HISTORY OF AUTOMOBILE AND ITS MANUFACTURING

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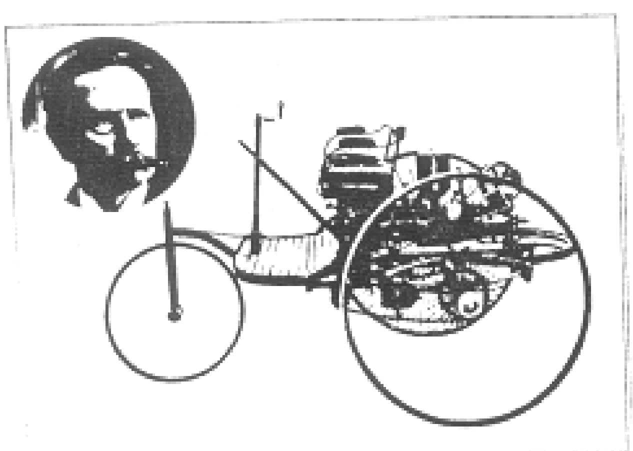
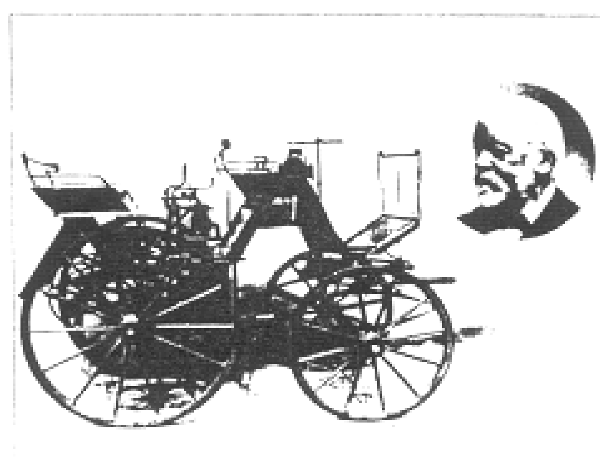
Exactly who invented the motor car is to a great extent lost in the mists of history. Many engineers in different countries were working on the same general lines in the middle of the nineteenth century deriving inspiration from the early steam buses and coaches. They all felt the need for a more compact and convenient prime mover to get into a horseless age.

EUROPE: Belgium and Germany

Etienne Lenoir in Belgium demonstrated a self-propelled vehicle driven by a type of atmospheric engine in 1860. Though the engine was hopelessly inefficient, it did have the merit of quick starting, and unlike steam vehicles, did not need frequent and large dose of water. This engine interested Nicholas Otto, a young German, as he observed its lack of punch and reasoned that more power could be obtained by compressing the charge before feeding it into the cylinder. Otto did this with great success and the idea was an essential step towards the true four-stroke engine. Around 1872, Otto was helped and encouraged to develop the four-stroke system by Gottfried Daimler and Wilhelm Maybach, who joined Otto's company (by then called Gasmotoren-Fabrik Deutz). Otto perfected the true four-stroke cycle and it was this power unit that opened the way to the motor age. Another pioneer in the area, Karl Benz had worked with Daimler at one time in their careers for the same locomotive works in Karlsruhe. Karl Benz is credited with being the first to make a gasoline-engined car for people to buy: a car conceived as entity and not just a carriage with an engine replacing the horse. This first car was built and was running by late 1885 with a water-cooled, single-cylinder engine that developed about 0.8 hp at 400 rpm- fast for an engine of the day. A simple handle arrangement steered two front wheels and his subsequent models were four-wheeled. Daimler concentrated on four stroke engine after setting up his own company.



1885, Karl Benz's First Petrol-Burning Car.



1886, Gottlied Daimler's First Four-Wheeled Vechicle.

FRANCE

In France, Edouard Delamare-Deboutteville constructed a four-wheeled engine-driven vehicle in 1884 and patented it. However, as one motoring historian points out: " There is no evidence that this unwieldy machine actually ran in that year. What we know is that when it did actually get going, it got halfway across the workshop and broke in half." It was only in 1891 Armand Peugeot, the grandson of the famous bicycle manufacturer with Levassor produced a four-wheeled rear-engined car with a two-cylinder Daimler engine of 2.5 hp - a quite advanced version with full suspension, four-speed gearbox and capable of 15 mph(24 km/h). Louis Renault's first car was a three-wheeled DeDion that he converted to four wheels. He threw out the jumble of belts and chains that made up the drive to the rear wheels and replaced them with a solid shaft. The shaft was driven through a gearbox of his own design with three forward speeds and reverse. This has been claimed as one of the most significant developments in automobile history : for the first time a car was available without side chains and belts. By 1903, France was by far the most advanced motoring nation in Europe, producing half the world's output of cars, some 60,000 per year.

BRITAIN

The famous restrictive legislation that a man with a red flag should precede all powered vehicles, stifled the development of the automobile in Britain. Otherwise it has been said that Britain's horseless age could have started fifty years earlier than it did. So the first cars to run on British roads were of German or French origin. In 1896, the Red Flag Act was amended and the permitted road speed was raised from 4 to 14 mph(6.4-22.5 km/hr). Very soon bicycle makers (mostly based in Coventry) like Riley, Swift, and Sunbeam graduated to cars. Herbert Austin, the manager of The Wolseley Sheep Shearing Machine Co. was one of the early pioneers. He later left Wolseley and started his own company. Standard was one that specialized in moderately priced cars at the lower end of the market. Vauxhall Iron Works designed its first car in 1902 and put it on sale the following year. Henry Royce came into business of car by accident. Royce imported a used Decauville in 1903, but was grossly dissatisfied with its performance, and as skilled and meticulous engineer, he redesigned and rebuilt a far superior car. Later, Charles Rolls joined Royce and the first Silver Ghost was on road in 1906. However, F. W. Lanchester was one of the most remarkable of all British automobile engineers, who launched his first experimental car in 1896. The car had many essential features of a modern car: a torsionally rigid frame, a perfectly balanced and almost noiseless engine; dynamically stable steering; and epicyclic gear for low speed and reverse, with direct drive for high speeds. This car was underpowered. Lanchester designed a new one - a two-cylinder one of 8 hp and added some remarkable features for its time: a new Lanchester-designed ignition system based on a magneto generator and new valve gear, a worm-and-wheel instead of a chain transmission or bevel gear. (Lanchester even designed and built new gear cutting machines to enable him to make his transmission.)

ITALY

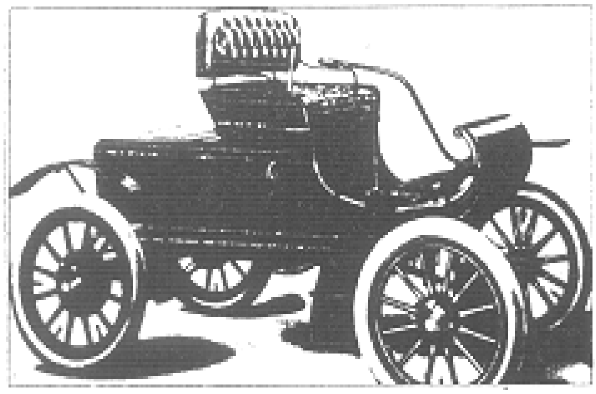
In Italy too, the first horseless carriages were imported from France and Germany. It was in !898, Giovanni Ceirano of Turin, a bicycle builder by trade with help of an engineer, Aristide Faccioli, put together a car called Welleyes, using his bicycle trade-name. A group of businessmen including the far-sighted lawyer named Giovanni Agnelli approached the two. And after a meeting on July 11, 1899 the Societa Anonima Fabbrica Italiana di Automobili Torino (better known by its initials, FIAT) was formed that destined to become one of the biggest industrial enterprises in Italy and a world-famous car maker. Fiat's first model was a two-to-three seater powered by a 679 cm^3 engine developing 3.5 hp. In 1900, Faccioli who was technical director started work on the next model with a larger engine of 1082 cc that developed 6 hp and propelled the car at 60 kph.

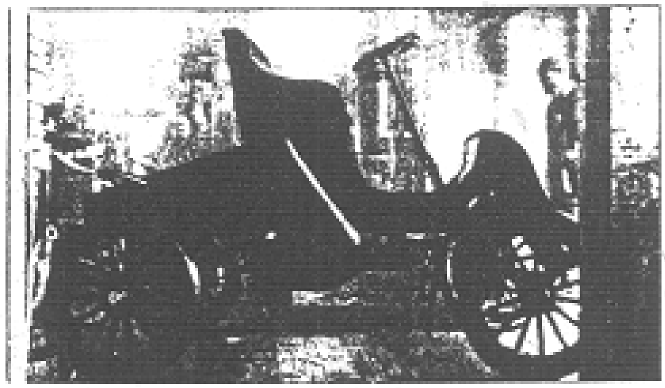
JAPAN

Japan's first auto import arrived in 1899 from Locomobile Co. of the US, purchased by one Mr. J.W. Thompson. In 1904 Torao Yamahane took his place in the history of automobile industry by producing Japan's first automobile - more specifically, a steam bus in his home garage with a sponsorship by two wealthy Okayama businessmen. The first car to be built with an internal combustion engine was introduced in the spring of 1907, named after its principal investor, Shintaro Yoshida who owned a bicycle shop in Tokyo. The car was developed by Russian-educated engineer Komanosuke Uchiyama. Approximately 10 to 15 "Yoshida-type" vehicles were produced between 1907 and 1908. Yoshida's car sold for about 5000 yen. Yamahane's car, three years earlier, sold between 10,000 and 15,000 yen. Keeping in mind that the average salary for a new employee only amounted to between 3 and 7 yen a month, this represented a rather sizable investment. Approximately the same investment was required for foreign models. Fiat carried the highest price tag, approximately 15,000 yen, a 40-hp Packard cost about 7000 yen, and Ford's original Model T was approximately 4000 yen.

