Decline and Resurgence

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"When the history of the automobile is written, scholars will necessarily focus careful attention on the crucial period of the late sixties and the early seventies," John Jerome predicted in 1972. "During that period the largest industry the world had ever known . . . peaked out. The automobile industry began to die." Jerome considered the railroads to have been "the ultimate example of a throwaway economy." However, he thought that "automobiles have a shorter past and a shorter future. It is unlikely that public control of corporate excess will become powerful enough to kill the automobile so long as there is any profitability to be wrung from it. But as our technology becomes more sophisticated, so does our cost accounting, and new costs—social ones—are being fed into a ledger at a much faster rate than new areas of automotive profitability can be discovered." His conclusion was, "The automobile must go." [1]

Jerome's book was one of the more important in the "death of the automobile" literature that enjoyed a brief vogue in the early 1970s. Other noteworthy titles were Helen Leavitt's 1970 *Superhighway—Super-Hoax*, Kenneth Schneider's 1971 *Autokind vs. Mankind*, Ronald Buel's 1972 *Dead End*, and Emma Rothschild's 1973 *Paradise Lost*. Up to this point, as we have seen, the complaints against the American automobile culture appearing between hard covers had been overwhelmingly consumer-oriented and directed against the automobile industry rather than the road and the car in themselves. John Keats's *The Insolent Chariots*, the most notable and outspoken, was a biting satire on Detroit's styling excesses and shoddy marketing practices. Ralph Nader's 1965 *Unsafe at Any Speed*, the most influential, was a narrowly based attack on the automobile industry that did not question the benefits of mass personal automobility per se. The critics of the early 1970s, in contrast, saw the ending of what Rothschild called "the auto-industrial age," especially in urban transit, as both inevitable and desirable.

The 1973 and 1979 oil shocks capped the critics' concerns about automotive safety, atmospheric pollution, traffic congestion, urban sprawl, and devastation of the natural environment. Oil dependence and escalating fuel prices seemed to represent a far greater threat to the future of mass personal automobility than its alleged social costs. To make matters worse, the automobile industry was widely conceived as stagnant in both its product and production technologies. Making cars more fuel efficient, like making them safer and less polluting a decade earlier, had to be forced on the automobile industry by federal legislation. And in explaining why federal standards could not be met, the auto makers projected an image of defensiveness and helplessness.

Increasing Japanese penetration of our domestic and world markets by the end of the 1970s also called into question the continuing economic viability of our "leading sector" industry. Would the world's foremost automobile culture soon be dependent not only on OPEC for oil but also on the Japanese for motorcars? With the shift overseas of motor vehicle and related industry jobs—17 percent of all American jobs in 1981—where would the economic base be to support our current level of automobile ownership and use?

Resuscitating Mass Transit

By the late 1970s mass transit had been transformed from an essentially private business expected to make a profit into a publicly owned and subsidized social responsibility. Mass transit ridership plummeted from 13.8 million in 1950 to 7.5 million in 1960 and to 5.9 million in 1970. As private transit companies went broke, leaving many small and medium-sized cities with no alternative to the automobile, government became involved. The publicly owned metropolitan transit districts that replaced the private companies integrated mass transit into more comprehensive urban planning and developed a broad base of political support. Indeed, mass transit came to be considered a panacea for urban problems much as the automobile had been considered one at the turn of the century. The new involvement of the federal government was particularly notable.

The first legislation providing for federal aid for urban mass transit was the Housing Act of 1961, which authorized $42.5 million in loans and grants to urban mass-transit companies and commuter railroads. The Urban Mass Transportation Act of 1964 provided $50.7 million for capital grants on a two-thirds federal funding basis for metropolitan areas with comprehensive transit plans. Then in 1968 the Urban Mass Transit Authority (UMTA) was created in the Department of Transportation to oversee experiments to improve urban mass transit in the United States. Funding remained minuscule until the mid-1970s, however. In 1965 only $51 million in federal capital grants was approved for urban mass transit, versus $4.105 billion spent for highway construction; in 1970 only $133 million was approved for mass transit, versus $4.678 billion for highway construction. In contrast, federal capital grants for mass transit totaled $1.430 billion in 1975, while highway construction expenditures increased only slightly to $4.821 billion. In 1974 federal legislation first provided for assistance in offsetting operating deficits. Gordon J. Fielding assesses the magnitude of the change in federal involvement: "Prior to 1961 there had been no federal role in transit assistance, and even as late as 1970, the federal contribution was overwhelmed by state, regional, and local contributions. By 1978, however, the federal government actually funded a greater percentage of the total operating and capital subsidy in the United States than all other government levels combined."[2]

The recognition that there were limits to energy resources, which sank into the minds of policymakers in the 1970s, made rehabilitating mass transit seem critical. By the time of the first diversion of the Highway Trust Fund to urban mass transit in 1973, the American Automobile Association remained the only important holdout against diversion. Even the Motor Vehicle Manufacturers Association had dropped its opposition. Ford and GM both formed mass-transit divisions, and there was speculation for a time that they might diversify into "total transportation" companies by the turn of the century—companies whose main business would be selling modular transportation systems to municipal governments.

In contrast with the narrow concentration of the federal government on highway transportation up to 1973, by the early 1980s there was strong federal and local commitment to building balanced transportation systems. Total federal expenditures on ground transportation from 1980 through 1984 show $14.932 billion spent on urban mass transit and an additional $8.198 billion on railroads (Amtrak), versus $36.541 billion on highway construction.

The most significant diversion of highway revenues to urban mass transit has come as a result of the Surface Transportation Act of 1982, as implemented by the Highway Revenue Act of the same year. President Ronald Reagan's November 1982 message to Congress on the draft bill made clear the administration's intention to treat urban mass transit and highway transportation as interdependent rather than competitive. The main goal of the legislation was to rehabilitate our eroding highway system. Nevertheless, one cent of the five-cent-per-gallon gasoline surtax imposed by the legislation was earmarked for urban mass transit; and the federal government committed itself to paying up to 80 percent of the capital costs for building or refurbishing urban rapid rail systems. The legislation also provided for subsidization of up to 50 percent of their operating deficits, even though the administration in 1981 had announced its intention to end all operating assistance by 1985. Metropolitan governments responded to the federal initiative with ambitious construction programs. As of the end of 1984, sixteen cities planned to extend existing rapid rail systems a total of 167.5 miles at an estimated cost of $12.325 billion, while ten more cities planned to build new rapid rail systems totaling 297.6 miles at an estimated cost of $11.106 billion.

The most impressive rapid rail system under construction is the Metro in Washington, D.C., intended by President Lyndon B. Johnson to be a national showcase and an example for other cities to emulate. Construction money for the Metro was appropriated under special legislation so that the system would not have to compete for funds. Capital costs for the planned 101-mile rail network have mushroomed from an initial estimate of $2.5 billion to a current estimate of $12 billion, and the targeted 1979 completion date will be exceeded by at least fourteen years. The Metro currently carries about 350,000 riders on weekdays, a load 10 percent less than projections, and ran an operating deficit of $190 million in 1984. On the credit side, however, in an article highly critical of urban rapid rail transit, *Business Week* reports that "in some ways Metro really is a model for the country. It is clean, fast, and surprisingly free of crime . . . it is even a tourist attraction."[3]

Less spectacular but probably more important is the effort by many metropolitan transit districts to upgrade their bus fleets by buying modern buses and extending service. The number of motor buses in public transit service, excluding sightseeing and school buses, increased from an estimated 49,600 in 1960 to 62,114 in 1982, while the number of electric railway cars decreased slightly from 11,866 to 10,926 over the same period. Miles of bus route doubled from 56,696 in 1960 to 122,169 in 1980. A few cities have even developed plans for special accommodation to buses.

