OCTOBER 2014
McKinsey Quarterly

A road map to the future for the auto industry

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As the sector transforms itself, will the automobile keep its soul?

Automakers took center stage at the 1964 New York World's Fair. General Motors exhibited the Firebird IV concept car, which, as the company explained, "anticipates the day when the family will drive to the super-highway, turn over the car's controls to an automatic, programmed guidance system and travel in comfort and absolute safety at more than twice the speed possible on today's expressways."[1] Ford, by contrast, introduced a vehicle for the more immediate future: the Mustang. With an eye toward the segment that would later be named the baby boomers, the Ford Division's general manager (a not-yet-40-year-old engineer named Lee Iacocca) explained that the car brought "total performance" to a "young America out to have a good time."[2] Ford estimated it would sell 100,000 Mustangs during that first year; in fact, it would sell more than 400,000.

The marriage of an exciting car to an exuberant generation was clearly the right idea for Ford. And over the past 50 years, automobiles have continued to be our "freedom machines," a means of both transportation and personal expression. Even so, as the industry recognized, the automobile is but one element of a mobility system—an element governed by extensive regulations, constrained by a need for fuel, and dependent on a network of roadways and parking spaces. Automobiles are also a force for change. Over the past half century, their very success has generated pollution and congestion while straining the supply of global resources. The rapid surge of emerging markets, particularly China, has heightened these dynamics.

[1] Source materials for the 1964 New York World's Fair are available at nywf64.com.

[2] For a transcript of Lee Iacocca's remarks, see "Ford Mustang introduced by Lee Iacocca at the 1964 World's Fair, @Ford Online, posted on August 21, 2013, on ford.com.

Even more transformative change is on the way. Global competitive intensity will rise as Chinese players expand from their vast domestic market. Governments are examining the entire automotive value chain and beyond with an eye toward addressing externalities. Technological advances—including interactive safety systems, vehicle connectivity, and, ultimately, self-driving cars—will change the game. The automobile, mechanical to its soul, will need to compete in a digital world, and that will demand new expertise and attract new competitors from outside the industry. As value chains shift and data eclipses horsepower, the industry's basic business model could be transformed. Indeed, the very concept of cars as autonomous freedom machines may shift markedly over the next 50 years. As mobility systems gain prominence, and vehicles are programmed to drive themselves, can the soul of the car endure? This is just one of the difficult questions (see sidebar, "Challenging choices") that confront the automotive industry as a result of the forces described in this article.

The China factor

Fifty years of innovations in horsepower, safety, and rider amenities have helped automobile sales grow by an average annual rate of 3 percent since 1964. This is roughly double the rate of global population growth over the same period and makes for a planet with over one billion vehicles on its roads.[3] For the past 20 years, though, sales in North America, Europe, and Japan have been relatively flat. Growth has come from emerging markets—much of it in China, which over the past decade has seen auto sales almost triple, from slightly less than 8.5 million cars and trucks sold in 2004 to, estimates suggest, about 25 million in 2014. IHS Automotive predicts that more than 30 million vehicles a year will be sold in China by 2020, up from nearly 22 million in 2013. China's promise has attracted more players to the country, so margins will naturally compress. Yet the country's importance transcends these short-term results. In the decades ahead, China's emergence as a dominant market and production center should have major implications for how cars are designed. Chinese tastes and standards, particularly at the luxury end, where automakers are notably raising the bar, will have a global influence.

[3] John Sousanis, "World vehicle population tops 1 billion units," Ward's Auto, August 14, 2011, wardsauto.com.

