THE NEXT AUTOMOTIVE REVOLUTION

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When motor vehicles were a new technology a century ago, their development was a push-pull affair. Innovators and investors drove the fledgling industry while an expanding and enthusiastic group of motorists absorbed its products. A paucity of good roads and services initially limited car use, but road building after World War I fueled demand for cars and trucks. Early discussions of regulation concerned the obvious nuisances and hazards of these new machines. These basic forces: automotive innovation and market demand, fueled by an expanding road system and shaped by minimal regulation, have transformed the twentieth century.

Automobiles evolved, and roads expanded, before clear ideas of their potential uses and impacts emerged. Within little more than a decade, American automotive design settled on a configuration that dominated for 60 to 70 years: a water-cooled internal combustion engine and attached transmission at front driving the rear wheels through a solid axle with a passenger compartment atop the frame behind the engine.

In the ensuing decades, motor vehicles became the overwhelming choice for personal transportation, now providing 88 percent of all personal miles of travel. Trucks are the major carriers, by value, of manufactured goods. Automobiles and trucks have become so integral to our society that, except in special cases, it is unrealistic to talk about replacing automobiles with mass transit, or trucks with trains within the next few decades. Thus, I have chosen to concentrate on how motor vehicle transportation can become less environmentally damaging, demanding of natural resources, and brutal to life and limb.

The public has been regularly seduced by style and other nonessential aspects of motor vehicles. Few car buyers have demanded high levels of efficiency or safety. However, public concern has meant that even before Federal regulation, the industry gradually reduced the most obvious emissions and hazards from their vehicles. It increased fuel efficiency primarily to enhance acceleration, speed, and range.

In contrast with automobiles, the evolution of commercial airplanes was strongly driven by government-sponsored research—particularly from the National Advisory Committee for Aeronautics—by military needs, and by the needs of the airline industry. Even today, the National Aeronautics and Space Administration spends about $1 billion annually on aviation research. This resulted in dramatic improvements in airline safety, speed, efficiency, and range. Summary comparisons for aircraft and automobiles are shown in Table 1. Airlines are much more sophisticated and demanding consumers than car buyers.

TABLE 1 Some Comparisons of Commercial Airplane and Automobile Development

Vehicle	Passengers	Cruising Speed	Fuel Economy[1]	Fatality Rate
1930 Ford Trimotor	14	122 mi./hr.	20 gal./pass .mi.	5[2]
1996 Boeing 777	up to 500	650 mi./hr.	45 gal./pass. mi.	0.01[3]
1930 Ford Model A	6	50 mi./hr.	30 gal./pass. mi.	11[4]
1996 Ford Taurus	5	75 mi./hr.	35 gal./pass. mi.	1

[1]Fuel economy is calculated based on typical load factors: 70 percent for airliners and 30 percent for automobiles.
[2]Fatality rate for the Ford Trimotor calculated based on 141 known fatalities in a total of 199 planes in their first ten years of operation at an estimated operation of 6 hours/day, 200 days per year, at a passenger load factor of 0.7.
[3]There have been no fatalities in the Boeing 777. The figure is the average for commercial aviation in 1996.
[4]The fatality rate for passenger cars is the average for all cars in the given year.

Although safety was not explicitly identified in the 1997 Asilomar conference agenda, respect for the preservation of life and limb is a critical dimension of sustainable transportation. Since many subtleties of this field are well illustrated by safety, I will use some examples from that field.

Now, a century after the first production car, what tools do we have to address the ill-effects of cars and trucks while enhancing the freedom and flexibility they provide? Just as in the early days, three essential forces still shape the automobile: the push of entrepreneurs and competition; the pull of consumer demand; and the governance of adverse automotive impacts, their regulation, and other market-shaping factors. These forces have produced three revolutions and one counterrevolution, outlined in Table 2, which have had profound impacts on this industry.

TABLE 2 Automotive Revolutions

1909	The Productivity Revolution (Ford)
1927	The Marketing Revolution (General Motors)
1975	The Quality/Efficiency Revolution (Federal Regulation, the Energy Crisis, and Japanese Entrants)
1984	The Light Truck and Van Counterrevolution (Chrysler introduces the minivan)

The next revolution will result from similar major dynamic forces such as an energy or environmental crisis, a major new market entrant, or a substantial shift in the public's transportation needs and desires. Unfortunately, the specific confluence of those forces, and the direction of the next revolution cannot be accurately predicted or yet clearly discerned. Our best hope for the future of motor vehicles as a

key part of sustainable transportation is for advocates to be prepared to shape the next revolution when it comes.

First Revolution: Push for Productivity

The first mass producer of automobiles, Ford, began its inexorable drive toward providing cars for the masses by concentrating on productivity in highly integrated manufacturing processes. Ford's goal was to sell its standardized vehicles at ever lower prices. In 1907, even before the Model T, Ford became the first company to sell more than 10,000 cars in one year. Between 1911 and 1920, Ford built 40 percent of all cars sold in the U.S. (Automotive News, 1996, p. 105-107.). This was the first automotive revolution following the inception of the auto industry, which I will call the productivity revolution. The force behind it was the push of Ford's productivity innovations.

