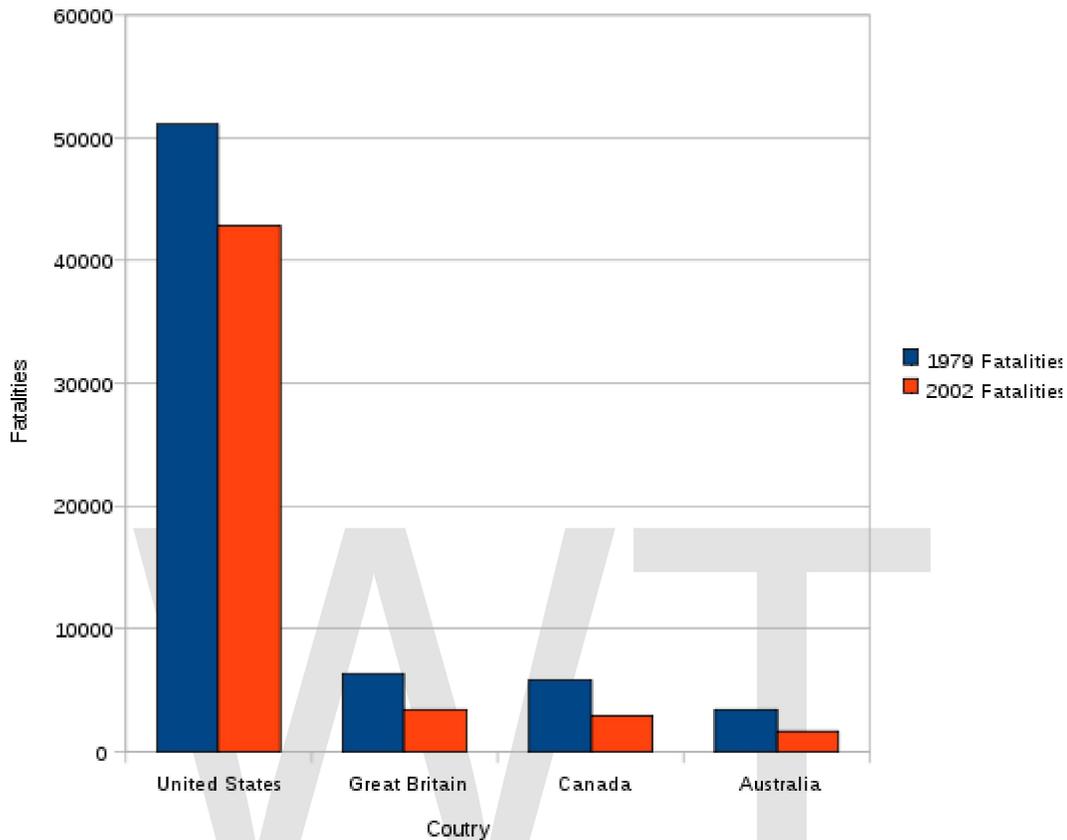
The sizable traffic safety lead enjoyed by the USA since the 1960s had narrowed significantly by 2002, with the US improvement percentages lagging in 16th place behind those of Australia, Austria, Canada, Denmark, Finland, Germany, Great Britain, Iceland, Japan, Luxembourg, the Netherlands, New Zealand, Norway, Sweden, and Switzerland in terms of deaths per thousand vehicles, while in terms of deaths per 100 million vehicle miles travelled, the USA had dropped from first place to tenth place.

Government-collected data, such as that from the U.S. Fatality Analysis Reporting System, show other countries achieving safety performance improvements over time greater than those achieved in the U.S.:

	<i>1979 Fatalities</i>	<i>2002 Fatalities</i>	<i>Percent Change</i>
United States	51,093	42,815	-16.2%
Great Britain	6,352	3,431	-46.0%
Canada	5,863	2,936	-49.9%
Australia	3,508	1,715	-51.1%

International Comparison of Change in Automobile Fatalities

1979 - 2002



Data From Table above showing data from the U.S. Fatality Analysis Reporting System

Research on the trends in use of heavy vehicles indicate that a significant difference between the U.S. and other countries is the relatively high prevalence of pickup trucks and SUVs in the U.S. A 2003 study by the U.S. Transportation Research Board found that SUVs and pickup trucks are significantly less safe than passenger cars, that imported-brand vehicles tend to be safer than American-brand vehicles, and that the size and weight of a vehicle has a significantly smaller effect on safety than the quality of the vehicle's engineering. The level of large commercial truck traffic has substantially increased since the 1960s, while highway capacity has not kept pace with the increase in large commercial truck traffic on U.S. highways. However, other factors exert significant influence; Canada has lower roadway death and injury rates despite a vehicle mix comparable to that of the U.S. Nevertheless, the widespread use of truck-based vehicles as passenger carriers is correlated with roadway deaths and injuries not only directly by dint of vehicular safety performance *per se*, but also indirectly through the relatively low fuel costs that facilitate the use of such vehicles in North America; motor vehicle fatalities decline as fuel prices increase.

NHTSA has issued relatively few regulations since the mid 1980s; most of the vehicle-based reduction in vehicle fatality rates in the U.S. during the last third of the 20th Century were gained by the initial NHTSA safety standards issued from 1968 to 1984 and subsequent voluntary changes in vehicle design and construction by vehicle manufacturers.

Pregnant women

When pregnant, women should continue to use seatbelts and airbags properly. A University of Michigan study found that *"unrestrained or improperly restrained pregnant women are 5.7 times more likely to have an adverse fetal outcome than properly restrained pregnant women"*. If seatbelts are not long enough, extensions are available from the car manufacturer or an aftermarket supplier.

Infants and children

Children present significant challenges in engineering and producing safe vehicles, because most children are significantly smaller and lighter than most adults. Safety devices and systems designed and optimised to protect adults — particularly calibration-sensitive devices like airbags and active seat belts — can be ineffective or hazardous to children. In recognition of this, many medical professionals and jurisdictions recommend or require that children under a particular age, height, and/or weight ride in a child seat and/or in the back seat, as applicable. In Sweden, for instance, a child or an adult shorter than 140 cm is legally forbidden to ride in a place with an active airbag in front of it.

Child safety locks and driver-controlled power window lockout controls prevent children from opening doors and windows from inside the vehicle.

Infants left in cars

Very young children can perish from heat or cold if left unattended in a parked car, whether deliberately or through absentmindedness. In June 2009, a 1 year old girl was accidentally forgotten in a car in Denmark on an extremely hot day and died from heat exhaustion.

Teenage Drivers

In the UK, a full driving licence can be had at age 17, and most areas in the United States will issue a full driver's license at the age of 16, and all within a range between 14 and 18. In addition to being relatively inexperienced, teen drivers are also cognitively immature, compared to other drivers. This combination leads to a relatively high crash rate among this demographic.

In some areas, new drivers' vehicles must bear a warning sign to alert other drivers that the vehicle is being driven by an inexperienced and learning driver, giving them opportunity to be more cautious and to encourage other drivers to give novices more

leeway. In the US New Jersey has Kyleigh's Law citing that teen drivers must have a decal on their vehicle.

Some countries, such as Australia, the United States, Canada and New Zealand, have graduated levels of driver's licence, with special rules. In Italy, the maximum speed and power of vehicles driven by new drivers is restricted. In Romania, the maximum speed of vehicles driven by new drivers (less than one year in experience) is 20 km/h lower than the national standard (except villages, towns and cities).

Automobile Accidents



Result of a serious automobile accident

Motor vehicle collision



A head-on collision of two cars

ICD-10 V99.

ICD-9 E810 - E819

A **traffic collision (motor vehicle collision, motor vehicle accident, car accident, or car crash)** occurs when a road vehicle collides with another vehicle, pedestrian, animal, road debris, or other geographical or architectural obstacle. Traffic collisions can result in injury, property damage, and death.

A number of factors contribute to the risk of collision including; vehicle design, speed of operation, road design, and driver impairment. Worldwide motor vehicle collisions lead to significant death and disability as well as significant financial costs to both society and the individual.

Terminology

Many different terms are commonly used to describe vehicle collisions. The World Health Organization use the term *road traffic injury*, while the U.S. Census Bureau uses the term *motor vehicle accidents (MVA)* and Transport Canada uses the term "motor vehicle traffic collision". Other terms that are commonly used include *auto accident, car accident, car crash, car smash, car wreck, motor vehicle collision (MVC), personal injury collision (PIC), road accident, road traffic accident (RTA), road traffic collision (RTC), road traffic incident (RTI), road traffic accident* and later *road traffic collision*, as well as more unofficial terms including *smash-up* and *fender bender*.

Some organizations have begun to avoid the term "accident". Although auto collisions are rare in terms of the number of vehicles on the road and the distance they travel, addressing the contributing factors can reduce their likelihood. For example, proper

signage can decrease driver error and thereby reduce crash frequency by a third or more. That is why these organizations prefer the term "collision" rather than "accident".

However, treating collisions as anything other than "accidents" has been criticized for holding back safety improvements, because a culture of blame may discourage the involved parties from fully disclosing the facts, and thus frustrate attempts to address the real root causes.

Classification

Motor vehicle collisions can be classified by mechanism. Common mechanisms include head-on collisions, run-off-road collisions, rear-end collisions, side collision, and rollovers.

Causes

A 1985 study by K. Rumar, using British and American crash reports as data, found that 57% of crashes were due solely to driver factors, 27% to combined roadway and driver factors, 6% to combined vehicle and driver factors, 3% solely to roadway factors, 3% to combined roadway, driver, and vehicle factors, 2% solely to vehicle factors and 1% to combined roadway and vehicle factors.

Driver behavior

A 1985 report based on British and American crash data found driver error, intoxication and other human factors contribute wholly or partly to about 93% of crashes.

An RAC survey found most British drivers think they're better drivers than non-British drivers. Nearly all drivers who'd been in a crash did not believe themselves to be at fault. One survey of drivers reported that they thought the key elements of good driving were:

- controlling a car including a good awareness of the car's size and capabilities
- reading and reacting to road conditions, weather, road signs and the environment
- alertness, reading and anticipating the behaviour of other drivers.

Although proficiency in these skills is taught and tested as part of the driving exam, a 'good' driver can still be at a high risk of crashing because:

...the feeling of being confident in more and more challenging situations is experienced as evidence of driving ability, and that 'proven' ability reinforces the feelings of confidence. Confidence feeds itself and grows unchecked until something happens – a near-miss or an accident.

An AXA survey concluded Irish drivers are very safety-conscious relative to other European drivers. However, this does not translate to significantly lower crash rates in Ireland.

Accompanying changes to road designs have been wide-scale adoptions of rules of the road alongside law enforcement policies that included drink-driving laws, setting of speed limits, and speed enforcement systems such as speed cameras. Some countries' driving tests have been expanded to test a new driver's behavior during emergencies, and their hazard perception.

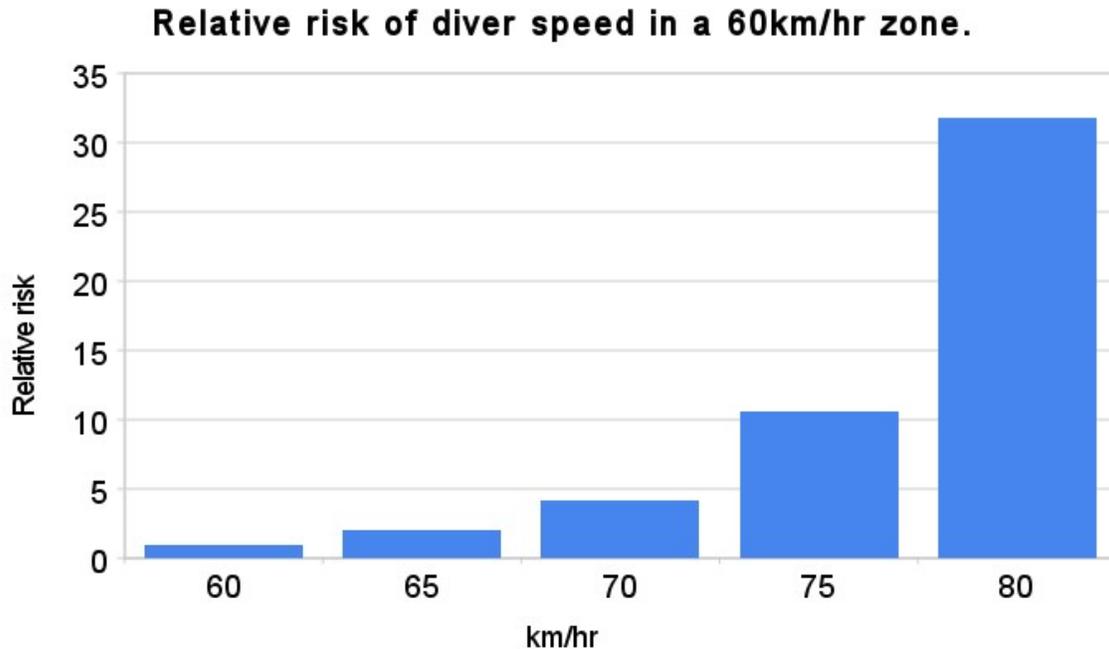
There are demographic differences in crash rates. For example, although young people tend to have good reaction times, disproportionately more young male drivers feature in accidents, with researchers observing that many exhibit behaviors and attitudes to risk that can place them in more hazardous situations than other road users. This is reflected by actuaries when they set insurance rates for different age groups, partly based on their age, sex, and choice of vehicle. Older drivers with slower reactions might be expected to be involved in more accidents, but this has not been the case as they tend to drive less and, apparently, more cautiously. Attempts to impose traffic policies can be complicated by local circumstances and driver behaviour. In 1969 Leeming warned that there is a balance to be struck when "improving" the safety of a road:

Many places that look dangerous have few or no accidents. Conversely, a location that does not look dangerous may have a high crash frequency. This is, in part, because if drivers perceive a location as hazardous, they take more care. Accidents may be more likely to happen when hazardous road or traffic conditions are not obvious at a glance, or where the conditions are too complicated for the limited human machine to perceive and react in the time and distance available.