USA

In US, the early motor cars were seen as logical replacement for the farm buggy, and were born therefore in the blacksmith's shop. The first successful US gasoline-engine motor vehicle, designed by Charles E. Duryea and built by his brother Frank, was run on Sep.21, 1893. The vehicle was propelled by a single-cylinder engine with a spray carburetor and electric ignition. In the same year Ohio's Wooster Pike near Cleveland was laid with a brick surface to become the first rural road. Elmer and Edgar Apperson built a car to Elwood G. Haynes' design in 1894 that is generally considered to be the first successful gasoline car in the US. The 820-lb. Haynes was powered by a one-cylinder engine and achieved 6 mph on July 4, 1894 on the Pumpkinville pike in Kokomo, Indiana. The Duryea Motor Wagon Co. was established in 1895 to become the first American company to build gasoline-powered automobiles. In 1896 the company built 13 cars. And George H. Morill, Jr. of Massachusetts bought a Duryea and become the first American purchaser of a gasoline car. The marketable vehicle of the Duryea brothers named 'Buggynaut' was described in the first edition of HORSELESS AGE thus: " ....in appearance, the vehicle does not differ materially from an ordinary heavy-built buggy. It weighs about 700 lb. and has ball-bearing and rubber-wheeled tires...". On June 4, 1896, Henry Ford successfully operated his two-cylinder, 4-hp "Quadricycle" in Detroit. However, the Ford Motor Co. was incorporated only in 1903 with Henry Ford as vice-president and Chief Engineer. Some famous automanufacturers came from different industries: Ransom E. Olds started with stationary engines, William C. Durant - the founder of General Motors in 1908, had made his fortune by manufacturing carriage, Henry M. Leland who built the Cadillacs started with machine tools. Ransom Eli Olds drove a single-cylinder, 6-hp gasoline car on the streets of Lansing, Michigan in September 1896. The Cadillac Automobile Co. was formed out of the Detroit Auto Co. In 1902. William C. Durant founded the General Motors Co. in New Jersey in 1908 with William Eaton as the company's first president.





1900, First 3-hp curved-dash Olds. **1902, A Cadillac**

MANUFACTURING TECHNIQUES

Manufacturing techniques followed among the early automakers were similar to those used in other engineering industries. A large number of car companies evolved from bicycle manufacture. (By the time the first cars appeared the bicycle was accepted as a valuable means of personal transport.) Companies like Peugeot in France and Humber and Riley in Britain switched to powered tricycle and quadricycles.

The earliest cars were painstakingly constructed by skilled and usually gifted engineers in very modest workshops, often little more than back-street garages. General-purpose machines and the techniques that were very largely developed in the horse-drawn era, were used. As volume increased, batch production got underway from one-off system. A common system was for the cars to be constructed through the middle of the workshop, but the lines were static and the workers and the parts moved to the cars. The machines were grouped according to type-grinding machines would be in one area of the factory, drilling machines in another and brazing equipment in yet another. All the work in process had to be dragged and pushed from one group of machines to the other. It was Ford who installed his equipment in the order in which it was needed in the manufacturing process. A grinding machine was placed next to a drilling machine that was placed next to the brazing equipment. Ford was able to greatly reduce the amount of work in progress and increase the speed of production process. The parts and components still had to be pushed and dragged from one operation to the next, but the distance reduced.

The assembly was pretty much done in one spot, (Fig 1.1) All parts and components were assembled on benches. Each person was generally assigned to assemble a component one at a time. Ransom Olds developed 'stage' manufacture in US. In 1903 Ransom E. Olds introduced his curved dash motor car that was the first automobile to go on for "mass" production. Olds built 4000 cars in 1903, and went up to 6500 cars by 1905 - an astronomical figure for the time. The American journal, AUTOMOBILE, in 1904 wrote: " The motors are passed, step by step, down the assembly bench towards the testing department in the next room, a new piece being added at each move with clockwork regularity."

El Whitney, the inventor of the cotton gin, showed the practicability of interchangeable parts in the late 18th Century. In 1908, Henry Leland who set up the Cadillac Car Company, proved the inherent advantages of interchangeable parts. He took three Cadillacs to England to participate in the prestigious Dewar Trophy. To win this trophy, the three Cadillacs were disassembled, the parts were jumbled together, then reassembled to form three new cars which were then run at top speed for 500 miles without a problem. At a time when all other cars had to be hand-fitted together, this was an astonishing accomplishment.

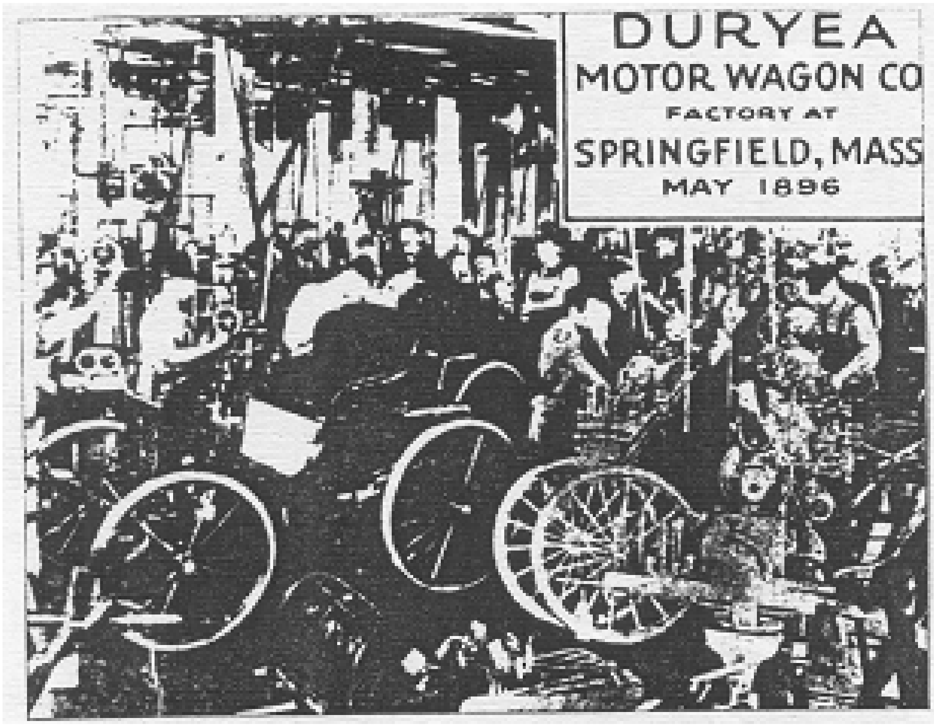


Fig. **1.1 An Early American Automobile Assembly Plant.**

Henry Ford is credited with the next logical step for mass production by installing moving conveyor lines, breaking down the operations to the simplest elements and bringing the parts to the line. Henry Ford got the idea of moving line from a strange place. In a Chicago meat-packing plant, one day he had been impressed with the efficiency gained by moving the carcasses from one worker to another by means of a moving overhead trolley. Time was saved bringing the work to the person, instead of the other way around, and because each butcher specialized in one operation, he could do his cutting work much faster and more expertly.

On March 1,1914 the Ford Motor Co. introduced what was probably the first moving assembly line of all time. The sliding rail system used on the magneto (which generated current for ignition) assembly line at the company's Highland Park plant was replaced with a chain driven assembly line, (Fig. 1.2) At first Ford tried to run the line at 60 in. (152.4 cm) a minute but that was found to be too fast. So they slowed it down to 18 in. (45.7 cm) a minute but that was too slow. A lucky guess set the speed at 44 in. (111.7 cm) a minute and that turned to be perfect. The workforce on the line was cut by over 20%. With 29 workers, each doing one function, a magneto could be assembled in 13 minutes. As a result of further refinements of the system, the assembly time was cut to five minutes per magneto. When the chain drive proved itself on magneto line, it was implemented on the engine assembly line, though not without some false starts and setbacks.

Experiments with a moving chassis line took place even before it was tried on magneto line. A rope was tied with a chassis and it was winched down the line. A group of six workers walked along with it, putting on parts that were brought to them by other workers. It worked well. But it was decided to place parts along the line, with a worker assigned to each “station” who would install a part as the car passed slowly by. The moving line was put in production for chassis assembly on April 29, 1914. When Ford had built up the chassis in one stationary spot, the process took 14 hours per chassis and took up 6000 ft(182.8 m) of floor space to do it. With the moving assembly line, the time was shaved down to 1.5 hours per chassis and only 300 ft (91 m) of floor space was needed. The refinement of the subdivision of assembly continued.

Fig. **1. 2 Ford’s Highland Park Flywheel Magneto Assembly Line.**

Ford almost at the same time raised the basic wage in his factories from $2.5/day to $5/day. This was simply unbelievable. Production efficiencies of a moving assembly line enabled him to sell cheap while paying highest wages, and he was hailed a genius by intellectuals and was rated even higher by common folk. As production techniques were refined, the cost of the car dropped, once as low as $260. Ford dreamt of a car for multitude that could be realised with the Model T that though awkward looking, was distinguished by its lightness, simplicity of design, and superior power-to-weight ratio. Model T was dubbed as the Tin Lizzie as it looked almost as flimsy as tin next to other heavier cars. Actually, Ford had begun exploiting the strong, lighter weight vanadium steel. First Model T rolled out of the Ford assembly plant in Detroit in mid-1908. By early 1914, the cars were being driven off the moving line virtually complete, (Fig. 1.3) Production tripled between 1912 and 1915. The production reached 2 million in 1924. Every other car in the world was a Model T. Mass production system devised by Ford (known in Germany by the term *Fordismus*) spread to a host of other industries, becoming not just the fact of life but a way of life.