By 1920, Ford dominated the United States market, and heavily influenced the world automobile business. This dominance is illustrated in Figure 1 by its advantage in vehicle sales compared to General Motors. By offering solid, functional vehicles that middle class families could purchase, Ford was responsible for the almost explosive growth of motor vehicle transportation.

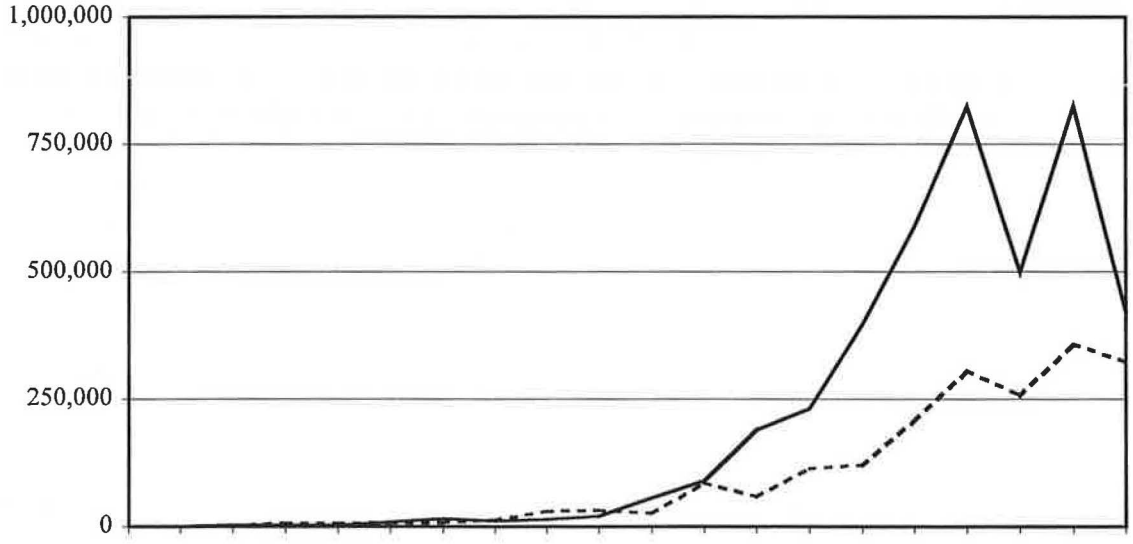

FIGURE 1 Passenger car sales by Ford and General Motors from 1901 through 1920.

Second Revolution: Pull of Marketing

In the following decade, General Motors successfully challenged Ford's dominance by playing to the pull of the market. GM formed General Motors Acceptance Corporation (GMAC) in 1919 to help new car buyers finance their purchases. This was the first shot fired in the marketing revolution. During the 1920s, GM made more comfortable, stylish, and easily operated cars that sold at prices only moderately higher than Ford's. GM's annual model change—incremental improvements in its vehicles—and trivial product differentiation between its various car lines priced in increasing steps, appealed to buyers. GM marketing also facilitated a more active used car market to encourage people who already had functional cars to trade them in for new ones (Sloan, 1965).

TABLE 3 The Marketing Revolution

• Credit financing of new car purchases
• Annual model change
• Trivial product differentiation
• Price class stratification without gaps
• A formal used car market
• Styling
• Improved ease of operation:
-self-starter
-synchromesh and automatic transmissions
-power steering and brakes

As seen in Figure 2, from 1923 through 1926, Ford sold more than a million cars per year, but in 1927, GM solidified its revolution when its car sales overtook Ford's (Automotive News, 1996, p. 105-107). Before the end of the decade, Ford was forced to shut down and substantially redesign its cars. Even its 1932 introduction of V-8 engines in low priced cars did not help Ford regain market domination.

