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Connected car report 2016

Opportunities, risk, and turmoil on the road to autonomous vehicles

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Executive summary

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The race to build the fully connected car, and ultimately the completely autonomous vehicle, is already under way. Who will cross the finish line successfully, and where exactly that finish line is, remains to be seen. In this report — based on extensive market research, interviews with auto industry experts, and engagement with auto manufacturers, suppliers, and technology companies across the globe — the automotive practice of Strategy&, PwC's strategy consulting group, addresses these questions.

Today, 70 percent of global connected service sales come from premium brands. By 2022, that number will fall to 50 percent, at the expense of falling margins. Although connected services will generate sales of US$155 billion, most of this value will be offset by falling sales from legacy features such as navigation, entertainment, and safety systems. These trends will contribute to a squeeze in profits for OEMs and suppliers. Higher R&D expenses will not convert into higher overall sales. On the supply side, by 2030, profits available to traditional automakers and suppliers may drop from 70 percent to less than 50 percent of the industry total. The balance of $120 billion may be captured by new entrants, including suppliers of new technology, mobility services, or digital services. Many of today's manufacturers and suppliers lack the skill, agility, and boldness to turn their companies digital quickly enough to take advantage of this change.

The report is divided into seven sections, each of which focuses on one key question about the opportunities and risks to be found in the industry's business models, ecosystem, market growth, geographic distribution, and technologies involved in developing the connected car:

- How does technological change affect the distribution of value in the rapidly restructuring automotive industry? *Page 8.*

- How can automakers recoup their investments in connected and autonomous vehicles? *Page 17.*

- How quickly will the market for connected car packages grow, and how will the revenue opportunities break down in terms of region, car segment, and type of package? *Page 23*.

- How will suppliers be transformed by this industry-wide change, and what will it take for them to succeed? *Page 31*.

- How will China move into the connected car market, and how will those efforts, abetted by its digitally sophisticated car buyers and broad range of innovation, affect the car of the future? *Page 41*.

- How will connected car technology be protected against cyber-attack, and how can automakers effectively meet the related organizational and technical challenges? *Page 48*.

- How will autonomous vehicle technologies, now in the early stages of development, transform the driving experience of tomorrow? *Page 54*.

Automakers, suppliers, and technology companies are beginning to jockey for position. Our goal here is to provide you with a deep understanding of where your company stands, and what it will take for you to win.
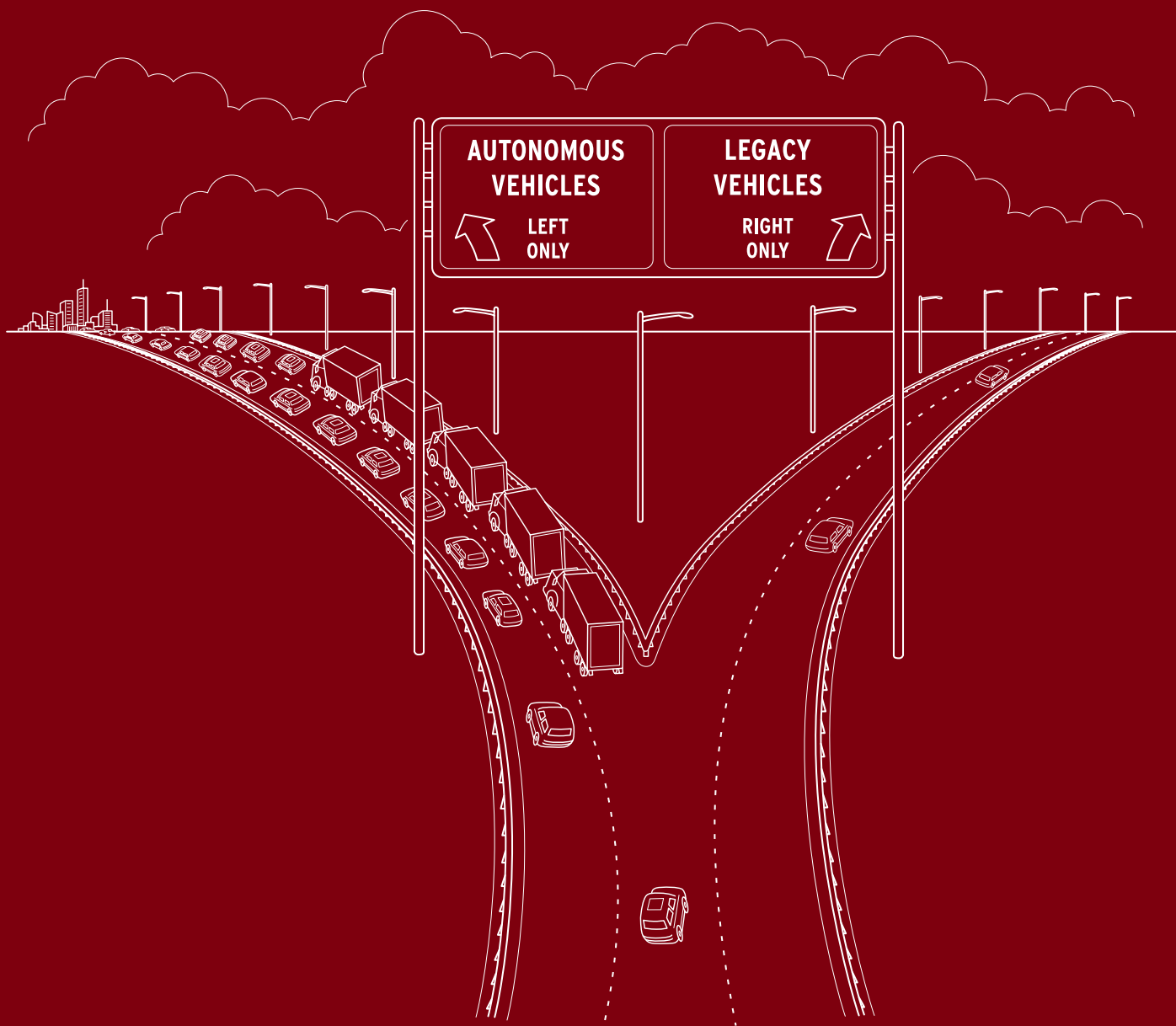
Contents

Introduction:
Industry profits at risk

by Dietmar Ahlemann, Evan Hirsh, Alex Koster, Felix Kuhnert, and Richard Viereckl

Drivers around the world are getting used to the increasing amount of digital technology in their cars. Many of the normal features of the car — monitors of performance data like speed, fuel efficiency, and gas tank levels; heating and air conditioning; and the audio system — all have been digitized in hopes of providing the driver with easier operation and better information. And the car — including smartphones and other devices carried onboard by drivers and passengers — now reaches out to the surrounding world for music streamed from the cloud, real-time traffic information, and personalized roadside assistance. Recent innovations allow automobiles to monitor and adjust their position on the highway, alerting drivers if they are drifting out of their lane, and slowing down if they get too close to the car in front of them. All in all, the car of today is a technological marvel.

And there's much more to come.