China's emergence as the world's largest automotive market also is fueling a burgeoning domestic auto industry to compete alongside more established global players. For decades, Japanese, North American, and European OEMs formed a triad that, at its height, produced an overwhelming majority of the world's automobiles (Exhibit 1). South Korea has since taken its place among the automotive leaders, capturing over 10 percent of the world market in the past 15 years. The growth of Chinese players is changing the equation—and things are moving fast. Ten years ago, only one Chinese OEM, Shanghai Automotive Industry Corporation, made the Fortune Global 500. The 2014 list has six Chinese automakers.[4] Given surging local demand, the Chinese may just be getting started. While South Korean OEMs Hyundai and Kia have created brands with global reach, China's OEMs do not yet export automobiles in a significant way. With strong local demand as a base, a number of Chinese automakers will probably consolidate, become better able to serve their domestic market, and then seek to achieve an international impact, perhaps through joint ventures, partnerships, or other combinations with global companies.

Regulating from 'well to wheels'

Governments have been driving automotive development for decades. Initially, they focused on safety, particularly passive safety. The process started with seat belts and padded dashboards and moved on to airbags, automotive "black boxes," and rigorous structural standards for crash-worthiness, as well as requirements for emissions and fuel economy.

More recently, the automobile's success has strained infrastructure and the environment, especially as urbanization has accelerated. Brown haze, gridlock, and a shortage of parking now affect many urban areas in China, as they do in other cities around the world. Municipalities have begun to push back: Mexico City's *Hoy No Circula* ("no-drive days") program uses the license-plate numbers of vehicles to ration the number of days when they may be used, and dozens of cities across Europe have already established low-emission zones to restrict vehicles with internal-combustion engines.

[4] The Fortune Global 500 issue (July 2014) lists Shanghai Automotive Industry Corporation (now known as SAIC Motor), China FAW (First Automobile Works) Group, Dongfeng Motor Group, Beijing Automotive Group, Guangzhou Automotive Industry Group, and Zhejiang Geely Holding Group. For more, see fortune.com/global500.

Challenging choices

Clearly, issues at play in the automotive industry are interrelated. Emerging economies and widespread urbanization will not only affect global sales and the competitive intensity of the industry but also help to shape its digitization. Regulations will continue to compel innovation. And self-driving technology—one of the industry's greatest disruptions in the last hundred years—will play out differently in different markets and regions, depending on their regulatory, competitive, and customer landscape. Interrelated uncertainties about these forces will create challenging questions for industry leaders.

Emerging markets. What's our strategy for China as annual sales there increase to 30 million vehicles a year by 2020 and its aftermarket blossoms? How will we respond if competition in China becomes too intense? Which other emerging markets demand our focus now?

Demand constraints. To what extent do our future growth plans incorporate the shifting attitudes of younger consumers toward car ownership, the impact of rapid urbanization, and efforts to fight congestion and other regulatory trends that could constrain demand?

Ownership models. How could developments such as car sharing change who purchases our vehicles, how they are used, and when people and organizations buy them?

Competencies and distinctions. What's our plan for sourcing the digital talent we need? How can we ensure that the soul of the car, as reflected in our brand, endures—even as our offerings become more digital and more autonomous?

Connectivity. What value can we contribute and capture in an environment of increasingly networked mobility? What killer applications can we deliver to meet growing demand for integrated transportation, active safety, and seamless communication?

Mandated standards. What technology portfolio (engines, energy sources, and lightweight materials) will best address increasingly stringent emissions and fuel-economy requirements around the world—and still keep our customers in different segments and geographies happy?

Engaging the public. As the scope of regulation expands beyond well to wheels and as debates about congestion, pollution, carbon emissions, and safety intensify, how can we contribute to the dialogue? How can we best ensure a fair hearing for the social and economic benefits of mobility and an equitable distribution of regulatory burdens across the value chain?