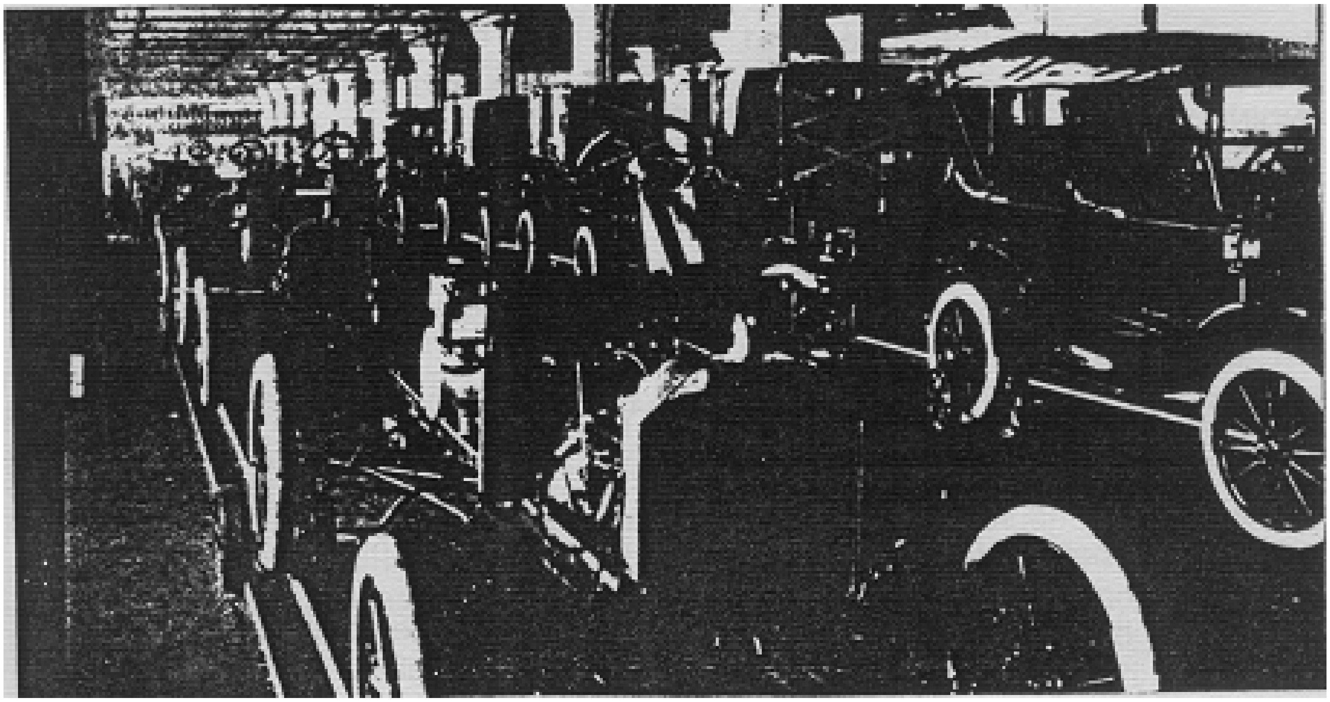


Fig. **1.3 Model Ts Coming off the Final Assembly Line at Ford's Highland Park Plant.**

MACHINE TOOLS OF PRE-AUTO AREAS

Fortunately, much before car production started going in higher gears, the growth of the market of arms, bicycles and sewing machines had led to a rapid expansion of machine tool industry. From lathes, in 1845 Stephen Fitch of Middlefield, Connecticut, designed and built the world's first turret lathe. It had long, cylindrical turret that revolved on a horizontal axis and carried eight tools mounted on spindles- each of which could be advanced as required. The turret carriage was advanced and the feed applied by a three-armed capstan. Thus eight successive operations could be rapidly performed without stopping the machine to change tools. The logical development of the turret lathe was the fully automatic screw machine. In 1871, Edward G. Parkhurst patented a collet chuck and closing mechanism for his screw machine to help it make automatic. The first completely automatic turret lathe was designed and built by Christopher Miner Spencer, who very soon came out with a radical arrangement of tools on a three-spindled turret lathe so that the tools could be brought to bear simultaneously.

In 1855, Elisha Root designed a vertical slotting machine for cutting splines in the magazine of the Colt revolver through which the cartridge ejector spindle slides. Multispindle drilling machines were designed and produced to drill many holes in parts for arms to improve interchangeably and speed of production. Twist drill replaced the old spearpoint drill.
Joshep R. Brown of the firm of Brown & Sharpe designed and built the first truly universal milling machine that provided solution to the twist drill manufacturing. It normally cut right-hand spirals, but Brown arranged the change gears train so that the machine could cut a left-hand spiral if desired. Brown is credited with many machines. He invented and built an automatic linear dividing engine for graduating rules and from it came steel rules, the vernier

calipers, hand micrometers and precision gauges that provided solution for quality production. Brown also devised an improved formed milling cutter for gear cutting, and in 1855 he built a gear-cutting machine using a formed milling cutter for producing involute teeth. Brown's cutter had segmental teeth, each of which in cross-section conformed exactly to the contour of the tooth form required. This tool could be sharpened by grinding away the face of each tooth.

GRINDING WHEELS AND UNIVERSAL GRINDING MACHINES

In 1872, silicate wheels began being produced. A year later, a potter named Sven Pulson made a better wheel with a mixture of emery and clay. In 1877, F. B. Norton patented the process. Again, it was Joseph Brown and his staff who removed the defects in existing grinders and came up with an improved "Universal Grinding Machine" in 1876. On this machine, the workpiece traveled past the wheel instead of the wheel traversing the workpiece. The head and tailstock units were mounted on a traversing table. The length of travel of the table was automatically controlled by adjusting trips at the front of the machine. For taper grinding, slides at the upper table could be angled by means of an adjusting screw. The guideways were protected from abrasive dust, and a water coolant was used. This grinder was the parent of all subsequent precision grinding machines.

Henry Leland had worked as foreman in the Brown & Sharpe shop, and later became the President of the Cadillac Motor Company. He wrote later about the grinding machine of Brown : " What I consider Mr. Brown's greatest achievement was the Universal Grinding Machine. In developing and designing this machine he stepped out on entirely new ground and developed a machine which has enabled us to harden our work first and then grind it with the utmost accuracy...." These new and better grinding machines facilitated the production of precision gauges and measuring instruments as well as accurate hardened steel cutting tools such as drills, taps, reamers and milling cutters.

By 1891, an American, Edward G. Acheson, produced a synthetic abrasive of controlled quality by fusing a mixture of carbon and clay in an electric arc furnace. Crystals (silicon carbide) produced were of a hardness then surpassed only by diamonds. Acheson called his synthetic material carborundum. Another American, Charles B. Jacobs, in 1897 produced another synthetic abrasive by fusing aluminium oxide(bauxite) with small quantities of coke and iron borings and called it alundum.

Charles H. Norton secured the rights to this product and became the person responsible for the production grinding machine and better abrasive wheels. First, Norton invented a machine for dynamically balancing grinding wheels to make them perfectly balanced. Norton also improved the processes of dressing and truing the grinding wheel. Norton then redesigned the Brown & Sharpe Universal Grinding Machine making it more robust and improving the bearings. This new machine was more accurate, but with only 1/2 inch wide grinding wheel, the productivity was low. As the machine was used only as a superfinishing tool, the narrow wheel was adequate. But Norton wanted to make the grinding machine capable of reducing the workpiece to finished dimensions from the rough machined stage with speed and accuracy, eliminating thereby the slow finishing cut on the lathe. By building a heavier, stronger grinding machine, and by using much wider wheels, Norton conceived the technique of plunge grinding. This new grinder was not only applicable to plain grinding but also made possible form grinding by the use of wheels shaped to the contours desired. In 1903, Charles Norton produced a crankshaft-journal grinding machine. A wide wheel was capable of grinding a journal to finished diameter in a single plunge cut. The cycle time of the operation was reduced to 15 minutes that previously took five hours of turning, filing and polishing. Henry Ford ordered 35 of these machines for his new Model T production plant.

Norton is also credited with incorporating its own micrometer in the grinding machine to reduce the workpiece by precisely the desired amount - say 0.00025 of an inch.

GEAR MANUFACTURING MACHINES

Gear mathematics developed through several centuries without having much practical effect on the way mechanics actually cut gears. Edward Sang produced a treatise in Edinburgh in 1852 that ultimately laid the groundwork for the generating type of gear-cutting.

By 1867, William Sellers had exhibited a milling machine gear cutter in which the sequence of automatic motions was so controlled by stops. The cutter could not advance unless and until the gear blank had been correctly indexed for the next tooth. When all the teeth had been cut, the machine stopped automatically. Then the moulding generating cutter was devised. Instead of indexing the gear blank, the cutter and the gear blank are given synchronous motions, so that the two are correctly meshed together. In 1880 Ambrose Swasey for Pratt & Whitney developed one machine that operated on the "describing-generating" method. In 1889, George B. Grant developed another one and started a gear-cutting shop.

In 1884, Huge Bilgram of Philadelphia came out with a gear shaper working on the moulding generating principle to make small bevel gears for the chainless bicycle. In 1898, James E. Gleason invented a machine that generated bevel gears by using a rotary cutter and a combination of motions- rotary, swinging of the cutter carrier, and lateral. Gleason's machine was fully automatic that provided the manufacturing solution to bevel gearing used in differential drive. Oscar J. Beale developed the other bevel-gear generator for Brown & Sharpe in 1900 that was of significant commercial significance.

The most advanced gear cutting machine of the moulding generating type was Fellows' gear shaper of 1897 that was invented just in time to produce gears that would be needed for automobiles. Edwin Fellows designed the teeth of his cutter in such a way that one cutter could be used to make gears of any diameter provided the pitch was the same. The only qualification was that their teeth must be of the specific helix angle the cutter was designed to produce. To make hardened cutters for his shaping machine, Fellows created another machine.

Hobbing was the last to come. The first attempt to cut gears by using a worm with teeth on it may have been by Ramsden in England in 1766. In 1835, Josheph Whitworth produced a machine that would hob spiral gears. Many improvements by others followed. But the hobber did not become practical until Pfauter, working in Germany built a machine with a cutter axis that was not at 90^0 to the gear axis. There were many problems in developing the process, but by 1909, there were at least 24 firms manufacturing gear-hobbing machines.