This phenomena has been observed in risk compensation research, where the predicted reductions in accident rates have not occurred after legislative or technical changes. One study observed that the introduction of improved brakes resulted in more aggressive driving, and another argued that compulsory seat belt laws have not been accompanied by a clearly-attributed fall in overall fatalities.

In the 1990s Hans Monderman's studies of driver behavior led him to the realization that signs and regulations had an adverse effect on a driver's ability to interact safely with other road users. Monderman developed shared space principles, rooted in the principles of the woonerven of the 1970s. He found that the removal of highway clutter, while allowing drivers and other road users to mingle with equal priority, could help drivers recognize environmental clues. They relied on their cognitive skills alone, reducing traffic speeds radically and resulting in lower levels of road casualties and lower levels of congestion.

Motor vehicle speed



Relative risk of speeding in an urban 60 km/hr zone

The U.S. Department of transportation's *Federal Highway Administration* review research on traffic speed in 1998. The summary states:

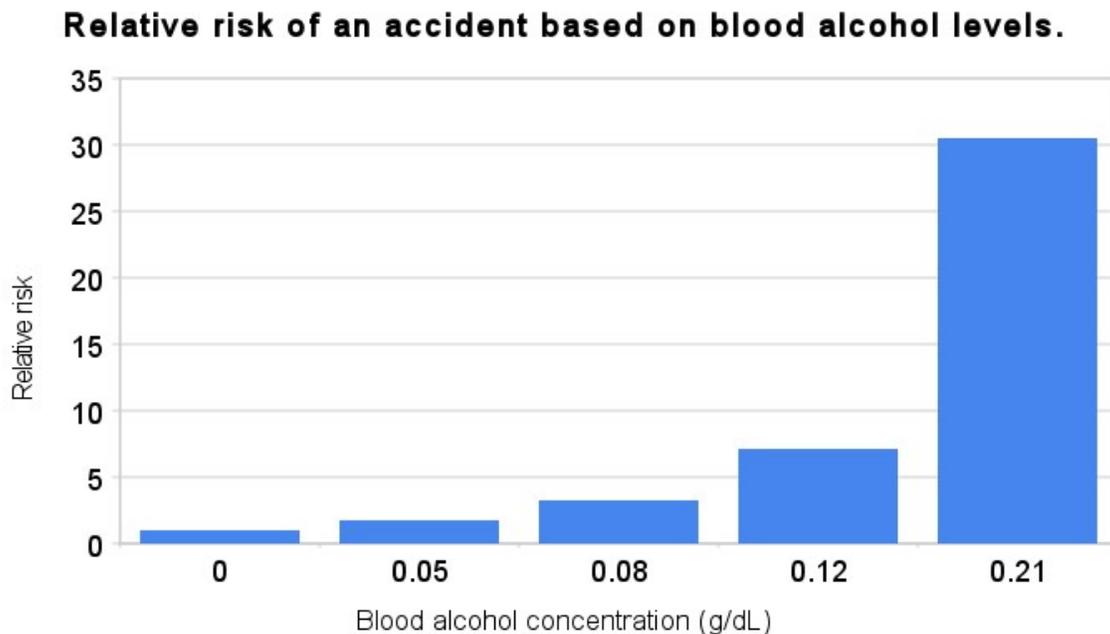
- That the evidence shows that the risk of having a crash is increased both for vehicles traveling slower than the average speed, and for those traveling above the average speed.
- That the risk of being injured increases exponentially with speeds much faster than the median speed.
- That the severity of a crash depends on the vehicle speed change at impact.
- That there is limited evidence that suggests that lower speed limits result in lower speeds on a system wide basis.
- That most crashes related to speed involve speed too fast for the conditions.
- That more research is needed to determine the effectiveness of traffic calming.

The *Road and Traffic Authority* (RTA) of the Australian state of New South Wales (NSW) asserts speeding (travelling too fast for the prevailing conditions or above the posted speed limit) is a factor in about 40 percent of road deaths. The RTA also say speeding increases the risk of a crash and its severity. On another webpage, the RTA qualify their claims by referring to one specific piece of research from 1997, and stating "research has shown that the risk of a crash causing death or injury increases rapidly, even with small increases above an appropriately set speed limit."

The contributory factor report in the official British road casualty statistics show for 2006, that "exceeding speed limit" was a contributory factor in 5% of all casualty crashes (14% of all fatal crashes), and that "travelling too fast for conditions" was a contributory factor in 11% of all casualty crashes (18% of all fatal crashes).

Driver impairment

Alcohol



Relative risk of an accident based on blood alcohol levels

In Canada 33.8% of motor vehicle deaths were associated with alcohol use.

Physical impairment

Poor eyesight and/or physical impairment, with many jurisdictions setting simple sight tests and/or requiring appropriate vehicle modifications before being allowed to drive;

Old age

Old age, with some jurisdictions requiring driver retesting for reaction speed and eyesight after a certain age;

Sleep deprivation

Fatigue;

Drug use

Including some prescription drugs, over the counter drugs (notably antihistamines, opioids and muscarinic antagonists), and illegal drugs.

Several conditions can work together to create a much worse situation, for example:

- Combining low doses of alcohol and cannabis has a more severe effect on driving performance than either cannabis or alcohol in isolation, or
- Taking recommended doses of several drugs together, which individually will not cause impairment, may combine to bring on drowsiness or other impairment. This could be more pronounced in an elderly person whose renal function is less efficient than a younger person's.

Thus there are situations when a person may be impaired, but still legally allowed to drive, and becomes a potential hazard to themselves and other road users. Pedestrians or cyclists are affected in the same way and can similarly jeopardize themselves or others when on the road.

Research suggests that the driver's attention is affected by distracting sounds such as conversations and operating a mobile phone while driving. Many jurisdictions now restrict or outlaw the use of some types of phone within the car. Recent research conducted by British scientists suggests that music can also have an effect; classical music is considered to be calming, yet too much could relax the driver to a condition of distraction. On the other hand, hard rock may encourage the driver to step on the acceleration pedal, thus creating a potentially dangerous situation on the road.

Road design



A potential long fall stopped by an early guardrail, ca. 1920. Guardrails, median barriers, or other physical objects can help reduce the consequences of an accident or minimize damage.

A 1985 US study showed that about 34% of serious crashes had contributing factors related to the roadway or its environment. Most of these crashes also involved a human factor. The road or environmental factor was either noted as making a significant contribution to the circumstances of the crash, or did not allow room to recover. In these circumstances it is frequently the driver who is blamed rather than the road; those reporting the accident have a tendency to overlook the human factors involved, such as the subtleties of design and maintenance that a driver could fail to observe or inadequately compensate for.

Research has shown that careful design and maintenance, with well-designed intersections, road surfaces, visibility and traffic control devices, can result in significant improvements in accident rates. Individual roads also have widely differing performance in the event of an impact. In Europe there are now EuroRAP tests that indicate how "self-explaining" and forgiving a particular road and its roadside would be in the event of a major incident.

In the UK, research has shown that investment in a safe road infrastructure programme could yield a $\frac{1}{3}$ reduction in road deaths saving as much as £6billion per year. A consortium of 13 major road safety stakeholders have formed the Campaign for Safe Road Design, which is calling on the UK Government to make safe road design a national transport priority.

Vehicle design and maintenance



A Chevrolet Malibu involved in a rollover crash

Seatbelts

Research has shown that, across all collision types, it is less likely that seat belts were worn in collisions involving death or serious injury, rather than light injury; wearing a seat belt reduces the risk of death by about two thirds. Seat belt use is controversial, with notable critics such as Professor John Adams suggesting that their use may lead to a net increase in road casualties due to a phenomenon known as risk compensation.

Maintenance

A well-designed and well-maintained vehicle, with good brakes, tires and well-adjusted suspension will be more controllable in an emergency and thus be better equipped to avoid collisions. Some mandatory vehicle inspection schemes include tests for some aspects of road worthiness, such as the UK's MOT test or German TÜV conformance inspection.

The design of vehicles has also evolved to improve protection after collision, both for vehicle occupants and for those outside of the vehicle. Much of this work was led by automotive industry competition and technological innovation, leading to measures such as Saab's safety cage and reinforced roof pillars of 1946, Ford's 1956 *Lifeguard* safety package, and Saab and Volvo's introduction of standard fit seatbelts in 1959. Other initiatives were accelerated as a reaction to consumer pressure, after publications such as Ralph Nader's 1965 book *Unsafe at Any Speed* accused motor manufacturers of indifference towards safety.

In the early 1970s British Leyland started an intensive programme of vehicle safety research, producing a number of prototype experimental safety vehicles demonstrating various innovations for occupant and pedestrian protection such as: air bags, anti-lock brakes, impact-absorbing side-panels, front and rear head restraints, run-flat tyres, smooth and deformable front-ends, impact-absorbing bumpers, and retractable headlamps. Design has also been influenced by government legislation, such as the Euro NCAP impact test.

Common features designed to improve safety include: thicker pillars, safety glass, interiors with no sharp edges, stronger bodies, other active or passive safety features, and smooth exteriors to reduce the consequences of an impact with pedestrians.

The UK Department for Transport publish road casualty statistics for each type of collision and vehicle through its Road Casualties Great Britain report. These statistics show a ten to one ratio of in-vehicle fatalities between types of car. In most cars, occupants have a 2–8% chance of death in a two-car collision.

Center of gravity

Some crash types tend to have more serious consequences, Rollovers have become more common in recent years, perhaps due to increased popularity of taller SUVs, people

carriers, and minivans, which have a higher center of gravity than standard passenger cars. Rollovers can be fatal, especially if the occupants are ejected because they were not wearing seat belts (83% of ejections during rollovers were fatal when the driver did not wear a seat belt, compared to 25% when they did). After a new design of Mercedes Benz notoriously failed a 'moose test' (sudden swerving to avoid an obstacle), some manufacturers enhance suspension using stability control linked to an anti-lock braking system to reduce the likelihood of rollover. After retrofitting these systems to its models in 1999–2000, Mercedes saw its models involved in fewer crashes

Now about 40% of new US vehicles, mainly the SUVs, vans and pickup trucks that are more susceptible to rollover, are being produced with a lower center of gravity and enhanced suspension with stability control linked to its anti-lock braking system to reduce the risk of rollover and meet US federal requirements that mandate anti-rollover technology by September 2011.

Motorcycles

Motorcyclists have little protection other than their clothing; this difference is reflected in the casualty statistics, where they are more than twice as likely to suffer severely after a collision. In 2005 there were 198,735 road crashes with 271,017 reported casualties on roads in Great Britain. This included 3,201 deaths (1.1%) and 28,954 serious injuries (10.7%) overall. Of these casualties 178,302 (66%) were car users and 24,824 (9%) were motorcyclists, of whom 569 were killed (2.3%) and 5,939 seriously injured (24%).

Prevention

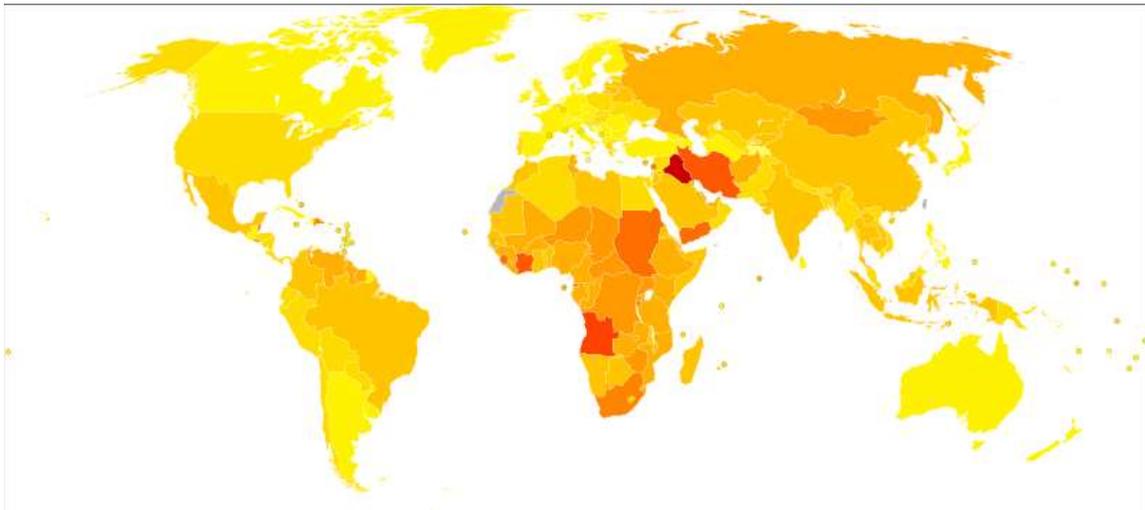
A large body of knowledge has been amassed on how to prevent car crashes, and reduce the severity of those that do occur.