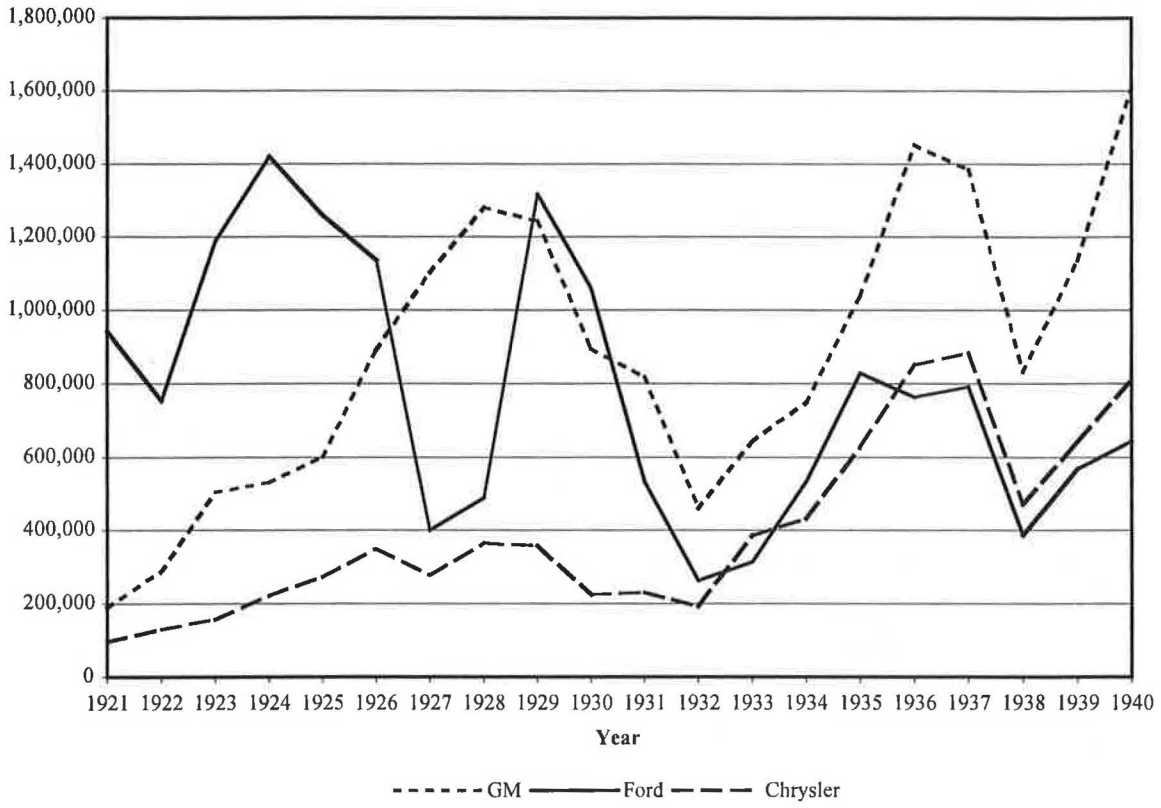

FIGURE 2 Car sales from 1921 through 1940.

Until the 1970s, Chrysler provided the only other serious competition in the mass American market. Chrysler acquired the Dodge Brothers' very successful auto company in 1928, and initiated the Plymouth and DeSoto lines. Chrysler was called an engineering company, but found that the public did not appreciate its engineering prowess. Chrysler's modestly innovative 1934 Airflow, a car designed and styled by engineers, did not precipitate a revolution. Nevertheless, many ideas pioneered in the Airflow made their way into its future cars (Automotive News, 1996b, p, 87), and Chrysler outsold Ford from 1936 to 1949

Consolidating the Revolution: Oligopoly Market Control

While GM competed openly and successfully against other automakers, it had a covert strategy to neutralize another competitor: urban mass transit. In the twenties, GM joined with Standard Oil and Firestone to establish the National Capital Transit Company. That company bought up and dismantled many rail transit systems and substituted buses to provide clearer urban streets for cars and to stimulate demand for motor vehicles (Snell, 19XX).

Although automobiles almost certainly would have proliferated regardless, the systematic destruction of the nation's rail mass transit had a highly adverse impact on people who could not afford automobiles. It increased gasoline consumption, urban air pollution, and traffic congestion. GM's victory over the other automakers and over mass transit consolidated its marketing revolution for nearly fifty years. Ford and Chrysler were forced to adopt GM's strategy of competing on

price, style, speed, comfort, and ease of operation. The major post-World War II fruits of GM's strategy were automatic transmissions, powerful V-8 engines, power steering and brakes, tail fins, and air conditioning. All of this was hung on the same stale, decades-old platform.

With one interesting exception, auto makers rarely competed or innovated to improve what economists call externalities of automotive transportation: safety, fuel consumption and emissions. The exception was Ford's foray into safety in the 1950s. It offered lap safety belts, padded instrument panels and sun visors, and dished steering wheels in its 1956 models. Many have claimed "Ford sold safety while Chevrolet sold cars." In fact, Ford officials later testified that it could not meet demand for its safety options and that the campaign added substantially to the sales of its lackluster cars that year. Ford had identified a latent public concern, but dropped the safety campaign after only one year, allegedly under pressure from GM.

TABLE 4 Some Key Vehicle Safety Improvements

1920	Four wheel hydraulic brakes (Dusenberg and Lockheed)
1934	Safety glazing becomes common in new cars
1939	Sealed beam headlamps and two tail/brake lights
1956	Interlocking door latches to reduce ejection.
1956	Ford offers lap belts, dished steering wheels, and padded instrument panels and sun visors
1964	Federal standards for brake fluid and front seat lap belts
1968	Federal motor vehicle safety standards take effect
1980	New Car Assessment Program: crash safety information
1987	Air bags introduced to meet Federal standards

GM's success also killed the most successful postwar insurgent, Kaiser, and various other companies that survived the Depression and World War II (Studebaker, Packard, Nash, Hudson, and Crosley) leaving only the big three. But this victory of GM's William Durant and Alfred P. Sloan lasted only one more generation.

Third Revolution: Efficiency and Quality

The first sign of a third revolution was Volkswagen's entry into the U.S. market in the late 1950s. VW's "Beetle" was well-built, functional, cheap, easy to repair, and got good gas mileage. They were also small, noisy, and not particularly safe.

The next sign was an epidemic of public concern about smog and highway deaths. In the 1960s, baby boomers got drivers licenses in large numbers and sporty muscle cars proliferated. Not surprisingly, highway fatalities increased sharply. Around the same time, air pollution in Los Angeles and other cities became oppressive and could be associated directly with increased motor vehicle use.