CUTTING TOOL MATERIALS

The first improved tool steel was produced in 1868 in England by Robert Mushet that proved to be far superior to carbon steel used for tool earlier. With this new tool steel, John Fowler & Co. of Leeds turned iron shafts in the lathe at the rate of 75 feet per minute. For machining steel wheels in their boring mill, they could make roughing cuts 1/2 inch deep. Frederick W. Taylor (1856-1915) is credited with the revolutionary research on cutting tool materials. In 1900 Paris Exhibition Taylor amazed the visitors with chips peeling away at blue heat from an American lathe while the tip of the cutting tool was red hot.

Taylor was the first to carry out methodical experiments with cutting tools that lasted over 26 years and cost over $ 200,000 - a large R&D expenditure for the time. Mushet's steel contained 7% tungsten, 2% carbon and 2.5% manganese. Taylor with Maunsel White in the Bethlehem Steel Works discovered that chromium was an effective substitute for manganese used to give the steel self-hardening character, while giving better performance. They then increased both the chromium and tungsten (the tungsten to 14%) and added silicon that was found to increase shock resistance. The experiment with the heating temperature concluded that if a tool is heated to 2000^0 F (just below fusion point) instead of 1550^0 F, the cutting speed would be increased to 80 to 90 feet per minute (as against 30 feet per minute in earlier case) before failure occurred in the same time. Titanium and molybdenum were tried but rejected as being too costly, but the addition of 0.7% vanadium produced further improvement.

EFFECT OF NEW CUTTING TOOLS

With this radically improved new cutting material, all the existing machine tools were to become obsolete. As proof of this, the Ludwig Loewe Company, A.G., a reputable German machine-tool builder, tested the new steel tools in one of their lathes and drilling machines, running them so as to give maximum performance. In four weeks both machines were reduced to junk! Main drive spindles were twisted; thrust bearings were destroyed; keys fell out of gears and shafts; cast gears were broken and the lubrication systems proved inadequate. To take advantage of the new cutting tools, new machines had to be designed and built heavier, with increased feed and drive power, with hardened steel gears and better lubrication and with increased speed range of both drives to obtain optimum cutting speeds for different materials, different diameters of workpiece, and different depths and thickness' of cut. Taylor had not only given the machine designer a new tool but also the specifications by which its performance could be translated into terms of tool pressure, speed and feed..

It is interesting that machine-tool gear boxes owe a great deal to the automobile, but the range of speed needed on a machine was much closer and wider than was required on a car. The problems of higher shaft speeds and stresses, though, were similar. The long, unsupported shafts of the existing machines tended to deflect and vibrate under load. To remedy this defect, automobile-type gears of hardened nickel-chrome steel were adopted. Automobile practice was also adapted to machine tool lubrication. Oils of stable and enduring quality were available since they had been developed for automobiles.

OTHER MACHINES DEVELOPED FOR AUTO INDUSTRY

The pressure and excitement of supplying car components were responsible for development of many production methods:

With widespread electrification after the turn of the century, the arc welding was put in use. John C. Lincoln started experimentation to build arc-welding equipment around 1902, but it was only in 1912 that Lincoln Electric Co. started producing such equipment. Full commercial acceptance was to wait until the joining procedure was to prove itself during the World War I production effort. In 1918, Lincoln patented for using carbon oxide as a shielding agent for arc welding, a process that enjoyed minor popularity with contemporary automakers, but was revived on a large scale in automotive industry only in the 1950s.

In 1903, A.B. Landis patented an automatic magazine feed release for short cylindrical parts enabled efficient production grinding of connecting-rod pins. L.R.Heim obtained his patent for the centerless-grinding principle in 1915 where he provided precision to the system used by David Wilkinson's spindle grinder of 1820 by making subtle, yet crucial improvements. In 1922, Cincinnati Milling Machine Co. acquired Heim's invention and introduced its first production centerless grinder. The machine gained immediate acceptance in the automobile industry, where its 20 in. diameter wheel was used to grind shoulder work like push rods and valve tappets. By 1925, automobile valve stems were being finished ground on centerless machines at the rate of 350 an hour. It was necessary to plunge cut and retract the regulating wheel to release the workpiece. This was too slow for automotive requirements (even at that time). It was between 1932 and 1935 the Cincinnati Company developed a cam-type regulating wheel for their grinder that finished a component in one revolution of the cam wheel.

Though a significantly advance grinding machine was developed by Brown, Charles H. Norton, and A.B. Landis, it was in 1905 that both Norton Co. and Landis Tool co. offered specialized grinding machines for automobile crankshafts that eliminated torsion in the shaft by mounting the work on two live heads, counterbalanced by the journal bearings.

In 1910, A.B. Landis severed his connection with both Landis Tool Co. and Landis Machine Co. and opened an engineering laboratory for perfecting inventions, and brought out his 1912 camshaft grinder that provided automatic feed from one cam to the next on a shaft. Master camshafts were geared to the workpiece and were larger than the workpiece, thus reducing error. Norton also developed the camshaft grinder at about the same time. The machine enabled engine designers to specify one-piece camshafts of a hardened alloy steel instead of having to build up these controlling mechanisms from individually ground pieces.

James Heald developed internal grinders almost at the same time. Until Heald's 1905 planetary-motion I.D. grinder, engine cylinders were bored, then reamed and lapped. Inclusions in the castings often deflected the boring tool, producing uneven cylinders. Subsequent finishing operations did little to improve cylinder-wall straightness, and engine designers were hampered in the amount of efficiency they could squeeze out of the internal-combustion process. By operating a smaller grinding wheel eccentric to the cylinder axis, the planetary I.D. grinder could impose unprecedented straightness to the internal walls of the engine. Parallelism with Heald's prototype machine was held within 0.00025 in.

A precision-ground cylinder bore needed a piston fitted with rings of compatible accuracy. Using a mandrel, the wearing face of a piston ring could be finished, but the top and bottom faces also needed a ground finish to ensure an exact fit in the ring grooves of the piston. In 1902, a German, Reinecker, created a machine for grinding the sides of the rings used in steam and gas engines. Two years later, Heald designed a similar machine for automotive industry. The grinding wheel was mounted on a horizontal axis, and the piston ring was held on the worktable by a magnetic chuck. The edge of the grinding wheel was brought to bear as the worktable was rotated.

Broaching as production technique though probably dated back to Englishman Josheph Whitworth's method of cutting internal keyways, was redeveloped in 1873 by Anson P. Stephens in America for its present potential in automobile industry. In 1898, John N. Lapointe obtained the patent for pull-broaching which was till date being done by pushing the serrated tool through a hole in the workpiece that was severely limited by the physical strength of the broach under compression. In 1918, special form-grinding machines for broach production were developed, and the first hydraulic broaching machine was produced in 1921. Later, in 1934, external or surface broaching was introduced.

The automakers made just as strong an impact on machine tools. With cut in assembly time for Model T from a day and a half to an hour and a half, it was realised that no machine shop could supply components that fast. E.P.Bullard Jr. set about designing a new machine for multi-station manufacture. When it was ready, Bullard headed for Detroit, where he arranged for an appointment with Ford. Seated beside Ford was C. Harold Wills, chief of car design and factory operations. The two men listened attentively to Bullard, but, when they both expressed their skepticism, the machine-tool builder unleashed his strongest argument. " Mr. Ford," said Bullard, "how long does it take you to make a flywheel?" "Eighteen minutes," was the reply. Wills nodded. "Will you test our machine if I guarantee to cut that down to two minutes?" Bullard asked. Ford smiled, "Cut our time in half, and we'll do business." The first Bullard Mult-Au-Matic to arrive at Highland Park was subjected to a test run that lasted 54 days and nights. Finished flywheels were taken off the machine at intervals of just over a minute.

CEMENTED CARBIDES

Cemented tungsten carbide was first produced by Krupps of Essen, Germany. In 1926, a Krupp machinist tried this new material as a lathe cutting tool. After the Leipzig Fair in 1928, where the carbide tool was demonstrated under working conditions, it was an instant sensation. The first titanium-based carbide cutting tool appeared in 1930. The introduction of tungsten carbide cutting tools resulted in the second machine tool revolution. This new cutting tool material also made possible the new machining technique of fine boring. In Germany, Ernst Krause used tungsten carbide in a similar way to bore iron cylinders. He patented his process that was adopted by the motor industry supplanting the planetary grinding machine that was used before it.

EVOLUTION OF NEW MACHINE TOOLS

The history of manufacturing is marked by the development of mass production in the automotive industry, and was followed by the improvements in machine tools and cutting tools, and the introduction of new and better materials with which to manufacture the cars. By early 1920s, machine tool builders competed fiercely with one another in bringing out machines of higher production capacity, especially for the auto industry. The methods of transmitting power to machine tools were constantly improving. Helical gears for connecting parallel shafts were used more and more to provide smooth transmission. Special steels and heat-treated gears were common, where hardened-and-ground gears were gaining favour where greater accuracy was required. The use of motor drives and of ball bearings and a growing trend toward hydraulic instead of mechanical transmissions was the outstanding developments in machine tools of the 1920s. Centralised control became popular and, in several types of machines, it was possible to shift speed instantaneously, without stopping the machines, through a combination brake-clutch. By 1927, another definite trend became noticeable; a trend toward single-purpose equipment of so-called manufacturing type and away from machine of a more universal nature. The design of this single purpose machine was such that only a few key parts needed to be interchanged to make the machine adaptable to a wide variety of work. By the early 1930s the trend got completely reversed.

The interesting involvement of changes of equipment during a model change will be clear from the details of work done during a changeover from Model T to Model A by Ford in 1927.

To do it, the company spent nearly $ 10 million for the purchase of 4500 new machine tools and alteration of 15,000 more. Preparing to make the new rear axle alone necessitated construction of an entire group of machine tools. Some 160 gear-generating machines were completely rebuilt, at a cost of $3000 each, to produce two gears for the new rear-axle assembly. Ford introduced a new V-8 model ($460-$650) to replace the Model A in 1932 and became the first company to use a cast alloy-steel crankshaft in place of a forging.

OTHER MANUFACTURING TECHNOLOGY DEVELOPED FOR AUTO INDUSTRY

Automakers did also influence other manufacturing technologies:

In 1920, Henry Ford improved foundry practises by conveying moulds to the metal-pouring station instead of carrying molten metal to stationary moulds. The same year, Ford introduced continuous pouring of molten iron and produced gray-iron castings directly from ore.

