The Automotive Idea

1

The idea of the self-propelled road vehicle dates from at least as early as the speculations made by Roger Bacon and Leonardo da Vinci in the thirteenth and fifteenth centuries. Its development during the nineteenth century was multinational. Sociocultural differences reflected by national political boundaries were far less significant than the evolution of a modern urban-industrial social order in Western Europe and the United States. This involved a widely disseminated, shared state of scientific and technical knowledge. It was thus inevitable that a number of people on both sides of the Atlantic should perceive the possibility and social utility of the automotive idea—the combination of a light, sprung, wheeled vehicle; a compact, efficient power unit; and hard-surfaced roads.

The earliest experiments with cumbersome steam-powered vehicles did not get very far. We know next to nothing about two steam-powered, self-propelled vehicles reported to have been constructed in China about 1665 by the French Jesuit missionaries Ferdinand Verbeist and Philippe-Marie Grimaldi. A century later, between 1765 and 1770, Nicholas Joseph Cugnot, a Swiss engineer, was subsidized by the French government to experiment with steam tractors for pulling cannon. Cugnot's 1769 vehicle was less efficient than horses, and further development was halted when a change in government policy cut off his funds. Richard Trevithick, a Cornish engineer who pioneered the development of the high-pressure steam engine in England, built steam carriages in 1801 and 1803. Although his vehicle ran reliably at speeds up to 12 mph, Trevithick was unable to obtain financial backing to develop it further. Oliver Evans, an American inventor, obtained a patent from the Maryland legislature in 1787 giving him exclusive rights to operate steam-powered vehicles on the public roads. In 1805 a steam-powered dredge that he built for the city of Philadelphia, the "Orukter Amphibolos" or "Amphibious Digger," moved under its own power through the streets of Philadelphia at about 4 mph. Onlookers thought the vehicle would be too slow for turnpike travel, and Evans was unable to raise the $3,000 he needed to launch an experimental company to build steam-powered wagons.

These experiments were a prelude to many other demonstrations of self-propelled road vehicles during the first half of the nineteenth century. Great Britain and the United States led the civilized world in the development and application of steam power. In both countries attempts were made to establish stage lines utilizing steam-powered road vehicles for the long-distance transportation of freight and passengers. The main reason for the failure of these attempts was that the railroad was a far superior technological alternative, given the bulk and weight of the steam engines and the incredibly poor roads of the day.

Competition from cheaper, more reliable rail and water transportation was a major factor in the United States. Our unexcelled waterways and the rapid development of the railroad network here, heavily subsidized by government, reduced the stage lines to the role of short-haul feeders and discouraged the building of improved roads.

In England, under the influence of horse-drawn transportation interests, the turnpike trusts that administered the highways levied discriminatory tolls against mechanical road vehicles. Then in 1865 Parliament passed on behalf of the railroad monopolists the notorious Locomotive Act. This so-called Red Flag Act limited the speed of "road locomotives" to 2 mph in towns and 4 mph on the open highway and required that an attendant walk sixty yards ahead carrying a red flag by day and a red lantern by night. Until its repeal at the request of wealthy automotive pioneers in 1896, the act militated against development of the automotive idea, for by 1890 light steam vehicles were capable of being driven 15 mph for long distances over British roads.

The automotive idea stood the best chance for early implementation in France. Cugnot's experiments are only one indication of early French interest in the military potential of the motor vehicle. Even before the French Revolution, the government had perceived the need for good roads upon which to move the heavy wheeled traffic of its armies; since the founding of the Ecole des Ponts et Chaussées in 1747 to train competent civil engineers, it had given special attention to building a national highway network. Also, local governments in France were required by an 1836 law to maintain local roads and were authorized to collect taxes for this purpose. The result was that by the advent of the automobile in the 1890s, French roads were unexcelled. Elsewhere in Europe and especially in the United States, implementation of the automotive idea necessitated a massive reawakening of interest in highway transportation.

Precursors: The Trolley and the Bicycle

Land transportation improved very little from the domestication of the horse and invention of the wheel in prehistory until it was revolutionized by several mechanical innovations in the nineteenth century. Of these the first to be perfected were the steam railroad and the electric streetcar. The potential of the former for low-cost long-distance intercity transportation was reaching full realization by the mid-1870s.