The mid-sixties provided a climate for Federal regulatory intervention. Ralph Nader's book, *Unsafe at Any Speed* (Nader, 1965), and the first Earth Day were catalysts. In response, Congress passed the National Traffic and Motor Vehicle Safety Act of 1966 which established the predecessor of the National Highway

Traffic Safety Administration (15 U.S.C. 1381, *et sec.*). Shortly afterward, it passed the Clean Air Act and set up the Environmental Protection Agency (EPA) (42 U.S.C. 7401 *et sec.*). These laws initiated major Federal regulation of automobiles.

Eight years later, in 1973, the first energy crisis was the defining event in the third automotive revolution—a revolution I call the efficiency/quality revolution. A growing Japanese auto industry that had gained a foothold in the U.S. market in the decade before the energy crisis, capitalized on consumer demand for high fuel economy. Although VW had been more successful in these pre-energy crisis years, its Beetle and initially dismal-quality Rabbit were overwhelmed by more successful revolutionaries: Toyota, Nissan, Honda, Mazda, and Subaru.

In late 1975, Congress passed a strong automotive fuel economy law (15 U.S.C., 2001 *et sec*). Over the next decade, under regulations set by this law, passenger car fuel economy (as measured according to the legislation) and doubled, and light truck fuel economy increased significantly. The smaller, more efficient Japanese cars were effective competitors in the U.S. market. Under the GM marketing model, small cars were cheap imitations of larger cars. The results were the Falcon (which persisted only after being transformed into the Mustang), the infamous Corvair, the Vega with a self-destructive engine, and inflammable Pinto (all cars their makers would forget). In contrast, Japanese cars were not designed and built to be cheap, starter cars for the young and poor. Ultimately in the closing decades of the twentieth century, Honda and Toyota successfully challenged the Big 3 US manufacturers, and their up-market lines of cars put major pressure on manufacturers such as Mercedes-Benz in the luxury car field.

TABLE 5 Elements of the Quality/Efficiency Revolution

• Entry of European imports in the late 1950s and 1960s
• Initial regulation of safety and emissions
• Energy crises of 1973 and 1979 provide public support
• Japanese begin major exports to, and marketing in, the U.S. in the 1970s; open U.S. manufacturing plants in the 1980s
• Fuel economy standards double passenger car fuel economy
• Quality of Japanese cars -improved fit and finish -fewer defects -more standard equipment
• Front wheel drive, unit bodies become the dominant design

This competition forced major improvement in the quality and performance of U.S. cars. Of course, the Japanese had two other advantages: a favorable exchange rate and high levels of productivity. The Japanese also make mistakes. Their first air conditioners worked poorly and their cars could not withstand the winter salt typical of the northeast. Nevertheless, they quickly garnered a quarter of the U.S. market, carving the bulk of it from GM's share. Finally, in the late 1970s, the Japanese

agreed to a voluntary limit on imports of their vehicles to the US, but they maintained sales by building numerous North American assembly plants.

Fuel economy regulations compounded the disarray of the Big 3, who had only known how to make small, evolutionary changes in cars. Chrysler nearly went bankrupt and Ford was on the ropes. They survived, however, and became substantially better managed, more productive companies because of this revolution. The Chrysler minivan and the Ford Taurus helped these manufacturers recover some market share. Unfortunately, because of its sheer market power, GM could postpone its corporate crisis which, its current pattern of strikes show, has yet to be resolved.

Counterrevolution: Light Trucks and Vans

A combination of the unequal application of fuel economy regulations to cars and light trucks, and new market demands created a major market shift beginning in 1984. It was the light truck and van counterrevolution to increasing fuel efficiency and safety. As the auto companies made vans and trucks more civilized, the public bought them in increasing numbers because they offered more interior space, a better view of the road, a sense of personal security, and a kind of anti-style aesthetic. Today, light duty trucks (which include all vans, minivans, sport utility vehicles and pickup trucks) are approaching half of all new light motor vehicle sales.