Tomorrow's car will represent a step change in form and function, compared with what's being offered now. Although many commentators have described this future in terms of the autonomous vehicle, that's just a part of the change to come. The vehicle of the future is already taking shape in a variety of forms, although it is unlikely to reach full fruition on public streets and highways for 10 to 20 years. Nonetheless, there will be enough innovation before then to transform the automobile. There will be new levels of connectivity among vehicles, enabling new services inside and outside the car. There will be new kinds of cars, many dedicated to specific uses, such as ride-hailing and ride-sharing fleets. The culture of the automobile, including conventional wisdom about how vehicles should be owned and driven, will also change. Already, the very notion of what a car is *for* is being radically rethought.

These changes to motor vehicles will, of course, also transform the auto industry. As the connected car matures technologically, it will influence market trends and automakers' relationships. Features like safety sensors, detailed engine maintenance signals, and smartphone integration are already becoming common in new upmarket vehicles. Industry leadership will shift, in some cases, to new players, while conventional original equipment manufacturers (OEMs) will be pressed to substantially accelerate their drive for innovation — not just in technology, but in their cultures, merger and acquisition approaches, management styles, and recruitment of talent.

In this report, we will take an in-depth look at how the car is being transformed through technology, and what the economic consequences of that transformation will be for the many stakeholders in the auto industry around the globe — the auto manufacturers, suppliers,

technology and software companies, fleet operators, and others. But first, it will be useful to put it all in context, and look at the market shifts and structural changes that are underpinning the current and future development of the connected car and autonomous vehicle.

For the purposes of this report, we use the following definitions:

- **Connected cars** are those that have access to the Internet and a variety of sensors, and that are thus able to send and receive signals, sense the physical environment around them, and interact with other vehicles or entities.

- **Autonomous vehicles** (also known as self-driving cars or robotic cars) are motor vehicles that operate without a human driver, which reduces the cost of transportation and improves convenience and (in most cases) safety.

This report contains the results of the 2016 Connected Car Study, the fourth since 2013. This annual study is conducted by the automotive practice at Strategy&, the strategy consulting group of PwC. It is based on analysis of market volume, innovation and sector growth data, consumer research, and interviews with industry leaders. It explores the technologies involved in developing these new motor vehicle forms, the likely industry dynamics, and the emerging market for them — present and future.

Four trends changing automotive competition

Progress toward connected cars and autonomous vehicles is being spurred by four interrelated trends. All of these are leading to changes in what cars are and how they're used.

- **Radically new technology at low prices:** Technological innovation is accelerating, particularly the quality of connectivity (based on fifth-generation wireless technology able to stream data from the cloud in near real time); the computing speeds required to operate artificial intelligence and steer a self-driving vehicle; the evolution of complex low-cost sensors that can make a car act as if it is aware of its surroundings; and the software that binds all of this together. Innovative companies, both established automakers and new entrants from the technology industry, are investing accordingly in new technologies and new services. This is especially true in the premium market, where carmakers like BMW and Tesla are pushing technology to the limit, but other kinds of connected vehicles are being developed as well, including low-cost urban "pods," robo-taxis, even 3D-printed buses.

- **New high-tech entrants drive faster:** Nontraditional tech companies are not just offering new services as add-ons to automobiles. They are gaining traction in the very technology that makes cars run — and in so doing, they are disrupting the traditional vehicle technology value chain. Mobileye, for example, offers entire "system-on-a-chip" solutions for advanced driver assistance systems, and Nvidia makes systems for dashboard functions and autonomous driving and mapping. Meanwhile, Apple is reported to have invested as much as US$10 billion in an iCar, while Google is working on an entire operating system for connected and autonomous cars. Google's own self-driving cars have already driven more than 1.5 million miles. These and other new entrants operate differently from traditional automakers and suppliers, with a greater willingness to test new ideas and speed up product development cycles. Their data-centric business models are different too, being far more dependent on revenue from ongoing services and the sale of information. As such, they have the potential to significantly change not just the car itself, but how the entire industry operates. Who will be where in the supply chain from foundry to customer? Who has the right to win? Many new players have identified the car as the most attractive place to enter this industry.

- **New mobility concepts and increasingly urban customers:** The tastes and interests of potential car buyers are undergoing a substantive shift. Urban residents in Western markets appear to be losing interest in owning their own cars, a trend exacerbated by their desire to move to urban areas, where cars simply aren't a requirement, and where public transport and ride-sharing apps can easily fulfill their needs. Millennials face affordability issues; some live with their parents or in shared households and put off home ownership for this reason. Although car sales are reaching all-time highs in the U.S., affordability of automobiles remains a key limitation for future growth. The movement toward car-sharing and ride-sharing services will be driven in large part by the dramatic reductions in transportation costs that are expected with connected cars. Meanwhile, in China — where members of an enormous and growing middle class still dream about owning their own cars, making them by far the largest new car market in the years to come — new drivers already expect highly sophisticated levels of connectivity and services in the cars they buy.

- **Evolving regulatory and policy constraints:** Policy and regulations typically lag behind technological progress, at least in the beginning of a new phase. For example, seat belts were first offered as options in 1949, but legislation requiring their use did not appear until 1970, in Victoria, Australia. We may expect regulators to respond to the new technology with laws ensuring the safety of driverless vehicles,

once that technology is available. However, cities are providing momentum by discouraging the use of private cars, especially those not driven by electricity, either through public policies such as congestion pricing and additional bike lanes or by regulating emissions directly.

These trends explain why automakers have been investing so heavily in connected technologies, new ride-sharing services, and other transportation options, including such deals as Toyota's investment in Uber, VW's in Gett, and GM's in Lyft. And it explains the entry into the market of data-centric digital players such as Google, Apple, and Alibaba, all of which are well attuned to the changing demographic of the driving (and non-driving) public.