Should these trends continue and existing plans materialize, the balanced transportation systems that critics of the road and the car advocated in the early 1970s will have become a reality in American cities by the turn of the century. At present, however, there is doubt whether this will occur and whether, even if it does, mass transit will meet the high expectations of its proponents. "American transit has reached a crossroads," Fielding observes. "More than a decade of public investment in transit has not changed the propensity of Americans to commute by automobile. . . .

Also, transit's ability to solve energy, environmental and social ills has come under serious question. And there is growing recognition that the fiscal appetite of transit is both voracious and out of control." [4]

So far, improved public transit has proved unable to recapture riders from the private passenger car. Between 1970 and 1982 only slight increases in vehicle miles operated were registered—from 1.409 billion to 1.669 billion for buses and from 448 million to 450 million for electric railways. Over the same period, the number of paying passengers carried by buses also increased slightly, from 4.058 billion to 4.417 billion, but that number declined from 1.746 billion to 1.528 billion for electric railways. During the 1970s there was actually a decline nationwide of 10.6 percent in the use of public transit for metropolitan-area work trips.

Ridership has failed to materialize despite improved service and despite fares that are kept low. Since 1979 operating assistance for transit from federal, state, and local governments has been greater than operating revenues—$4.587 billion versus $3.152 billion in 1982. Since 1978 transit expenses have been greater than all revenues and operating assistance combined—$8.324 billion versus $8.044 billion in 1982. "As a result of the subsidies that they accepted, transit managers lost the incentive to operate their systems efficiently," Fielding reports. "Transit's success was now being measured in terms of fare stabilization, ridership gains, service expansion, and compliance with a host of special requirements governing labor practices, vehicle procurements, and service to the elderly and handicapped. This combination proved financially devastating."

The most significant obstacle to lowering transit operating expenses has been Section 13(c) of the 1964 Urban Mass Transportation Act. This was the price for labor support essential to passage of the legislation. Section 13(c) provided that the terms and conditions of employment of transit workers would not worsen with the transfer of transit systems from private to public ownership. The transit unions have used Section 13(c), in Fielding's words, "to obstruct changes in work rules and capital investments which would have increased labor efficiency." As a consequence, by far the greatest beneficiaries of government subsidization of transit have been the 197,000 transit employees. In 1982 the transit payroll amounted to $3.736 billion—some $648 million more than operating revenues. Clearly, for transit to succeed on a cost-efficiency basis, substantial automation of service combined with massive reduction and rationalization of the work force is essential.

Actually, nowhere in the world does urban rapid rail transit pay its own way except in densely populated Hong Kong, which suffers from perhaps the worst traffic congestion in the world at a ratio of only one motor vehicle for every 27 persons. Outside the United States transit is considered an essential public service and as such is not expected to pay its own way. Accordingly, the most important standard for evaluating transit in Europe is the quality of service, not its cost effectiveness. Although the opposite historically has been true in the United States, by the early 1980s "American transit had been given unrealistic social and political objectives, incompatible with operating and financial efficiency." This leads Fielding to conclude, "it is still not clear whether transit should be evaluated as an essential public service, with due consideration of the inherent costs of government intervention; or as a business, with cost-effectiveness and self-sufficiency the prime objectives. And there is growing concern, given the unique character of the industry, that the latter objective may not be economically feasible." [5]

Regulating the Automobile

As the automobile came to be perceived as a social problem, federal standards were adopted in the United States concerning automotive safety (1966), emission of pollutants (1965 and 1970), and energy consumption (1975). Up to 1975 there were 273 changes in federal standards and regulations pertaining to automobiles and light trucks. Since 1975 a major difficulty for the automobile manufacturers has been achieving the Corporate Average Fuel Economy (CAFE) level of 27.5 miles per gallon mandated by the 1975 Energy Policy and Conservation Act while meeting the stringent antiemission standards of the 1970 Clean Air Act.

Fulfilling federal safety, emissions, and energy requirements has all but ended the annual cosmetic model change, put a new emphasis on functional design, and stimulated innovation in automotive technology. Retail price increases to cover the cost of meeting federal standards since 1968, adjusted to 1983 dollars, amounted to $1,699.20 of the average $10,481 retail price of an American-made passenger car by the 1984 model year—$475.92 for safety equipment and $1,223.28 for emission controls and changes to improve fuel economy.

Safety

As measured by traffic fatality rates per 100 million miles traveled, the United States has the best traffic safety record in the world, and that record has improved progressively over time. In 1981, for example, traffic fatalities per 100 million motor vehicle miles were only 3.1 in the United States, versus 3.4 in Finland, 3.5 in the U.K., 4.3 in Canada and Denmark, 4.7 in Japan, 4.9 in Austria, 5.1 in the Netherlands, 6.1 in Italy, 6.3 in

Germany, 7.1 in France, 7.9 in Belgium, and 11.4 in Spain. In these countries as well as in the United States, traffic fatalities have declined as the driving population has become more experienced, but especially as roads have been improved. The crucial role of limited-access, express highways in reducing traffic deaths is demonstrated by the traffic fatality rate of 1.28 for Interstate highways in the United States in 1982, versus 3.12 for highways not in the Interstate System.

The U.S. rate of traffic fatalities per 100 million miles of motor vehicle travel declined from an average of 18.20 during 1923–1927 to 10.52 during 1943–1947; with further improvement of highways, especially under the Interstate Highway Act of 1956, it fell to only 5.53 in 1966, when safety standards for 1968 model-year cars were mandated by passage of the National Traffic and Motor Vehicle Safety Law. By 1972 the traffic fatality rate had been further reduced to 4.28, even though almost half of the U.S. motor vehicle population antedated the 1968 model year and despite the failure of most drivers to use the seat belts required as equipment by law—a failure to which were attributed 10,000 of that year's 56,278 traffic deaths.

The lowering of speed limits in several states in 1973 as a fuel conservation measure was followed by the imposition of a 55-mph national speed limit on January 1, 1974. In addition to fuel savings, a dramatic drop in the traffic fatality rate to 3.33 in 1974 was attributed to lower highway speeds. Virtual completion of the Interstate System, the 55-mile-per-hour speed limit, and the incorporation of federal safety standards into the motor vehicle population further combined to reduce the traffic fatality rate in 1983 to a low of 2.73 and the total number of traffic deaths to 44,300.

Despite the decline in the traffic death rate, there was good reason for concern about automotive safety in the mid-1960s. In absolute numbers, traffic fatalities had risen sharply from 34,763 in 1950 to 39,628 in 1956, had dipped to 38,070 in 1960, and then had accelerated to 53,041 in 1966 and peaked, as noted, at 56,278 in 1972. How could one explain this rising carnage? Highways were being greatly improved after passage of the Interstate Highway Act of 1956, at the very time that the ratio of traffic fatalities per capita was dramatically increasing. A major reason undoubtedly was the phenomenal increase of inexperienced drivers on American roads, as family ownership of cars grew from 59 percent in 1950 to 83 percent in 1970. But a more compelling explanation at the time was that far more powerful, far less maneuverable cars, designed for looks rather than the protection of occupants in a collision, were traveling at faster speeds on our express highways. The result was that concern over automotive safety shifted its focus from road conditions and driving skills to the designed-in dangers of the car itself.