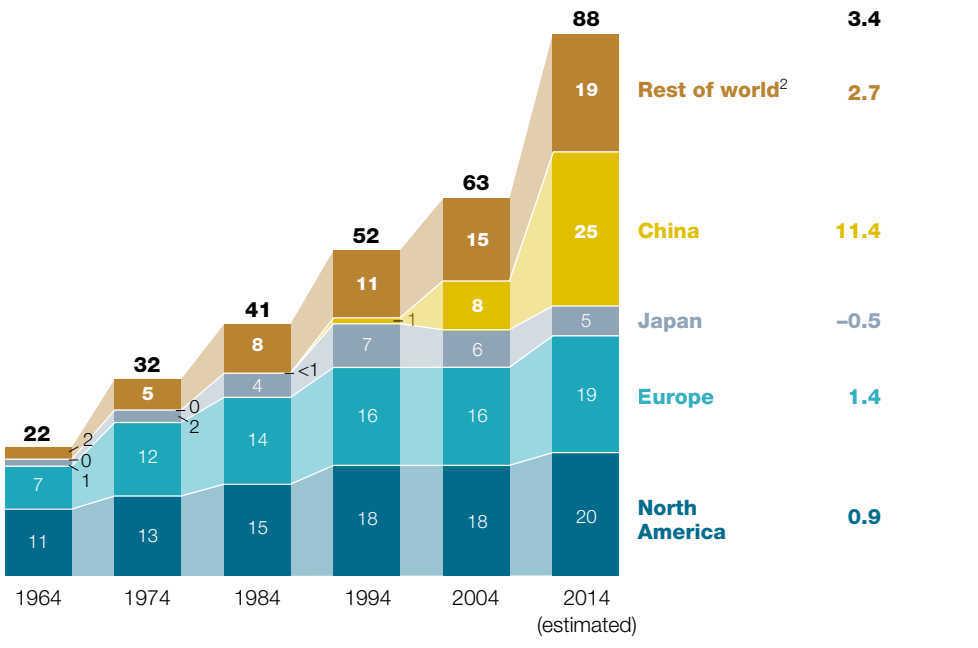
China too is acting. Influenced by its dependence on foreign oil and by urban-pollution concerns, the government has indicated that it favors electric vehicles, even though burning domestic coal to power them can leave a larger carbon footprint.[5] In Beijing, a driver wishing to purchase a vehicle with an internal-combustion engine must first enter a lottery and can wait two years before receiving a license plate. Licenses are much easier to get for people who buy state-approved electric vehicles.

We expect vehicle-use restrictions to grow more stringent as the level of urbanization increases. Regulators are considering a more aggressive "well to wheels" approach to gauge the social impact of automobiles across the product life cycle rather than focusing on

[5] Alice Park, "Why electric cars are more polluting than gas guzzlers—at least in China," *Time*, February 14, 2012, time.com.

Exhibit 1

Global motor-vehicle sales have grown by nearly 3 percent a year for the past two decades, with substantial variation in regional growth.



[1] Estimate of 1964–2004 data based on geographic sales trends of subsegments. Figures may not sum to total, because of rounding.
[2] Eastern Europe, Mexico, Middle East, South America, and South Korea.

Source: IHS Automotive/Polk; Ward's Auto InfoBank; McKinsey analysis

the automobiles themselves. This approach requires authorities to make an integrated assessment of the costs and effects of extracting, processing, and delivering a fuel or energy source to automobiles ("well to tank") and of using that fuel or energy source and generating emissions ("tank to wheels").

For automakers, these developments mean a more challenging environment in which the industry's plans for growth and mix of vehicles could collide with regulatory priorities. It could also lead to a new type of segmentation. The reality of zero tailpipe emissions could result in cars categorized by use. Instead of one type of vehicle meant to do everything, smaller vehicles with no tailpipe emissions could be designed specifically for urban travel. Larger, extended-range vehicles could be used for longer routes.

Regulation would also create new opportunities beyond traditional industry competencies. For example, some automakers are investigating potential plays across the value chain—such as developing alternative fuels or investing in wind farms to generate power for electric vehicles—to offset the emissions created by the vehicles they sell.

In any event, the automotive industry should expect to remain under regulatory scrutiny, and future emissions standards will probably require OEMs to adopt some form of electrified vehicle.[6] Indeed, we believe that regulatory pressures, technology advances, and the preferences of many consumers make the end of the internal-combustion engine's dominance more a matter of "when" than of "if." The interplay of those forces will ultimately determine whether range-extended electric vehicles, battery electric vehicles, or fuel-cell electric vehicles prevail.