A shift in industry profits

Given the many factors now affecting the auto industry, and the many new entrants looking to grab a share of the action — not to mention the dense fog of hype obscuring what's real from what isn't — there is real opportunity and risk in the industry right now. As revenues and profits shift from hardware to software, from products to services, and from the old economy to the new one, some players will succeed and others will falter. *Exhibit 1, next page,* breaks down how the industry is likely to change between 2015 and 2030, if current trends continue as expected.
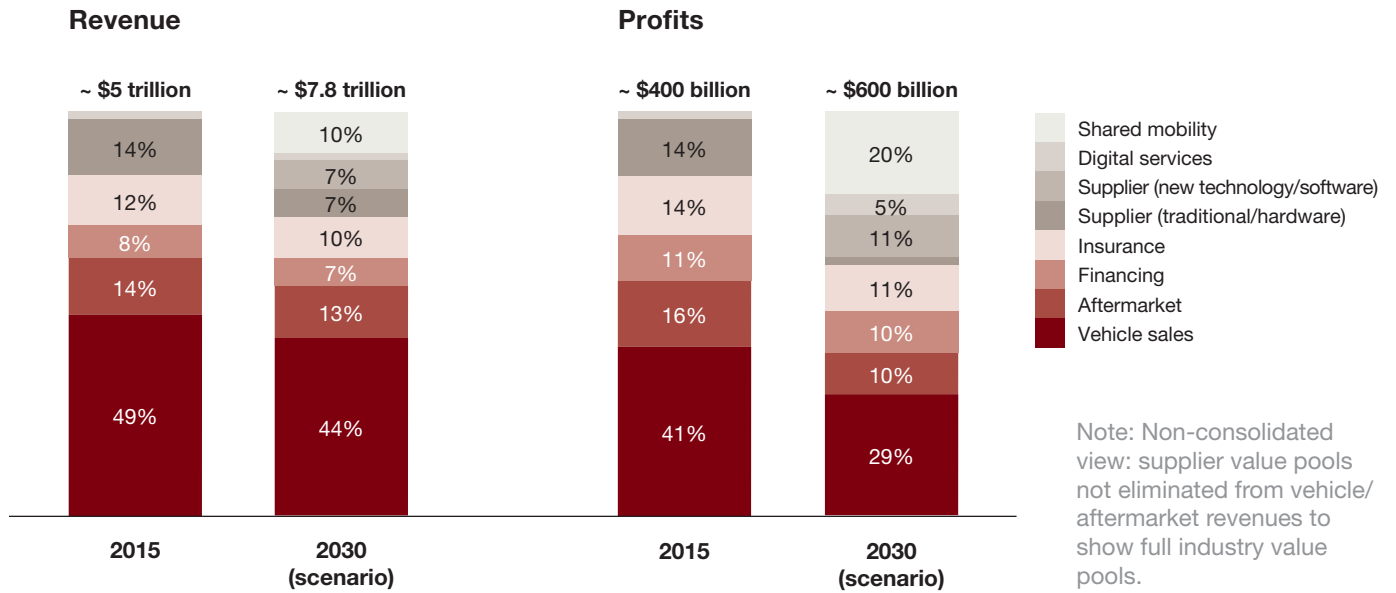
Overall, the automotive industry appears healthy, with revenues increasing from $5 trillion to as much as $7.8 trillion, and earnings from $400 billion to as much as $600 billion. A closer look, however, indicates that the shifts in value will be significant. Much of the growth overall will come from emerging markets, while Western markets' growth will be flat or even decline slightly. Automakers' revenues will rise, but their proportion of overall revenues will decline, as will their proportion of earnings. The automobile aftermarket will grow faster than average, at least in the near term, as shared mobility increases utilization, but it will decline later with the growth of electric vehicles. Supplier revenues will shift from engines, interiors, and chassis to electronics, software, cloud services, and batteries. And revenues from ride-sharing, robofleet, and similar sectors will grow even more rapidly, along with revenues from pure digital services such as onboard entertainment and location-based information providers.

The industry's earnings will thus most likely bifurcate. Profits from new cars will decline as the industry shifts to less differentiated, low-cost vehicles such as robo-taxis, as robofleets put pricing pressure on the automakers, and as the cost of the technology in cars rises. But suppliers

Much of the industry's growth overall will come from emerging markets, while Western markets' growth will be flat or even decline slightly.

Exhibit 1
Scenario for value shifts in the auto industry, 2015–30

Revenue

~ $5 trillion	~ $7.8 trillion

2015	2030 (scenario)

Revenue 2015 (~ $5 trillion):
- 14%
- 12%
- 8%
- 14%
- 49%

Revenue 2030 scenario (~ $7.8 trillion):
- 10%
- 7%
- 7%
- 10%
- 7%
- 13%
- 44%

Profits

~ $400 billion	~ $600 billion

2015	2030 (scenario)

Profits 2015 (~ $400 billion):
- 14%
- 14%
- 11%
- 16%
- 41%

Profits 2030 scenario (~ $600 billion):
- 20%
- 5%
- 11%
- 11%
- 10%
- 10%
- 29%

Legend:
- Shared mobility
- Digital services
- Supplier (new technology/software)
- Supplier (traditional/hardware)
- Insurance
- Financing
- Aftermarket
- Vehicle sales

Share addressable by today's OEM model declining to less than 70%

Share addressable by new entrants (digital services, mobility, new technology supply, Fintech, startup EV players) growing to more than 45% or $3.5 trillion

Share addressable by OEM declining from ~70% to less than 50%

Share that can be captured by new entrants growing to 60% or $360 billion

Note: Non-consolidated view: supplier value pools not eliminated from vehicle/aftermarket revenues to show full industry value pools.

of electronics and technology (including batteries) will benefit from strong volume growth and the comparably high margins their more sophisticated components will bring. And shared mobility and digital services will capture a much larger portion of overall profits, thanks to significant growth in these businesses, and the healthy margins they can achieve.
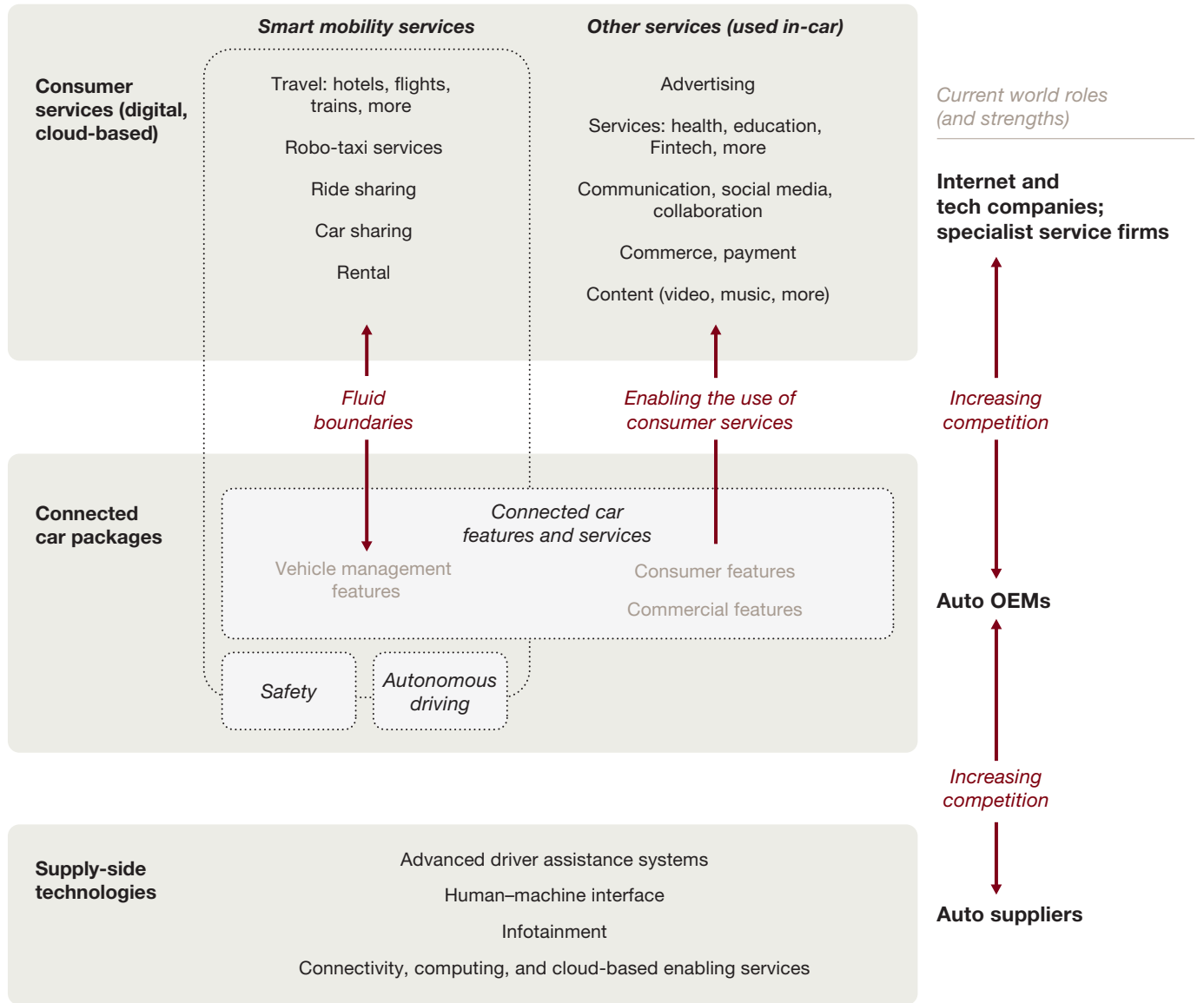
Core or noncore?