In 1964 Congress set safety standards for motor vehicles purchased by the General Services Administration (GSA) for the federal government. By late 1965 several government groups and individual officials in addition to Senator Abraham Ribicoff's Subcommittee on Executive Reorganization were concerned with the issue of automotive safety. The most important were the staff of Senator Gaylord Nelson; the Senate Commerce Committee, chaired by Senator Warren Magnuson; and Joseph Califano, a special assistant to President Lyndon Johnson in charge of working up a 1966 legislative program that included a traffic safety bill. That an administration-backed bill would become law was guaranteed by the poor performance of automobile industry executives before congressional committees and by a scandalous case of personal harassment of Ralph Nader by GM, for which GM president James Roche apologized before the Ribicoff Committee and a national television audience. Nader brought a civil suit against GM for invasion of privacy, which the corporation settled out of court for $425,000.

The National Traffic and Motor Vehicle Safety Act of 1966 established an agency under the secretary of commerce whose function was to set safety standards for new cars beginning with the 1968 model year. This agency became the National Highway Traffic Safety Administration (NHTSA) in the Department of Transportation. The seventeen standards issued by the GSA for 1967 model cars purchased by the government were the first ones adopted. These standards included seat belts, padded visors and padded dashboards with recessed control knobs, safety door latches and hinges, impact-absorbing steering columns, dual braking systems, standard bumper heights, and glare-reduction surfaces. Twenty-eight standards had been adopted by the 1969 model year. The act also attempted to goad automobile manufacturers into eliminating defects from their cars by requiring public announcements of recalls. This resulted in the recall of 30.6 million motor vehicles by mid-1972. To induce state governments to institute periodic safety inspections of all motor vehicles registered, in 1973 NHTSA set standards giving states the choice of periodically inspecting brakes, steering, suspension, and tires or losing 10 percent of their federal highway funding. It had been determined that wear of these components caused 6 percent and contributed to an additional 11 percent of all motor vehicle accidents.

The major problem in implementing NHTSA safety standards remains the refusal of Americans to buckle up their seat belts. Despite the well-documented and well-publicized knowledge that they reduce serious and fatal injuries in accidents by about half, seat belts are used by only about 15 percent of Americans, compared with 85 percent of West Germans and 90 percent of Swedes. Laws have been enacted in almost all states and the

District of Columbia requiring the use of child-restraint devices. Until very recently, however, states have been reluctant to require adult seat belt use. In this the United States stands in marked contrast to the rest of the world. Seat belt use is required by law in 33 countries, including all of Western Europe, Canada, Japan, Australia, New Zealand, Israel, South Africa, Brazil, the U.S.S.R., and several other Eastern bloc countries.

Rather than working for federal legislation requiring Americans to buckle up, NHTSA first tried mandating that cars be equipped with ignition interlock systems that prevented them from being started unless seat belts were fastened. The public outcry was so great that the ignition interlock ruling was repealed by Congress in 1976. The market for the ignition interlocks that NHTSA had forced the auto makers to develop collapsed in one year from 11 million units to zero.

As early as 1969, NHTSA had given notice of its intention to require that cars be equipped with "inflatable occupant restraint systems," otherwise known as air bags, which would inflate automatically upon frontal impact to protect the driver and front-seat passenger. A controversy ensued that is still not resolved. In 1984 NHTSA issued a ruling requiring that all new passenger cars sold in the United States be equipped with "passive restraints" by the 1990 model year. Passive restraints may include air bags, seat belt systems automatically activated by entering the vehicle, and/or energy-absorbing interiors and laceration-resistant windshields. They must protect the driver and front-seat passenger in a 30-mph crash into a stationary barrier. Passive restraints are to be phased in with 10 percent of 1987 models, 25 percent of 1988 models, and 40 percent of 1989 models. The kicker in the NHTSA ruling is that the passive restraint requirements will be rescinded if states representing two thirds of the U.S. population enact by April 1, 1989, laws mandating seat belt use that will become effective by September 1, 1989. Such laws had been enacted by a number of states by mid-1985, and NHTSA mounted a seat belt use awareness program.

Air bags give less protection than seat belts, because they only protect in frontal collisions. They are useless in side impacts, rear enders, and rollovers. So seat belts still must be worn for adequate protection. Air bags are expensive. GM estimates that, with no profit to itself, full front-seat air bags would cost $1,100 per unit at production of 250,000 units per year, or $850 at 3 million per year, versus only $45 for front seat belts. GM has led in air bag technology, with dismal results. In 1974 the company invested $80 million in an air bag program to produce 300,000 units offered as options on 1974–1976 Cadillacs, Buicks, and Oldsmobiles. Even though the bags were priced below cost at $300, they ended up costing GM $8,000 each, because only 10,000 were ordered by consumers.

As cars have become safer, concern about automotive safety has reverted to the driver, particularly to the drinking driver. In the mid-1970s it was estimated that alcohol abuse was involved in about half of all our highway fatalities, and the Department of Transportation estimates that in the ensuing decade 250,000 Americans have been killed and 700,000 injured in alcohol-related automobile accidents. Tougher state and local laws and more vigorous law enforcement against drinking and driving have become increasingly evident across the nation. In December 1983 a presidential commission on drunk driving recommended stiffer penalties for drunk drivers, making alchohol consumption in automobiles illegal, and the adoption of a nationwide minimum drinking age of 21 because of the close correlation between the minimum drinking age and the frequency of alcohol-related accidents.

Federal legislation passed in 1987 gave the states the right to increase the speed limit to 65 mph on portions of rural express highways. The impact on traffic safety remains to be seen.

Emissions

Recognition that cars were a major source of air pollution came in the 1950s in smog-ridden Southern California. As with automotive safety, the automobile industry did little toward solving the problem until forced by government. Although a joint committee to study the role of the automobile in causing atmospheric pollution was formed by the Automobile Manufacturers Association in 1953 and a cross-licensing agreement covering pollution control devices was signed in 1954, manufacturers were reluctant to add devices that would raise costs without adding sales appeal. "The compiled correspondence between Kenneth Hahn, Los Angeles County Supervisor, and the auto companies from 1953–1967 on the subject of automotive air pollution seems to be an accurate reflection of the companies' attitudes," notes Lawrence White. "While assuring Hahn of their sincerest interest in the subject, they tended to take refuge behind the AMA committee and behind the issuance of technical papers; more information was needed, they said, more research required. And, besides, better maintenance of vehicles would probably solve most of the problems." [6]

In 1966, of an estimated 146 million tons of pollutants discharged into the atmosphere in the United States, 86 million tons were attributed to motor vehicle traffic. For every 10,000 miles traveled, the average car without pollution controls discharged into the atmosphere 1,700 pounds of carbon monoxide, 520 pounds of hydrocarbons, and 90 pounds of nitrogen oxides. Motor vehicles were the major source of these pollutants and of lead compounds. While both the level of pollutants and the proportion attributable to motor vehicles varied from place to place and over time, from 60 to 80 percent of atmospheric pollution generally was attributed to motor vehicles, with a figure of 97.5 percent reported for Orange County, California, in 1973.

California framed the first legislation to reduce motor vehicle emissions. Positive crankcase ventilation (PCV) systems to reduce hydrocarbon discharge were required on all cars sold in California beginning with the 1963 model year. Exhaust control devices to reduce emissions of carbon monoxide, oxide of nitrogen, and lead compounds became mandatory in California beginning with the 1966 model year. The automobile manufacturers balked at installing nationally the devices required by law in California. But public pressure to do so became irresistible once it was seen from California's experience that the basic technological problems had been solved.