United Nations response

Owing to the global and massive scale of the issue, with predictions that by 2020 road traffic deaths and injuries will exceed HIV/AIDS as a burden of death and disability, the United Nations and its subsidiary bodies have passed resolutions and held conferences on the issue. The first United Nations General Assembly resolution and debate was in 2003. The World Day of Remembrance for Road Traffic Victims was declared in 2005. In 2009 the first high level ministerial conference on road safety will be held in Moscow.

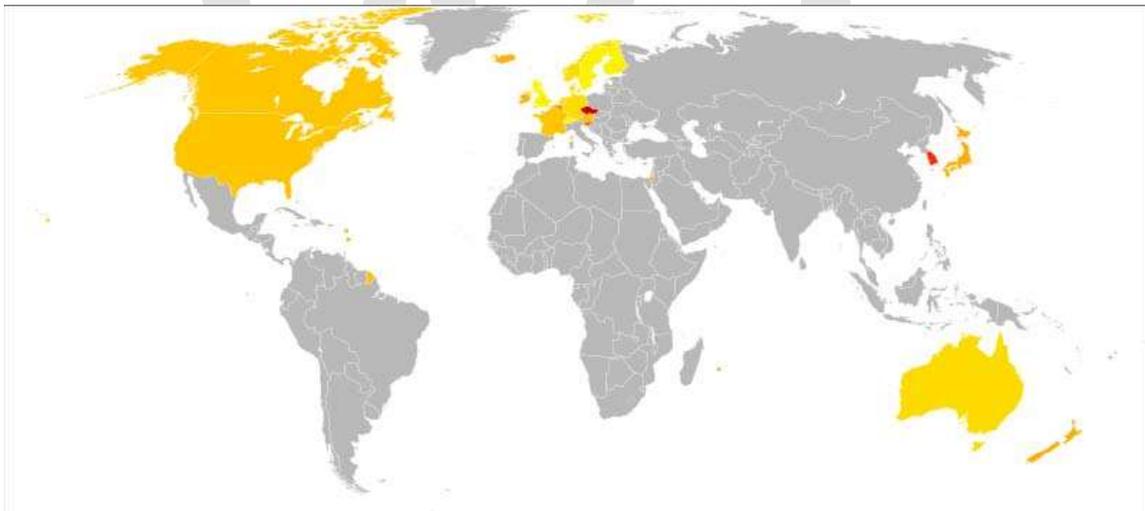
The World Health Organization, a specialized agency of the United Nations Organization, in its Global Status Report on Road Safety 2009, states that over 90% of the world's fatalities on the roads occur in low-income and middle-income countries, which have only 48% of the world's registered vehicles, and predicts that road traffic injuries will rise to become the fifth leading cause of death by 2030

Epidemiology



Deaths for road traffic accidents per 100,000 inhabitants in 2004.

no data < 5 5-12.5 12.5-20 20-27.5 27.5-35 35-42.5 42.5-50 50-57.5 57.5-65 65-72.5 72.5-80 > 80



Road fatalities per vehicle-km (fatalities per 1 billion km)

no data < 5.0 5.0-6.5 6.5-8.0 8.0-9.5 9.5-11.0 11.0-12.5 12.5-14.0 14.0-15.5 15.5-17.0 17.0-18.5 18.5-20.0 > 20.0

Worldwide it was estimated in 2004 that 1.2 million people were killed (2.2% of all deaths) and 50 million more were injured in motor vehicle collisions. This makes motor vehicle collisions the leading cause of death among children worldwide 10 – 19 years old (260,000 children die a year, 10 million are injured) and the sixth leading preventable cause of death in the United States (45,800 people died and 2.4 million were injured in 2005). In Canada they are the cause of 48% of severe injuries.

Crash rates

The safety performance of roadways are almost always reported as rates. That is, some measure of harm (deaths, injuries, or number of crashes) divided by some measure of exposure to the risk of this harm. Rates are used so the safety performance of different locations can be compared, and to prioritize safety improvements.

Common rates related to road traffic fatalities include the number of deaths per capita, per registered vehicle, per licensed driver, or per vehicle mile or kilometer traveled. Simple counts are almost never used. The annual count of fatalities is a rate, namely, the number of fatalities per year.

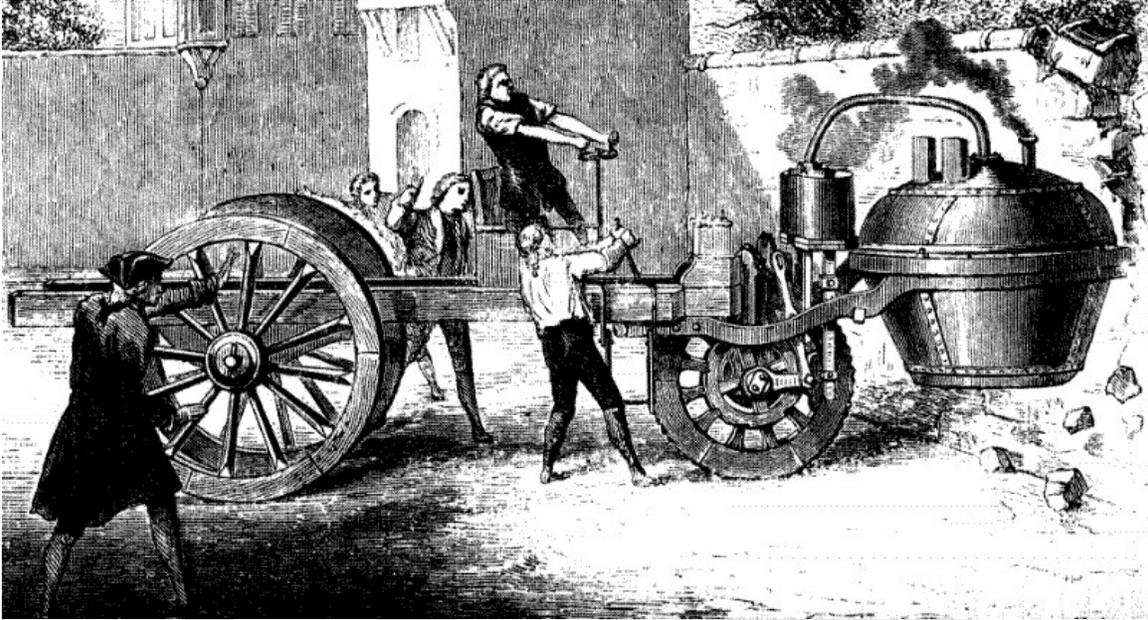
There is no one rate that is superior to others in any general sense. The rate to be selected depends on the question being asked – and often also on what data are available. What is important is to specify exactly what rate is measured and how it relates to the problem being addressed. Some agencies concentrate on crashes per total vehicle distance traveled. Others combine rates. The State of Iowa, for example, selects high accident locations based on a combination of crashes per million miles traveled, crashes per mile per year, and value loss (crash severity)

Fatality

The definition of a road-traffic fatality varies from country to country. In the United States, for example, the definition used in the Fatality Analysis Reporting System (FARS) run by the NHTSA is a person who dies within 30 days of a crash on a US public road involving a vehicle with an engine, the death being the result of the crash. In the U.S., therefore, if a driver has a non-fatal heart attack that leads to a road-traffic crash that causes death, that is a road-traffic fatality. However, if the heart attack causes death prior to the crash, then that is not a road-traffic fatality.

The definition of a road accident fatality can change with time in the same country. For example, fatality is defined in France as a person who dies in the 6 days (pre 2005) after the accident; in the 30 days (post 2005) after the accident.

History



The *fardier à vapeur* of Nicholas Cugnot allegedly crashed into a wall in 1771

The world's first road traffic death involving a motor vehicle is alleged to have occurred on 31 August 1869. An Irish scientist Mary Ward died when she fell out of her cousins' steam car and was run over by it.

German-English composer George Frideric Handel was seriously injured in a carriage crash in 1752.

The British road engineer J. J. Leeming, compared the statistics for fatality rates in Great Britain, for transport-related incidents both before and after the introduction of the motor vehicle, for journeys, including those once by water that now are undertaken by motor vehicle: For the period 1863–1870 there were: 470 fatalities per million of population (76 on railways, 143 on roads, 251 on water); for the period 1891–1900 the corresponding figures were: 348 (63, 107, 178); for the period 1931–1938: 403 (22, 311, 70) and for the year 1963: 325 (10, 278, 37). Leeming concluded that the data showed that "*travel accidents may even have been more frequent a century ago than they are now, at least for men*".

In 1969 a British road engineer, compared the circumstances around road deaths as reported in various American states before the widespread introduction of 55 mph speed limits and drunk-driving laws.

'They took into account thirty factors which it was thought might affect the death rate. Among these were included the annual consumption of wine, of spirits and of malt beverages — taken individually — the amount spent on road maintenance, the minimum temperature, certain of the legal measures such as the amount spent on police, the number

of police per 100,000 inhabitants, the follow-up programme on dangerous drivers, the quality of driver testing, and so on. The thirty factors were finally reduced to six on elimination of those which were found to have small or negligible effect. The final six were:

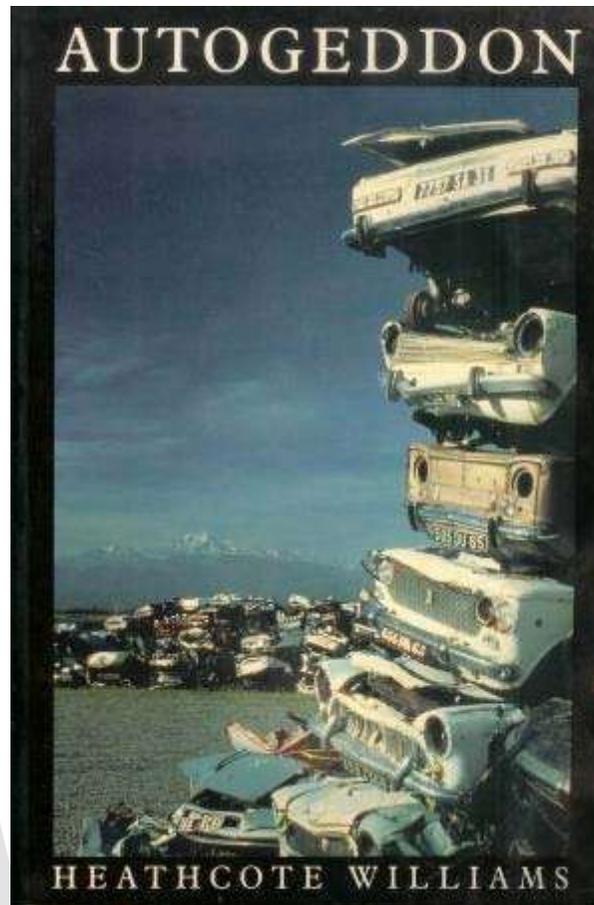
- (a) The percentage of the total state highway mileage that is rural.
- (b) The percent increase in motor vehicle registration.
- (c) The extent of motor vehicle inspection.
- (d) The percentage of state-administered highway that is surfaced.
- (e) The average yearly minimum temperature.
- (f) The income per capita.

'These are placed in descending order of importance. These six accounted for 70% of the variations in the rate.'

Society

Economic costs

The global economic cost of MVCs was estimated at \$518 billion per year in 2003 with \$100 billion of that occurring in developing countries. The Center for Disease Control and Prevention estimated the U.S. cost in 2000 at \$230 billion.



Cover of Heathcote Williams' *Autogeddon* (UK edition, 1991)

Legal consequences

In the United States, individuals involved in motor vehicle accidents can be held financially liable for the consequences of an accident, including property damage, injuries to passengers and drivers, and fatalities. Because these costs can easily exceed the annual income of the average driver, most US states require drivers to carry liability insurance to cover these potential costs. However, in the event of severe injuries or fatalities, victims may seek damages in civil court, often for well in excess of the value of insurance.

Additionally, drivers who are involved in a collision frequently receive one or more traffic citations, usually directly addressing any material violations such as speeding, failure to obey a traffic control device, or driving under the influence of drugs or alcohol. In the event of a fatality, a charge of vehicular homicide is occasionally prosecuted, especially in cases involving alcohol.

Convictions for traffic violations are usually penalized with fines, and for more severe offenses, the suspension or revocation of driving privileges. Convictions for alcohol

offenses generally result in the revocation or long term suspension of the driver's license, and sometimes jail time and/or mandatory alcohol rehabilitation.

Due to increase in availability of cable news and Internet news, exposure to such legal actions has increased in recent years, specifically with coverage of cases and class action suits concerning SUV rollovers and recent incidents of sudden acceleration crashes highlighted by the 2010 Toyota Recall. Increased exposure has resulted in larger class action suits, and automobile owners' ability to link their collision causes and issues to ones from other regions resulting in knowledge of external causes of which they were not previously aware.

Gallery



A BMW Z3 after rolling in a ditch.



Emergency responders at an accident in Colorado Springs, Colorado.