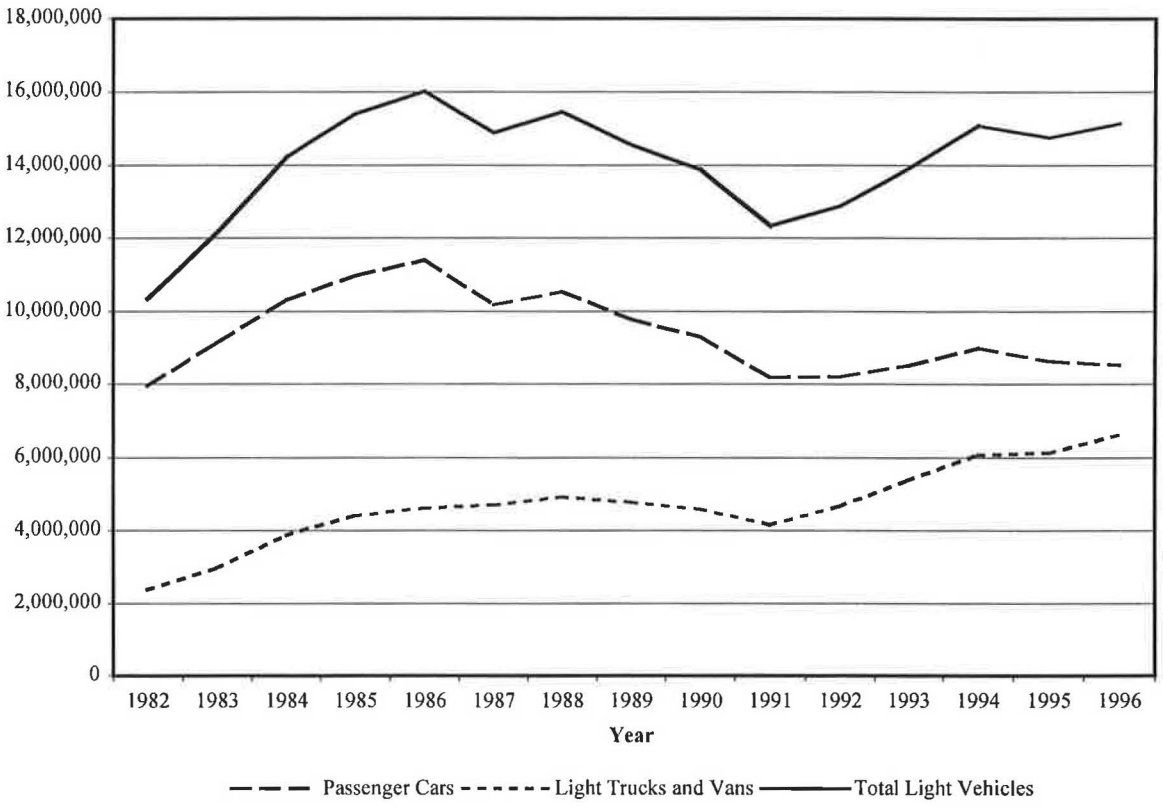

FIGURE 3 Passenger car, light truck, and van sales since 1970.

As a result of this trend, part of the gain from the doubling of passenger car fuel economy between 1975 and 1985 has been lost since light duty trucks are not required to meet the same fuel economy standard. In addition, light trucks and vans

compromise safety both because of their poor rollover safety and because they pose a serious collision threat to smaller passenger cars.

This was a counterrevolution driven by market pull. It is hard to imagine that automakers could have pushed these homely, impractical, overpriced vehicles on the public. However, once car buyers decided they liked them, automakers could not make enough of them. Light-duty trucks are particularly attractive to vehicle makers because they have very high profit margins and they are subject to weaker fuel economy standards. Chrysler invented the minivan in 1984 and bought Jeep (and its popular Cherokee) in 1987. It has been a big winner in the market shift to light trucks and vans. Today, two out of three Chrysler products are light trucks or vans. Nearly all automakers in the U.S. market have gone heavily into this highly profitable segment of the market. Even as these vehicles have become increasingly like passenger cars, their future is not clear. A new energy crisis could take the steam out of this market.

Dynamics of Automotive Development

I have chronicled this automotive history to illustrate the forces and conditions that drive change. Sustainable personal transportation will depend upon some fairly serious changes in motor vehicles and the industry that makes them. The first question is what forces will drive future changes? The second is what direction will those changes take? The last counterrevolution shows that change can go in unplanned directions. Third, what can be done to direct those changes more toward sustainable transportation?

TABLE 6 Marketplace Forces

Push Forces
• New products, performance, and features
• A new manufacturing or sales entrant into the market
• Price/productivity competition
• Advertising
• Roads and land use patterns
• Alternatives: transit, airlines, telecommunications, etc.
Shaping Forces
• Fuel price and availability
• Use and product regulation
• Responsibility laws and insurance systems
• Objective consumer information
Pull
• Customer needs, desires, and wishes
• Purchasing power and credit

Push Forces

Automotive revolutions have been pushed by companies that make vehicles with new appeal to buyers. Some companies have been driven primarily by the profit motive while others, like Ford, were driven by owners who had a vision. Individual companies drove each of the first two automotive revolutions. The third was pushed by a group of Japanese companies that capitalized on the opportunity offered by the energy crisis and fuel economy regulation.

Advertising plays a major role in market push. It became an increasingly essential part of the marketing revolution because it can so effectively sell the elements of that revolution. The auto industry and its dealers are one of the largest advertisers in the country.

Because so little money is spent on serious research and development in the auto industry, new discoveries or innovations rarely play a role in major changes in motor vehicles unless there is strong market pull or regulatory pressure. For example, in the early 1920s, GM toyed with air-cooled engines, but management and technical difficulties, and the lack of obvious market demand caused them to abandon the idea.

In an attempt to retain its dominance in the latter half of the twentieth century, GM has been more innovative than the other U.S. companies during the past few decades. However, the fruits—the Corvair with its air-cooled rear engine, the Vega aluminum cylinder block without liners, the first generation air bags, the front wheel drive X-body cars, the plastic-body Fiero, the Oldsmobile diesels, the Cadillac 8-6-4 engine, plastic-bodied vans, and most recently its EV-1 electric car—were all market failures. Whatever pull these technologies may have had quickly evaporated as problems with their implementation arose.