The Motor Vehicle Air Pollution and Control Act of 1965 resulted in national standards comparable to California's for the 1968 model year. These standards allowed an average of no more than 275 parts per million hydrocarbon emissions and 1.5 percent carbon monoxide emissions. By the 1970 model year the standards had been raised to permit no more than 180 parts per million of hydrocarbons and 1.0 percent carbon monoxide emissions. Controls to eliminate pollutants from gasoline evaporation also were required nationwide by 1971.

The passage in 1970 of Senator Edmund Muskie's amendments to the Federal Clean Air Act brought a further reduction of about 90 percent in emissions—in grams per vehicle mile, to 0.41 carbon monoxide and 3.4 hydrocarbons by 1975, and to only 0.40 nitrogen oxide by 1976 (versus actual 1970 emsissions, in grams per vehicle mile, of 46 carbon monoxide, 4.7 hydrocarbons, and 6.0 nitrogen oxide). In 1973 the Environmental Protection Agency (EPA), charged with enforcing the Clean Air Act, bowed to industry pressure—automobile manufacturers insisted that the 1975–1976 standards could not be met—and granted the manufacturers a two-year extension. Industry critics noted that the 1975–1976 standards already had been met by three imports—the rotary-engine Mazda, the CVCC-powered Honda, and the diesel-powered Mercedes-Benz.

Rather than risk large amounts of capital on developing new engine technologies, Detroit pursued the conservative path of proliferating the desmogging devices on already overly complicated conventional engines. By the early 1970s desmogged conventional engines got 10 to 15 percent less gas mileage than earlier uncontrolled engines, were more difficult and expensive to maintain, and had unsafe tendencies to surge from idle, stall, and "diesel" (keep running after the ignition key was turned off). And despite the performance-impairing devices, EPA tests in early 1973 demonstrated that the vast majority of cars built between 1968 and 1971 failed to meet existing antipollution standards.

The main way American auto makers met the 1977 federal emission standards with conventional engines was to install the catalytic converter, to be used with unleaded fuels. Catalytic converters were required on all 1975 model cars sold in California, and in that model year GM installed them on all its cars nationwide, Chrysler on 75 percent of its cars, and Ford on 70 percent of its cars. The catalytic converter had been perfected by GM. It became the only short-run option for meeting government standards, even though the National Academy of Sciences had declared it the least promising way in the long run of controlling exhaust emissions. The catalytic converter is a technology basically intended for large conventional engines. Consequently, foreign cars with smaller engines were able to meet federal emissions standards by alternative engine technologies, and only 9.6 percent of imports were equipped with catalytic converters in the 1977 model year.

Chrysler argued unsuccessfully for meeting the standards through fast-burn/lean-burn technology. Adoption of the catalytic converter further weakened Chrysler's position in the American automobile industry, because as the least backwardly integrated of the Big Three it had to purchase its catalytic converters while GM sold them at a profit. As a result, equipping a conventionally powered car with the total emissions system required by 1977 cost $200 a unit at GM versus over $400 at Chrysler.

Fuel Economy

The 1975 Energy Policy and Conservation Act (EPCA) mandated that American auto makers each achieve the Corporate Average Fuel Economy (CAFE) level of 27.5 miles per gallon by the 1985 model year, to be phased in beginning with 18 mpg in the 1978 model year, while still meeting the stringent antiemission standards of the 1970 Clean Air Act. CAFE is the annual production-weighted average of the overall fuel consumption for a manufacturer's full line of vehicles. In 1974 the fleet average for American-made cars was only 13.2 mpg, versus 22.2 mpg for the import fleet. The EPCA provided a stiff civil penalty of $5 for each tenth of a mile that the fleet average of an automobile manufacturer fell below the CAFE standard in a year, multiplied by its total production for that year. In recognition that conditions might change, Congress gave authority to the secretary of transportation to lower the CAFE standard for 1985 and later model years from 27.5 mpg to 26 mpg. And in 1980 Congress approved a proposal that the automobile manufacturers might accrue credits by exceeding the standard in any year, these credits to be calculated on the same basis as the penalty for not meeting the standard. Accumulated credits could be carried forward for three years, or anticipated credits could be projected for three years to offset a current CAFE deficit.

To encourage further the production of more fuel-efficient cars, the "gas guzzler tax" contained in the 1978 Energy Tax Act provided for graduated taxes on purchases of new cars with combined city/highway fuel economy ratings 5 mpg or more below the CAFE standard. In 1980 these taxes ranged from $200 on cars averaging 14.5–15.0 mpg to $550 on cars averaging 0–12.5 mpg. The 1985 tax range was from $500 on cars averaging 20.5–21.0 mpg to $2,650 on cars averaging 0–12.5 mpg.

Underlying the Energy Policy and Conservation Act and the Energy Tax Act was the grim reality of increasing American oil dependence in an increasingly oil-short world. Domestic oil reserves in mid-1973 were reported to be 52 billion barrels—about a ten-year supply—and the United States was importing about 27 percent of its crude petroleum. Gasoline prices were rising, and an imminent fuel shortage was being predicted months before the Organization of Arab Petroleum Exporting Countries (OAPEC) implemented oil diplomacy following the October 1973 war with Israel. OAPEC announced production cuts of at least 5 percent a month until Israel withdrew from occupied territories and the "legitimate rights" of the Palestinians were restored. The cuts were to be borne by the "enemies" of the Arab cause, which turned out to mean that only the United States and the Netherlands were under a "total embargo" by December. OAPEC also announced that henceforth oil prices would be determined unilaterally by the producing nations rather than through negotiations with the major oil companies.

Posted prices for Persian Gulf oil rose 130 percent over the October price of $5.11 to $11.65 per barrel by January 1974; a year earlier the price had been $2.59 per barrel. Other oil-producing nations naturally followed suit: Nigerian oil jumped from $6.00 to $10.80 per barrel, and new export taxes raised the price of Canadian oil from $6.40 to $10.40 per barrel. In response, the Nixon administration's Cost of Living Council authorized a $1 per barrel increase in "old" domestic crude oil—enough alone to raise the retail price of gasoline 2.3 cents a gallon—and generously pegged at $10 per barrel "new" domestic crude (oil produced in excess of the quantity produced in 1972).

Long lines developed at filling stations because of shortages until the embargo was lifted on March 13, 1974. By then the average retail price of regular gasoline in the United States had climbed to 54 cents a gallon, as opposed to 38 cents a year earlier. In anticipation of rising fuel prices, sales of small cars rose to 39 percent of total U.S. sales and as high as 60 percent in the Los Angeles area during the first four months of 1974. In December 1973 sales of cars with wheelbases under 112 inches surpassed sales of "standard-size" cars for the first time in history; they continued to account for 53 percent of the market during the first quarter of 1974, while inventories of larger models piled up to double the normal 60–65 days in storage lots and dealers' showrooms. First-quarter 1974 sales slipped 27 percent below those in the first quarter of 1973, and first-quarter profits were down 85 percent at GM, 66 percent at Ford, and 98 percent at Chrysler. With 90 percent of its production in small cars, AMC was the only American automobile manufacturer to increase its sales in the first quarter of 1974. Automobile workers were laid off in great numbers, as assembly lines were shifted to the production of smaller models.

GM began significant downsizing of its cars in the 1975 model year. By 1979 gasoline prices in the United States had risen some 80 percent over their 1970 level, putting an end to the era of the all-purpose road cruiser as the predominant type of American car.

The market conditions first made apparent by the 1973–1974 OAPEC embargo became permanent with the "oil shock" following the 1979 Iranian revolution. The establishment in Iran of a Moslem fundamentalist state hostile to the United States meant that Persian Gulf oil no longer could be counted on to fuel the American automobile culture. As a result of the oil shock and further OAPEC price increases, gasoline prices in the United States rose 109 percent between 1978 and 1981, compared with 22 percent in Western Europe and 9 percent in Japan. The cost of gas and oil for an intermediate-size car in the United States, 4.18 cents per mile in 1974, shot up from 4.11 cents in 1979 to 5.86 cents in 1980, then leveled off at 6.74 cents in 1982 and 6.64 cents in 1983.