The estimates cited so far depend on the connected car, and eventually the self-driving car, evolving to include a wide range of technologies and services. *Exhibit 2, next page,* breaks them down into three main categories:

- **Consumer services.** These offerings include Internet- and cloud-based digital services that add to the driving experience. Some are general Internet services like entertainment, e-commerce, social platforms, and healthcare — adaptations of services consumed outside the car — which will likely continue to be provided by their current industry players. Others, called "smart mobility services," are more specific to auto travel, and may be part of a bundled option. They include ride sharing, car sharing, and navigation-related services (such as finding recommended nearby hotels and booking rooms there). Many of the industry's leaders, the OEMs that make and sell automobiles under their brands, are pouring significant amounts of money into innovation and M&A in this area. The role these automakers will ultimately play in this space, beyond providing the necessary in-car connectivity and screens, remains to be seen.

- **Connected car packages.** These functions, which use advanced features to improve or help manage the car's operation, will be offered as bundles to both retail and commercial car buyers. Currently, most are provided as one-off, built-in features, but they may also come in the form of subscription-based services or aftermarket systems, or be made available through smartphone apps. Eventually, they may be absorbed into standard features. Today's safety package, for example, includes features such as automatic braking systems, collision protection, and emergency assistance, but as this category matures, it will increasingly become part of the autonomous driving package, which will gradually automate the activity of driving the car. Connected car features and services also cover vehicle management services like fuel-efficient driving, remote maintenance, logbooks, and other capabilities.

- **Supply-side technologies.** These are the underlying systems that connect the car to the wider world and support the provision of the

Exhibit 2
The full range of connected car technologies and services

	Smart mobility services	**Other services (used in-car)**	
Consumer services (digital, cloud-based)	Travel: hotels, flights, trains, more Robo-taxi services Ride sharing Car sharing Rental	Advertising Services: health, education, Fintech, more Communication, social media, collaboration Commerce, payment Content (video, music, more)	*Current world roles (and strengths)* **Internet and tech companies; specialist service firms**

Fluid boundaries — *Enabling the use of consumer services* — *Increasing competition*

Connected car packages	*Connected car features and services*		**Auto OEMs**
	Vehicle management features	Consumer features Commercial features	
	Safety *Autonomous driving*		

Increasing competition

Supply-side technologies	Advanced driver assistance systems Human–machine interface Infotainment Connectivity, computing, and cloud-based enabling services	**Auto suppliers**

Source: Strategy& analysis

other two groups. In the past, these would have been provided by the industry's traditional suppliers. Going forward, such systems will increasingly be provided by newer technology companies, and even carmakers themselves, if they can integrate vertically fast enough to compete. (Integration, however, is already proving very difficult.) Supply-side technologies include advanced driver assistance systems (ADAS); the human–machine interface (HMI); infotainment support; and the enabling services that provide access to connectivity, computing, and the cloud.

Underlying all this is the car itself, of course, which will go through its own transformation. We expect more electric vehicles to be sold, and the car to take on more specialized forms, including high-end long-distance vehicles, low-cost/high-volume urban pods, and robo-taxis and other ride-sharing vehicles.

Clearly, the traditional carmakers and suppliers need to significantly accelerate their transformation capability. Their current rate of innovation is too slow to keep up with all the new players entering the field. This is particularly true in the areas of new technology capabilities, piloting and launching new products, and overcoming legacy mind-sets and functional silos.

The answer is not necessarily to pump more investment into connected car or autonomous driving technologies, but to invest more thoughtfully: to recognize where your company's strengths fit with the new technologies, and how to build the capabilities to differentiate your company and stand out in the new technological environment. You may also need to accelerate your own internal management transformation to become more agile and keep up with change, while maintaining and enhancing your distinctive identity as a carmaker.

Prospects and profits for makers of connected cars

by Alex Koster and Jonas Seyfferth
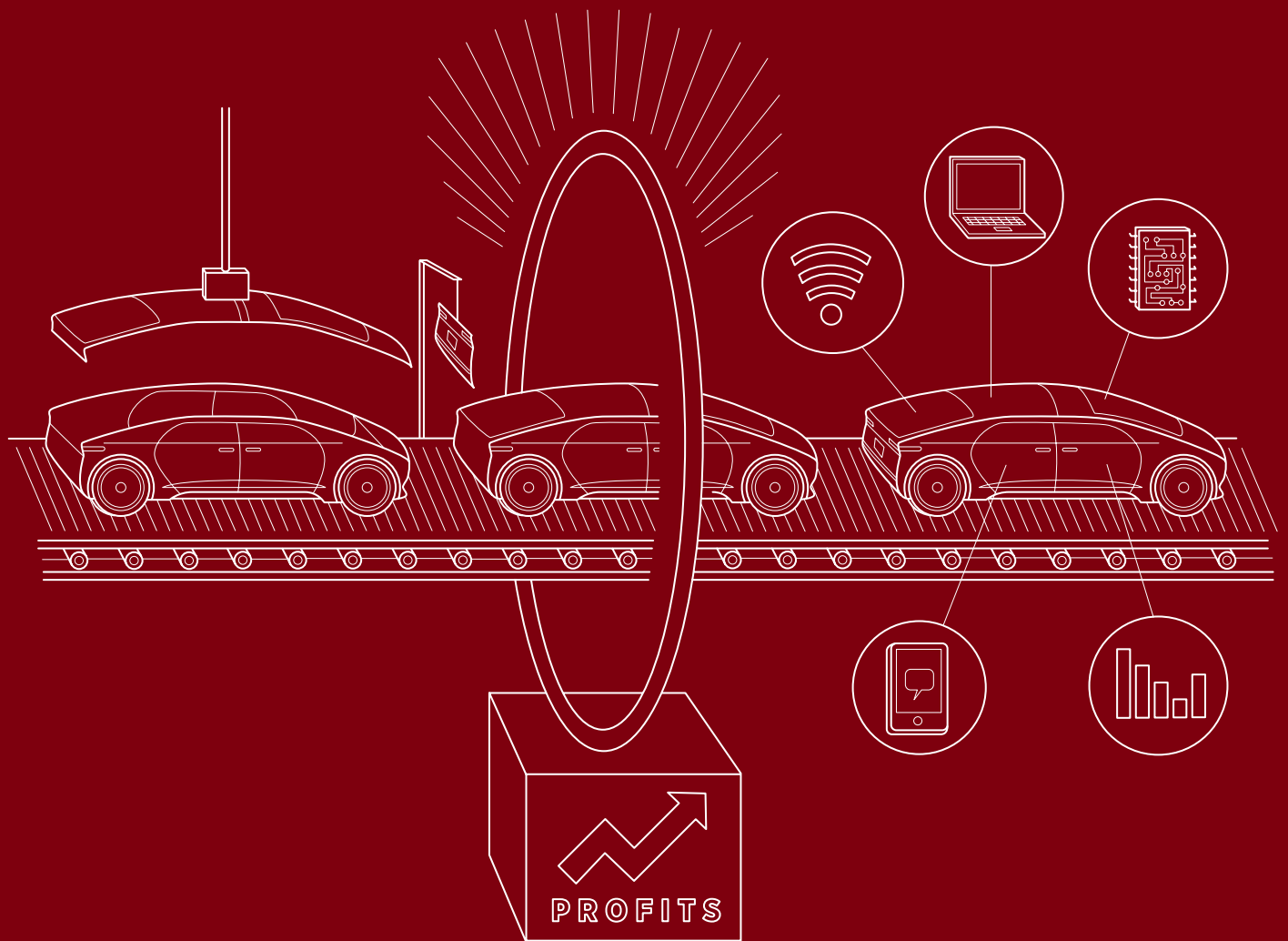
Aside from the distinctions between low-cost and luxury, cars look pretty much alike. Most of them now offer dashboard screens that allow drivers to manage various in-car functions and monitor the car's status through a digital interface, but otherwise, cars have not evolved all that much from the models of the 20th century. Moreover, the current digital features are expensive, complex, nonintuitive, and unsexy; a $500 smartphone offers a more compelling user experience.