Better motor vehicles have, in recent years, been a response to regulatory and market pressures. For example, the use of catalytic converters and electronic controls has been driven by emissions and fuel economy regulations and problems with drivability, as much as by new technological developments.

Major product improvements typically result from the entrance into the market of new or revitalized competitors that do not subscribe to the overt or tacit agreements within the old oligopoly. The Japanese high quality smaller cars set a level of productivity and quality (ironically introduced to them by the American, W. Edwards Deming) that has had a dramatic impact on U.S. auto makers. Chrysler similarly redefined the terms of competition and market demand for family vehicles with its minivan. By defining new products, a new or reinvigorated competitor can be the most effective force for change in the auto industry.

It initially appeared that the Japanese might be more innovative than U.S. car makers. Honda has made various engine innovations, Mazda successfully developed and marketed the Wankel rotary engine, and Subaru pioneered four-wheel drive on inexpensive cars. However, Toyota has been the most successful Japanese company by perfecting its very conventional products.

The industry does not like to compete on externalities. It prefers minimum standards for all. As a result, when two highly visible safety factors arose, the New Car Assessment Program (NCAP) and air bags, manufacturers quickly redesigned their vehicles to get good NCAP scores and installed air bags in all new vehicles. They could then advertise that they had a high level of safety without having to compete by trying to make safer cars than their competitors.

Pull Forces

GM discovered early that car buyers wanted style, easy operation, and a chance to out shine the Joneses. It also found that people were willing to go into debt to buy new cars. Occasionally, when it has been offered, the public has shown some interest in safety and fuel economy in their vehicles as well. More and better roads, cheap fuel and parking, and suburban living have also fueled demand for motor vehicles. Roads and cars made the major move to low-density suburbs possible. Although suburbs were initially facilitated by streetcar lines, public transportation as we know it could not have supported suburban sprawl of the type that is now common.

Factors That Shape the Market

The factors that moderate the push and pull of the market fall into several categories: opportunity, economics, regulation, and information. Opportunity is provided by the road system, land use patterns, and alternatives to motor vehicle transportation. Economics includes the cost of vehicles, gasoline, insurance, maintenance, parking, taxes and fees; in relation to how much the public is willing to spend. Regulation controls use (such speed limits and restrictions on truck access to certain roads) and vehicles (such as safety and fuel economy standards). Information helps make markets more efficient by supporting more intelligent vehicle purchase and use decisions.

Here, I would like to address vehicle regulation as a key factor shaping changes in vehicles in the last thirty years. Regulation has many achievements to its credit, but it has limitations.

Federal Regulatory Role

Federal regulation of automotive design has dramatically reduced vehicle emissions and enhanced safety. However, recent experiences with air bags and fuel economy show the limits of regulation when industry vigorously opposes it. The quality and success of regulation are dependent on several factors—factors that are mostly political.

TABLE 7 Strengths of Federal Regulation

• Strong public support
• Authorization to promulgate performance standards
• Effective use of agency appropriations
• Courts supportive when agencies do their jobs well and are well prepared for litigation
• Results are generally highly cost-beneficial

The quality of authorizing legislation defines the powers of government to develop, impose, and enforce the regulations. NHTSA and EPA have relatively good automotive legislation. An exception, however, is the loophole in the fuel economy legislation that treats light trucks and vans differently from passenger cars because,

at the time the regulations were originally promulgated, light-duty trucks were primarily work vehicles. Congress did not anticipate widespread use of light-duty trucks as substitutes for passenger cars.

An agency's appropriations affect its ability to operate in a more effective and timely manner. This includes approval of agency manpower levels. NHTSA has been squeezed for most of its life, but it has used its resources effectively. Appropriations have limited how much supporting research an agency can conduct. Congress has also used the appropriations process to "discipline" agencies that have used their regulatory powers too aggressively (as perceived by key congressional representatives). A good example is the current prohibition against NHTSA spending any appropriations to increase passenger car fuel economy.

TABLE 8 Weaknesses of Federal Regulation

• Political interference can curtail agency powers
• Appropriations language may limit agency action
• Novice or ineffective agency leadership is too common
• Data collection and analysis are given low priority
• Fuel economy legislation has a loophole for LTVs
• Innovative solutions are rare in Federal programs

Political appointments can determine whether an agency has strong leadership and a willingness to achieve its goals imaginatively and effectively. There have been bright spots, but the norm has too often been weak or ineffective leadership of the automotive regulatory agencies.

The courts have further defined agency powers. In decisions such as Chrysler V. DOT (which said that NHTSA could force new technology through its regulations) and State Farm V. DOT (in which the Supreme Court reaffirmed the agency's responsibility to meet the need for motor vehicle safety), the courts have been very supportive. On the other hand, Paccar (which said that NHTSA was required to demonstrate the practical viability of technologies required by regulation) and the GM X-body case (which said that NHTSA must demonstrate the specific causes of safety defects) have diminished NHTSA's authority.

The auto industry has welcomed Federal regulation to deflect public relations problems, to provide a shield against product liability, and to preempt state regulations. Nevertheless, it uses its political and legal powers to minimize regulatory impacts.