Oil prices appear to have stabilized in the mid-1980s. World demand has been reduced by conservation measures, vast new reserves have begun to be tapped in Mexico and the North Atlantic, and the successor to OAPEC, the Organization of Petroleum Exporting Countries (OPEC), has lost its ability to enforce prices and production quotas among its member nations. In the spring of 1986 this became evident in significant declines in prices at the pump.

The reversal in oil prices, however, is apt to be as short as it is sweet to motorists. The long-term trend inevitably must be toward significantly higher oil prices. On April 5, 1984, for example, ABC News reported a Royal Dutch Shell prognosis, based on Saudi Arabian reserves, that gasoline prices could be expected to double within a decade from their then current $1.20 average and to increase by as much as sixfold early in the twenty-first century. With no alternative to some form of internal combustion engine in sight as a viable automotive power plant, this necessitates great advances in fuel economy over the 1985 CAFE standards if mass personal automobility is to survive into the next century.

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Decline in world and domestic demand and an abrupt shift to smaller, more fuel-efficient cars following the 1979 oil shock brought the American automobile industry to its lowest ebb in history. The small-car share of the U.S. market doubled from 27 percent in 1978 to 54.2 percent in 1979, and rose further to 61.5 percent by 1981. The share of the U.S. market held by imports correspondingly increased from 17.7 percent in 1978 to 27.9 percent in 1982, because despite years of warning that the era of the gas guzzler was over, the oil shock caught the Big Three with insufficient small-car production capacity to adjust to the changed demand pattern.

The American automobile industry's historic pattern of primary dependence on internal financing was broken in 1979, when funds from operations fell $4.6 billion below capital needs for new plants and equipment to meet the changed demand pattern. The shortfall reached a record $10.7 billion in 1980, then gradually declined to $1.4 billion in 1983 before a surplus of $3.2 billion was recorded for the first half of 1984. "The long-term debt of the top four U.S. producers rose from $3.3 billion at the end of 1978 to nearly $9.5 billion at the end of 1982, while industry net working capital fell almost 100 percent from $12.3 to $0.4 billion during the same period," observed the 1984 Report of the Secretary of Commerce to Congress on the automobile industry. "By late 1982, aggressive cost-cutting measures had halted the severe financial drain of the previous four years, but industry balance sheets remained extremely weak." [7]

Chrysler was the hardest hit. Only a government guarantee of Chrysler's loans saved the corporation from bankruptcy. In addition to the general problem of adjustment to changed market conditions following the oil shock and to Chrysler's history of mismanagement, federal safety and emissions standards affected Chrysler more severely than larger, more integrated GM and Ford. Indeed, Lee Iacocca rationalized going to the government for aid largely through the argument that "government helped us get into this mess, so government should be willing to help us get out." He explained in 1984, for example, that some $19 billion in research and development costs on automotive safety since 1966 had been spread by GM over 5 million units, by Ford over 2.5 million units, and by Chrysler over only 1 million units a year and that even greater economies of scale had accrued to GM and Ford in the manufacturing of the mandated equipment. He further noted "the sheer volume of staff time and paperwork necessary to report on our EPA regulatory confirmation. In 1978 alone [Chrysler] had to file 228,000 pages to the EPA!"[8] In sharp contrast with the cooperative research among Japanese auto makers to meet federal standards, American automobile manufacturers were forbidden to pool their knowledge by our antiquated antitrust laws.

Meeting Governmental Mandates

Industry critics have viewed the impact of federal standards very differently. "When Detroit claimed that it would be impossible to meet the emission deadlines mandated by the Clean Air Act, Japanese manufacturers produced vehicles that met them and at modest cost," note C. Kenneth Orski, Alan Altshuler, and Daniel Roos. "More recently, while U.S. industry spokesmen publicly doubted ... that 1985 fuel economy standards could be achieved without size and performance sacrifices that the public would find unacceptable, foreign companies led the way in demonstrating that the combination of excellent performance and low fuel consumption was both technically feasible and attractive in the market." They go on to assert that "were it not for government intervention, the [American] automotive sector would be even worse off [vis-à-vis foreign competition].... [P]ractically every recent move by U.S. automakers to adopt advanced features—lightweight metals, high-strength plastics, electronic ignition management devices—can be traced to the influence of government regulations."[9]

Significant technological progress has been made in increasing fuel economy while decreasing emissions and improving performance through electronic engine controls. Chrysler introduced its lean-burn system in 1976. Ford introduced electronic engine controls on its 1978 Pintos and Mercury Bobcats for the California market. GM installed electronic engine controls on 4,000 of its 1978 California cars. By the early 1980s electronic engine controls had come into general use.

By 1983 passenger car emissions of hydrocarbons and carbon monoxide had been reduced 96 percent and nitrogen oxides 76 percent from precontrol levels. Hydrocarbon emissions had been reduced from 10.6 grams per mile to 0.41 grams, carbon monoxide from 84 grams to 3.4 grams, and nitrogen oxides from 4.1 grams to 1.0 grams. As a source of air pollution in the United States, in 1982 motor vehicles accounted for 63 percent of carbon monoxide, 39 percent of nitrogen oxide, 26 percent of volatile organic compounds, 15 percent of suspended particulates, and

2 percent of sulphur oxides. By 1983 some 67 percent of all cars in operation in the United States were equipped with a catalytic converter or equivalent technology as well as fuel evaporation and exhaust and crankcase control devices. Only 5.2 percent of cars on the road remained with no controls.

CAFE standards were met or exceeded by American auto makers through the 1982 model year. American Motors and Chrysler have continued to meet or exceed CAFE standards, as has the import fleet. GM and Ford, however, stopped meeting the standards after 1983, as consumers reverted to buying larger cars with the stabilization of gasoline prices. To avoid stiff penalties, both Ford and GM petitioned the secretary of transportation to lower the CAFE standard to 26 mpg for 1985 and subsequent years. Compared to a 1984 standard of 27 mpg, the actual domestic fleet average was 25.4 mpg and the import fleet average 31.5 mpg. Among domestic producers in 1984 GM averaged 24.7 mpg, Ford 25.8 mpg, Chrysler 27 mpg, and American Motors 35.2 mpg. Perhaps an even better illustration of the progress made is that family-size cars today achieve better fuel economy than compact models did in 1975.

Renaissance

In 1982, at a conference of automotive historians and industry representatives sponsored by the Detroit Historical Society, Ford president (now chairman of the board) Donald Petersen spoke about "new realities," which represented "a major crossroads for our industry. They require that American industry—and its array of new magic machines—become competitive in every respect.... [T]he industry will have to change dramatically to survive. And change it will." To document his point, Petersen reported that "across-the-board retooling under way in our industry is the most massive peacetime private-sector reconversion ever attempted, anywhere. At a cost of more than $80 billion, it involves the retooling and re-equipping, by 1985, of 49 new engine and transmission lines and 89 new or fully re-equipped assembly lines. Few machine tools or parts will remain unchanged in the industry's 260 domestic plants and the plants of more than 5,000 suppliers of automotive parts and materials." Additional substance was given to Petersen's assertions by the fact that in 1982 alone the American automobile industry spent almost $4.5 billion on research and development, more than any other single industry in the United States.[10]

Critics of the early 1970s who had viewed the American automobile industry as technologically stagnant or hopelessly impaled on the horns of a Fordist/Sloanist dilemma were being proved wrong a decade later. More than simply showing survival ability in the face of the Japanese challenge, the American automobile industry by the early 1980s was experiencing an organizational and technological renaissance.