Digital disruption

The car of the future will be connected—able not only to monitor, in real time, its own working parts and the safety of conditions around

[6] For more on the global prospects for energy and conservation, see Steve Chen, Maxine Fu, and Arthur Wang, "Seizing China's energy-efficiency opportunity: A case study," *McKinsey Quarterly*, June 2013, on mckinsey.com; and David Frankel, Stefan Heck, and Humayun Tai, "Sizing the potential of behavioral energy-efficiency initiatives in the US residential market," McKinsey Global Institute, November 2013, available for download on mckinsey.com.

it but also to communicate with other vehicles and with an increasingly intelligent roadway infrastructure.[7] These features will be must-haves for all cars, which will become less like metal boxes and more like integrators of multiple technologies, productive data centers—and, ultimately, components of a larger mobility network. As every vehicle becomes a source for receiving and transmitting bits of information over millions of iterations, safety and efficiency should improve and automakers should be in a position to capture valuable data. Electronic innovations have accounted for the overwhelming majority of advances in modern vehicles. Today's average high-end car has roughly seven times more code than a Boeing 787.[8]

Digital technology augurs change for the industry's economic model. Over the past decades, automakers have poured their cost savings into mechanical, performance-oriented features, such as horsepower and gadgetry, that allow for higher returns. But that dynamic is shifting; in the United States, a squeeze is developing as content requirements of cars in emissions and safety continue to rise while consumers pay no more for these features than they did a decade ago.[9]

While it's unlikely that regulatory and competitive pressures will abate, the shift from mechanical to solid-state systems will create new opportunities to improve the automakers' economics. The ability to analyze real-time road data should improve the efficacy of sales and marketing. Digital design and manufacturing can raise productivity in a dramatic way: big data simulations and virtual modeling can lower development costs and speed up time to market. That should resonate with customers conditioned to the innovation clock speed of consumer electronics, such as smartphones.

Common online platforms can connect supply and demand globally to increase the efficiency of players across the supply chain. Embedded data sensors should enable more precise monitoring of the performance of vehicles and components, suggesting new opportunities for lean-manufacturing techniques to eliminate any-

[7] For more, see "What's driving the connected car," September 2014, on mckinsey.com.

[8] *Digits*, "Chart: A car has more lines of code than Vista," blog entry by Brian R. Fitzgerald, *Wall Street Journal*, November 11, 2013, blogs.wsj.com.

[9] See Russell Hensley, Srikant Inampudi, Hans-Werner Kaas, and John R. S. Newman, "The future of the North American automotive supplier industry: Evolution of component costs, penetration, and value creation potential through 2020," March 2012, available for download on mckinsey.com.

thing customers don't value and dovetailing with the digitization of operations to boost productivity, including the productivity of suppliers, in unexpected ways.[10] As automobiles become more digitally enabled, expect connected services to flourish. When the demands of driving are lifted, even the interiors of vehicles may give automakers opportunities to generate revenue from the occupants' connectivity and car time.

The industry's digitization will create challenges as well as opportunities for OEMs. Disruptive technologies will give companies a chance to leapfrog existing automotive leaders whose competence lies in established ones. Attracting talent will be more difficult as the core of automotive research and engineering migrates to software-driven innovation hubs, such as Silicon Valley, Tel Aviv, or Bangalore. And acquiring actionable data will become increasingly critical for the design and operation of systems, drivetrains, safety features, and more. The most difficult challenges may be cybersecurity and emerging regulatory oversight. In the United States, for example, the National Highway Traffic Safety Administration (NHTSA) recently announced that it may make vehicle-to-vehicle communications mandatory.[11] Among other implications, this move would call into question whether and to what extent OEMs can protect their driver-generated data and keep them proprietary.