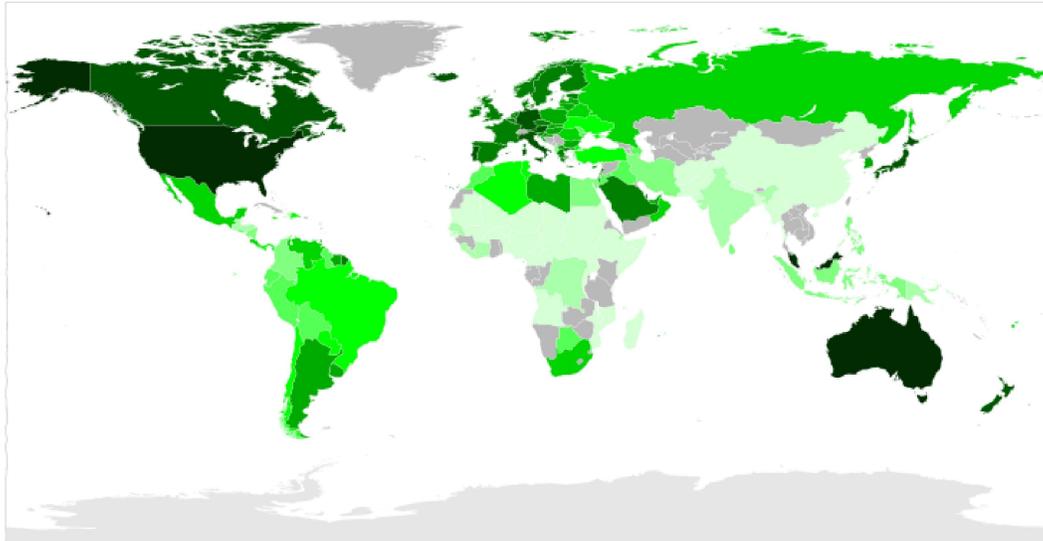
A Honda Accord after colliding with a building.

Chapter- 4

Effects of the Automobile on Societies



Urban land use is often dominated by automobiles. Pictured: São Paulo, Brazil



World map of automobiles per capita

Over the course of the 20th century, the automobile rapidly developed from an expensive toy for the rich into the *de facto* standard for passenger transport in most developed countries. In developing countries, the effects of the automobile have lagged, but are emulating the impacts of developed nations. The development of the automobile built upon the transport revolution started by railways, and like the railways, introduced sweeping changes in employment patterns, social interactions, infrastructure and goods distribution.

The effects of the automobile on everyday life have been a subject of controversy. While the introduction of the mass-produced automobile represented a revolution in mobility and convenience, the modern consequences of heavy automotive use contribute to the use of non-renewable fuels, a dramatic increase in the rate of accidental death, social isolation and the disconnection of community, rise in obesity, the generation of air and noise pollution, and the facilitation of urban sprawl and urban decay.

Access and convenience



A drive-through lane at a United States post office

Worldwide the automobile has allowed easier access to remote places. However, average journey times to regularly visited places have increased in large cities, especially in Latin America, as a result of widespread automobile adoption. This is due to traffic congestion and the increased distances between home and work brought about by urban sprawl.

Examples of automobile access issues in underdeveloped countries are:

- Paving of the Mexico Pacific Coast highway through Baja California, completing the connection of Cabo San Lucas to California, allowing the first routine travel along that route and the first convenient access to the outside world for villagers along the route. (occurred in the 1950s)
- In Madagascar, approximately 30 percent of the population does not have access to reliable all weather roads.
- In China, there are currently 184 towns and 54,000 villages that have no access to automobile use (or roads at all)
- The origin of HIV explosion in the human population has been hypothesized by CDC researchers to derive in part from more intensive social interactions afforded by new road networks in Central Africa allowing more frequent travel from villagers to cities and higher density development of many African cities in the period 1950 to 1980.

The following developments in retail are partially due to automobile use:

- Drive-thru fast food purchasing
- Gasoline station grocery shopping

Economic changes



The main reason for the height of these signs is to attract the attention of drivers on the adjacent freeway.

The development of the automobile has contributed to changes in employment distribution, shopping patterns, social interactions, manufacturing priorities and city planning; increasing use of automobiles has reduced the roles of walking, horses and railroads.

Infrastructure

Aside from industries, one of the most visible effects the automobile has had on the world is the huge increase in the amount of surfaced roads. For example, between 1921 and 1941, the United States spent US\$40 billion on roads, increasing the amount of surfaced

road from 387,000 miles (619,000 kilometers) to over 1,000,000 miles (1.6 million kilometers) which does not even take into account road widening.

United States

In addition to federal, state, and local dollars for roadway construction, car use was also encouraged through new zoning laws that required that any new business construct a certain amount of parking based on the size and type of facility. The effect of this was to create a massive quantity of free parking spaces and to push businesses further back from the road. Many shopping centers and suburbs abandoned sidewalks altogether, making pedestrian access dangerous. This had the effect of encouraging people to drive, even for short trips that might have been walkable, thus increasing and solidifying American auto-dependency. As a result of this change, employment opportunities for people who were not wealthy enough to own a car and for people who could not drive, due to age or physical disabilities, became severely limited.

Environmental impact

For much of the early history of the car, no consideration was given to various environmental effects caused by the automobile. Automobiles are a major source of air pollution and noise pollution. The manufacture and use of automobiles makes up 20 to 25 percent of the carbon dioxide emissions that are believed to be causing global climate change. There are over 600 million cars and light vehicles (excluding heavy trucks and buses) worldwide, The automobile contributes significantly to noise pollution worldwide; in response to these impacts, an entire technology of noise barrier design and other noise mitigation has emerged. In the United States the typical car emits approximately 3.4 grams per mile of carbon monoxide

With increased road-building came negative effects on habitat for wildlife, primarily through habitat fragmentation and surface runoff alteration. New roads built through sensitive habitat can cause the loss or degradation of ecosystems, and the materials required for roads come from large-scale rock quarrying and gravel extraction, which sometimes occurs in sensitive ecological areas. Road construction also alters the water table, increases surface runoff, and increases the risk of flooding.

Cultural changes

Prior to the appearance of the automobile, horses, walking and streetcars were the major modes of transportation within cities. Horses require a large amount of care, and were therefore kept in public facilities that were usually far from residences. The manure they left on the streets also created a sanitation problem.

The automobile made regular medium-distance travel more convenient and affordable, especially in areas without railways. Because automobiles did not require rest, and were faster than horse-drawn conveyances, people were routinely able to travel farther than in earlier times. The construction of highways half a century later continued this revolution

in mobility. Some experts suggest that many of these changes began during the *Golden age of the bicycle*, the preceding era from 1880—1915.

Changes to urban society



Modern automobiles on an American highway, the Downtown Connector in Atlanta, Georgia.

Beginning in the 1940s, most urban environments in the United States lost their streetcars, cable cars, and other forms of light rail, to be replaced by diesel-burning motor coaches or buses. Many of these have never returned, though some urban communities eventually installed subways.

Another change brought about by the automobile is that modern urban pedestrians must be more alert than their ancestors. In the past, a pedestrian had to worry about relatively slow-moving streetcars or other obstacles of travel. With the proliferation of the automobile, a pedestrian has to anticipate safety risks of automobiles at high speeds because cars may cause serious damage to a human.

According to many social scientists, the loss of pedestrian-scale villages has also disconnected communities. Many people in developed countries have less contact with their neighbors and rarely walk unless they place a high value on exercise.



People visiting a suburban warehouse-club store via vehicles

Advent of suburban society

Because of the automobile, the outward growth of cities accelerated, and the development of suburbs in automobile intensive cultures was intensified. Until the advent of the automobile, factory workers lived either close to the factory or in high density communities farther away, connected to the factory by streetcar or rail. The automobile and the federal subsidies for roads and suburban development that supported car culture allowed people to live in low density communities far from the city center and integrated city neighborhoods. The developing suburbs created few local jobs, due to single use zoning. Hence, residents commuted longer distances to work each day as the suburbs expanded.

Car culture

The car had a significant effect on the culture of the middle class. Automobiles were incorporated into all parts of life from music to books to movies. Between 1905 and 1908, more than 120 songs were written in which the automobile was the subject. The automotive themes of these songs reflected the general culture of the automotive industry: sexual adventure, liberation from social control, and masculine power. Books centered on motor boys who liberated themselves from the average, normal, middle class life, to travel and seek adventure in the exotic. Car ownership came to be associated with independence, freedom, and increased social status.

George Monbiot writes that widespread car culture has shifted voter's preference to the right of the political spectrum. He thinks that car culture has contributed to an increase in individualism and fewer social interactions between members of different socioeconomic classes.

Since the early days of the automobile, car manufacturers and petroleum fuel suppliers successfully lobbied governments to build public roads. Road building was sometimes also influenced by Keynesian-style political ideologies. In Europe, massive freeway building programs were initiated by a number of social democratic governments after World War II, in an attempt to create jobs and make the automobile available to the working classes. From the 1970s, promotion of the automobile increasingly became a trait of some conservatives. Margaret Thatcher talked of a "great car economy", and increased government spending on roads.

Safety

Motor vehicle accidents are attributed to 37.5% of accidental deaths in the United States, making them the country's leading cause of accidental death.

Costs

In countries such as the United States the infrastructure that makes car use possible, such as highways, roads and parking lots is funded by the government and supported through government zoning and construction requirements. The gas tax covers about 60% of highway construction and repair costs. Payments by motor-vehicle users fall short of government expenditures tied to motor-vehicle use by 20–70 cents per gallon of gas. Zoning laws in many areas require that large, free parking lots accompany any new buildings. Municipal parking lots are often free or do not charge a market-rate. Hence, the cost of driving a car in the US is subsidized, supported by businesses and the government who cover the cost of roads and parking. This government support of the automobile through subsidies for infrastructure, the cost of highway police enforcement, recovering stolen cars, and many other factors makes public transport a less economically competitive choice for commuters when considering direct out-of-pocket costs. Consumers often make choices based on the direct out-of-pocket costs and underestimate the indirect costs of car ownership, auto insurance and car maintenance. However, globally and in some US cities, tolls and parking fees partially offset these heavy subsidies for driving. Transportation planning policy advocates often support tolls, increased gas taxes, congestion pricing and market-rate pricing for municipal parking as a means of balancing car use in urban centers with more efficient, less environmentally and socially destructive modes of transportation such as buses and trains.

When cities charge market rates for on-street parking and municipal parking garages, and when bridges and tunnels are tolled, driving becomes less competitive in terms of out-of-pocket costs than other modes of transportation. When municipal parking is underpriced and roads are not tolled, most of the cost of vehicle usage is paid for by general government revenue, a subsidy for motor vehicle use. The size of this subsidy dwarfs the federal, state, and local subsidies for the maintenance of infrastructure and discounted fares for public transportation.

By contrast, although there are environmental and social costs for rail, there is a very small impact.

Chapter- 5

Motor Vehicle Emissions



Appearance of car exhaust on a poorly maintained or cold-running car



Typical appearance of car exhaust on a correctly maintained and warmed car. 99.4% of pollutant gases are invisible

Motor vehicle emissions are composed of the by products that comes out of the exhaust systems or other emissions such as gasoline evaporation. These emissions contribute to air pollution and are a major ingredient in the creation of smog in some large cities.

The below sections summarize typically regulated emissions (pollution) from motor vehicles.

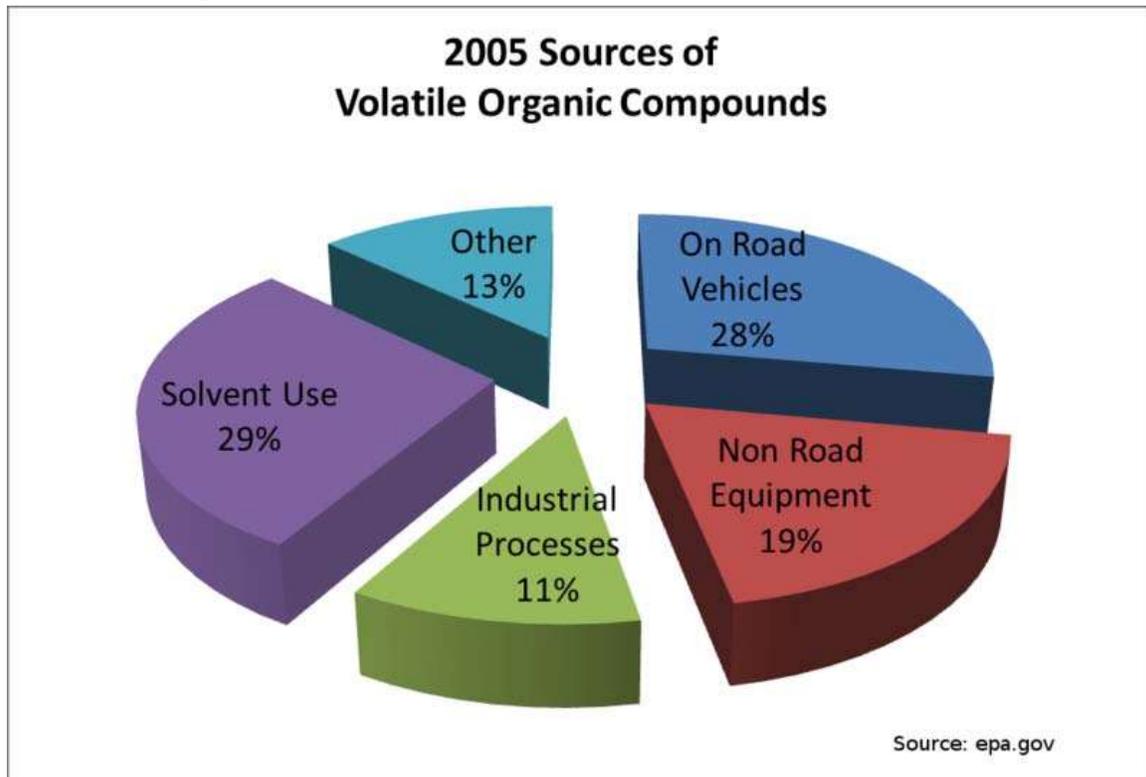
NO_x



Smog in New York City as viewed from the World Trade Center in 1988. A 2009 report indicates that, despite the City's air being close to the EPA's short-term ozone standard, that New Yorkers still face a 25 per-cent increased risk of dying from lung disease.