The revitalization of the American automobile industry has been particularly associated in the public mind with the "turnaround" of Chrysler under Iacocca's chairmanship. As we have seen, Chrysler disposed of its overseas operations in 1978–1979. Iacocca also took immediate steps upon becoming chairman in 1979 to modernize the Chrysler management, to improve relationships with dealers, and to upgrade the quality of Chrysler cars. In unprecedented moves, Douglas Fraser, president of the UAW, was given a seat on the Chrysler board of directors, and a joint UAW-Chrysler Management Quality Program was inaugurated.

Then in December 1979 negotiations with the federal government resulted in passage of a controversial loan guarantee act that permitted Chrysler to survive at about half its former size. The act created a loan guarantee board authorized to issue up to $1.5 billion in loan guarantees over the next two years, to be repaid by 1990. These guarantees were fully secured by Chrysler's assets, which were conservatively estimated by the government at $2.5 billion in liquidation value, so no public funds were ever at risk. Other stipulations were that current lenders to Chrysler were required to extend $400 million in new credit and $100 million in concessions on existing loans; foreign lenders were required to extend an additional $150 million in credit; suppliers had to provide Chrysler with $180 million, $100 million of which had to be in stock purchases; the governments of states and municipalities where Chrysler had plants were to provide the corporation with $250 million; Chrysler had to raise $300 million through the sale of assets and issue $50 million of new stock; concessions of $462.2 million were required from UAW employees, and pay cuts or freezes of $125 million from nonunion employees. Before receiving the first $550 million in guaranteed loans in June 1980, Chrysler issued to the loan guarantee board warrants entitling the bearer to purchase at $13 some 14.4 million shares of Chrysler stock, which was then selling at $5.

A far leaner and tougher corporation emerged. In addition to selling off its operations abroad to raise operating revenues, Chrysler sold Chrysler Defense, the nation's only maker of military tanks, to General Dynamics for $348 million. Twenty plants were closed, and the remaining plant facilities modernized. White-collar personnel were trimmed from 40,000 in 1978 to 21,000 in 1983, while salaries were reduced up to 10 percent. Concessions by the UAW averaged $10,000 a worker during the first nineteen months of the loan guarantee, and labor productivity was raised 50 percent. As a result of these cutbacks and increased labor productivity, Chrysler's fixed costs were cut in constant dollars from $4.7 billion in 1979 to $3.54 billion in 1983, and the firm's break-even point was reduced from 2.4 million units to 1.1 million units. Sales increased with the introduction of the fuel-efficient, front-wheel-drive K-series and the popular Caravan, Voyager, and Dodge Mini Ram minivans. The Aries and Reliant K-cars won *Motor Trend's* Car of the Year award for 1981. Between 1979 and 1983 Chrysler claims a 36-percent improvement in the quality of its cars, on the basis of repairs done under warranty. It also claims the lowest number of recalls of any automobile manufacturer.

Government-guaranteed loans totaling $1.2 billion were fully repaid in 1983, seven years early. With Chrysler stock at $30, the government put up the warrants at auction to the highest bidder. Chrysler bought them back and retired them at a cost of $311 million. Over the three-year period of the loan guarantees, Chrysler also had paid $404 million in interest, plus $33 million in administrative fees to the government and $67 million to lawyers and investment bankers.

Losses of $1.77 billion in 1980 and $475.6 million in 1981 were translated into profits of $170.1 million in 1982, $700.9 million in 1983, and a record $2.38 billion in 1984. Chrysler's debt/equity ratio in 1984 was 19.7 percent, down from 69.8 percent in 1982 and the lowest ratio in seventeen years. Chrysler's share of the North American market reached 11.6 percent in 1984. The corporation's relationships with lending institutions and its labor force were becoming normal for the first time in years.

While the regeneration of Chrysler has received wide publicity, an even more impressive turnaround at Ford has gone largely unnoticed. After net losses of $1.54 billion in 1980, $1.06 billion in 1981, and $657.8 million in 1982, the Ford Motor Company posted record after-tax profits of $1.87 billion in 1983 and $2.91 billion in 1984. In 1984 Ford's share of the U.S. passenger car market reached 19.2 percent, the highest level in five years and a 2-percent increase over 1983, while Ford led in European automobile sales with a record 13 percent of the market. Between 1980 and 1984 Ford closed seven plants, reduced salaried employees by more than 20,000, and reduced hourly employees by 44,000. As a consequence, Ford lowered its break-even point 40 percent, to 2.5 million vehicles, and reduced its operating costs some $12 million a day, or $4.5 billion annually.

The driving force of the Ford turnaround has been Donald Petersen, president of Ford under Philip Caldwell, who replaced Henry Ford II as chairman in 1979. Petersen became chief executive officer with Caldwell's retirement in 1985. Petersen is a product-oriented engineer with a Stanford M.B.A. He attended the Bob Bondurant School of Performance

Driving in Northern California so that he could personally evaluate Ford cars on the test track. Training executives in performance driving has since become Ford policy. Petersen personally supervised the introduction of six new Ford models in twenty months at a development cost of $10 billion. The 1983 Ford Thunderbird/Mercury Cougar and the 1984 Ford Tempo/Mercury Topaz broke sharply with conventional design concepts. Their advanced aerodynamic designs have made Ford the styling pacesetter in the automobile industry. Petersen also put a new emphasis on manufacturing quality at Ford. *Consumer Reports* has rated Ford cars the most improved, and Ford claims an average improvement of over 50 percent in the quality of its cars and light trucks from 1980 to 1985. *Motor Trend* named as its Car of the Year the Ford Taurus sedan for 1986 and the Ford turbocharged Thunderbird coupe for 1987. In 1986 Ford surpassed GM in profits for the first time in 62 years.

Under the chairmanship of Roger B. Smith, a revitalized General Motors has recently undergone the most important organizational change in its history since development in the 1920s of the decentralized multidivisional structure. The corporation has also made a massive commitment of resources to ensure the technological leadership that Sloanism eschewed. That these changes have been instituted under Smith's leadership is especially noteworthy, because his background at GM was in finance.

In early 1984 GM established for its North American operations an organizational structure consisting of two cars groups and the Body and Assembly Group. One car group includes Chevrolet, Pontiac, and GM Canada; the other includes Oldsmobile, Buick, and Cadillac. (Previous to this organizational change, GM consolidated its worldwide truck and bus engineering and assembly operations into the corporate Worldwide Truck and Bus Group.) The Body and Assembly Group—Fisher Body, General Motors Assembly Division, and Guide—has been phased out, and body engineering and assembly responsibilities have been integrated fully into the two car groups. The new structure reverses Frederic Donner's centralization of GM into the the hands of the bean counters. Decentralizing decisions down to the engineers and sales experts in the operating divisions is expected to improve greatly GM's ability to respond to fast-changing markets. It is also expected to lead to a greater diversity in GM's line of passenger cars.