That's why automakers, suppliers, and various tech companies have already invested billions of dollars in developing new technologies and services that might differentiate their offerings. The top five OEMs spent $46 billion on R&D in 2015, an 8 percent increase year-over-year. For most of the industry, however, success has been elusive and there is very little noticeable differentiation between players.

Not surprisingly, these levels of spending have also raised the hackles of auto company CFOs, who continue to challenge the current and future returns on these investments. Infighting also continues between the carmakers' traditional R&D departments and their new "digital" innovation shops. Uncertainty about the technological feasibility and business cases for connected services has also slowed progress.

The question remains this: How can companies within the auto industry make money in the world of connected cars? Specifically, how can they profit from the new services they develop for cars? The answers are not obvious, but they are evident when you start to differentiate the options and opportunities based on the capabilities that automakers already have in generating profits and customer loyalty.

Five ways to monetize connected services

The sources of value available to the auto industry and its surrounding ecosystem are coming into focus. Some of these revenue gains can be realized today, whereas others will not become viable for several more years, or even decades. Five of the most likely value creation levers are as follows, ordered so that those with short-term cash flow potential come first, and those with long-term attractiveness later:

- Sales of connected car packages to consumers, mostly bundled with new cars (Audi, Mercedes-Benz, and Tesla are already doing this)

- Use of connected car data to increase internal efficiency, quality, and product differentiation

- Defense of list price levels through differentiation, using connected services to reinforce customer loyalty

- Establishment of a comprehensive ecosystem of consumer services, with revenue sharing

- Creation of systems for using customer data, such as a database of customer information, to be monetized through future (and yet unspecified) business models — especially in mobility services and multi-modal transportation options

Success in these endeavors won't depend on working out what customers want and then building it. Rather, it will require a full-on rethinking of how OEMs, suppliers, and technology companies operate, separately and together, within the emerging business ecosystem for connected car development. This will demand that companies reassess the strategies they use to create value, the capabilities needed to carry out those strategies, and even the corporate cultures that underpinned their traditional, pre-digital ways of doing business.

If you are an automaker, we see six primary moves you can make to capture some of the value available in the world of connected cars.

1. **Change your mental model.** Remember that the connected car is not a product but a set of technologies that will change your core business model. It will require a corresponding change in company executives' mental models. For example, whereas a typical new car has a seven-year development cycle, cloud-based services are routinely developed in months and deployed in real time to customers globally. The combination of services and data allows for instant, sometimes customer-led service innovation. Moreover, cloud infrastructures allow for the separation of hardware, services, software, and data, enabling specialists to enter the realm of car manufacturing at any number of points.

   You must also understand the value of analytics and machine learning technologies in creating real-time dynamic processes in services and customer interactions, enabling companies to capture significant efficiencies through automation and the prediction of customer behavior. Indeed, the entire customer relationship will change, as digital access will create a direct link to end customers, with whom OEMs can interact virtually every day, not just when they're considering the purchase of a new car.

2. **Cannibalize your cash cows and build a premium experience.** Today's OEMs take a micropricing approach to selling connected services, encouraging customers to buy a variety of legacy navigation, infotainment, and safety features on an à la carte basis. This approach creates too much complexity for customers, dealers, and OEMs themselves, with little added value. It will soon be

Companies must reassess the strategies they use to create value, the capabilities needed to carry out those strategies, and even the corporate cultures that underpinned their traditional ways of doing business.

replaced with cheaper and better connected services, offered by OEMs and third-party digital players alike.

According to our research, at the moment of initial purchase customers are willing to pay up to 15 percent of a car's list price, or as much as $10,000, for connected car technology. But this figure drops by 90 percent or more the instant customers complete the online configurator, and few companies in the automotive industry — or any other — have so far managed to make customers subscribe to lifetime services. Consider the struggles of music streamer Spotify to shift its users to a subscription model; to date, just 30 percent have done so.

If you wish to establish connected services as a source of revenue, you must learn to sell not the technologies themselves but a premium experience, in which such services are reconfigured into several digital bundles that can be sold at different prices, depending on their sophistication. The key is to take a page from companies like Apple and Samsung on how to use digital services to maintain premium pricing in the market. Think in particular about cloud-based services that can create stickiness, even lock-in, if migrating their data to another provider is painful enough to make customers hesitate. Core mobility services might, for instance, be complemented with services like "Siri at the wheel" using natural language processing software as part of the brand experience and learning from the behavior of drivers — who would have to start "training their car" all over again if they switched brands.

3. **Set reasonable expectations for your own innovation focus.** You can't expect future business prospects to depend on services you aren't equipped to provide. For example, many carmakers dream of maintaining a platform for third-party content businesses directed at drivers and passengers. Unfortunately, this strategy is likely to continue to be a dream.

To be sure, the connected car, and especially the autonomous car, will eventually emerge as the "fifth screen" in people's lives: the next media consumption nexus point after movies, televisions, personal computers, and mobile phones. But if you're an automaker, it's highly unlikely that you will ever be in a position to monetize that screen — beyond providing the hardware and software in the car itself. You face the same dilemma as telecom companies, which provide the pipes through which many online services travel but don't generally receive revenues from content.

Most automakers don't have the capabilities needed to create a content-focused business or maintain it with the speed and flexibility

of a true digital provider. Even when they've turned to acquisitions to gain expertise, differences in culture and priorities have so far kept these ventures from success. You may be able to provide some mobility-related services, such as finding a hotel or the cheapest gas station in the area, but such offerings won't create much stand-alone value except as part of your services bundles.

Instead, focus your innovation on the driving experience. Create frictionless access to your car's many features and seamless interfaces to technological partners. Why not let established businesses and digital entrepreneurs — digital media; online fashion, grocery, and electronics retailers; online healthcare providers; and the like — access your captive audience, while you take a share of what they sell?