In American cities, horsecars running on fixed rails had supplanted horse-drawn omnibuses as the main mode of transit by 1860. The 5¢ fare was beyond the reach of $1-a-day workers, however, so the horsecar did little to change the settlement patterns of the "walking city." People of necessity lived close to their workplaces, and shopping and leisure-time activities were centered in the neighborhood.

The cable car, powered by being linked through a grip to a continuously moving cable, was introduced in 1873 in San Francisco. By the mid-1890s, 626 miles of cable car lines were in operation in American cities.

The first electric streetcar, or trolley, system was installed by Frank Sprague in 1887 in Richmond, Virginia. The electric streetcar rapidly displaced horse-drawn cars and ended the construction of cable car systems. As late as 1890, urban rail transit in the United States was 70-percent horse powered, but by the turn of the century electrified rail transit prevailed. Some 850 electric trolley systems operated over 10,000 miles of track. The first electric interurban track in the United States was laid in 1889. Electric interurban mileage proliferated from 2,107 miles in 1900 to a peak of 15,580 in 1916.

Individualized long-distance transportation in the form first of the safety bicycle (1885) and then of the motor vehicle (1895) followed close behind. Many contemporary observers saw the automobile revolution and the rail revolution as complementary. Improved transportation, whether by auto or by rail, increased personal mobility, brought city amenities to the countryside, decentralized urban space, sanitized the central city, and created an integrated national culture, economy, and society. But the unparalleled flexibility of the motor vehicle made its potential impact far greater.

Early in the nineteenth century, John L. McAdam and Thomas Telford in Great Britain developed new techniques of highway design and construction that made possible much smoother, tougher road surfaces and easier grades. But this "highway renaissance" soon collapsed under competition from the steam locomotive running on fixed rails. Interest in improved roads was heightened in France and revived in Great Britain and the United States by the bicycle craze of the 1880s and 1890s.

The bicycle industry began in Paris in the 1860s with the invention of the velocipede by Pierre Michaux, then spread to the rest of Europe and the United States after Michaux's vehicle was demonstrated at the 1867 Paris Exposition. British output of high-front-wheeled velocipedes soon surpassed French output, and the British in particular continued to develop the vehicle. Use of the bicycle became widespread with the introduction of the modern geared, low-wheeled "safety bicycle" in 1885 by James Kemp Starley of Coventry, England, and after quantity production reduced the price of a bicycle to about $30. By 1893 there were some 150,000 bicylces in use in France. And William Plowden relates that in Great Britain, "for the first time since the rise of the railways the roads were crowded with through traffic; and, for perhaps the first time ever, the idea was born of travelling the road for pleasure." [1]

The bicycle required better roads, with much smoother surfaces, than horse-drawn traffic. Even the excellent French gravel roads of the day left something to be desired. So bicycle periodicals and organizations both in Europe and in the United States energetically began to agitate for improved roads. By the 1890s at least a dozen bicycle periodicals throve in France, the most important of which was the daily *Le Vélo*, founded in 1891 by Pierre Giffard. In Great Britain the Cyclists' Touring Club and the National Cyclists' Union, both founded in 1878, in 1886 jointly organized the Roads Improvement Association, which published and distributed widely a booklet entitled *Roads, Their Construction and Maintenance*. Yet cyclists in Europe, who in general were not men of substance, at best had only limited local successes in getting roads improved.

Cyclists were somewhat more successful in the United States, where the crest of the bicycle movement coincided with the climax of several decades of agrarian discontent. The Farmers' Alliances and the Populist movement had made the abuse of monopoly power by the railroads a prime target. Farmers were beginning to perceive highway transportation as an alternative and to complain about the lack of good farm-to-market roads. Good roads thus became a popular political issue in the United States during the 1890s.

The League of American Wheelmen (LAW) was organized in 1880, one of its main goals being "the improvement of public roads and highways." The major figure in the good-roads movement in the United States was Colonel Albert A. Pope, the nation's leading bicycle manufacturer. Pope aided the bicycle periodicals *Bicycle World*, *Wheel*, and

Wheelman (later *Outing*) in their good-roads efforts, and helped found in 1892 the LAW *Good Roads Magazine* (later the *LAW Bulletin of Good Roads*). At the national level, a petition to Congress drafted by the LAW resulted in 1893 in the creation of the Office of Road Inquiry in the Department of Agriculture. This agency became the Office of Public Roads and conducted the first census of American roads in 1904—revealing that only 7 percent of American roads were surfaced, that only one mile of improved road existed for every 492 inhabitants, and that most of this mileage was of poor quality.