Recently, GM has advanced toward implementing its intention to lead in technological innovation: it has successfully completed a program of strategic diversification to increase its high-technology capabilities. In the summer of 1984 GM purchased, for $2.55 billion, Electronic Data Systems Corporation of Dallas, Texas, a computer-services company. And in June 1985 GM outbid Ford and Boeing Aircraft to acquire Hughes

Aircraft Company, for $2.7 billion in cash and 50 million shares of a new class of common stock. Smith explained that the acquisition of Hughes would help GM to "redefine" the automobile "from a mechanical product with a few electrical subsystems to one with major electromechanical and electronic elements." The *Wall Street Journal* reported that GM expects the Hughes acquisition to result in "a marketing edge over competitors. It sees lasers one day helping guide vehicles under poor visibility conditions; microelectronics and sensors under the hood improving engine performance; cockpit-like computerized dashboards, and space age materials in a range of uses. And on the factory floor, Hughes's advanced computer science—especially artificial intelligence capabilities—could offer far more efficient ways to assemble a car."[11]

The World Car, Downsizing, and the New Technology

Beyond significant organizational changes within Detroit's Big Three, the organization of the automobile industry has become increasingly multinational—as evidenced by the location of assembly plants in host countries, joint manufacturing operations, control of domestic auto makers by foreign investors and foreign governments, captive imports, and the outsourcing of components manufacture to the lowest foreign bidder. These trends make it increasingly difficult to speak of an American automobile industry, or to know precisely what one means by an American automobile.

National differences in automobile design reflecting unique domestic market conditions have all but disappeared, and design is now fairly well standardized worldwide. In the early 1980s Detroit turned to the production of "world cars"—cars designed by engineers and assembled from components made in many countries for worldwide markets. The first of these cars were the 1980 Ford Escort/Mercury Lynx and the 1981 GM J-series.

The world-car concept is best exemplified by the Ford Escort/Mercury Lynx. With minor local variations, the Escort/Lynx is assembled in the United States, the United Kingdom, West Germany, Portugal, and Brazil. Its components are outsourced from seventeen countries. It has been the best-selling car in the world since 1981, and its design characteristics have become standard for state-of-the-art small cars.

The Escort/Lynx is available as a four-passenger two-door hatchback, four-door hatchback, or station wagon. It has a wheelbase of 94.2 inches, height of 53.3 inches, front tread of 54.7 inches, rear tread of 56 inches, and width of 63 inches. The hatchback versions have an overall length of 163.9

inches and a curb weight of 2,080 pounds, the station wagon a length of 165 inches and a curb weight of 2,176 pounds. Until mid-1985 the Escort/Lynx was powered by a 1.6-liter, four-cylinder, transverse-mounted engine with front-wheel drive through a transaxle, a combination that increases fuel economy, improves handling, and adds room to the passenger compartment. A 1.9-liter fast-burn engine that gives better performance at the same fuel economy became standard in the 1985½ models. A 2.0-liter diesel and an electronic fuel-injected conventional engine are offered as options. The Escort/Lynx conventional engine features a compound valve semihead configuration and specially designed pistons to improve combustion. Four- or five-speed manual transaxles are standard, depending on the engine, with an automatic transaxle available as an option. The Escort/Lynx features as standard equipment rack-and-pinion steering, front disc brakes, and four-wheel independent suspension with MacPherson struts on the front wheels. The front disc brakes and front-end alignment are self-adjusting. Unitized body construction results in a more rigid, hence safer, body compartment and reduces rattles.

The trend toward overall downsizing continues. The average weight of American-made passenger cars has been reduced from 3,800 pounds in 1975, when downsizing began, to only 2,700 pounds in 1985. This has been accomplished not only by making cars smaller but also by the greatly increased use of lighter-weight materials—plastics, cast-aluminum engines, and new high-strength steels that permit thinner gauges and as much as 20 percent weight reductions in materials. The development of lighter and stronger materials continues, with ceramics and plastics reinforced with glass or graphite fibers emerging as replacements for steels, and with adhesive bonding replacing welding.[12]

Ford engineers estimate that a reduction in drag coefficient from Cd .40 to Cd .36 in an Escort-size car saves half a mile per gallon of gas in city driving and two miles per gallon on the highway. Ford hopes to achieve an 18-percent improvement in the aerodynamic efficiency of its cars by 1990 compared with 1977, which alone would translate into an average increase in fuel economy of 1.5 mpg. The advanced aerodynamic Ford Probe IV concept car has a rating of only Cd .15, a drag coefficient previously equaled only in land-speed record cars and jet aircraft.

Electronic sensors and controls have become standard equipment, and their further sophistication can be expected. At the present state of the art, it is estimated that it would take a person with a hand calculator about 45 years to perform the calculations that the Ford EEC-IV computer, used to control engines on about two thirds of 1984 Ford cars, performs each minute. The computer-controlled Ford 2.3-liter "high swirl combustion" engine can react to as many as 250,000 commands each second. Other emerging technologies that are radically altering cars under the hood include fast-burn/lean-burn engines, turbocharging/supercharging, the continuously variable (as opposed to step) automatic transmission (CVT), and air suspension systems.

The Electronic Age Dawns: Computer-Integrated Manufacturing and Flexible Robotics

Traditional engineering know-how and cut-and-try methods are being abandoned in favor of computer-aided engineering (CAE) and computer-aided design (CAD) to complement computer-aided manufacturing (CAM). By eliminating much of the need for engineering manpower, CAE and CAD greatly reduce both the cost and the lead time for developing new models. Electronic scanners trace the form of a clay model to gather precise data that is stored in the computer in three-dimensional form. The computer then directs a pen over a drawing board to produce engineering drawings for die making. The computer not only can be used to design parts but also can be programmed to show the effects of the stresses to which the parts will be subjected. Weaknesses in design are shown in colors, and the computer aids in redesign. "The product design, development, and manufacturing process of the future will rely on the integration of a wide range of computer-based application programs," the Ford technical staff predicts. "Properly implemented, the boundaries between CAE, CAD, and CAM will disappear, and the term 'computer-integrated manufacturing' (CIM) can properly be used to refer to this level of development."[13]

Chrysler has installed a unique computer network that uses a central data bank for all design and engineering functions; the car maker has also undertaken a joint venture with Control Data Corporation to develop a new generation of CAD software. Chrysler claims that its 1984 Chrysler Le Baron and Dodge Lancer GTS were the world's first completely computer-designed cars.

In 1983, at a cost of $400 million, Chrysler's Windsor plant in Ontario, Canada, was retooled to produce Caravan, Voyager, and Dodge Mini Ram minivans. This was the first in-line-sequenced automobile plant. Ninety-seven percent of the body welding—there are 3,800 body welds in each minivan—is performed by 112 robots at Windsor. The entire ten-mile assembly line is computerized. Each unit is locked into the assembly process according to a predetermined schedule; it passes through 1,837 assembly stations before emerging as a finished vehicle. Chrysler's Sterling Heights Assembly Plant, opened in 1984 to assemble the Le Baron and the Lancer GTS, is an even more fully integrated in-line-sequenced plant. It is equipped with 57 welding robots, 32 material handling robots, and 162 lasers and cameras that inspect 350 points on the car bodies passing through assembly. Chrysler employs the "just-in-time" inventory system at Windsor and Sterling Heights, necessitating high quality control and precise coordination in manufacturing. A single defect in a part, or a delay in its delivery, can shut down the entire factory. Chrysler expects to install such advanced systems in all of its plants by 1988 and to revamp all of its car lines by 1990.