Mono-nitrogen oxides NO and NO₂ react with ammonia, moisture, and other compounds to form nitric acid vapor and related particles. Small particles can penetrate deeply into sensitive lung tissue and damage it, causing premature death in extreme cases. Inhalation of such particles may cause or worsen respiratory diseases such as emphysema, bronchitis it may also aggravate existing heart disease. In a 2005 U.S. EPA study the largest emissions of NO_x came from on road motor vehicles, with the second largest contributor being non road equipment which is mostly gasoline and diesel stations.

Volatile Organic Compounds

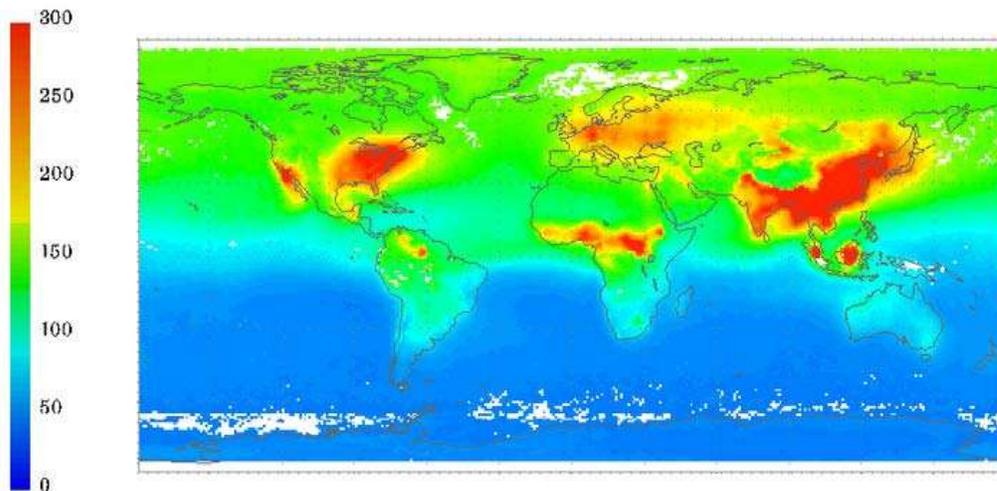


Non road equipment is mostly gasoline and diesel stations

When oxides of nitrogen (NO_x) and volatile organic compounds (VOCs) react in the presence of sunlight, ground level ozone is formed, a primary ingredient in smog. A 2005 U.S. EPA report gives road vehicles as the second largest source of VOCs in the U.S. at 26% and 19% are from non road equipment which is mostly gasoline and diesel stations. 27% of VOC emissions are from solvents which are used in the manufacturer of paints and paint thinners and other uses.

Ozone is beneficial in the upper atmosphere, but at the ground level this gas irritates the respiratory system, causing coughing, choking, and reduced lung capacity. In the United States, ozone is responsible for an estimated \$500 million in reduced crop production each year.

Carbon monoxide (CO)



MOPITT CO Mixing Ratio at Surface (ppbv)

MOPITT satellite computer image of carbon monoxide March 2010

Carbon monoxide poisoning is the most common type of fatal air poisoning in many countries. Carbon monoxide is colorless, odorless and tasteless, but highly toxic. It combines with hemoglobin to produce carboxyhemoglobin, which is ineffective for delivering oxygen to bodily tissues. In the U.S. 60% of carbon monoxide is caused by on road vehicles.

In the UK, in the period from 1970 to 2007 carbon monoxide emissions from motor vehicles dropped by 83%.

Hazardous air pollutants (toxics)

Chronic (long-term) exposure to benzene (C_6H_6) damages bone marrow. It can also cause excessive bleeding and depress the immune system, increasing the chance of infection. Benzene causes leukemia and is associated with other blood cancers and pre-cancers of the blood.

Particulate Matter (PM_{10} and $PM_{2.5}$)

The health effects of inhaling particulate matter have been widely studied in humans and animals and include asthma, lung cancer, cardiovascular issues, and premature death. Because of the size of the particles, they can penetrate the deepest part of the lungs. A 2007 UK study estimates 90 deaths per year due to passenger vehicle PM. In a 2006 publication, the U.S. Federal Highway Administration (FHWA) state that in 2002 about 1 per-cent of all PM_{10} and 2 per-cent of all $PM_{2.5}$ emissions came from the exhaust of on-road motor vehicles (mostly from diesel engines).

Carbon dioxide (CO₂)

Carbon dioxide is a greenhouse gas. Motor vehicle CO₂ emissions are part of the anthropogenic contribution to the growth of CO₂ concentrations in the atmosphere which is believed by a majority of scientists to play a significant part in climate change. Motor vehicles are calculated to generate about 20 per-cent of the European Union's man-made CO₂ emissions, with passenger cars contributing about 12 per-cent. The European Union average new car CO₂ emissions figure dropped by 5.4 per-cent in the year to the first quarter of 2010, down to 145.6 g/km.

Passenger car emissions summary

U.S. Environmental Protection Agency estimates of average passenger car emissions in the United States for July 2000

Component	Emission Rate	Annual pollution emitted
Hydrocarbons	2.80 grams/mile	77.1 pounds (35.0 kg)
Carbon Monoxide	20.9 grams/mile	575 pounds (261 kg)
NO _x	1.39 grams/mile	38.2 pounds (17.3 kg)
Carbon Dioxide - Green house gas	0.916 pounds per mile (258 g/km)	11,450 pounds (5,190 kg)

Localised effects

The California Air Resources Board (C.A.R.B.) found in studies that 50% or more of the air pollution (smog) in Southern California is due to car emissions.

Other negative effects

Residents of low-density, residential-only sprawling communities are also more likely to die in car collisions which kill 1.2 million people worldwide each year, and injure about forty times this number. Sprawl is more broadly a factor in inactivity and obesity, which in turn can lead to increased risk of a variety of diseases.

Chapter- 6

Driverless Car



A robotic Volkswagen Passat shown at Stanford University

A **driverless car** is an autonomous vehicle that can drive itself from one point to another without assistance from a driver; in other words, with an autopilot system. Some believe that autonomous vehicles have the potential to transform the transportation industry while virtually eliminating accidents, and cleaning up the environment.

Driverless passenger car programs include the 800 million EC EUREKA Prometheus Project on autonomous vehicles (1987–1995), the 2getthere passenger vehicles (using the FROG-navigation technology) from the Netherlands, the ARGO research project from Italy, and the DARPA Grand Challenge from the USA.

According to urban designer and futurist Michael E. Arth, driverless electric vehicles—in conjunction with the increased use of virtual reality for work, travel, and pleasure—could reduce the world's 800,000,000 vehicles to a fraction of that number within a few decades. Arth claims that this would be possible if almost all private cars requiring drivers, which are not in use and parked 90% of the time, would be traded for public self-driving taxis that would be in near constant use. This would also allow for getting the appropriate vehicle for the particular need—a bus could come for a group of people, a limousine could come for a special night out, and a Segway could come for a short trip down the street for one person. Children could be chauffeured in supervised safety, DUIs would no longer exist, and 41,000 lives could be saved each year in the U.S. alone.

History

The history of autonomous vehicles starts in 1977 with the Tsukuba Mechanical Engineering Lab in Japan. On a dedicated, clearly marked course it achieved speeds of up to 30 km/h (20 miles per hour), by tracking white street markers (special hardware was necessary, since commercial computers were much slower than they are today).

In the 1980s a vision-guided Mercedes-Benz robot van, designed by Ernst Dickmanns and his team at the Bundeswehr University of Munich in Munich, Germany, achieved 100 km/h on streets without traffic. Subsequently, the European Commission began funding the 800 million Euro EUREKA Prometheus Project on autonomous vehicles (1987–1995).

Also in the 1980s the DARPA-funded Autonomous Land Vehicle (ALV) in the United States achieved the first road-following demonstration that used laser radar (Environmental Research Institute of Michigan), computer vision (Carnegie Mellon University and SRI), and autonomous robotic control (Carnegie Mellon and Martin Marietta) to control a driverless vehicle up to 30 km/h. In 1987, HRL Laboratories (formerly Hughes Research Labs) demonstrated the first off-road map and sensor-based autonomous navigation on the ALV. The vehicle travelled over 600m at 3 km/h on complex terrain with steep slopes, ravines, large rocks, and vegetation.

In 1994, the twin robot vehicles VaMP and Vita-2 of Daimler-Benz and Ernst Dickmanns of UniBwM drove more than one thousand kilometers on a Paris three-lane highway in standard heavy traffic at speeds up to 130 km/h, albeit semi-autonomously with human interventions. They demonstrated autonomous driving in free lanes, convoy driving, and lane changes left and right with autonomous passing of other cars.

In 1995, Dickmanns' re-engineered autonomous S-Class Mercedes-Benz took a 1600 km trip from Munich in Bavaria to Copenhagen in Denmark and back, using saccadic computer vision and transputers to react in real time. The robot achieved speeds exceeding 175 km/h on the German Autobahn, with a mean time between human interventions of 9 km, or 95% autonomous driving. Again it drove in traffic, executing manoeuvres to pass other cars. Despite being a research system without emphasis on long distance reliability, it drove up to 158 km without human intervention.

In 1995, the Carnegie Mellon University Navlab project achieved 98.2% autonomous driving on a 5000 km (3000-mile) "No hands across America" trip. This car, however, was semi-autonomous by nature: it used neural networks to control the steering wheel, but throttle and brakes were human-controlled.

From 1996–2001, Alberto Broggi of the University of Parma launched the ARGO Project, which worked on enabling a modified Lancia Thema to follow the normal (painted) lane marks in an unmodified highway. The culmination of the project was a journey of 2,000 km over six days on the motorways of northern Italy dubbed MilleMiglia in Automatico, with an average speed of 90 km/h. 94% of the time the car was in fully automatic mode, with the longest automatic stretch being 54 km. The vehicle had only two black-and-white low-cost video cameras on board, and used stereoscopic vision algorithms to understand its environment, as opposed to the "laser, radar - whatever you need" approach taken by other efforts in the field.

Three US Government funded military efforts known as Demo I (US Army), Demo II (DARPA), and Demo III (US Army), are currently underway. Demo III (2001) demonstrated the ability of unmanned ground vehicles to navigate miles of difficult off-road terrain, avoiding obstacles such as rocks and trees. James Albus at NIST provided the Real-Time Control System which is a hierarchical control system. Not only were individual vehicles controlled (e.g. throttle, steering, and brake), but groups of vehicles had their movements automatically coordinated in response to high level goals.

In 2002, the DARPA Grand Challenge competitions were announced. The 2004 and 2005 DARPA competitions allowed international teams to compete in fully autonomous vehicle races over rough unpaved terrain and in a non-populated suburban setting. The 2007 DARPA challenge, the DARPA urban challenge, involved autonomous cars driving in an urban setting.

In 2008, General Motors stated that they will begin testing driverless cars by 2015, and they could be on the road by 2018.

In 2010 VisLab launched VIAC, the VisLab Intercontinental Autonomous Challenge, a 13,000 km test run for autonomous vehicles, from Italy to China.

Recent projects

The work done so far varies significantly in its ambition and its demands in terms of modification of the infrastructure. Broadly, there are three approaches:

- Fully autonomous vehicles
- Various enhancements to the infrastructure (either an entire area, or specific lanes) to create a self-driving closed system.
- "assistance" systems that incrementally remove requirements from the human driver (e.g. improvements to cruise control)

An important concept that cuts across several of the efforts is vehicle **platoons**. In order to better utilize road-space, vehicles are assembled into ad-hoc train-like "platoons", where the driver (either human or automatic) of the first vehicle makes all decisions for the entire platoon. All other vehicles simply follow the lead of the first vehicle.

Fully autonomous

Fully autonomous driving requires a car to drive itself to a pre-set target using unmodified infrastructure. The final goal of safe door-to-door transportation in arbitrary environments is not yet reached though.