The first automatic production line for large-scale manufacture of a complex automotive assembly (frame line) went into operation in 1921, that could perform 552 separate operations in a ten-second cycle.

Nickel plating was started for auto radiators and lamps in 1921 and chromium plating followed in 1925. Continuously rolled sheet steel was developed in 1924 and provided the automakers with improved metal surfaces and better thickness and width control; and steel became the logical material for automobile exteriors. The painting was applied by brush, a time consuming process, as it took 24 hours for it to dry, (Fig. 1.4) In 1925, the use of synthetic, quick-drying pyroxylin finishes with spraying followed by baking started.

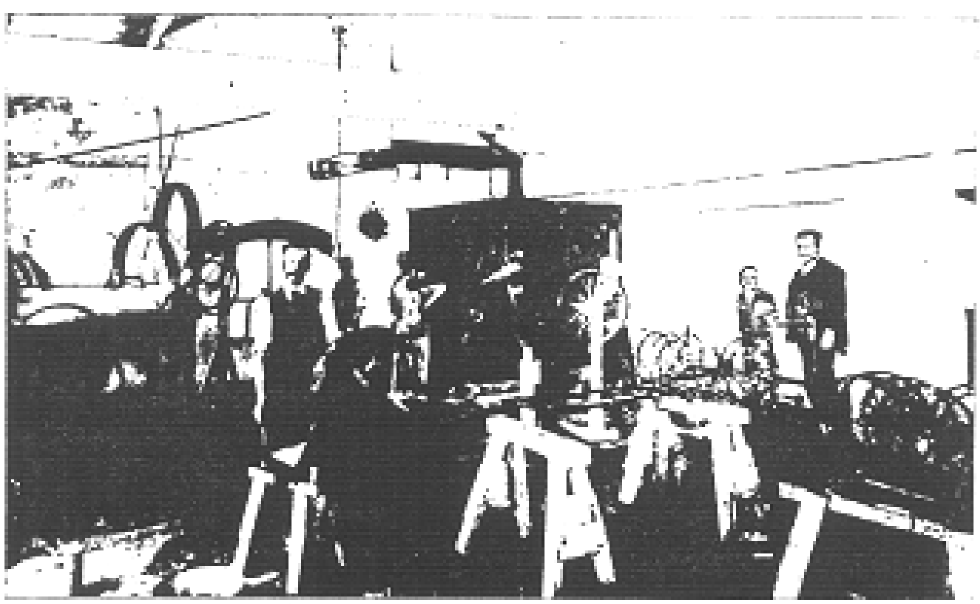


Fig. **1. 4 Turn-of-the-Century Paint Shop.**

These Duco finish replaced paints and varnish, cutting days from the total auto-production cycle, and then came the paint spraying, (Fig. 1.5) By 1927 an automobile plant was producing 1300 cars in a nine-hour day.

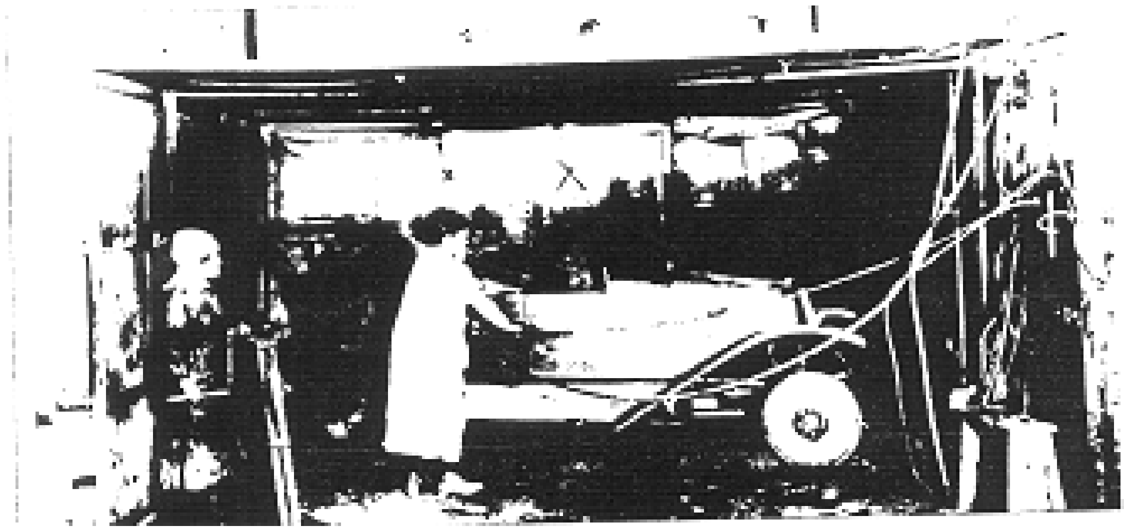


Fig. **1.5 Early Paint Spraying Equipment.**

Body assembly operations in 1920s relied a good deal of hand labour, (Fig. 1.6) The workers were to shape panels over a wooden frame to bring them to matching condition.

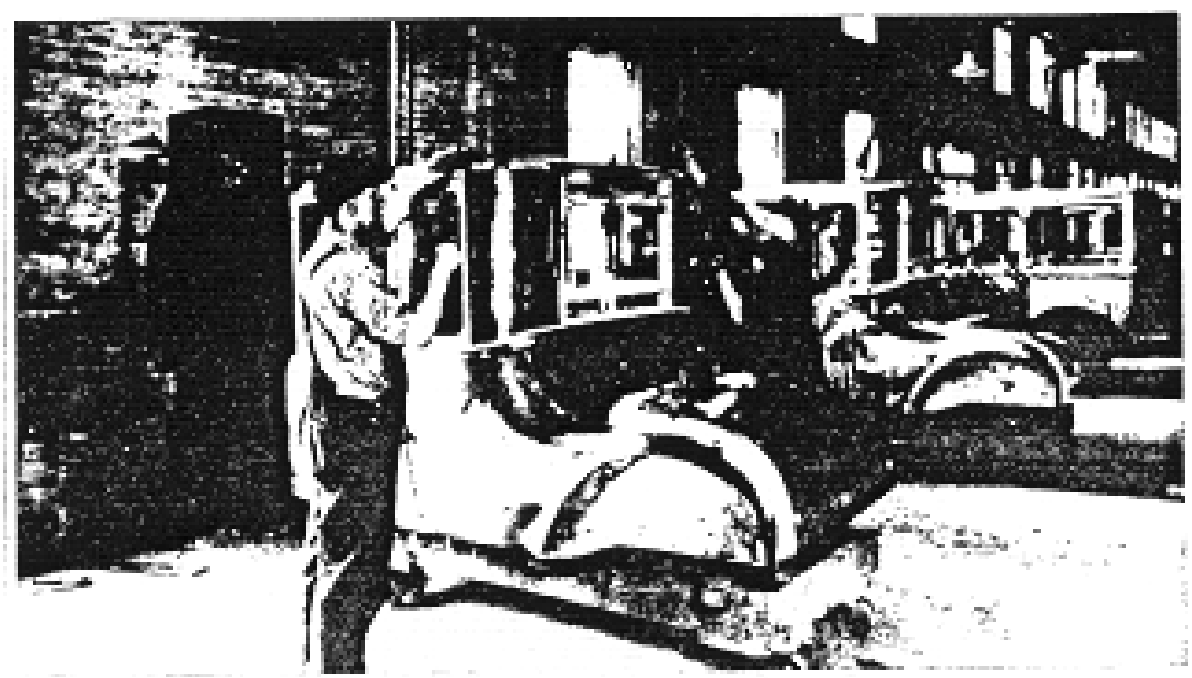


Fig. **1.6 Body Shop Operations - A Good Deal of Hand Labour.**

MACHINE TOOLS AFTER WORLD WAR II

World War II put a stop to car industry, as most of the plants were requisitioned to produce war machinery and equipment. After the War, many automakers were in bad shape. The effort of rebuilding the industry started with a new zeal and many new technological strategies evolved for the manufacturing of 'The Machine that Changed the World'. It is evident from activities such as setting up of an Automation Department in Ford in 1946. The department devoted to making equipment operate at its maximum rate (which usually can not be done without automatic loading and unloading) and to making work safer by eliminating hand loading of presses. By Oct.21, 1948, Automation Department had approved more than 500 devices, costing $3 million, that were expected to increase production by 20% and to eliminate 1,000 jobs. Most of the early work was on presses and included sheet feeders, extractors, turnover devices, stackers, loaders, unloaders, etc.

Next automation project related to the machining line for engine block, where automation meant mechanical handling of blocks in, out, and between machines. Another approach to automation by combining operations into a single machine instead of providing mechanical handling between machines was pioneered by the Morris automobile plant in Coventry, England in 1924. A collection of standard machines was attached to a continuous, **181- ft** long bed to perform 53 operations on engine blocks. The machine had a total of 81 electric motors. In 1929. Graham Paige installed in its cylinder department a system of operations that included automatic jigs and fixtures with transfer bars to move work from machine to machine; all the basic elements of the modern transfer machine were present in the system.

Many improvements were incorporated in manufacturing processes of automobile over the years. Perhaps sometime in 1950 door-off / -on concept got a start. By 1970 possibly the first welding robot was put in use in the auto industry. This was developed by Fisher body. This 6-axis manipulator (SAM) was capable of handling 510 commands distributed over 10 separate programs.