Rethinking ownership

Technology and connectivity pose the question of whether it's necessary to own an automobile. Car sharing is a prominent example: the consumer pays to use vehicles only as needed and foregoes the responsibilities—and benefits—of individual ownership. Car-sharing services, which allow people to make a reservation at the tap of a personal mobile device, are expected to grow significantly in the next two years, with dramatic increases in the number of users and in revenues.[12] These developments also defy the very notion of a car as a personal, autonomous machine. Already,

[10] See Ewan Duncan and Ron Ritter, "Next frontiers for lean," *McKinsey Quarterly*, February 2014, on mckinsey.com.

[11] See National Highway Traffic Safety Administration 49 CFR Part 571, "Federal Motor Vehicle Safety Standards: Vehicle-to-Vehicle (V2V) Communications," August 2014, gpo.gov.

[12] See Andreas Cornet, Arnt-Philipp Hein, Detlev Mohr, Florian Weig, and Benno Zerlin, "Mobility of the future: Opportunities for automotive OEMs," February 2012, available for download on mckinsey.com.

"millennials" (the 18–34 demographic) appear to place less importance on car ownership than previous generations do. They are more open to sharing cars and to the rapidly growing number of "mobility services," such as Uber and Lyft.

Yet increased car sharing does not necessarily translate into fewer car sales. Our analysis suggests that as it becomes more common, both car usage and wear and tear will rise in turn. The average distance driven per person probably will not decrease; in fact, it may creep up. We would expect a broad car-ownership regime to include a variety of vehicle types, at both ends of the spectrum: not only more utilitarian, almost "vandal-proof" fleet cars for shared rides but also higher-performance "fun" cars for those who still enjoy being behind the wheel for a Sunday drive. Often, the same drivers will be in both segments—just as, for example, a consumer may purchase fast food for some meals but still enjoy a Michelin-starred restaurant for special occasions. In an era of megacities and congested urban areas, personal-mobility services will help transportation become more flexible.

Autonomous vehicles and the soul of the car

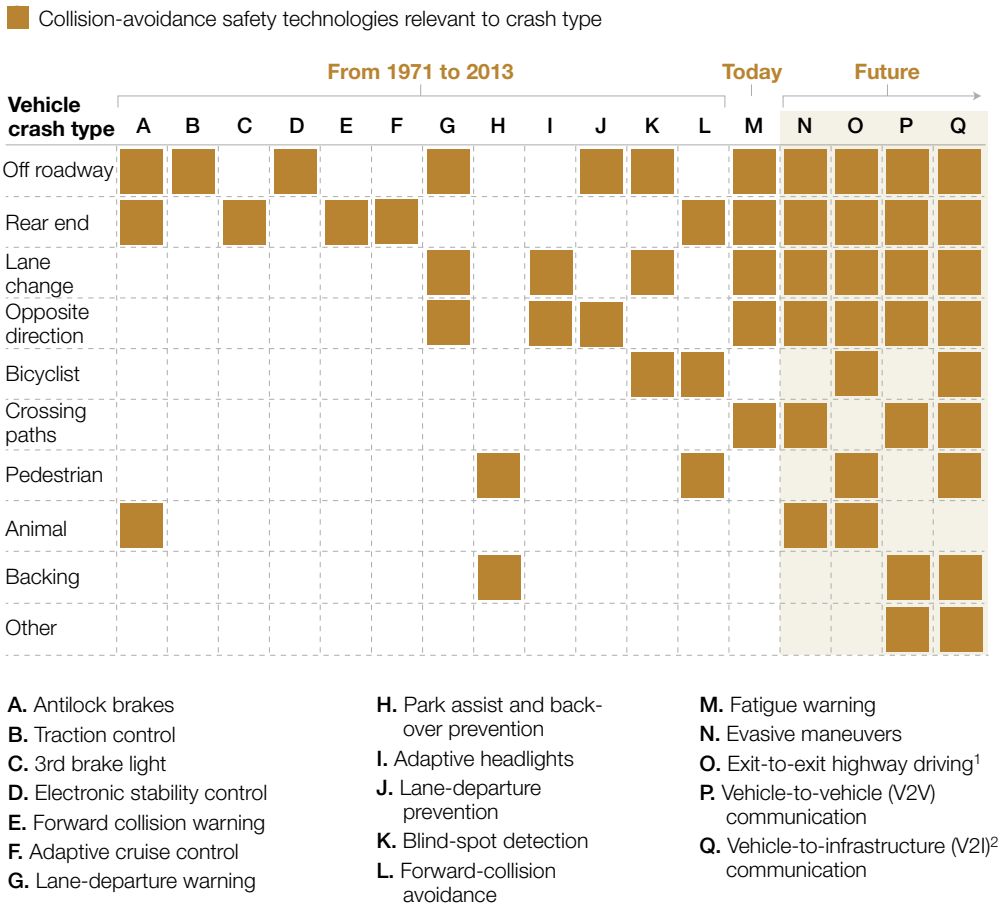
Currently, human error contributes to about 90 percent of all accidents,[13] but autonomous vehicles programmed not to crash are on the horizon. To be sure, some technological issues remain, emissions issues will linger, and regulators are sure to have a say. Furthermore, combining autonomous and nonautonomous vehicles in a single traffic mix will be a significant challenge. The most difficult time is likely to be the transition period, while both kinds of cars learn to share the road before self-driving ones predominate. ("Self-drive only" lanes and dedicated roadways might be the first step.) The technology, though, is no longer science fiction.