4. **Use your data.** In many industries, such as retail, banking, airline, and telecom, companies have long used the data they gather from customers and their connected devices to improve products and services, develop new offerings, and market more effectively. The auto industry has not had the frequent digital touch points to be able to do the same. The connected car changes all that. You can now have access to a high-frequency feedback channel from drivers and passengers that will provide insights into driving patterns, touch point preferences, digital service usage, and vehicle condition, in virtually real time. This data can be used for all sorts of things, including new product development, preventive and predictive maintenance, optimized marketing, upselling, and making data available to third parties. It's an opportunity not to be missed.

5. **Move steadily toward autonomous technology.** The death of a Tesla test driver in a June 2016 road accident will not slow down the development of the fully autonomous car. Within two months of the accident, Audi announced that it was setting up a self-driving subsidiary, Ford said it was targeting the release of a fully self-driving car in 2021, and Volvo said it would be testing an autonomous robofleet on the streets of Pittsburgh in early September.

The self-driving car will be the most valuable contribution to automakers' top and bottom lines in a generation. The share of drivers around the world who say they are looking forward to these technological miracles is growing rapidly, and these drivers say they're ready to pay a premium for the convenience. Of course, even autonomy will eventually become a standard feature on cars, but no OEM can afford to miss this opportunity.

6. **Resist diversifying into businesses where you lack the capabilities to win.** With the advent of the truly autonomous vehicle comes the opportunity to deploy a full range of mobility services — automated car rental, friction-free ride sharing, fleets of hailable robo-taxis, all available through cloud-based digital platforms. Many OEMs are chasing this vision, despite its many inherent risks. You may see huge potential here, based on the market cap of ride-sharing services.

   Most OEMs are realistic enough to admit that they do not possess the capabilities needed to succeed in the mobility space, even though they also understand that these platforms may very well become to the auto industry what Google and Facebook are to the Internet: points of convergence and control. So they have taken ownership positions in mobility businesses, under the assumption that this will give them access to capabilities, technologies, skills, and cloud-based platforms. Toyota has invested in Uber, GM in Lyft, Apple in Didi Chuxing, Daimler in Mytaxi, and VW in Gett, while BMW has its DriveNow.

   Unfortunately, most of these investments are unlikely to pay off. As an OEM, you are not likely to be the best owner of one of these businesses. It will be difficult to build scale, synergy with your core auto manufacturing business, and access to the right talent. The capabilities required for a successful digital platform — rapid product and services development, powerful digital customer relationship management, big data analytics — are poorly aligned to a typical OEM's strongest capabilities. Worse still, mobility investments can distract you from your primary business.

The risk–reward ratio

The road ahead for the auto industry is rife with uncertainties — speed bumps to overcome, pitfalls to be steered around, traffic jams to negotiate, as the number of players looking to capture some of the value to be had multiplies. Simply keeping up with the fast-moving technological revolutions taking place, and the many new business models they are enabling, is no easy task.

Clearly, many OEMs will struggle to participate fully in the large pool of value already being created as the industry digitizes. For them, the risk is that they will become mere manufacturers of increasingly commoditized vehicles — dumb pipes on wheels — through which the truly valuable connected and mobility services pass. But the rewards for those that can figure out how to move up the digital value chain and get ever closer to the customer will be significant.

Growth in a commoditizing market

by Dietmar Ahlemann, Alex Koster, David Crusius, and Henning Kerstan

Connected cars will be more entertaining, more efficient, and safer than traditional cars, and they will free up drivers to conduct other activities while en route to work, on errands, and during trips. But how much money will the auto industry's OEMs actually be able to make on the connected car? This is a difficult question to answer. The physical form that the car of the future will take remains uncertain, as does the exact nature of the connected and autonomous packages that automakers will likely sell with their cars.

Forces of commoditization

In the coming years, OEMs will likely sell their cars, and try to capture added value, with three primary connected package options: safety (including driver assistance, lane management, and the like), autonomous driving (including adaptive cruise control and self-parking, among others), and connected car features and services, including vehicle management, consumer-oriented, and commercial applications.

The specific content of each package will change over time. Most features of the current safety package, for example, will eventually converge with the autonomous driving package as cars become more autonomous. Until then, safety features are mostly sold as an integral part of a new car, and included in the car's list price. In the future, the autonomous driving package will grow to include new features such as predictive choice of driving profile, a range of levels of automation — standard driving, congestion mode, and parking mode — vehicle-to-vehicle communications designed to predict dangerous conditions, and active communications with surrounding infrastructure. And the connected services package will eventually include driver and passenger personalization via cloud services; voice, gesture, and motion control; augmented reality; biofeedback; integration with wearables and the home; and the ability to set the car's internal climate controls before drivers get in.
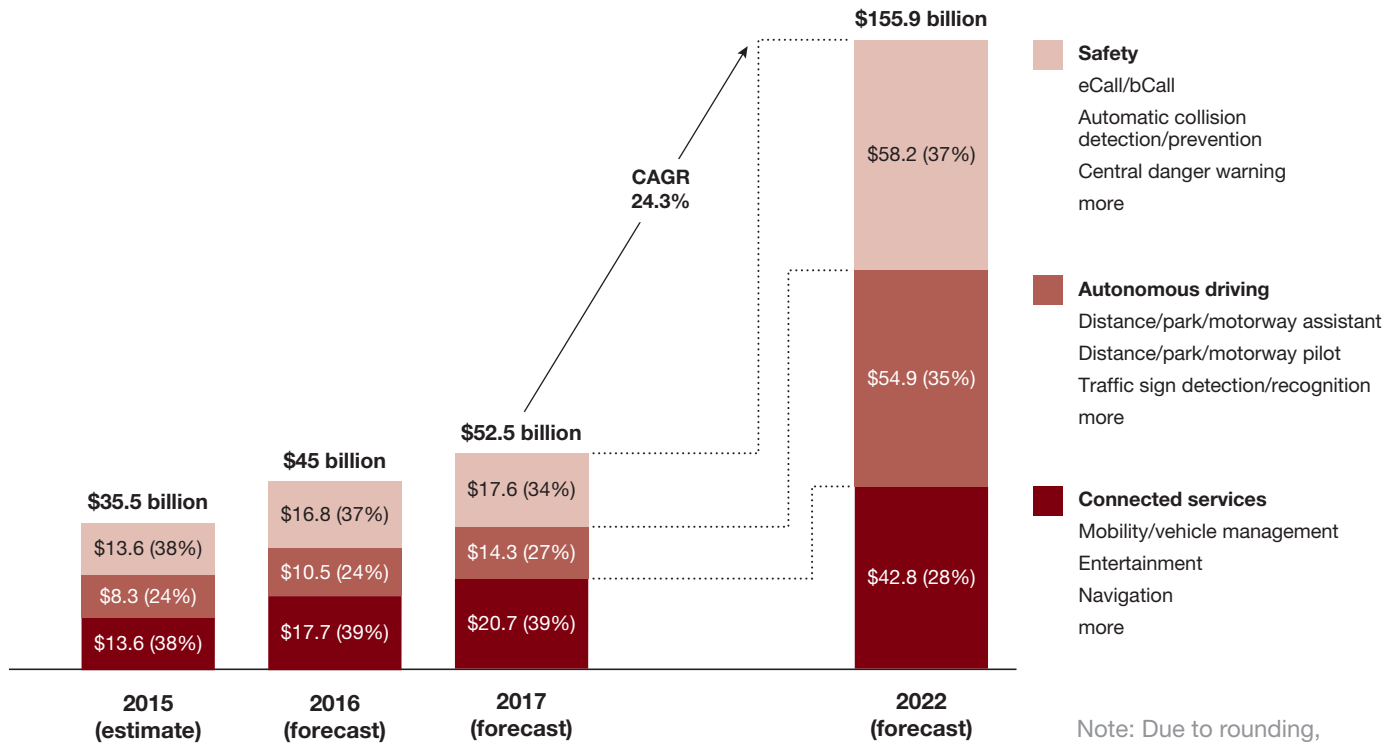
Our research shows that the global car market has the potential to build considerable value from the sale of connected car packages to end customers — fully $155.9 billion in 2022, up from $52.5 billion in 2017, an average annual growth rate of 24.3 percent (*see Exhibit 3, next page*). Realizing that value, however, will depend on a number of critical actions:

- **Improve sales channels for connected services.** If that value potential is to be fully realized, OEMs will have to sell 320 million connected car packages between now and 2022. Current data suggests that, by the end of 2016, OEMs around the world will be

Exhibit 3

Estimated connected car revenues (and market share) by product package, 2015–22

$155.9 billion

$35.5 billion

$13.6 (38%)

$8.3 (24%)

$13.6 (38%)

$45 billion

$16.8 (37%)

$10.5 (24%)

$17.7 (39%)

$52.5 billion

$17.6 (34%)

$14.3 (27%)

$20.7 (39%)

$58.2 (37%)

$54.9 (35%)

$42.8 (28%)

CAGR 24.3%

2015 (estimate)

2016 (forecast)

2017 (forecast)

2022 (forecast)

Safety
eCall/bCall
Automatic collision detection/prevention
Central danger warning
more

Autonomous driving
Distance/park/motorway assistant
Distance/park/motorway pilot
Traffic sign detection/recognition
more

Connected services
Mobility/vehicle management
Entertainment
Navigation
more

Note: Due to rounding, numbers shown here may not add up precisely to the totals provided.

Source: Strategy& analysis

capable of selling 1.4 million connected car packages a month. To reach the full value potential of the technology, they will have to increase that figure almost six times, to 8.2 million packages a month. That's a massive sales and distribution challenge that few companies are equipped to meet. Today's dealers and e-commerce channels are unable to explain the benefits to consumers or handle the service requests emerging from the complex functionalities of connected car technology. New investments and changes in sales and customer service practices will be required.

- **Integrate and bundle features into a simple car experience.** Simplicity sells. Other sectors such as telecom and media have demonstrated how bundles achieve better sales and brand loyalty.

Today, 40 percent of the connected car package value is priced into the car's basic list price (*see Exhibit 4, next page*). This ratio varies with the package.

Going forward, we expect that features will commoditize, and a much larger share of connected car services will be sold as part of the basic list price. This supports an overall simpler and more integrated experience for car owners.

By 2022, autonomous packages will have the largest incremental impact on new car sales — about $54.9 billion, up 31 percent annually from 2017. And while safety packages will generate $58.2 billion in 2022, an average annual growth rate of 27 percent, most of this value will be integrated into list prices, and eventually integrated into autonomous packages. Connected services packages will rank third in value in 2022, bringing in $42.8 billion, a 16 percent growth rate. And some of that potential will be captured by third-party players, driving down both the take-up rates and prices of the OEMs' offerings.
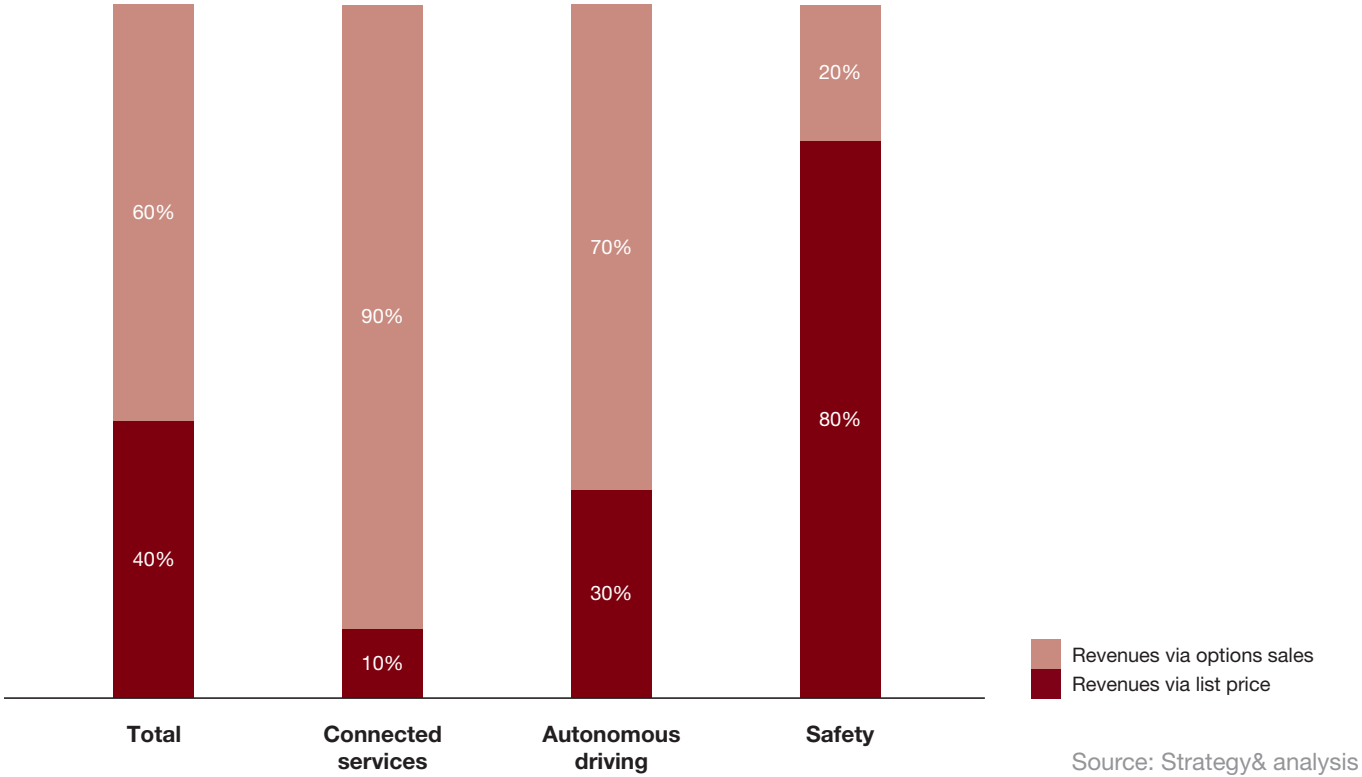
- **Be prepared to move from premium to volume sales.** The market for connected car packages in 2017 will continue to center on premium vehicles, where $33.8 billion, about two-thirds of the total value, will be captured. No surprise, since OEMs typically focus their product launches on the top end of the market, and these value-added services can help justify the premium prices they get for these cars. By 2022, however, the connected car value to be found in the volume market will catch up, reaching 50 percent of the total (*see Exhibit 5, page 28*). By then, 75 percent of connected car packages will be sold as part of smaller, less expensive cars, and the prices for the packages will be proportionately lower. The big rise in the volume market will drive down costs and put differentiation at risk. Yet companies that can design a distinctive, value-priced mainstream vehicle with significant connected car and autonomous vehicle features could carve out a powerful position.