The National League for Good Roads, with branches in most states, was founded by General Roy Stone at the 1893 Columbian Exposition, and later that year a Good Roads Convention was held in Washington, D.C. President Theodore Roosevelt and William Jennings Bryan were among the prominent political leaders attending the National Good Roads Convention at St. Louis in 1903, where resolutions were passed endorsing the principle of state aid to counties and municipalities and the support of the federal government for road construction. At the state level, New Jersey led in the passage of legislation in 1888 and 1891 that instituted the modern system of financing road improvements and maintenance through taxation by county and state governments. Between 1892 and 1913 comparable legislation was enacted by twenty-six more states. At the local level, cyclists succeeded in getting streets paved or repaved to accommodate bicycle traffic in a number of cities.

Apart from its impact on road improvement in the United States, no preceding technological innovation—not even the internal-combustion engine—was as important to the development of the automobile as the bicycle. Key elements of automotive technology that were first employed in the bicycle industry included steel-tube framing, ball bearings, chain drive, and differential gearing. An innovation of particular note is the pneumatic bicycle tire, invented by John B. Dunlop in Ireland in 1888. The bicycle industry also developed techniques of quantity production utilizing special machine tools, sheet metal stamping, and electric resistance welding that would become essential elements in the volume production of motor vehicles.

A number of the more important early automobile manufacturers were first bicycle manufacturers—among others, Opel in Germany; Clément, Darracq, and Peugeot in France; Humber, Morris, and Rover in Great Britain; Pope, Peerless, Rambler, Winton, and Willys in the United States. A substantial proportion of engineering talent as well in the early automobile industry was provided by former bicycle mechanics—including William Morris, who initiated volume production of automobiles in Great Britain; Charles E. and J. Frank Duryea, who built the first successful American gasoline car; and William S. Knudsen, production head first at Ford, then at Chevrolet, and later president of General Motors.

The greatest contribution of the bicycle, however, was that it created an enormous demand for individualized, long-distance transportation that could only be satisfied by the mass adoption of motor vehicles.

The Steamer

During the period 1860–1890, lightweight, high-pressure, self-condensing steam engines with automatic controls were developed; and the invention of the flash boiler, an instantaneous steam generator, by Léon Serpollet in 1889 made it possible to operate a steam-powered car without waiting to get up steam. Beginning in 1872 in France, Amédée Bollée of Le Mans built and demonstrated several steam cars and omnibuses, but he gave up his experiments a decade later. Comte Albert de Dion experimented with steam tricycles between 1881 and 1888. The first Peugeot cars, built in 1889, were heavy tricycles powered by Serpollet steam engines. Serpollet, the only French "apostle of steam," drove one of his own steam tricycles 295 miles from Paris to Lyon in January 1890. The journey took two weeks. After building several more tricycles, he switched to building omnibuses in 1892, and by 1897 about eighty of his steam buses were in use in Paris. When the first lines of the underground Paris Métro opened in 1900, Serpollet reverted to making light steam cars with the backing of an American named Frank Gardner. The Gardner-Serpollet cars set some speed records in France and England, and about 100 a year were produced for a few years, which at £600 sold for about three times the price of an American-made Locomobile steamer. The rapid technological development of the gasoline-powered car in France discouraged there the concurrent development of light, inexpensive steamers.

With experimentation in England stultified by the Red Flag Act, leadership in development of the steamer in the late nineteenth century passed to the United States. At least a dozen American inventors built operable steamers in the period 1860–1890. The most important was Sylvester H. Roper of Roxbury, Massachusetts, who began his experiments in 1859 and built ten or more steam-powered road vehicles in the next two decades. Ransom E. Olds completed steam-powered road vehicles in his Lansing, Michigan, machine shop in 1887 and 1891 and sold the latter vehicle for $400 to a London patent medicine firm for use at its branch house in Bombay, India.