Vehicles for paved roads

- The 800 million Euro EUREKA Prometheus Project on autonomous vehicles (1987–1995). Among its culmination points were the twin robot vehicles VITA-2 and VaMP of Daimler-Benz and Ernst Dickmanns, driving long distances in heavy traffic.
- The VIAC Challenge, in which 4 vehicles are scheduled to drive from Italy to China on a 13,000 km trip without any human intervention.
- The third competition of the DARPA Grand Challenge held in November 2007. 53 teams qualified initially, but after a series of qualifying rounds, only eleven teams entered the final race. Of these, six teams completed navigating through the non-populated urban environment, and the Carnegie Mellon University team won the \$2 million prize.
- The ARGO vehicle is the predecessor of the BRAiVE vehicle, both from the University of Parma's VisLab. Argo was developed in 1996 and demonstrated to the world in 1998; BRAiVE was developed in 2008 and firstly demonstrated in 2009 at the IEEE IV conference in Xi'an, China.
- Stanford Racing Team's Junior car is an autonomous driverless car for paved roads. It is intended for civilian use.
- The Volkswagen Golf GTI 53+1 is a modified Volkswagen Golf GTI capable of autonomous driving. The Golf GTI 53+1 features a implemented system that can be integrated into any car. This system is based around the MicroAutoBox from dSpace. This, as it was intended to test VW hardware without a human driver (for consistent test results).

Free-ranging vehicles

There are three clusters of activity relating to free-ranging off-road cars. Some of these projects are military-oriented.

- US military DARPA Grand Challenge

The US Department of Defense announced on the July 30, 2002 a "Grand Challenge", for US-based teams to produce a vehicle that could autonomously navigate and reach a target in the desert of the south western USA.

In March 2004, the first competition was held, for a prize-money of \$1 million. Not one of the 25 entrants completed the course. However, in the second competition held in October 2005 five different teams completed the 135-mile (217 km) course, and the Stanford University team won the \$2 million prize. November 3rd, 2007, the third competition was held and \$3.5 million dollar in cash prizes, trophies and medals were awarded. Six driverless vehicles were able to complete the 55 miles of urban traffic in the 2007 DARPA Urban Challenge rally style race. 1st Place - Tartan Racing, Pittsburgh, PA; 2nd Place - Stanford Racing Team, Stanford, CA; 3rd Place - Victor Tango, Blacksburg, VA.

- European Land-Robot Trial (ELROB)

The German Department of Defense held an exhibition trade show (ELROB) for demonstrating automated vehicles in May 2006. The event included various military automated and remotely-operated robots, for various military uses. Some of the systems on display could be ordered and implemented immediately. In August 2007 a civilian version of the event was held in Switzerland. The Smart team from Switzerland presented "a Vehicle for Autonomous Navigation and Mapping in Outdoor Environments".

- The Israeli Military-Industrial Complex

As a followup from its success with Unmanned Combat Air Vehicles, and following the construction of the Israeli West Bank barrier there has been significant interest in developing a fully automated border-patrol vehicle. Two projects, by Elbit Systems and Israel Aircraft Industries are both based on the locally-produced Armored "Tomcar" and have the specific purpose of patrolling barrier fences against intrusions.

The "SciAutonics II" team in the 2004 DARPA Challenge used Elbit's version of the Tomcar.

Pre-built infrastructure

The following projects were conceived as practical attempts to use available technology in an incremental manner to solve specific problems, like transport within a defined campus area, or driving along a stretch of motorway. The technologies are proven, and the main barrier to widespread implementation is the cost of deploying the infrastructure. Such systems already function in many airports, on railroads, and in some European towns.

Dual mode transit - monorail

There is a family of projects, all currently still at the experimental stage, that would combine the flexibility of a private automobile with the benefits of a monorail system. The idea is that privately-owned cars would be built with the ability to dock themselves onto a public monorail system, where they become part of a centrally managed, fully

computerized transport system—more akin to a driverless train system (as already found in airports) than to a driverless car. This idea is also known as Dual mode transit.

Groups working on this concept are:

- RUF (Denmark)
- BiWay (UK)
- ATN (New Zealand)
- TriTrack (Texas, United States)

Automated highway systems

Automated highway systems (**AHS**) are an effort to construct special lanes on existing highways that would be equipped with magnets or other infrastructure to allow vehicles to stay in the center of the lane, while communicating with other vehicles (and with a central system) to avoid collision and manage traffic. Like the dual-mode monorail, the idea is that cars remain private and independent, and just use the AHS system as a quick way to move along designated routes. AHS allows specially equipped cars to join the system using special 'acceleration lanes' and to leave through 'deceleration lanes'. When leaving the system each car verifies that its driver is ready to take control of the vehicle, and if that is not the case, the system parks the car safely in a predesignated area.

Some implementations use radar to avoid collisions and coordinate speed.

One example that uses this implementation is the AHS demo of 1997 near San Diego, sponsored by the US government, in coordination with the State of California and Carnegie Mellon University. The test site is a 12-kilometer, high-occupancy-vehicle (HOV) segment of Interstate 15, 16 kilometers north of downtown San Diego. The event generated much press coverage.

This concerted effort by the US government seems to have been pretty much abandoned because of social and political forces, above all else the desire to create a less futuristic and more marketable solution.

As of 2007, a three-year project is underway to allow robot controlled vehicles, including buses and trucks, to use a special lane along 20 Interstate 805. The intention is to allow the vehicles to travel at shorter following distances and thereby allow more vehicles to use the lanes. The vehicles will still have drivers since they need to enter and exit the special lanes. The system is being designed by Swoop Technology, based in San Diego county.

Free-ranging on grid

Frog Navigation Systems (the Netherlands) applies the FROG (**free-ranging on grid**) technology. The technology consists of a combination of autonomous vehicles and a supervisory central system. The company's purpose-built electric vehicles locate

themselves using odometry readings, recalibrating themselves occasionally using a "maze" of magnets embedded in the environment, and GPS. The cars avoid collisions with obstacles located in the environment using laser (long range) and ultra-sonic (short-range) sensors.

The vehicles are completely autonomous and plan their own routes from A to B. The supervisory system merely administers the operations and directs traffic where required. The system has been applied both indoors and outdoors, and in environments where 100+ automated vehicles are operational (container port). At this time the system is not suited yet for running the sheer number of vehicles encountered in urban settings. The company also has no intention of developing such technology at this time.

The FROG system is deployed for industrial purposes in factory sites, and is marketed as a pilot public transport system in the city of Capelle aan den IJssel by its subsidiary 2getthere. This system experienced an accident that proved to be caused by a Human error.

Frog Navigation Systems is one of few fully commercial companies in this field.

Driver-assistance

Though these products and projects do not aim explicitly to create a fully autonomous car, they are seen as incremental stepping-stones in that direction. Many of the technologies detailed below will probably serve as components of any future driverless car — meanwhile they are being marketed as gadgets that assist human drivers in one way or another. This approach is slowly trickling into standard cars (e.g. improvements to cruise control).

Driver-assistance mechanisms are of several distinct types, sensorial-informative, actuation-corrective, and systemic.

Sensorial-informative

These systems warn or inform the driver about events that may have passed unnoticed, such as

- Lane Departure Warning System (LDWS), for example from Iteris or Mobileye N.V.
- Rear-view alarm, to detect obstacles behind.
- Visibility aids for the driver, to cover blind spots and enhanced vision systems such as radar, wireless vehicle safety communications and night vision.
- Infrastructure-based, driver warning/information-giving systems, such as those developed by the Japanese government

Actuation-corrective

These systems modify the driver's instructions so as to execute them in a more effective way, for example the most widely deployed system of this type is ABS; conversely power steering is not a control mechanism, but just a convenience - it is not involved in decision making.

- Anti-lock braking system (ABS) (also Emergency Braking Assistance (EBA), often coupled with Electronic brake force distribution (EBD), which prevents the brakes from locking and losing traction while braking. This shortens stopping distances in most cases and, more importantly, allows the driver to steer the vehicle while braking.
- Traction control system (TCS) actuates brakes or reduces throttle to restore traction if driven wheels begin to spin.
- Four wheel drive (AWD) with a centre differential. Distributing power to all four wheels lessens the chances of wheel spin. It also suffers less from oversteer and understeer.
- Electronic Stability Control (ESC) (also known for Mercedes-Benz proprietary Electronic Stability Program (ESP), Acceleration Slip Regulation (ASR) and Electronic differential lock (EDL)). Uses various sensors to intervene when the car senses a possible loss of control. The car's control unit can reduce power from the engine and even apply the brakes on individual wheels to prevent the car from understeering or oversteering.
- Dynamic steering response (DSR) corrects the rate of power steering system to adapt it to vehicle's speed and road conditions.

A review of the overall "feel" to actuation-correction in a Jaguar XK convertible.

Driver-assistance preview from Popular Science (dated 2004).

Note: The electronic differential lock (EDL) employed by Volkswagen is not - as the name suggests - a differential lock at all. Sensors monitor wheel speeds, and if one is rotating substantially faster than the other (i.e. slipping) the EDL system momentarily brakes it. This effectively transfers all the power to the other wheel.

Systemic

- Automatic parking: e.g. technology from Ford or Toyota selling for \$700, with a 70% take-up rate. The Lexus LS can park itself (parallel/reverse) via the 'Advanced Parking Guidance System' – though only controlling the steering.
- Follow another car on a motorway ("Enhanced" or "adaptive" cruise control), like The Ford or Vauxhall(GM).
- Nissan's "Distance Control assist"
- Dead Man's Switch; there is a move to introduce deadman's braking into automotive application, primarily heavy vehicles, and there may also be a need to add penalty switches to cruise controls.

Existing and missing technologies

In order to drive a car, a system would need to:

1. Understand its immediate environment (Sensors)
2. Know where it is and where it wants to go (Navigation)
3. Find its way in the traffic (Motion planning)
4. Operate the mechanics of the vehicle (Actuation)

Arguably, 2½ of these problems are already solved: Navigation and Actuation completely, and Sensors partially, but improving fast. The main unsolved part is the motion planning.

Sensors

Sensors employed in driverless cars vary from the minimalist ARGO project's monochrome stereoscopy to Mobileye's inter-modal (video, infra-red, laser, radar) approach. The minimalist approach imitates the human situation most closely, while the multi-modal approach is "greedy" in the sense that it seeks to obtain as much information as is possible by current technology, even at the occasional cost of one car's detection system interfering with another's.

Mobileye N.V. is a technology company that focuses on the development of vision-based Advanced Driver Assistance Systems (ADAS) providing warnings for collision prevention and mitigation. Mobileye offers a wide range of driver safety solutions combining artificial vision image processing, multiple technological applications and information technology. Mobileye's vehicle detection systems, are currently only used for driver assistance, but are eminently suitable for a full-fledged driverless car. This video demonstrates the capabilities of the system: all pedestrians, cars, motorbikes etc. are clearly displayed in video, with a frame around them and the distance between "our" car and the object observed. The system also detects the objects' motion (direction and speed) and can so calculate relative speeds, and predict collisions.

- Japanese infra-red article
- some things from the DARPA challenge....
- Road-sign recognition

Navigation

The ability to plot a route from where the vehicle is to where the user wants to be has been available for several years. These systems, based on the US military's Global Positioning System are now available as standard car fittings, and use satellite transmissions to ascertain the current location, and an on-board street database to derive a route to the target. The more sophisticated systems also receive radio updates on road blockages, and adapt accordingly. There are also sensors that greatly affect the whole nature of it.

Motion planning

- PMP + SLAMMOT YouTube

This is current research problem.

Control of vehicle

As automotive technology matures, more and more functions of the underlying engine, gearbox etc. are no longer directly controlled by the driver by mechanical means, but rather via a computer, which receives instructions from the driver as inputs and delivers the desired effect by means of electronic throttle control, and other drive-by-wire elements. Therefore, the technology for a computer to control all aspects of a vehicle is well understood.

Work done in simulation

While developing control systems for real cars is very costly in terms of both time and money, much work can be done in simulations of various complexity. Systems developed using simpler simulators can gradually be transferred to more complex simulators, and in the end to real vehicles. Some approaches that rely on learning requires starting in a simulation to be viable at all, for example evolutionary robotics approaches - see this example.

Social issues

There are some social issues to address, such as

- Getting people to trust the car
- Getting legislators to permit the car onto the public roads
- Untangling the legal issues of liability for any mishaps with no person in charge.
- Despair of progress in the foreseeable future: The UK government seems to see little progress until 2015.
- Getting people to give up their freedom to drive wherever they want, whenever they want without the aide of a computer - though mixed systems with some human driven and some computer driven cars are possible.

Discussion and future prospects

Some systems control everything centrally, and in some the vehicle is truly autonomous in the sense that it "thinks" about its own situation in the first person — such a system can integrate with humans that think in first person.

Conversely, a system that centrally manages everything, though easier to build from a conceptual and engineering point of view, would face great economic barriers because of

the costs of converting an entire city or country to the new system at once. In order to be compatible with humans the "first person" point of view is key. This is for three reasons:

1. a distributed scheme in which each component (car) takes care of itself reduces complexity
2. a system that has the concept of first-person operation can understand what a human driver is up to
3. for the human driver to understand what the driverless car is doing, it needs to operate and "think" in as similar a way to a human as practical (and safe).

Key players

International

The European Union has a multi-billion Euro programme to support Research and Development by ad-hoc consortia from the various member countries, called Framework Programmes for Research and Technological Development. Several of these projects pertain to the subject of driverless cars, e.g.:

- INRIA's La Route Automatisée project gathered much useful data about the actual and possible deployments of Driverless Cars for **public transport**. The main system discussed is based on FROG.

Many of the EU-sponsored projects are coordinated by a group called Ertico.