Although not strictly a regulatory mechanism, taxes based on externalities can facilitate regulatory goals. Some states and foreign governments have traditionally taxed vehicles based on weight or horsepower. Although the primary purpose has been revenue generation, such taxes can dampen demand for larger, more powerful vehicles. The gas guzzler tax, for example, has virtually eliminated the really poor fuel economy cars.

Automotive Research and Development: Push Factor

Formal corporate research played a modest, but important role in the early development of motor vehicles. GM established its first research organization in 1911 (Sloan, 1965, p. 249). The self-starter, tetraethyl lead additives for gasoline, and fast drying lacquer body finishes were a few products of automotive R&D programs. In 1918, GM acquired United Motors, which had a more established, formal research organization—Dayton Engineering Laboratories—and got the innovative geniuses of Charles Kettering in engineering and Alfred Sloan in management, in the bargain (Sloan, 1965, pp. 23-25). Most automotive research and development before 1965 was directed toward making motor vehicles cheaper and easier to build, simpler to operate, more comfortable, and durable.

Small Federal safety research programs had been initiated in the National Bureau of Standards, the Public Health Department, and other agencies in the 1950s and early 1960s. These programs were combined in 1966 with the establishment of the National Highway Safety Bureau (NHSB), and became the beginning of a small, but important Federal automotive research program. Its purpose was to help the government deal with safety issues rather than to develop improved automobiles.

To provide a basis for regulation, the Federal government has conducted many research projects relating to automobiles beginning in the late 1960s. This research has focused on the epidemiology of motor vehicle crashes and air pollution, the biomechanics of human trauma, test equipment and procedures, and the construction of prototypes to demonstrate the feasibility of regulatory goals. The primary effect of Federal R&D on new cars thus far has been secondary, through the regulations it supports.

The federal EPA and Department of Energy have sponsored small R&D projects, primarily on alternative powerplants, automotive efficiency, and low emission power plants. The Program for a New Generation Vehicle (PNGV) pulled together some of these projects and coordinated them with industry research primarily to develop vehicles with substantially higher fuel economy. The goal of PNGV is to demonstrate the feasibility of tripling average fuel economy from 27.5 mpg to 82.5 mpg. The industry initially said that the goal was impossible. It has recently conceded that it is feasible, but claims that the cost of such high fuel economy vehicles would exceed the value of the fuel saved.

PNGV was the weak initiative of a President who talked about the importance of automotive fuel economy, but would not propose even a modest increase in passenger car fuel economy. Both the Congressional Office of Technology Assessment and the National Academy of Sciences found that an increase to 33 to 35 miles per gallon in passenger car fuel economy would be feasible and cost-effective. Had the President successfully proposed a one mile per gallon increase in fuel economy per year, next year's cars would have fuel economy ratings of 34.5 mpg and next year's light trucks and vans, 28.5 mpg.

The lack of impact of Federal R&D, beyond its support of regulation, is partly because of the relatively trivial amounts of money spent on it. Demonstrating potential or feasibility is quite different from developing a marketable product. Furthermore, there has been almost no incentive to use the results of the work on automotive efficiency because the market is biased too heavily against improved fuel economy.

Table 9 Some Economic Facts Relating to Motor Vehicle Transportation

Approximate Annual Costs of Automotive Transportation in the U.S.	
• New vehicles	$300 billion
• Gasoline and other fuels	$180 billion
• Crashes (including insurance)	$150 billion
• Roads	$100 billion
• Maintenance and repairs	$170 billion
Federal research budgets	
• Health and medicine (NIH)	$12 billion
• Aviation (NASA)	$1 billion
• Automotive transportation	$0.2 billion
Average direct family expenditures on automotive transport	$5,700

Auto industry spending on basic R&D (as opposed to specific new vehicle development) is also a small proportion of its income when compared with industries such as computers, telecommunications, aircraft, and pharmaceuticals.

Other Market Improvement Mechanisms

The market is potentially a much more robust motivator of change than regulation. Market mechanisms are often more acceptable to the public than regulation. Fuel economy could be a marketable characteristic if U.S. fuel costs were raised. However, even at $4 per gallon (which is typical in Europe) gasoline is less than half the cost of owning and operating most cars. Gasoline at this price has not had a major impact on automotive fuel economy in Europe. A price rise of this magnitude could be offset if a car got more than 80 miles per gallon, which would be realistic if gasoline were $4 per gallon! If the Federal government collected an additional $3 per gallon in gasoline taxes, at current fuel consumption rates, the income could replace personal income taxes for all but the richest Americans. Alternatively, this income could replace another regressive tax, the employment taxes for Social Security and Medicare.

Consumer information can have a significant impact on the market if it is relevant, accurate, useful, and readily available to purchasers. Nevertheless, the primary benefit of consumer information comes from its impact on manufacturers who do not want the bad publicity and potentially lost sales from poor product ratings. Standard consumer information on fuel economy was first available in the U.S. in the mid-1970s from the Environmental Protection Agency and the Department of Energy. After the oil crisis, Congress required that fuel economy be posted on every new car offered for sale in the U.S. Generally, consumers have

received information about new vehicles primarily from advertising. But advertising has never been a particularly reliable informant, even when it gives quantitative data. It plays on emotion and desire, rather than function and reality.