NUMERICAL CONTROL AND COMPUTERISED MANUFACTURING

Shortly after World War II, John T. Parsons envisioned the use of mathematical data to actuate a machine tool. An electronic control system for machine tools was developed with the US Air Force funded program. The first commercial production based NC unit was built by Bendix Corp. and was produced in 1954 for machine tools introduced in 1955. By 1957, Barnes Drill Co. built a drilling machine with four parallel horizontal drilling spindles, that moved on vertical ways to bring the desired spindle into position, and only that spindle would then feed. In 1958, Hughes Aircraft and Kearney & Trecker worked together to develop a flexible automatic line comprising of three machines: one each for milling, drilling(and tapping), and boring. The three machines were tied together by handling equipment, and the whole system was under tape control, called a Digitape that was developed by Hughes aircraft. The entire line was called the Milwaukee-Matic Model I. In December 1958, with the Milwaukee-Matic II - a NC horizontal spindle multifunction machine capable of automatically changing cutting tools in its spindle- the machine-tool industry's first numerically controlled machine, or machining centre, was born to make the beginning of the second industrial revolution. In 1960, the first controller with transistor technology was introduced. Integrated circuits(ICs) came in 1967 that permitted a 90% reduction in the number of components, as well as an 80% reduction in writing.

With increased automation, came increasingly specialized machinery for manufacturing processes that depend on the availability of unlimited markets and long model runs. However, even in automobile industry, the days of mass manufacturing system with dedicated machines are fast changing. Flexibility for quick model change without any stoppage is becoming the basic demand from the manufacturing system. Computerised manufacturing

may provide the answer. In chapters to follow, we shall be discussing the details of the trends in different areas of manufacturing activities of an automobile industry: machining in general, major engine components' manufacturing, gear manufacturing, stamping of auto-body panels, body welding, painting, trim and final assembly of automobiles.
ANNEXURE

Highlights of Automobile Industry

1884

- Edouard Delamare-Deboutteville is credited in France with building the first gasoline-powered automobile.

1885

- Karl Benz builds his first petrol-burning car with two seats and three wheels having a maximum speed of 8 mph (claimed).
- Nikolaus August Otto builds and runs a liquid-fueled engine.

1886

- Gottlieb Daimler builds his first four-wheeled vehicle by installing a 1.5 horsepower, high-speed (900 rpm) gasoline or mineral spirit single cylinder engine.
- Benz patents the first successful petrol-powered car not converted from a horse carriage.

1887

- Karl Benz sells the world's first car to a Frenchman named Emile Rogers.

1888

- Benz' tricycle cars are selling so well that he now employs 50 workmen. But Benz is r eluctant to redesign the single-cylinder trikes, believing that the original design cannot be improved upon.

1889

- Daimler introduces the first sliding pinion 4-speed gear system
- Gottlieb Daimler and Wilhelm Maybach are granted a German patent for a V-twin engine and a motor vehicle is displayed by them at the Paris Exposition.

1890

- Daimler founds his company, Daimler Motoren-Gesellschaft.
- The 'Good Roads' movement, the first national movement to improve roads in the US, started (by bicyclists).

1891

- The French firm of Panhard & Levassor is the first to install engines (Daimler) in front of the driver and the first to develop a chassis frame specifically designed for motor vehicles.
- Elwood Haynes and Charles Black build a car in US (Kokomo, IN).

1892

- Maybach develops a flat-type jet carburetor.

1893

- The first successful US single-cylinder gasoline -engine motor vehicle with a spray carburetor and electric ignition, designed by Charles Duryea and built by his brother Frank, is run.
- The Ohio's Wooster Pike near Cleveland becomes the first rural road to have a brick surface.

1894

- Rudolph Diesel exhibits the first working diesel engine with 2.75 horsepower
- Generally considered to be the first successful gasoline car in the US, Elmer and Edgar Apperson build a car to Elwood G. Haynes' design. The 820-lb. Haynes is powered by a one-cylinder engine and achieves 6 mph.
- Axle half-shafts and a transverse tube to position rear wheels is patented by DeDion-Bouton, that is still known as DeDion Axle.
- The Vacheron car utilises the first steering wheel.
  Benz begins mass production and builds 135 units.

1895

- The first pneumatic tire is made for motor vehicles by Andre and Edouard Michelin.
- The Duryea Motor Wagon Co.-the first American company, is established to build gasoline-powered automobiles.

1896

- Henry Ford successfully operates his two-cylinder, 4-hp "Quadricycle" .
- Ransom Eli Olds drives a single-cylinder, 6-hp gasoline car, after experimenting with steam-powered vehicles since 1886.
- The French word "automobile" first appears in published references to motor vehicles in the US.
- Dureyea Motor Wagon Co. builds 13 cars from the same design. George H. Morill, Jr., of Massachusetts, buys a Duryea and becomes the first American purchaser of a gasoline car.

1897

- The first front-wheel drive gasoline car is built by Austrian automaker Graf and Stift.

- The British Lanchester is equipped with epicycle gearbox, shaft drive, and a fully-balanced twin-cylinder engine with contra-rotating crankshafts. Lanchester also patents a high-pressure lubricating system.
- The first V4 engine is built by Mors of France.

1898

- The first four-cylinder OHV, air-cooled engine is built by John Wilkinson.
- Louis Renault builds his first car using a 1.75-hp, 273-cm^3 DeDion engine and live-axle drive.
- Haynes-Apperson Automobile Co. becomes the first US motor vehicle manufacturer to use aluminum alloy.
- Daimler builds the first in-line four cylinder engine.

1899

- Renault pioneers the use of shaft drive with spring rear axle, using universal joints.
- The first FIAT is built.
- Daimler introduces the honeycomb-type radiator with integral water tank, gated gear change and foot accelerator.

1900

- The first 3-hp curved-dash Olds is built; 425 of this model sold in 1901 and 5000 in 1904, making it the first commercially-successful US-built car.
- The G & J, the forerunner of the Rambler, is designed by Thomas Jeffry with its engine in front and steering on the left side.
- The Saturday Evening Post carries the first automobile advertising.

1901

- The first Mercedes is built. Designed by Maybach, it uses a pressed steel frame while most others used hard wood.

1902

- Autocar's Clarke designs porcelain spark plug insulation.
- Clarence Spicer introduces the Spicer universal joint
- The Locomobile - the first US gasoline car with a four-cylinder water-cooled, front-mounted engine - is introduced.
- The Elliot steering principle is put into practice, allowing both front wheels to turn in stead of the axle.
- Dr. Frederick Lanchester in England designs the disc brake.
  The Spyker company of the Netherlands builds the first four-wheel-drive gasoline car with a six-cylinder in-line engine.

1903

- The Ford Motor Co. is incorporated with Henry Ford as VP and chief engineer.
- The Buick Motor Co. is organized, building cars with OHV engines.

- State-of-the-art technology for this year includes sliding gear transmissions and shock absorbers.
- Maudsley of Britain produces the first overhead camshaft car engine.
- The Adder company of France builds the first V8 engine.

1904

- The Prest-O-Lite Co., founded by Graham Fisher and James Allison, perfect acetylene headlights for automobiles.
- An automatic transmission featuring a centrifugal clutch and an air brake system is pioneered by Sturtevant.
- Cadillac offers an anti-theft ignition lock as an optional extra.
- A novel chassis frame utilizing a tubular backbone enclosing the drive shaft appears on the British single-cylinder, 8-hp Rover car.
- The Winton is the first US car to mount the gearshift lever on the steering column.

1905

- Remy combines a magneto with a separate coil and distributor for automotive engines.
- The Locomobile is the first American car to use a four-speed gearbox.
- A compressed air self-starter is used by Mors in France.
- An enclosed driveshaft or "torque tube" is introduced by Hotchkiss in France.
  The Society of Automobile Engineers (SAE) is formed.

1906

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- Integral cylinder and crankcase construction is utilized on the four-cylinder Northern car, as are air brakes and air clutch control.
- The Marmon Co. displays the US' first automobile V8, an aluminum block, air cooled, 60-hp engine which does not go into production. Marmon goes on to pioneer the extensive use of aluminum alloys in engines.
- Buick includes a storage battery as standard equipment.
- A spring bumper, the forerunner of the present-day bumper, is developed by Ray Harroun.

1907

- Rolls-Royce begins to build its reputation for quiet operation with the Silver Ghost.
- Coil springs and friction-type shock absorbers are introduced in the US by Oakland and Brush.
  Prosper L'Orange develops the high-pressure diesel injector and prechamber, allowing the diesel to be built smaller to better suit automotive applications.

1908

- Cadillac is honoured for its parts interchangeability by the Royal Auto Club of Great Britain.
- Ford introduces the Model T in October.

- William C. Durant founds the General Motors Co. in New Jersey. William Eaton is the first president. Oakland, Oldsmobile, Buick and Rapid Motor Truck become part of GM.
- Vanadium steel is developed for Ford by C. Harold Wills.
- The Fisher Body Co. is organised by Fred J. and Charles T. Fisher.

1909

- DeDion Bouton introduces the first production V8 engine.
- The Hudson Motor Car Co. is organised and the first Hudson completed. The company introduces hydraulic shock absorbers on its Model 20 Runabout.
- At year's end over 200 various auto makes are being built in the US, Detroit accounts for 25, with a total of 45 in Michigan. Chicago and Indianapolis rank second and third.

1910

- Isotta-Fraschini of Italy and Scotland's Arrol Johnston introduce four-wheel mechanical brakes on passenger cars.
- Cadillac is the first car maker to offer closed bodies as standard equipment. Also claims 112 part tolerance of cars to be within 0.001 in.

1911

- Electric starters are listed as optional on the Porsche-designed Austro-Daimler in Austria.

1912

- Cadillac introduces the electric starter and generator battery lighting system as standard equipment. The system is developed by Charles F. Kettering of the Dayton Engineering Laboratories Co. (Delco).
- Peugeot builds the first double overhead-camshaft engine for its Grand Prix car. Designed by Ernest Henry, a Swiss , it features "hemi" combustion chambers and four valves per cylinder.
- Oakland and Hupmobile both offer open, all-steel bodies developed by Edward G. Budd.
- Packard introduces its "Twin-Six", the first mass-produced twelve cylinder car. The engine features aluminum pistons.

1913

- Henry Ford applies the moving conveyor belt to magneto assembly and in August to full automobile production.
- Hudson introduces the "Supersix", the first modern four-door sedan.
- Maxwell offers the first adjustable driver's seat in the US (in 1928, Buick becomes the second American car maker to offer same).
- The Bendix drive for electric starters is shown for the first time.
- Pierce-Arrow put the headlamps of its models on the mudguards.