Quantity production of steamers in the United States was initiated in the Boston area in 1898 by George Whitney and by Francis E. and Freelan

O. Stanley. The Stanley design was sold the following year to Amzi Barber, an asphalt magnate, and to John Brisbane Walker, the publisher of *Cosmopolitan* magazine. They formed companies that made identical steam cars—the Locomobile Company of America at Bridgeport, Connecticut, and the Mobile Company of America at Tarrytown, New York. The Stanleys then reentered the manufacture of steam cars by buying Whitney's business. The White Sewing Machine Company began producing steamers in 1901 and was the first American maker to use Serpollet's flash boiler. The Locomobile steamer was the best-selling car in the United States in 1900–1901, and the cheapest Locomobile model sold for only $600. About 5,000 were produced before the company, at the height of the steamer's popularity, switched over entirely to making high-priced gasoline-powered automobiles in 1903. White, too, replaced its famous steamer with a gasoline-powered car in 1910. A Stanley Steamer driven by Fred Marriot averaged 127.66 mph to set a new land speed record at Ormond Beach, Florida, in 1906. By then, in sharp contrast to the gasoline automobile, the steamer had reached a technological standstill. Stanley continued in business until 1925, making a few hundred steamers a year for an ever diminishing market.

Initially, the steam engine had some advantages over the internal-combustion engine. It was more flexible with fewer moving parts and was less critical of exact tolerances to perform at minimal efficiency. It could not stall, as could the internal-combustion engine, and it permitted much smoother transmission of power to the wheels, thus simplifying operation by reducing the formidable problem of shifting gears. It was easier to manufacture.

These apparent early advantages were more than canceled out, however, by the steamer's liabilities. Steam engines operated at lower thermal efficiencies than internal-combustion engines of the same capacity, so the steamer had the great disadvantage of loss of energy due to inherent problems of heat transfer and storage. Mechanical problems also resulted from the high pressures (about 600 psi) necessary to develop adequate power in an engine small enough for a motorcar. Furthermore, the steamer was practical only in places where an abundant supply of soft water was available in horse troughs; and in addition to the water it consumed, the steamer burned as much petroleum fuel as did the gasoline automobile. Therefore, once the internal-combustion engine had been made more powerful for its weight and more flexible through better basic design and closer precision in the machining of parts, the steamer could not compete in the ratio of horsepower generated to the combined weight of the engine and fuel supply carried.

The Electric

A few manufacturers, primarily in the United States, for a short time backed the electric-powered car. The storage battery itself was invented and perfected in France: the first one was devised by Gaston Planté in 1859, and subsequent improvement of its storage cells by Camille Faure about 1880 had the result that sufficiently heavy current could be generated to power road vehicles by electricity. The electric car was pioneered in France by Charles Jeantaud, a Paris builder of fashionable coaches. He completed his first electric in 1894 and made several more as a sideline. Alexandre Darracq also briefly experimented with electric power in 1896. The only significant French manufacturer of electrics, however, was the Société Civil des Voitures Electriques, Système Kriéger, formed in 1895 to produce electric taxicabs. It folded in 1907.

If it found little enthusiasm in France, the electric car briefly played a prominent role in the emerging American automobile industry. Perhaps the first and most successful early experiment was a vehicle built by William Morrison of Des Moines, Iowa, in 1891, which was driven on the streets of Chicago a year later. Given the poor storage batteries of the day, it is difficult to believe the claim that Morrison's car was capable of being operated for thirteen consecutive hours at 14 mph.

Another early American electric was the 1894 "Electrobat," built by Henry G. Morris and Pedro G. Salom in Philadelphia. They formed the Electric Carriage and Wagon Company, which began to operate twelve of its electric vehicles as a fleet of public cabs on the streets of New York City in January 1897. The firm was soon absorbed by the Electric Vehicle Company—a New Jersey holding company established in 1897 by Isaac Rice, a manufacturer of storage batteries—and moved to Hartford, Connecticut.

Still another early manufacturer of electrics was Andrew L. Riker, who built an experimental tricycle as early as 1884. He formed the Riker Electric Motor Company to make electric motors in 1888, then organized the Riker Motor Vehicle Company in 1898 at Elizabeth, New Jersey, to make electric cars. In late 1900 Riker's firm was sold to the Electric Vehicle Company. Riker, one of the foremost early automotive engineers, switched over to designing luxurious gasoline-powered automobiles as chief engineer at Locomobile after 1902. He became one of the founders and the first president of the Society of Automotive Engineers (SAE), a small but influential group of American automobile trade journalists and engineers who organized in 1905 to improve the state of automotive technology through the publication of articles.