There are several national associations around the world that are active in research in the field of intelligent transportation systems, a term that seems to encompass anything which applies technology to the improvement of transport. In recent years there has been a trend in this field to move efforts away from the more visionary projects, such as driverless cars, to the more short-term, such as public transport and traffic management. Many of these organizations are government sponsored, and they all cooperate at some level or another. Some of the countries involved are: USA, IEEE ITS Society, Australia, South Korea, Taiwan, India--(specifically Intelligent vehicles), and Japan, specifically a cruise assist effort (see below). A more complete list of its organizations can be found here.

Chapter- 7

Future Car Technology



The Chevrolet Volt is a plug-in hybrid electric car slated to go on sale in 2010



The Audi RSQ sports coupé from the 2004 film I, Robot, envisioned as being motivated by spherical "wheels"



The General Motors Hy-wire hydrogen car on display at the Test Track attraction at Disney World's Epcot.

Potential **future car technologies** include new energy sources and materials, which are being developed in order to make automobiles more sustainable, safer, more energy efficient, or less polluting. Cars are being developed in many different ways.

With rising gas prices, the future of cars is leaning towards fuel efficiency, energy-savers, hybrid vehicles, battery electric vehicles and fuel-cell vehicles (Xiang, Jia, Jianzhong, Zhibiao, Yuanzhang, & Qinglin 2008).

Advanced control

- Platoons of cars that are controlled by the lead car
- Automated highway systems
- Vehicle infrastructure integration

Energy source

One major problem in developing cleaner, energy efficient automobiles is the source of power to drive the engine. A variety of alternative fuel vehicles have been proposed or sold, including electric cars, hydrogen cars, and compressed-air cars.

In one experiment done to improve the future of cars, a new kind of battery was installed which can be easily removed, and recharged in two different ways. First, by a generator integrated with the IC and second by removing the cassettes so that they can be recharged off-board in the home.

Energy savers

Conventional automobiles operate at about 15% efficiency. The rest of the energy is lost to engine and drive-train inefficiencies and idling. Therefore, the potential to improve fuel efficiency with advanced technologies is enormous.

Various technologies have been developed and utilized to increase the energy efficiency of conventional cars or supplement them, resulting in energy savings.

- Regenerative braking Regenerative braking technology saves and stores energy for future use or as back up power. When conventional brakes are used, 30% of the energy is lost in the form of heat (Raunekk, 2009). Regenerative braking uses this energy to recharge the batteries in a hybrid vehicle.
- BMW's Turbosteamer BMW's Turbosteamer concept uses energy from the exhaust gases of the traditional Internal Combustion Engine (ICE) to power a steam engine which also contributes power to the automobile (Hanlon, 2005). This can increase energy efficiency up to 15 %.
- Compressed air Hybrid is an engine made by researchers at Brunel University in Britain, which forces highly compressed air into the engine, which they claim reduces fuel consumption by 30%.

- Utilization of waste heat from D.W. as useful mechanical energy through exhaust powered steam, stirling engines, thermal diodes, etc..
- Using computational fluid dynamics in the design stage can produce vehicles which take significantly less energy to push through the air, a major consideration at highway speeds. The Volkswagen 1-litre car and Aptera 2 Series are examples of ultra-low-drag vehicles.
- Installing Vortex prevention devices at the back of the roof of a car reduces drag and therefore improve fuel efficiency.

Materials

- Duraluminum, fiberglass, carbon fiber, and carbon nanotubes may totally replace all steel in cars (potentially improving lightness and strength). Aluminum, carbon fiber and fiberglass are currently being used more in cars today.

Open source development

There have been several projects aiming to develop a car on the principles of open design. The projects include OScar, Riversimple (through 40fires.org) and c,mm,n. None of the projects have reached significant success in terms of developing a car as a whole both from hardware and software perspective and no mass production ready open-source based design have been introduced as of late 2009. Some car hacking through on-board diagnostics (OBD) has been done so far.

Chapter- 8

Automotive Industry

The **automotive industry** designs, develops, manufactures, markets, and sells the world's motor vehicles. The automotive industry is one of the most important economic sectors by revenue.

The term *automotive industry* usually does not include industries dedicated to automobiles after delivery to the customer, such as repair shops and motor fuel filling stations.

Worldwide Trends

In 2007, worldwide production reached a peak at a total of 73.3 million new motorvehicles produced worldwide. In 2009, worldwide motorvehicle production dropped 13.5 percent to 61 million. Sales in the U.S. dropped 21.2 percent to 10.4 million units, sales in the European Union (supported by scrapping incentives in many markets) dropped 1.3 percent to 14.1 million units. China became the world's largest motorvehicles market, both by sales as by production. Sales in China rose 45 percent in 2009 to 13.6 million units. In recent years, private Chinese manufacturers emerge.

About 250 million vehicles are in use in the United States. Around the world, there were about 806 million cars and light trucks on the road in 2007; they burn over 260 billion gallons of gasoline and diesel fuel yearly. In the opinion of some, urban transport systems based around the car have proved unsustainable, consuming excessive energy, affecting the health of populations, and delivering a declining level of service despite increasing investments. Many of these negative impacts fall disproportionately on those social groups who are also least likely to own and drive cars. The sustainable transport movement focuses on solutions to these problems.

History

The first practical automobile with a petrol engine was built by Karl Benz in 1885 in Mannheim, Germany. Benz was granted a patent for his automobile on 29 January 1886, and began the first production of automobiles in 1888, after Bertha Benz, his wife, had proved with the first long-distance trip in August 1888 - from Mannheim to Pforzheim and back - that the horseless coach was absolutely suitable for daily use. Since 2008 a Bertha Benz Memorial Route commemorates this event.

Soon after, Gottlieb Daimler and Wilhelm Maybach in Stuttgart in 1889 designed a vehicle from scratch to be an automobile, rather than a horse-drawn carriage fitted with an engine. They also are usually credited as inventors of the first motorcycle in 1886, but Italy's Enrico Bernardi, of the University of Padua, in 1882, patented a 0.024 horsepower (17.9 W) 122 cc (7.4 cu in) one-cylinder petrol motor, fitting it into his son's tricycle, making it at least a candidate for the first automobile, and first motorcycle; Bernardi enlarged the tricycle in 1892 to carry two adults.

Crisis in the automotive industry

World motor vehicle production

By Year

Global Production of Motorvehicles

(cars and commercial vehicles)

Year	Production	Change
1997	52,987,000	
1998	57,987,000	-2.70%
1999	56,258,892	2.98%
2000	58,374,162	3.80%
2001	56,304,925	-3.50%
2002	58,994,318	4.80%
2003	60,663,225	2.80%
2004	64,496,220	6.30%
2005	66,482,439	3.10%
2006	69,222,975	4.10%
2007	73,266,061	5.80%
2008	70,520,493	-3.70%
2009	60,986,985	-13.50%

By Manufacturer

« previous year — **Top motor vehicle manufacturing companies by volume 2009 next year** »

Total motor vehicle production

Group	1,000,000	2,000,000	3,000,000	4,000,000	5,000,000	6,000,000	7,000,000	8,000,000	9,000,000	10,000,000
Key	Cars			Light Commercial			Heavy Commercial			

	Vehicles	Vehicles Heavy Buses
Toyota		7,234,439
G.M.		6,459,053
Volkswagen		6,067,208
Ford		4,685,394
Hyundai		4,645,776
PSA	3,042,311	
Honda	3,012,637	
Nissan	2,744,562	
Fiat	2,460,222	
Suzuki	2,387,537	
Renault	2,296,009	
Daimler AG	1,447,953	
Chana Automobile	1,425,777	
B.M.W.	1,258,417	
Mazda	984,520	
Chrysler	959,070	
Mitsubishi	802,463	
Beijing Automotive	684,534	
Tata	672,045	
Dongfeng Motor	663,262	
FAW	650,275	
Chery	508,567	
Fuji	491,352	
BYD	427,732	
SAIC	347,598	
Anhui Jianghuai	336,979	
Geely	330,275	
Isuzu	316,335	
Brilliance	314,189	
AvtoVAZ	294,737	
Great Wall	226,560	
Mahindra	223,065	
Shangdong	169,023	

Kaima			
Proton	152,965		
China National	120,930		
Volvo	105,873		
Chongqing Lifan	104,434		
Fujian	103,171		
Kuozui	93,303		
Shannxi Auto	79,026		
Porsche	75,637		
Ziyang Nanjun	72,470		
GAZ	69,591		
Navistar	65,364		
Guangzhou Auto	62,990		
Paccar	58,918		
Chenzhou Ji'ao	51,008		
Qingling Motor	50,120		
Hebei Zhongxing	48,173		
Ashok Leyland	47,694		
Key	Cars	Light Commercial Vehicles	Heavy Commercial Vehicles Heavy Buses
Total: 60,499,159	Cars: 51,075,480	LCV: 7,817,520	HCV: 1,305,755 Heavy Bus: 300,404

Reference: "World motor vehicle production by manufacturer: World ranking of manufacturers 2009". OICA. July 2010.

Company relationships

It is common for automobile manufacturers to hold stakes in other automobile manufacturers. These ownerships can be explored under the detail for the individual companies.

Notable current relationships include:

- Daimler AG holds a 20% stake in Eicher Motors, a 10.0% stake in KAMAZ, a 10% stake in Tesla Motors, a 6.75% stake in Tata Motors and a 3.1% in the Renault-Nissan Motors alliance. They are in the process of selling back their 40% stake in McLaren Group. This process will be finalized in 2011.
- Dongfeng Motor Corporation is involved in joint ventures with several companies in China, including: Honda, Hyundai, Nissan, Nissan Diesel, and PSA Peugeot Citroen.
- Fiat holds a 85% stake in Ferrari and a 20% stake in Chrysler, that can be increased to 35%; with the option of increasing its stake further.
- Ford Motor Company holds a 13.4% stake in Mazda and an 8.3% share in Aston Martin.
- Geely Automobile holds a 23% stake in Manganese Bronze Holdings.
- General Motors and Shanghai Automotive Industry Corporation (SAIC) have two joint ventures in Shanghai General Motors and SAIC-GM-Wuling Automobile.
- Hyundai Kia Automotive Group holds a 38.67% stake in Kia Motors, down from the 51% that it acquired in 1998.
- Renault Pars is a joint venture, 51 percent of which belongs to Renault of France. Forty-nine percent of Renault Pars' shares is jointly held by Iran's Industrial Development and Renovation Organization, IKCO and Saipa. The company was established in 2003.
- MAN SE holds a 17.01% voting stake in Scania.
- Porsche Automobil Holding SE has a 50.74% stake in Volkswagen Group. Due to liquidity problems, Volkswagen Group is now in the process of acquiring Porsche.
- Renault-Nissan Motors have an alliance involving two global companies linked by cross-shareholding, with Renault holding 44.3% of Nissan shares, and Nissan holding 15% of (non-voting) Renault shares. The alliance holds a 3.1% share in Daimler AG.
- Renault holds a 25% stake in AvtoVAZ and 20.5% of the voting stakes in Volvo Group.
- Toyota holds a 51% stake in Daihatsu, and 16.5% in Fuji Heavy Industries, parent company of Subaru.
- Volkswagen Group and FAW have a joint venture.
- Volkswagen Group and Shanghai Automotive Industry Corporation (SAIC) have a joint venture in Shanghai Volkswagen Automotive.
- Volkswagen Group holds a 37.73% stake in Scania (68.6% voting rights), and a 29% stake in MAN SE.

- Volkswagen Group has a 49.9% stake in Porsche AG. Volkswagen is in the process of acquiring Porsche, which will be completed in mid-2011.
- Volkswagen Group has a 19.9% stake in Suzuki, and Suzuki has a 5% stake in Volkswagen.

Top vehicle manufacturing groups (by volume)

The table below shows the world's largest motor vehicle manufacturing groups, along with the marques produced by each one. The table is ranked by 2009 *end of year* production figures from the International Organization of Motor Vehicle Manufacturers (OICA) for the parent group, and then alphabetically by marque. Joint ventures are not reflected in this table. Production figures of joint ventures are typically included in OICA rankings, which can become a source of controversy.