1914

- Cadillac develops thermostatic water circulation control and high-speed V8 engine.
- The first fully-automatic gearbox is offered by Mercedes on special limited production cars.
- Henry Ford announces a $5 minimum daily wage and eight-hour day.

1915

- Everyone who buys a Ford Model T gets a $50 rebate because sales pass their target figure-300,000 cars from August 1914 to August 1915. Ford production passes one million cars.
- Demountable rims replace the clincher types.

1916

- Slanting windshields become prevalent, along with hand-cranked windshield wipers.

1917

- Steel disc wheels enter production.
- Franklin introduces a push-button door lock on the top of its cars window sills.
- The first Nash appears with a six cylinder, OHV engine.

1918

- Production is up, and car registrations in America exceed 5 million for the first time.
- Four-wheel hydraulic brakes are developed by Malcolm Loughead in California.

1919

- Hispano-Suiza builds the first successful production cars using four-wheel mechanical brakes with servo assistance.
- Ford builds 750,000 cars - over one-third of total US car output.
- Duesenbergs are fitted with hydraulic, internally expanding four-wheel brakes.

1920

- The post-WWI recession causes gasoline shortages.
- Chauffeurs increasingly lose their jobs as owners take the seat behind the wheel.
- Standard auto equipment includes heaters, sloping windshields and wire wheels. Buick and McFarlan offer solid metal wheels.
- Luxury items like a compass and camera are standard on Templer's touring roadster; flower vases are standard on the sedan model
- Packard introduces the Lanchester vibration dampener.
- Mack features rubber engine mountings and spring shackles.

1921

- Backup lamps make their appearance.
- Studebaker utilizes molybdenum steel
- Leland Lincoln autos make turn signals standard equipment.

- Ford overcomes a financial crisis with the help of its dealers as its production surpasses the 5 million mark. Ford now produces 55.45% of the industry's total output.
- Nickel plating is used on radiators and lamps.
- Dr. Thomas Midgley and associates prove the effectiveness of tetraethyl lead in gasoline.

1922

- New models sport balloon tires, air cleaners and fuel gauges introduced.
- Daimler cars are equipped with Marconi wireless receivers.
- Lancia's production cars are powered by V6 engines and feature four-wheel independent suspension.
- Austin introduces the Seven, a small four-seater with 747 cm^3 engine.

1923

- Sheet steel is replacing wood for car bodies at Dodge, except on the roof where water proof fabric is stretched over wood bows and slats.
- Standard equipment in most cars now includes four-wheel brakes, foot controlled headlamps-dimmer switches and power-operated windshield wipers.
- DuCo develops and automotive lacquer finish.
- Ford produces a record 2 million autos this year.
- Fiat brings out an adjustable steering column.

1924

- The first Chrysler, its high-compression (4.5:1) six features a seven-bearing crankshaft, four-wheel hydraulic breaks and a replaceable cartridge oil filter.
- A new Du Pont quick-drying enamel paint speeds production.
- Statistics indicate one in seven US citizens owns an auto.
- Franklin develops a vibration damper in the clutch.
- Stock crankcase oil filters are introduced by Purolator.
- The adoption of SAE standards saves automakers an estimated $124 for each car produced.

1925

- Oldmobile's five passenger sedan marks the introduction of chromium plating.
- Common features of 1925 models are balloon tires, rumble seats, one piece windshields, mohair upholstery, crank-type window lifts and colourful high-gloss finishes.
- Chrysler Corp. emerges from the reorganization of Maxwell-Chalmers. The company offers rubber engine mounts this year.
- W.C. Durant manufactures the first US production car with full pressure lubrication-not to become an industry standard until after WWII.
- Accessories for the automotive consumer include: tire jacks, stop signals, locking radiator caps, trunk racks, all-weather enclosures for touring cars, mirrors, ash trays, cigar lighters and heat indicators.

1926

- Two years of joint marketing lead Benz and Daimler to merge and produce Mercedes-Benz cars.
- Mirror steel post construction offers better vision in ‘26 models which also feature “shock-proof” glass, heavier crankshafts, shorter strokes and faster engines.
- Dr. Graham Edgar develops the octane scale for gas.
- Stutz manufactures a windshield with wire running horizontally through the glass at intervals of several inches, while Rickenbacker makes a sandwich of transparent celluloid between two sheets of glass.
- Packard lowers the body line of its cars by lowering the driveshaft and using hypoid gears.
- Hot water in-car heaters are introduced.
- The Silentbloc non-lubricating bearing is invented in Belgium.

1927

- Volvo’s first model, the Jacob is exported.
- The 27th National Auto Show proves a trend toward small cars. Other common features are air cleaners, gasoline filters, crankcase ventilators, oil filters, and rearview mirrors.
- Carl Breer’s study of aerodynamics in relation to automobile body and chassis construction.
- At Lockheed, Malcolm Loughead introduces an internal expanding hydraulic brake system.
- Studebaker quiets its cars by using a steel wool-filled, direct flow muffler.

1928

- Ford’s Model A replaces the Model T, which remains the world’s most mass-produced car until eclipsed by the VW Beetle.
- Cadillac pioneers the synchro-mesh transmission.
- AC introduces a mechanical fuel pump.
- Westinghouse vacuum brakes reduce pedal pressure by two-thirds on Chandler models.
- A four-speed transmission is common on most Graham-Paige models.

1929

- US car production reaches a peak of 5,337,087, which is not exceeded until the 50s.
- The first series-produced front-wheel-drive cars in the US are marketed by Ruxton and Cord.
- Tail lamps appear on both sides of the car. Body rustproofing begins.
- Chrysler installs a down-draft carburetor for better fuel distribution and efficiency.
- The Luvax hydraulic shock absorber makes its appearance.

1930

- The use of rubber-cushioned chassis springs and aluminum pistons spreads in the industry. The quest for engine smoothness is on; internal engine work includes balancing of components, such as connecting rods on the finer models.

- Cadillac's 7.4-L (452 in^3) V16 engine debuts. Rated at 165-hp , the new V16 engine features hydraulic valve adjusters, a halfway step to the true hydraulic lifter.
- Daihatsu begins production of three-wheeled motor vehicles.
- Reo introduces a semi-automatic transmission featuring a dash-mounted selector lever.
- The fuel saving 'free-wheeling' and a carburetor intake silencer are introduced by Studebaker.
- Pontiac develops tin plated pistons and pressed steel axle housings.

1931

- Mercedes-Benz introduces the 170, the first passenger car with all-independent suspension..
- Standard and Rover in England adopt automatic clutches worked by engine vacuum.

1932

- Ferdinand Porsche designs an all-torsion-bar suspension system.
- Chrysler goes for silence with rubber-mounted engines and improvements to silence fans, air-intake and exhaust.
- Full-skirted fenders debut from Graham.
- Pierce-Arrow engines utilize hydraulic valve lifters.
- Oldmobiles and Packards get automatic chokes this year.

1933

- Streamlined design is the new fad; skirted fenders, V-front grilles, sweeping tail lines and slanted windshields.
- Chrysler markets anodized aluminium alloy pistons.
- Toyoda Automatic Loom Works, Japan, establishes its Automotive Dept. which will later become Toyota Motor Co.
- Power brakes become available.

  Jidosha Seizo Co. Ltd. is established that will be renamed Nissan Motor Co. Ltd. in 1934.

1934

- Independent front suspension is nearly universal.
- Reo offers automatic transmissions as do Chrysler and Desoto later in the year.
- The Chrysler Airflow is launched.
- The Continental transverse front spring shows the direct double action shock absorber at the central chassis mounting.
- Andren Citroen develops the Citroen with front drive unitary construction and all-independent suspension, but the car's costly development forces him to sell it to Michelin.

1935

- The world census counts 35 million motor vehicles in use.
- The Fiat 500 Topolino ("little mouse"), is introduced. The car features four synchromesh gears, hydraulic brakes and its engine ahead of the front wheels.
- The steel roof is studied at GM and Chrysler.

- A new electric hand fingertip control for gear shifting, mounted on the steering column, makes news on Hudson's Terraplane.
- Chevrolet's new frame has no X-member.
- Hand brakes are placed to the left of the driver for more room in the front seat.

1936

- Hitler's Nazi Party finances Porche's first Volkwagen.
- The world's first production diesel car, the Mercedes-Benz 260D, is introduced.
- New safety features highlight the Hudson: a steel torque arm which results in easier steering and eliminates "nosing down" when braking and a double automatic emergency braking system with a separate reserve that goes into use if the primary brakes fail.
- Sloping side windows and built-in defrosters appear.

1937

- Batteries are placed under the hood for better accessibility.
- Toyota Motor Co. Ltd. is established.
- A new trend moves gearshifts onto the steering column for "more appeal to women".
- Oldsmobile and Buick introduce an automatic gearshift and term the Automatic Safety Transmission.
- Plymouth introduces safety glass as standard on its models.

1938

- GM introduces a variable-rate, disc-type clutch spring.
- Coil springs begin to replace leaf springs on the rear of some cars.
- Construction begins on the Volkswagenwerk, planned by the Nazi government to be the world's largest automobile plant under one roof.
- New features for '38 include Chevrolet's vacuum-operated gearshift; Plymouth's safety signal speedometer and vacuum operated convertible top; Pontiac's "Duflex" rear springs which incorporate a smaller auxiliary leaf spring for uniform riding quality under load and Packard's "Econo-drive" overdrive transmission.

1939

- "Hydra-Matic Drive" highlights this year's Oldsmobile models, as well as all-coil-spring suspension with four-way stabilization.
- Pre-production Volkswagens tour Germany, whetting the public's appetite for a car which won't see production until after WWII.
- Packard offers an air conditioning unit.
- Sealed-beam headlights appear for the first time.
- Heaters go under the seat for better circulation.

1940

- Chrysler's safety-rim wheel keeps the tire on the rim in the event of a blowout. The company also offers two-speed electric windshield wipers.

- A dual-compound carburetor, introduced by Buick, allows a second carburetor to cut in when the throttle is depressed to the floor.