The most important early manufacturer of not only electric but all motor vehicles in the United States was the Pope Manufacturing Company of Hartford, Connecticut, the nation's leading bicycle manufacturer until surpassed in production by the Western Wheel Works in 1896. Pope's motor vehicle department, with Hiram Percy Maxim as chief engineer, began to produce electric automobiles in 1897. By the end of 1898 Pope had made some 500 electric and 40 gasoline automobiles. The Pope motor vehicle division became the Columbia Automobile Company and was consolidated into the aforementioned Electric Vehicle Comany in 1899. Pope then reentered the automobile business in 1901 by acquiring several small automobile manufacturing firms, one of which was the Waverly Company of Indianapolis, Indiana, a maker of electric cars since 1896. Pope went into receivership in 1907, but Waverly electrics were produced until 1915.

Probably the most notorious example of misplaced optimism and consequent overcapitalization, combined with poor technological judgment, in the early automobile industry was the so-called Lead Cab Trust, which resulted from the acquisition of the Electric Vehicle Company in 1899 by the William C. Whitney and P. A. B. Widener interests. In large part also a stock-jobbing venture, this holding company, formed with an inflated capitalization of $3 million, had as its announced aim the placing of fleets of public cabs on the streets of major American cities. Its manufacturing subsidiary, the Columbia and Electric Vehicle Company of Hartford, Connecticut, for a short time was the leading motor vehicle manufacturer in the United States. It produced some 2,000 electric cabs plus a few electric trucks in 1899, and it formed operating companies for its cabs in New York, Boston, Philadelphia, and Chicago. "Lead cab fever" affected Europe as well as the United States, with electric cabs of English and French make plus a few Pope-Columbias being put into service in London (1897), Paris (1898), and Berlin (1899).

The Lead Cab Trust's ultimate plans for a fleet of 12,000 vehicles and a $200-million capitalization were squelched by the failing performance of its electric cabs when put into service and by a financial scandal involving a fiscal manipulation that entailed a $2-million loan to a clerk. The operating subsidiaries collapsed, and on June 20, 1900, the Electric Vehicle Company became a manufacturing firm rather than a holding company, which through unwise mergers was again overcapitalized at $20 million by late 1900. The company progressively declined and as a result of the 1907 financial recession went into receivership on December 10, 1907, finally to be reorganized as the Columbia Motor Car Company in 1909 with a more realistic capitalization of $2 million. Ironically, the chief asset of this firm turned out to be its ownership of the Selden patent on the gasoline automobile. The Selden patent engendered a bitter organizational conflict in the early American automobile industry and profoundly influenced the industry's subsequent patent policy.

The electric car was the most conservative form of the automobile, in that it bore the closest resemblance to the horse-drawn vehicle in both appearance and performance. Manufacturers of electrics closely copied fashionable carriage forms. The Woods Motor Vehicle Company, a prominent early American maker of electric cars, for example, hoped to supply "hundreds of thousands of gentlemen's private stables with fine carriages in all variety of styles rather than the creation of a machine which will transport a man from town to town or on long country tours."[2] For city use, the electric offered some advantages over gasoline- and steam-powered cars as well as the horse. It was silent, odorless, and easy to control. Therefore, it was especially favored by women drivers, who were concerned foremost about comfort and cleanliness and who had a hard time either controlling a spirited team or starting a gasoline-powered car with a hand crank and learning to shift gears.

These advantages, however, were greatly outweighed by the many serious liabilities of the electric car. It was far more expensive than the gasoline automobile to manufacture and about three times more expensive to operate. As late as 1910, its range was only 50 to 80 miles on a battery charge; charging facilities were virtually nonexistent outside large cities; the storage batteries of the day deteriorated rapidly; and its hill-climbing ability was poor because of the excessive weight of the batteries for the horsepower generated. These relative liabilities of the electric car persist into the present, despite great recent improvements in storage batteries.

Developing the Gasoline Automobile

Although it was by no means obvious at the turn of the twentieth century, the four-cycle internal-combustion engine was vastly superior as an automotive power plant over alternatives. As an article in the June 1900 *American Monthly Review of Reviews* pointed out, the gasoline automobile had "developed more all-round good qualities than any other carriage. In spite of its clumsy and complicated mechanism, it does not get easily out of order. It will climb all ordinary hills; it will run through sand, mud, or snow; it makes good speed over long distances—say, an average of fifteen miles an hour. . . . It carries gasoline enough for a 70-mile journey, and nearly any country store can replenish the supply."[3] With the bringing in of the gusher "Spindletop" at Beaumont, Texas, on January 10, 1901, in the United States gasoline became a cheap commodity available at any crossroads general store, and farmers in midwestern hamlets early became familiar with the stationary gasoline engine. Electrics and steamers set speed records over short distances on tracks, but gasoline-powered cars excelled them in virtually all early endurance and reliability runs over public roads. The internal-combustion engine also was amenable to far greater short-range improvement than either the steam engine or the storage battery.