Marque	Country of origin	Ownership	Markets
1. Toyota Motor Corporation ( Japan)			
Daihatsu		Subsidiary	Global, except North America and Australia
Hino		Subsidiary	Asia Pacific, North America and South America
Lexus		Division	Global
Scion		Division	North America
Toyota		Division	Global
2. General Motors Company ( United States)			
Buick		Division	North America, Middle East, East Asia
Cadillac		Division	Global, except South America, South Asia, South East Asia, Pacific
Chevrolet		Division	Global, except Australia, New Zealand, South Korea
Daewoo		Subsidiary	South Korea
GMC		Division	North America, Middle East
Holden		Subsidiary	Australia, New Zealand, Japan
Opel		Subsidiary	Global, except North America, United Kingdom
Vauxhall		Subsidiary	United Kingdom
3. Volkswagen Group AG ( Germany)			
Audi		Subsidiary	Global
Bentley		Subsidiary	Global
Bugatti		Subsidiary	Global
Lamborghini		Subsidiary	Global
Scania		Subsidiary	Global

SEAT		Subsidiary	Europe, South America, North Africa, Middle East
Škoda		Subsidiary	Global, except North America and South Africa
Volkswagen		Subsidiary	Global
Volkswagen Commercial Vehicles		Subsidiary	Global

4. Ford Motor Company (United States)

Ford		Division	Global
Lincoln		Division	North America, Middle East, South Korea, Japan
Mercury**		Division	North America, Middle East
Troller		Subsidiary	South America and Africa

5. Hyundai Motor Company (South Korea)

Hyundai		Division	Global
Kia		Division	Global

6. PSA Peugeot Citroën S.A. (France)

Citroën		Subsidiary	Global, except North America, South Asia
Peugeot		Subsidiary	Global, except North America, South Asia

7. Honda Motor Company (Japan)

Acura		Division	North America, East Asia, Russia
Honda		Division	Global

8. Nissan Motor Company (Japan)

Infiniti		Division	Global, except South America and Africa
Nissan		Division	Global

9. Fiat S.p.A. (Italy)

Abarth		Subsidiary	Global, except North America
Alfa Romeo		Subsidiary	Global
Ferrari		Subsidiary	Global
Fiat		Subsidiary	Global
Fiat Professional		Subsidiary	Global, except North America
Irisbus		Subsidiary	Global, except North America
Iveco		Subsidiary	Global, except North America
Lancia		Subsidiary	Europe
Maserati		Subsidiary	Global

10. Suzuki Motor Corporation (Japan)

Maruti Suzuki		Subsidiary	India, Middle East, South America
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Suzuki  Division Global

11. Renault S.A. ( France)

Dacia  Subsidiary Europe, Latin America, Asia, Africa

Renault (cars)  Division Global, except North America, South Asia

Renault Samsung  Subsidiary Asia, South America

12. Daimler AG ( Germany)

Freightliner  Subsidiary North America, South Africa

Master  Subsidiary Pakistan

Maybach  Division Global

Mercedes-Benz  Division Global

Mitsubishi Fuso  Subsidiary Global

Orion  Subsidiary North America

Setra  Subsidiary Europe

Smart  Division North America, Europe, South East Asia, South Africa

Thomas Built  Subsidiary North America

Western Star  Subsidiary North America

13. Chana Automobile Company, Ltd ( People's Republic of China)

Chana  Division China, South Africa

Hafei  Subsidiary China

14. BMW AG ( Germany)

BMW  Division Global

MINI  Division Global

Rolls-Royce  Subsidiary Global

15. Mazda Motor Corporation ( Japan)

Mazda  Division Global

16. Chrysler Group, LLC ( United States)

Chrysler  Division Global

Dodge  Division Global

GEM  Division North America

Jeep  Division Global

Ram  Division North America

17. Mitsubishi Motors Corporation ( Japan)

Mitsubishi  Division Global

18. Beijing Automotive Industry Holding Corporation, Ltd ( People's Republic of China)

BAW  Division China

Foton  Subsidiary China

19. Tata Motors, Ltd ( India)

Hispano		Subsidiary	Europe
Jaguar		Subsidiary	Global
Land Rover		Subsidiary	Global
Tata		Division	India, South Africa
Tata Daewoo		Subsidiary	South Korea

20. Dongfeng Motor Corporation ( People's Republic of China)

Dongfeng		Division	China
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21. First Automotive Group Corporation ( People's Republic of China)

Besturn		Division	China
Freewind		Subsidiary	China
Haima		Subsidiary	China
Hongqi		Division	China
Jiaxing		Subsidiary	China
Vita		Subsidiary	China
Xiali		Subsidiary	China

22. Chery Automobile Company, Ltd ( People's Republic of China)

Chery		Division	China, Africa, South East Asia, Russia
Riich		Division	China
Rely		Division	China

23. Fuji Heavy Industries, Ltd ( Japan)

Subaru		Division	Global
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24. BYD Auto ( People's Republic of China)

BYD		Division	China, Russia
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25. Shanghai Automotive Industry Corporation ( People's Republic of China)

MG		Subsidiary	United Kingdom, Chile, Argentina
SsangYong***		Subsidiary	Global
Roewe		Division	China
Soyat		Division	China
Yuejin		Division	China

26. Anhui Jianghuai Automobile Company, Ltd ( People's Republic of China)

JAC		Division	China
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27. Geely Automobile ( People's Republic of China)

Geely		Division	China, Russia, North Africa
Maple		Division	China
Volvo (Cars)		Subsidiary	Global

28. Isuzu Motors, Ltd ( Japan)

Isuzu		Division	Global, except North America
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29. Brilliance China Automotive Holding, Ltd ( People's Republic of China)

Brilliance  Division China, North Africa
Jinbei  Subsidiary China

30. OAO AvtoVAZ ( Russia)

Lada  Division Russia, Europe, North Africa
VAZ  Division Russia, Europe

31. Great Wall Motor Company, Ltd ( People's Republic of China)

Great Wall  Division China, South Africa, Russia, North Africa, Australia

32. Mahindra & Mahindra, Ltd ( India)

Mahindra  Division India, South East Asia, Europe, North Africa, North America

33. Shandong Kaima ( China)

Kaima  Division China
Jubao  Division China
Aofeng  Division China

34. Proton Holdings, Bhd ( Malaysia)

Proton  Division Asia Pacific, South Africa, United Kingdom, Middle East
Lotus  Subsidiary Global

35. China National Heavy Duty Truck Company, Ltd ( People's Republic of China)

Sinotruk  Division China

36. AB Volvo ( Sweden)

Mack  Subsidiary Global
Nissan Diesel  Subsidiary Global
NovaBus  Subsidiary North America
Prevost  Subsidiary North America
Renault (trucks)  Subsidiary Global
Volvo (trucks)  Division Global

37. Chongqing Lifan Automobile Company, Ltd ( People's Republic of China)

Lifan  Division China

38. Fujian Motor Industry Group Company ( People's Republic of China)

Soueast  Division China

39. Kuozui Motors, Ltd ( Taiwan)

Kuozui  Subsidiary Taiwan

40. Shaanxi Automobile Group Company, Ltd ( People's Republic of China)

Shaanxi  Division China

41. Porsche ( Germany)

Porsche  Subsidiary Global

42. Ziyang Nanjun Automobile Co., Ltd. ( People's Republic of China)

Nanjun  Division China

43. GAZ Group ( Russia)

GAZ  Subsidiary Russia

KAvz  Subsidiary Russia

LiAZ  Subsidiary Russia

Ural  Division Russia

44. Navistar International Corporation ( United States)

IC  Subsidiary North America

International  Division North America, South Asia

45. Guangzhou Automobile Group ( China)

Changfeng  Division China

46. Paccar, Inc ( United States)

DAF  Subsidiary Global, except North America

Kenworth  Division North America

Leyland  Subsidiary Europe

Peterbilt  Division North America

47. Chenzhou Ji'ao ( China)

Ji'ao  Division China

48. Qingling Motors Company Ltd. ( China)

Qingling  Division China

49. Hebei ZXAUTO ( China)

Zhongxing  Division China

50. Ashok Leyland ( India)

Ashok Leyland  Division India

Chapter- 9

Auto Market and Alternative to the Automobile

Automotive Market

The **automotive market** is formed by the demand and the industry. This article is about the general, major trends in the automotive market, mainly from the demand side.

The European automotive market has always boasted smaller cars than the United States. With the high fuel prices and the world petroleum crisis, the United States may see its automotive market become more like the European market with fewer large vehicles on the road and more small cars.

For luxurious cars, with the current volatility in oil prices, going for smaller cars is not only smart, but also trendy. And because fashion is of high importance with the upper classes, the little green cars with luxury trimmings become quite plausible.

Following this trend, General Motors Corporation announced on 2008-06-03 its plans to cease production at four GM truck assembly plants in North America while adding additional shifts at two assembly plants for cars. According GM, U.S. consumer preferences are shifting permanently away from trucks and sport utility vehicles (SUVs) in favor of smaller cars and crossover vehicles. As a result, GM saw significant increases in the retail sales of its Chevrolet Malibu, Chevrolet Aveo and Pontiac Vibe in 2008 May, while its May sales of trucks to its dealerships are down by 36.7% from last year. Regarding cars and crossovers, higher gasoline prices are changing consumer behavior, and rapidly, significantly affecting the U.S. auto industry sales mix. GM thinks this is not a spike or temporary shift, but is, by and large, permanent

GM is also "undertaking a strategic review" of the Hummer brand and could either revamp the product line or sell the brand.

General Motors have cancelled a \$2 billion investment program to update their range of full-size SUVs.

Of course, GM's sales trends are not unique to the company; all the large automakers are seeing similar trends.

For instance, the biggest loser on the American Customer Satisfaction Index list is the struggling Ford's Lincoln-Mercury brand, with a 3.5% drop to 83 from 86 in 2007. Ford Motor Company, in general, saw a 20% increase in retail sales of its cars in 2008 May (compared to last year) and a 4% increase in car sales to its dealerships. Meanwhile, its SUV sales to dealerships were down 44% and its truck and van sales to dealerships were down 29% (note that both Ford and GM did not release retail sales information on their trucks and SUVs). Ford is top-heavy, with several big, gas-guzzling models that have put a damper on owner satisfaction. Ford announced in late 2008 July that it will bring its more fuel-efficient European models to the U.S., but the cars may not arrive in time to stem the company's slide in customer satisfaction.

Toyota Motor also saw big sales gains for its Yaris, Corolla, and Scion xB, although Toyota's car sales overall were down by 21.3% in May, compared to last year. Toyota's light truck sales are down by 15.9%, while Toyota's Lexus division suffered sales drops nearly across the board. "We are looking at the current shift towards fuel-efficient cars (in the United States) as a structural change in demand," Toyota President Katsuaki Watanabe told a news conference. "We intend to respond quickly and flexibly to this environment". As part of those efforts, Toyota said it would move forward the launch of a "plug-in" version of its Prius.

Likewise, American Honda Motor Company experienced a 30.7% increase in car sales in May, compared to last year, while truck sales were down 11.4% and sales in its Acura division were down by 9.9%.

Chrysler is facing continuous pressure from its rapidly decline sales of trucks, pick ups and minivans as consumers tend to buy more fuel-efficient vehicles given the soaring oil prices. Chrysler Chief Executive Bob Nardelli said the government loans would help speed the electric technology to market. But if they aren't approved, Chrysler will have to spend limited resources on developing new technology and would have to make cuts elsewhere, possibly in employment and development of conventional products. "Unfortunately we have had to furlough many families as a result of the economy turmoil and certainly the downward spiraling in the industry," he said. "I'd like to make sure that we don't have to go further to be able to support advanced technology work."



Mercury Mariner Hybrid

With gasoline at record prices, demand for some gas-electric hybrid vehicles is booming.

The average Toyota Prius is getting sold just 13 days after hitting the showroom floor, according to Power Information Network data sampled from dealerships. A year ago, it took 24 days to sell a Prius. Prius sales dropped 38% in May compared to a year ago, but that was because Toyota dealers were running out of cars to sell. Dealers had just 3,832 unsold at the end of a month during which they sold more than 15,000 cars. (Those same Toyota dealers had more than 19,000 Sequoia sport utility vehicles gathering dust at the end of May, according to Autodata Corp., after selling just 3,575 of the U.S.-made big rigs.)

Ford says its two hybrids — a version of the Escape SUV and Mercury Mariner — are selling well, and inventory levels are tight.

Car makers compete to demonstrate their pro-hybrid bona fides. The stampede toward hybrid technology reflects the much broader rush toward smaller, more fuel-efficient vehicles that has roiled the auto market as gasoline prices started in 2008 topping \$4 a gallon.

A sharp rise in gasoline prices and a consumer stampede from sport utility vehicles and pickups have renewed calls for US regulators to consider more aggressive fuel efficiency standards.

Alternative to the Automobile



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

Established alternatives for some aspects of automobile use include public transit (buses, trolleybuses, trains, subways, monorails, tramways), cycling, walking, rollerblading and skateboarding.

Car-share arrangements are also increasingly popular – the U.S. market leader has experienced double-digit growth in revenue and membership growth between 2006 and 2007, offering a service that enables urban residents to "share" a vehicle rather than own a car in already congested neighborhoods. Bike-share systems have been tried in some European cities, including Copenhagen and Amsterdam. Similar programs have been experimented with in a number of U.S. Cities.

An emerging alternative is personal rapid transit, in which small, automated vehicles would run on special elevated tracks spaced within walking distance throughout a city, and could provide direct service to a chosen station without stops. Another possibility is new forms of personal transport such as segway, which could serve as an alternative to automobiles and bicycles if they prove to be socially accepted.

All of these alternative modes of transport pollute less than the conventional (petroleum-powered) car and contribute to transport sustainability. They also provide other significant benefits such as reduced traffic-related injuries and fatalities, reduced space requirements, both for parking and driving, reduced resource usage and pollution related to both production and driving, increased social inclusion, increased economic and social

equity, and more livable streets and cities. Some alternative modes of transportation, especially cycling, also provide regular, low-impact exercise, tailored to the needs of human bodies. Public transport is also linked to increased exercise, because they are combined in a multi-modal transport chain that includes walking or cycling.

The benefits of possible future car technologies, not yet in widespread use, like zero-emissions vehicles over these alternatives, would be:

- Increased mobility in rural settings and in some other areas where traffic jams are not severe
- Possibly higher social status
- Overall a better provision for privacy
- Profit for the multinational firms producing cars, and possibly for their employees

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