1941

- The automotive styling look of the ‘40s is longer, broader and more massive. Grilles are wider, bumpers heavier and running boards absent or concealed.
- Hudson’s combination automatic has a semi-automatic clutch. By depressing controls on the dash, drivers can select to shift manually or semi-automatically.
- A four-speed semi-automatic transmission and hydraulic coupling are produced at Chrysler.

1942

- US Civilian passenger car production ends on February 9th. Gasoline rationing starts on Dec. 1.

1945

- US passenger car production resumes in July, but the cars are virtual 1942 models.
- Production of a lightweight car featuring an overhead cam.
- Gasoline rationing ends in August.

1946

- Ford’s Rouge plant suffers from post-war parts shortages which shut down almost all the company’s operations including the passenger car assembly line.
- Studebaker offers self-adjusting brakes.
- Power windows gain in popularity as drivers, used to war-imposed shortages, yearn for conveniences.

1947

- The American automobile industry celebrates its Golden Jubilee.
- Packard production hits the one million mark. Power-operated windows and seat adjustment are features.
- Henry Ford passes away at age 84.
- The first post-war Datsun cars are produced.
- Sun visors outside the windshield reappear for the first time since the early ‘30s.
- The 1,00,000th Volkswagen engine is produced.

1948

- US automakers take advantage of the wartime advances in high-octane gasoline.
- The Honda Motor Co. Ltd. is formed by Soichiro Honda. His first product is a small clip-on engine for the bicycles of war-torn Japan.
- The British Morris Minor features a front suspension system sprung by torsion bars.
- Buick’s Dynaflow transmission is a hydraulic torque converter.

- Double curved windshields shape Cadillacs, Buicks and Oldsmobiles.
- Tubeless tires appear from Goodrich.

1949

- Crosley, Chevrolet, Chrysler and Dodge market bonded brakes.
- Only an ignition key is needed to start this year's Chrysler.
- VW sells two cars in its first year in the US.
- Triumph's Mayflower combines a coil spring/damper unit and strut-type telescopic damper.

1950

- Goodrich adds puncture-sealing features to its tubeless tires.
- US car models for this year feature V8 engines and automatic transmissions (Studebaker); one-piece curved windshields, plastic-insulated ignition systems to guard against moisture (Nash); tinted non-glare glass (Buick); automatic transmission (Fordomatic and Merc-O-Matic) and an all-steel station wagon (Chrysler Town & Country).
- Toyota's only labour dispute is settled in two months.
- Ford of Britain adopts MacPherson strut independent front suspension.
- Hydraulic disc brakes are patented by Dunlop of Britain.
- Rover's front-mounted 200-hp gas turbine engine powers the world's first turbine car.

1951

- Mercedes-Benz patents safety bodywork with a rigid passenger compartment and impact absorbing zones at front and rear, becoming the basis for future safety bodies of other makes.

1952

- US industry innovations for the year include Olds' headlamp dimmer; Lincoln's suspended brake pedal and ball-joint front-wheel suspension; Chrysler's 12-volt electrical system on the Crown Imperial; Plymouth's automatic overdrive; Ford's suspended clutch and brake pedals; Pontiac's dual-range Hydra-Matic and Packard's four-way seats.
- Fisher Body and Dodge use plastic dies for steel parts stamping.

1953

- Air conditioning, automatic transmission, 12-volt electrical systems and oil pressure and generator lights are common standard features, while tinted plexiglass roofs appear as options on some US models.

1954

- The Mercedes 300SL Gullwing is the first production car with gasoline fuel injection. It sets new design standards with its vertically-opening doors, and sets new performance standards with 215-hp.
- GM builds its 50 millionth car in the United States.
- Volkswagen starts a vigorous export drive.

1955

- US auto production tops 9 million units, an industry record.
- Toyota introduces the Crown model in Japan-the nation's first wholly domestic made passenger car.
- Push-button automatic transmissions appear late in the year on various Chrysler Corp. and Packard cars. Packard goes further with electrically controlled door latches. Chrysler offers an optional record player.
- Replaceable body panels, fiberglass roof, hydro-pneumatic suspension, front disc brakes and hydraulic gears highlight the Citroen DS19.
- Polyurethane foam is introduced to US automakers.
- Safety door latches are standard and seatbelts more prominent.
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1956

- GM stages a 30 mph car crash for a Congressional Committee studying auto safety.
- Chrysler adopts torsion bar front suspension.
- New features include electric door locks, non-slip differentials and six-way power seats. Controls on Mercury's dash operate the retractable rear window, while Ford's convertible features an all-metal top which retracts back into the body.

1957

- Ford's short-lived Edsel car features a push-button automatic transmission control in the steering wheel center.
- Toyota becomes the first Japanese automaker to export models to the US. The Crown is later withdrawn because of unsuitability for the high speed, long distance car travel in much of the US market.
- Three-wheeled "bubble" cars sell fairly well in Europe and are briefly exported to the US but remain a curiosity in US as power, chrome and tailfins still rule.
- Unit-body construction highlights this year's Lincoln and Continental models. More than half the US makes have rear coil springs. Paper air cleaners begin replacing the oil-bath type. Buick offers aluminium brake drums with cooling fins. Cadillac and Chrysler have cruise control system.

1958

- The US' "price label law" mandates labeling vehicles with a complete specifications list and suggested retail price.
- Goodyear unveils a double-chambered, captive-air tire.
- The Subaru 360 is introduced in Japan.

1959

- The Morris Mini Minor, designed by Alec Issigonis- the granddaddy of the modern front wheel-drive, transverse-engined econocars that will begin to appear over 15 years later, is introduced in England.
- Mercedes-Benz begins the first crash and roll-over safety tests.
- Crankcase ventilation valves-the first of the pollution control devices-begin to appear.

1960

- Mazda's first light passenger car appears in Japan.
- Ford claims its new process for making open hearth steel cuts production time in half.

1961

- Mercedes-Benz introduces front and rear servo-assisted disc brakes.
- Dual brake systems are standard on AMC and Cadillac products.
- Major tire producers develop four-ply tires as a replacement for two-plys on compacts.
- At AMC the Rambler gets factory-installed front and back seat belts and an E-stick automatic clutch transmission-although the driver shifts gears manually, the clutch automatically engages/disengages.

1962

- Goodyear introduces a polyester fibre tire cord. General Tire and Rubber claims its new tire lasts 50,000 miles or more US Rubber's chemical bonding agent is touted to end ply and tread separation.
- Front disc brakes are standard on the Studebaker Avanti and optional on other Stude models. An optional fully-transistorized ignition is available on Pontiacs.
- Honda introduces its first car.
- The Hillman Imp engine launched by Rootes is the first mass-produced engine with die-cast aluminum parts.

1963

- VW adds a fully-automated assembly line to its Wolfsburg facility, greatly increasing output of Beetle bodies.
- Goodyear Tire & Rubber Co. shows a safety tire featuring an inner spare which can run for over 100 miles after the outer carcass blows.

1964

- GM builds over four million vehicles.
- Cibie of France and Philips jointly develop the iodine vapor bulb for automotive headlights.
- The selector pattern of automatic transmission is standardized as Park-Reverse-Neutral-Drive-Low. Some manufacturers begin switching to anti-glare suede paint for dashboards. Ford's new primer paint process-electrocoating-is applied on '64 T-Birds and Lincolns.

1965

- US automobile and commercial vehicle production peaks at over 9.3 million units.
- Ralph Nader publishes *Unsafe At Any Speed*, subtitled "The designed-in dangers of the American automobile". The controversial book leads to tougher US automotive safety regulations.
- The first Audi is built by Auto Union/NSU.

1966

- Concern for safety becomes an issue as the National Traffic and Motor Vehicle Safety Act.

1967

- Fiats are now being manufactured or assembled in 18 countries.
- Chevrolet introduces its pony car, the Camaro while Pontiac brings out the Firebird.
- GM produces its 100 millionth vehicle in the US on April 21.
- Nissan builds its three millionth car and introduces the all-new Datsun 510 in Japan.
- The VW Beetle gets a semi-automatic "Automatic Stickshift" transmission.
- GM fits "key in ignition" buzzers to curb thefts. Chrysler makes access to the rear of the ignition switch more difficult.
- Concealed windshield wipers are standard on most GM cars, and become a design trend on other US cars as well.

1968

- Toyota introduces the Corolla in the US. Toyota's annual production passes the one million unit mark.
- Exhaust emission control systems are standard equipment on 1968 models, which also sport safety features such as seatbelts for all passengers, side marker lights, non-reflective windshields, padded interiors and front seat backs.
- British Leyland is formed from the B.M.C. and Leyland companies.
- Checker Motors Corp. offers a diesel engine option on taxicabs and passenger cars - the only US manufacturer with such an option.

1969

- Toyota's cumulative vehicle exports reach one million units.
- Nissan introduces the Datsun 240Z in Japan, with the US models arriving a year later.
- Ford Motor Co. is reorganized. Henry Ford II is chairman; Lee Iacocca becomes president of North American automotive operations. The company's Maverick compact car is introduced.
- Saab-Scania is formed in Sweden. Saab opens a Finnish factory.
- Assembly of the VW Beetle is discontinued at the Ingolstadt, Germany, plant to free capacity for the new Audi 100.
- Airbags designed to inflate and cushion a car's occupants in a crash are tested in the US.
- Under the Federal Truth in Lending Law, dealers are required to state cost, terms and conditions to car buyers.

1970

- Japan, with a monthly output of 200,000 cars, is now the world's second largest automobile manufacturer.
- Lee Iacocca becomes Ford Motor Co. president. Ford introduces the Pinto and announces the withdrawal of its North American Operations from racing.
- Mercedes-Benz develops an analog anti-lock brake system.
- The Russian "Lunochod" is the first vehicle on the moon.
- Citroen's Maserati-engined SM model has power-assisted rack and pinion steering with a power-centering device.

And the improvement continued. Very soon, Japan became the leader in automobile manufacturing. The West had to start copying the production management(Lean Manufacturing) and quality improvement systems used in Japanese automobile plants with Toyota as pioneer for many of them.