The internal-combustion engine was first perfected in Germany and France, and it is unequivocal that Continental automobile manufacturers were at least a decade ahead of their British and American counterparts in the technological development of the gasoline automobile. Like the automobile itself, the internal-combustion engine had no single inventor. Two-cycle versions were patented by Stuart Perry, a New York inventor, in the United States in 1844 and 1846, and by Etienne Lenoir, a Belgian mechanic, in France in 1860. There were others. Credit for being "first" is generally given to Lenoir, because his engine was commercially successful. A major innovation of the Lenoir engine was the use of an electric spark plug powered by a battery and coil to ignite the fuel mixture of air and illuminating gas.

Demand from farmers and small industrial plants for a cheap and simple source of power stimulated the development of more advanced internal-combustion engines. By far the most important was the four-cycle engine introduced in 1876 by Nicolaus Otto, a German manufacturer. His engine was the first to compress the fuel-air mixture inside the working cylinder, as well as the first to embody the four-cycle principle of consecutive intake, compression, power, and exhaust strokes (instead of every stroke being a power stroke, as in a reciprocating steam engine). The Otto engine was exhibited and won several competitions at the 1878 Paris Exposition. Etienne Lenoir then designed a four-cycle engine in 1883–1884 for the Paris machine builder Rouart Frères. A resulting suit over patent infringement was decided against Otto in the German and French courts, because the four-cycle principle had been conceived theoretically in 1862 by the Parisian Alphonse Beau de Rochas. This decision placed the Otto-type four-cycle engine in the public domain.

The original Otto Silent Engine was too cumbersome and slow to be efficient in a self-propelled vehicle. But by 1885 Gottlieb Daimler, who had been one of Otto's engineers, and his assistant, Wilhelm Maybach, had developed a 1.5-horsepower, 110-pound, 600-rpm vertical "high-speed" engine that proved to be the prototype of the modern motorcar's power plant. To demonstrate the capability of their engine, Daimler and Maybach built four experimental motor vehicles between 1885 and 1889. Then in 1893 Maybach invented the modern carburetor, which sprayed a fine jet of gasoline into the air stream being sucked into the engine.

From this point on, the dramatic improvement of the four-cycle, Otto-type engine stood in sharp contrast to developments not only in electric and steam engines but also in the isothermal-combustion/adiabatic expansion engine patented by Rudolf Diesel in 1893 in Germany. The diesel engine sought to obtain higher efficiencies through introducing the fuel into a cylinder in which air had already been compressed to a very high (ca. 250:1) pressure. The engine had the additional theoretical advantage that it could use lower grades of fuel and needed no ignition system because the fuel-air mixture was ignited by pressure. By 1897 Diesel had produced an engine that would run on heavy oil, with a compression ratio of 30:1 and an efficiency of 26 percent. This was about twice the efficiency of an Otto-type, low-pressure engine of the day, but still far less than the 75-percent efficiency that Diesel had anticipated. In producing a practical engine, he further had to justify a change in his patent from a constant-temperature to a constant-pressure engine, because temperatures inevitably went up as more fuel was burned.

Development of the diesel as an automotive power plant proved quite slow. Achieving a proper mixture of fuel and air in the brief time available for combustion was a major problem. "After seventy years of development," Lynwood Bryant pointed out as recently as 1976, "there are still plenty of uncertainties in this area, and in the first decade getting the engine to run smoothly was mostly a matter of accidentally hitting on the right combination of fuel, injection mechanism, and shape of combustion chamber, and sticking to the right formula with fingers crossed ... it was twenty-five years before the development of direct injection made the small diesel practical."[4] Ultimately, diesel engines would permit heavier loads to be transported over highways at greater economies of operation. But because of the diesel's high weight-to-power ratio, its initial impact was on rail transportation, and even diesel-powered heavy trucks and buses did not come into general use until after World War II.