The possible benefits, by contrast, read like fantasy. If we imagine cars programmed to avoid a crash—indeed, programmed *never* to crash—we envision radical change (Exhibit 2). Passengers, responsible only for choosing the destination, would have the freedom to do what they please in a vehicle. Disabled, elderly, and

[13] See "Human error as a cause of vehicle crashes," blog entry by Bryant Walker Smith, Center for Internet and Society at Stanford Law School, December 18, 2013, cyberlaw.stanford.edu.

Exhibit 2

Adoption of safety-related technology has grown dramatically, addressing more types of vehicle crashes.



[1]Systems programmed to make smart decisions about navigating interstate on- and off-ramps.
[2]For example, communication between vehicle and traffic light.

Source: McKinsey analysis

visually impaired people would enjoy much greater mobility. Throughput on roads and highways would be continually optimized, easing congestion and shortening commuting times.

And that would be only the beginning. Crash-free vehicles mean no traffic police, no ticketing, no alcohol-impaired driving. Freed from safety considerations such as crumple zones, bumpers, and air bags, OEMs could significantly simplify the production of cars, which would become considerably lighter and therefore less expensive to buy and run. Related industries, such as automobile insurance,

could be affected as well. While car insurance would of course still be necessary for incidents such as catastrophe, theft, and vandalism, insurance claims related to highway accidents (admittedly a small portion of the total) might nearly disappear. Automobiles could also last longer as collisions stop happening and built-in sensors facilitate the creation of parts on demand.

But what about the soul of the car: its ability to provide autonomy and a sense of self-directed freedom? Google's prototype autonomous vehicle has no steering wheel, brake pedal, or accelerator. The vision of a connected car, in fact, challenges even the most essential concepts of personal car ownership and control. When a rider need only speak a destination, what becomes of the driving experience—indeed, why even purchase a car at all? Manufacturers may continue to refine the feel of the ride and to enhance cabin infotainment. Still, there's probably a limit to how "special" a cabin can be or even to how special consumers would want it to be.

In other words, if a ubiquitous fleet of on-demand vehicles provided drivers with the transportation they need, would it also provide them with the feelings of independence that have attracted drivers for more than 100 years and continue to make cars popular in new markets? While the timing and impact of the forces we've described remain fluid, they seem likely to transform the automotive industry and perhaps alter our very concept of what an automobile is. But we also believe that people will still look to their cars as a means of self-expression, with some very human elements. Tomorrow's winning OEMs will still manage to capture the public's imagination, much as Ford and its Mustang did on the fairgrounds of New York half a century ago.

The authors wish to thank Patrick Hertzke, Nicolai Müller, and Paul Wilbur for their contributions to this article.

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