Consumer information can complement Federal regulation. The New Car Assessment Program has effectively raised the frontal impact test speed for restraints to 35 mph from the regulatory 30 mph. Consumer information could be effective in describing vehicle rollover safety, an area that does not lend itself readily to regulation. Alternatives to Federal consumer information that have not been seriously tried are to develop voluntary consensus standards for measuring vehicle performance and to have the insurance industry sponsor comparative testing to provide comprehensive safety consumer information. The Insurance Institute for Highway Safety already has an incipient program of this type.

Where performance involves an insurable loss, such as from traffic crashes, insurance rates and conditions can be market incentives. Because the insurance industry is even more conservative than the auto industry, insurance has had an influence only with dramatically unsafe situations such as drivers with poor records and muscle cars.

The model of insurance doesn't apply to fuel economy or emissions. In fact, auto insurance may work perversely against fuel economy. An obvious way to improve fuel economy is to reduce vehicle weight, but it is well known that lighter cars are less safe than heavier ones. There is, however, a potential positive connection between insurance and fuel economy. Automobiles release carbon dioxide into the atmosphere which is believed to contribute to global warming. Hurricanes, floods, and other major weather hazards that have resulted in massive losses to the property insurance industry seem to be a consequence. Insurers are sufficiently concerned about the problem that they have established and funded the Insurance Institute for Property Loss Reduction to study the problem. This organization might become a useful ally in a campaign to reduce worldwide automotive fuel consumption.

CONCLUSIONS

Thomas Jefferson once said "...a little revolution now and then, is a good thing, and as necessary in the political world as storms in the physical...It is a medicine for the sound health of government." This idea is as true in business as in politics. The American automobile market got a valuable boost from the stimulation given by the oil shortages twenty years ago and the challenge of Japanese competition. What we need today is a similarly cleansing storm. It might be initiated by an economic or environmental crisis. It could also come from competition from a company that arises from or goes outside the current club of auto companies.

TABLE 10 Crises that Might Initiate the Next Automotive Revolution

• Public concern about global warming
• A new energy crisis
• A major environmental crisis
• International political or economic pressure

The least likely motivator of a revolution is research results without market push and pull to make them part of the market. Technological innovation may serve a new revolution when it occurs, however. But without a well-defined market demand or a radical new competitor, innovation rarely forces change in a mature industry.

TABLE 11 Technological Changes that Could Serve the Next Revolution

- Major gains in power system efficiency
- Breakthroughs in structural or engine materials
- New applications of computer and telecommunications systems to motor vehicles
- Further developments in communications that permit it to compete more successfully with transportation
- Blurring of the distinction between private vehicles and mass transit

Pressure for change can come from social factors and external competition. We are increasingly shopping and being entertained at home through electronic media. Telecommuting and shopping by mail or through the Internet may replace some uses of motor vehicles. Communications will be a force shaping transportation in the next century. However, in trying to define its effects, we shouldn't forget that TV did not eliminate the movies and that computers have not led to the paperless office.

TABLE 12 Examples of Competition Between Transportation and Communications

- Catalog shopping versus the mall
- Broadcast and Cable TV versus movies and clubs
- Telecommuting versus commuting by car
- Telephones and beepers versus visiting
- Teleconferencing versus live meetings
- The Internet:
  - -for research versus the library
  - -for shopping versus the mall
  - -for education versus schools
  - -for software versus computer stores
  - -for conversation versus visiting
  - -for e-mail versus the Postal Service

Competition provides a stimulus for change when there is an active, fluid market. One need only look at the computer and telecommunications industries for examples of fast developing markets. However, as capital concentrates in an industry, there is a natural tendency toward stabilization unless there are strong pressures for continuing innovation and cost cutting.

Regulation in the U.S. has been the product of crisis and public concern. A future crisis may come from international political and economic conditions as did the 1973 and 1979 energy shortages or from environmental factors such as increased pollution or global warming.

TABLE 13 Business Initiatives Toward the Next Automotive Revolution

- Entry of a new competitor
- Revitalization of an existing company
- Further international auto industry evolution
- New automotive marketing techniques
- A breakthrough in energy source or storage
- Increased competition from telecommunications
- New developments in mass transit

Looking at more traditional types of competition, a natural entrant in the automobile business might come from the computer industry. New materials and manufacturing techniques could radically cut capital costs for such a venture into a thin market. Its products could incorporate computer technologies to a far greater extent than current automobiles. A new smart car might even drive itself on ordinary highways in the future. Cars already have the power of a personal computer on board and can obtain access to satellite communications. However, this capability has been mostly invisible to car users. If computers and communications were used with the same innovation in automobiles as in personal computers, cars could be transformed to the point that the line between mass transit and motor vehicles might forever blur.

The leaders of the next revolution might be computer entrepreneurs who are looking for new markets. They could be foreign automakers—perhaps even from China, India, Korea or Eastern Europe—looking for a repeat of the Japanese success of the third revolution. Environmental educators may convince Americans that global warming is affecting their or their children's lives, and the public could demand that politicians take bold steps toward taming our transportation beast. We may not yet have identified the source of the revolution, but those of us who care about sustainable transportation must try to catalyze the revolution and to be ready to shape it when it occurs.

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