It was Carl Benz, a German manufacturer of stationary gas engines, who brought the automobile to the stage of commercial feasibility. Benz built his first successful motor vehicle in 1885–1886, a tricycle powered by an 0.8-horsepower, two-cycle, one-cylinder engine. His third vehicle was exhibited at the Paris Exposition in 1889. The tricycle had been purchased the preceding summer and shipped to Paris by Emile Roger, a French engineer who became Benz's agent in France. For several months Roger found no buyers, and as late as 1892 he had sold only about a dozen cars.

Under prodding from Roger, in 1893 Benz came out with a greatly improved four-wheel car with a redesigned 3-horsepower engine capable of 700 rpm. Benz also introduced electric ignition, a great advance over the open-flame ignition used by Daimler. Given the limited market expectations of the day, the 1893 Benz sold well and was fairly reliable, as was a smaller model that he brought out in 1894. The Benz design was widely imitated. Benz is estimated to have sold 1,132 cars by 1898, 509 of them in France, 334 in Germany, 120 in England, and a handful in the United States, where they were first imported for sale by three New York City department stores in 1895. With sales of 603 cars in 1900, Benz was one of the emerging industry's leaders. But he retained the same basic design for a decade and was soon surpassed technologically by other manufacturers.

One of the pervasive myths of automotive historiography is that early automotive pioneers worked largely in ignorance of one another's accomplishments. Hiram Percy Maxim, in particular, gave credence to this notion in his 1937 autobiography. Maxim was "amazed that so many of us began work so nearly at the same time, and without the slightest notion that others were working on the same problems."[5] Maxim's own experiments in the early 1890s do illustrate his appalling ignorance of the state of the automotive technological art at the time. His procedures, for example, included igniting drops of gasoline in empty cartridge cases to determine whether or not they would explode! His experience cannot be generalized, however.

The diffusion of key technological innovations from a single source is generally what occurred in the development of the automobile; simultaneous, independent invention/discovery is far less common. We have noted, for example, that Daimler was one of Otto's engineers and that the Otto Silent Engine and the Benz tricycle were exhibited respectively at the 1878 and 1889 Paris Expositions, where they attracted worldwide attention. It is known that Charles E. and J. Frank Duryea were first motivated to design their own car after reading a description of the Benz tricycle in the 1889 *Scientific American*. The Duryeas were Springfield, Massachusetts, bicycle mechanics; they built the first successful American gasoline car in 1893, then initiated the commercial manufacture of gasoline cars in the United States in 1896. Still another prime example of the diffusion of key innovations is that the most important early French and British manufacturers—Panhard et Levassor, Peugeot, and British Daimler—all powered their cars with Daimler engines produced under license. To be sure, Carl Benz and Gottlieb Daimler developed their very first vehicles independently in the mid-1880s, and it is asserted that they never met. But after the Paris Exposition of 1889 virtually no development of importance in automotive technology went unreported in one or another of the engineering journals, bicycle periodicals, automobile trade journals, newspapers, and popular magazines of the day. Consequently, knowledge about such developments was widely disseminated worldwide from the very beginning of the automobile industry.

The Emerging Industry

2

Paris was the center of the nascent automobile industry. That this was the case had virtually nothing to do with French culture or social conditions—possibly excepting the French roads, the best in the world at that time. Rather, early French hegemony resulted from the historical accident of a unique network of social relationships emanating from the Germans Benz and Daimler through the French and Belgian intermediaries Emile Roger and Edouard Sarazin to the French industry leaders Emile Constant Levassor and Armand Peugeot.

Gottlieb Daimler himself produced only about a dozen cars in the early 1890s. Production began to expand in 1898, but Daimler Motoren Gesellschaft (later Mercedes) did not become prominent in the early automobile industry until after Daimler's death in 1900. The right to manufacture Daimler engines under license was secured in the United States about 1890 by the piano manufacturer William Steinway, who never got into production. In the United Kingdom, rights were obtained in 1893 by the Anglo-German automotive pioneer Frederick Simms, who had been born in Germany and knew Daimler well. Simms formed the short-lived Daimler Motor Syndicate in London before selling his British rights to the Daimler patents in 1895 to Harry J. Lawson, a leading figure in the British bicycle industry. Simms went on to found the British Motor Car Club and the Automobile Club of Great Britain and Ireland (later the Royal Automobile Club) in 1897, then to collaborate with Robert Bosch in the development of the magneto.

Despite the American and British licensing, technological development of the Daimler engine occurred only in France, where in 1890–1891 it powered the early Panhard et Levassor and Peugeot models. As a young engineer in 1860–1861, Gottlieb Daimler had worked briefly for the Paris