The most extensive single plant modernization has been GM's construction of Buick City from the sixty-year-old Buick assembly plant at Flint, which had been scheduled to be shut down in 1986. GM planned Buick City, together with the UAW, as "a totally integrated facility" with "total employee involvement." Buick City employs the kanban-jidoka system. Some 90 percent of the parts used are manufactured within a 300-mile radius, and several suppliers are relocating within sight of the complex. The plant's 250 flexible robots perform a variety of assembly operations, including windshield and back glass setting and wheel and tire installation. A guided vehicle system replaces the traditional conveyor in engine and chassis assembly. More modular components, such as fully assembled dashboards, are used. No provision is made for repair or inspection, because none is needed. In cooperation with three Flint educational institutions and the UAW, 630 employees have been given "high-technology training" and the skills to train the other 4,000 to 5,000 employees required to operate the entire assembly complex. The corporation reports, "The realization of the 'Buick City' concept will bring GM closer to the goal of establishing a totally automated and computer-integrated automotive manufacturing facility." [14]

The revolution that has taken place in automobile manufacturing is due primarily to the introduction of the electronic machine tool. Until very recently, robots could be programmed to perform only a few repetitive operations. Now, however, the microprocessor gives robots the ability to handle complex materials, select and distribute parts, and discriminate in the performance of tasks in much the same way as can a human operator. For example, new robot welding systems can perform precise and uniform welds on a variety of models moving through the assembly process in random order, and parts can be moved from machine to machine as required by the model rather than following a fixed itinerary. The MIT Report observes that this new flexible robotics system at Volkswagen "takes the first steps along the path to automated final assembly, with robots installing the engine, brake lines, battery, and wheels. The system is able to produce not only Golfs in several body styles but also Jettas without changing tools or stopping production. In addition, Volkswagen and other producers are experimenting with more flexible tooling and automated material handling in engine and transmission plants to permit, for example, machining of a whole family of engines on the same transfer lines."[15]

Flexible robotics thus has reconciled Fordism and Sloanism, with truly revolutionary implications for automobile manufacturing. It permits economies of scale to be realized on much smaller model runs. This means both that we can expect more diversity of product and that small specialized producers can remain competitive within the automobile industry. Manufacturing techniques are more precise, improving quality. Labor costs are significantly lowered, because flexible robots can perform routine tasks much more cheaply than can human beings. This promises soon to erase the labor cost advantages of Japan and Third-World countries. To program, monitor, and repair robots requires a far more skilled work force than to perform repetitive assembly-line tasks.

Half of all current sales of robots in the United States are to the automobile industry, and the adoption of flexible robotics is proceeding at a rapid pace. In 1987 some 26,000 robots were being used in final assembly plants in the American automobile industry, and about the same number in the auto factories of Western Europe. The Japanese claimed 90,000, but counted as "robots" many fairly low-level automatic machine tools.

It is estimated that the general adoption of electronic machine tools will eliminate 40 to 70 percent of the jobs in automobile production. The MIT Report conservatively projects that total employment in automobile manufacturing in the United States, Japan, and the seven Western European Auto Program Countries will shrink 37 percent, from 3,642,400 workers in 1979 to 2,279,600 by the turn of the century, even as the number of motor vehicles in the world grows from 396.2 million in 1979 to 678.5 million in the year 2000. "Significant gains in productivity are anticipated from this [flexible robotics] system," understates Jean-Pierre Bardou. "But the salient point is that the introduction of electronic machine tools challenges the traditional sequential operation process, whether it is a line formed by human operatives or a line formed by a succession of machines. If the assembly line someday disappears, this will not only mark a page turned in the history of the automobile industry, but also in the history of labor." Stephen Meyer III puts it another way: "Industrial engineers finally may have found their technical solution to the problem of 'the human element in production.' But who, or what, will the labor historian of the future study?"[16]

The most ambitious attempt "to leapfrog the foreign competition" is GM's Project Saturn, launched in 1982 after a study revealed that the

Japanese could build a small car for about $2,000 under GM's cost. The goal of Project Saturn is to build a small car in the United States that is cost-competitive with imports. It has been given the largest commitment of resources of any GM experimental project. In conjunction with Saturn, GM and the UAW announced in late 1983 the formation of a study center to explore alternative ways to make cars in the United States. Saturn is intended "to be an advanced manufacturing process for an automobile employing new tools, new facilities, new management systems, and new forms of employee participation never before realized in General Motors.... [I]mprovements that flow from Saturn in product design, manufacturing, and assembly will be applied throughout the corporation."[17]

In early 1985 GM announced the creation of a separate, wholly owned subsidiary to build the Saturn car. The prototype Saturn is smaller and 600 pounds lighter than current GM subcompacts. It is slated to go into production in 1990. Saturn Corporation will operate its own manufacturing and assembly complex and set up its own distribution system, initially of some 100 franchised dealers. Although the Saturn headquarters will be in Detroit, its plant is being built in Spring Hill, Tennessee, 30 miles south of Nashville. Initial production is slated at 250,000 units a year, turned out by 3,000 workers on a two-shift operation, an unprecedented labor productivity rate of 83 cars annually per worker. A tradition-shattering contract with the UAW provides that the Saturn workers will be paid annual salaries rather than hourly wages and that 80 percent of them will be guaranteed lifelong employment.

About 80 percent of the technology that will be employed to produce the Saturn is already in use, the remaining 20 percent being new technology innovated at GM. CAE, CAD, and CAM for Saturn are being developed simultaneously, with CIM as the result. A computer-designed fender, for example, will be stamped out by a computer-designed die. All stamping presses will have quick die-change capability and will use a new die-making material developed by GM. Special attention is being given to increasing the number of parts made from a given amount of raw material and to decreasing the amount of energy used in processing operations. Advances in high-speed machining technology will permit boring, drilling, and milling operations to be performed much faster. The Saturn assembly line will be much shorter than traditional lines, because extensive use will be made of modular assembly of subsystems of the car by teams of workers in an environment designed for optimal workplace ergonomics. Just-in-time inventory control will be used. Sophisticated new data-processing systems will permit the Saturn plant to operate with a minimum of paperwork. GM expects to have 4,000 computer graphics terminals in place by 1990, versus 1,000 in 1981.

After being outbid for Hughes Aircraft by GM, Ford began looking for another major high-technology acquisition to bolster its already strong position as a leader in automotive electronics and satellite communications through Ford Aerospace and Communications Corporation. And Chrysler, in the same month that GM acquired Hughes—June 1985—announced its acquisition of Gulfstream Aerospace for $637 million.

Thus the Automobile Age, three generations of historical development dominated by the impact of the motor vehicle and the automobile industry, melds into the era of space exploration and an emerging Age of Electronics.

Epilogue
The Future of the Automobile

Mass personal automobility appears to have a new lease on life. In contrast with the disappointing past, disillusioning present, and clouded future of mass transit in the United States, the renaissance in automotive technology is making cars safer, less polluting, and more energy efficient with every model year. Predictions of the imminent death of the automobile have given way to a new optimism. The MIT Report comes to the particularly rosy conclusion that "the automobile's future as the prime means of personal transport is quite secure because of the flexibility of the basic concept and robustness of automotive technology. . . . [T]here is no basis whatever for projecting that in the end auto technologists will fail to cope. Thus, the auto industry can continue to be one of the world's foremost manufacturing activities far into the future, serving the need for personal transportation in developed and developing nations." [1]

Notably, however, the futurists are merely projecting that present trends will persist for another decade and a half to the year 2000. Thus they deal with a sociological rather than a truly historical time span. The long-range future of mass motorization—say, over the next half-century—remains as problematic and clouded as that of mass transit.

There can be no doubt that the automobile will continue into the twenty-first century to be the dominant mode of personal transportation in the advanced capitalist countries and that there will be some growth in automobile ownership and use in both the advanced socialist countries and the Third World. The MIT Report forecasts that by 2000 demand for passenger cars will have increased to 48.8 million units and that 536 million passenger cars will be owned in the world, versus an actual demand of 30.5 million cars and ownership of 396.2 million in 1979. Demand for commercial motor vehicles is expected to increase from 10.8 million units