On a per-car basis, connected car packages will account for 8.3 percent of the total price of premium cars, or $4,243, in 2017, and that proportion will rise to 14.2 percent, or $7,513, by 2022. The volume market won't see similar gains, however; the respective 2017 figure is 5.4 percent of the total, rising to 6.9 percent (*see Exhibit 6, page 29*). This discrepancy is in part a result of more premium car buyers opting for these packages, while just two-thirds of cars in the volume market will be connected. Thus, if automakers hope to slow down the commoditization of their connected car packages, they will have to figure out how to further monetize those packages in volume car markets.

By 2022, 75 percent of connected car packages will be sold as part of smaller, less expensive cars, and the prices for the packages will be proportionately lower.
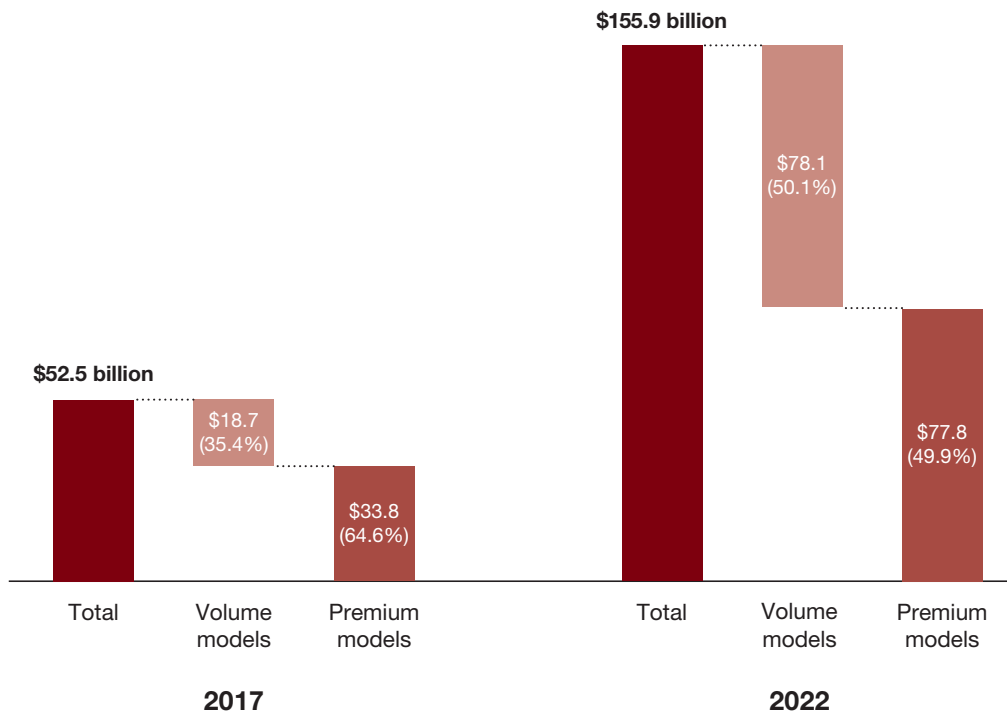
Exhibit 4
Connected car package value potential, list price vs. option sales, 2016

60%	90%	70%	20%
40%	10%	30%	80%
Total	**Connected services**	**Autonomous driving**	**Safety**

Revenues via options sales
Revenues via list price

Source: Strategy& analysis

Exhibit 5
Projected connected car revenue share between premium and volume cars, 2017–22
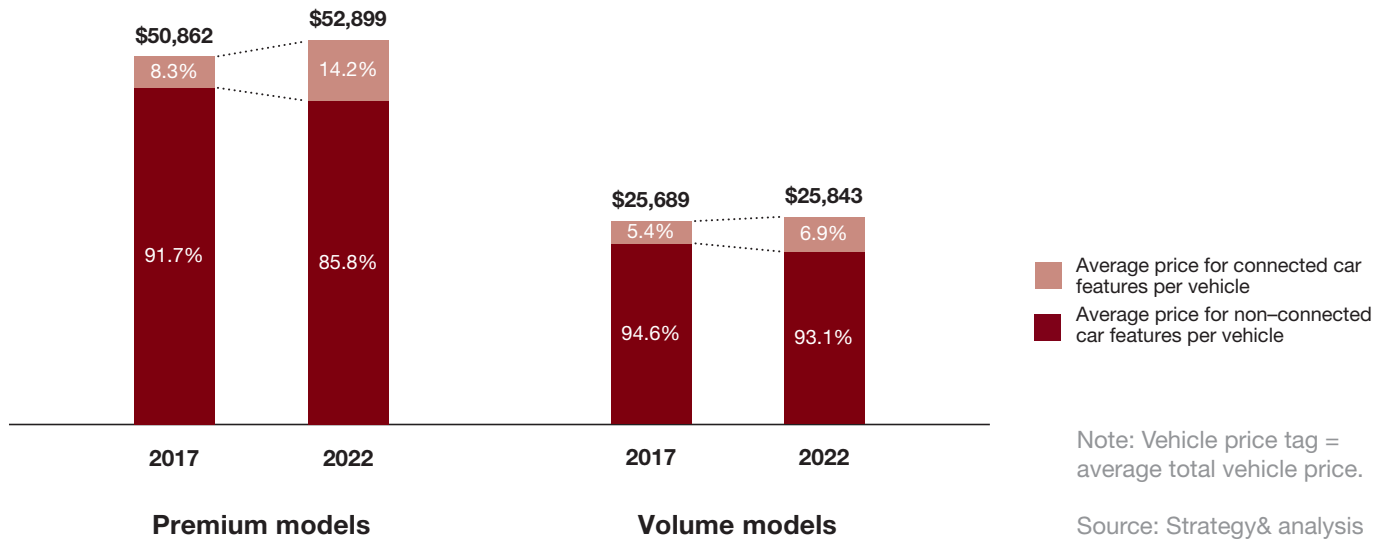

Source: Strategy& analysis

This imperative is made more difficult by the fact that smaller cars — compacts and subcompacts — will take an increasing share of the volume markets and make up 67 percent of total market potential by 2022. This would be a move up from 55 percent in 2017. The smaller the car, the lower the list price — and thus the lower the value potential of connected car packages. As a result, it seems likely that connected car functionalities will further mature, decrease in price, become as commonplace as air bags are today — and eventually lose their ability to provide differentiation.

- **Remain in developing markets — but don't depend on them.**
  Many automakers see developing economies, notably the BRIC countries — Brazil, Russia, India, and China — as a huge growth market for their cars. But the impact on potential value gains in connected cars, we believe, won't be as large as hoped; as auto markets, these economies will not outgrow the rest of the world. For one thing, although the growth in the sheer volume of cars sold there

Exhibit 6

Pricing of connected car packages as a percentage of total vehicle price
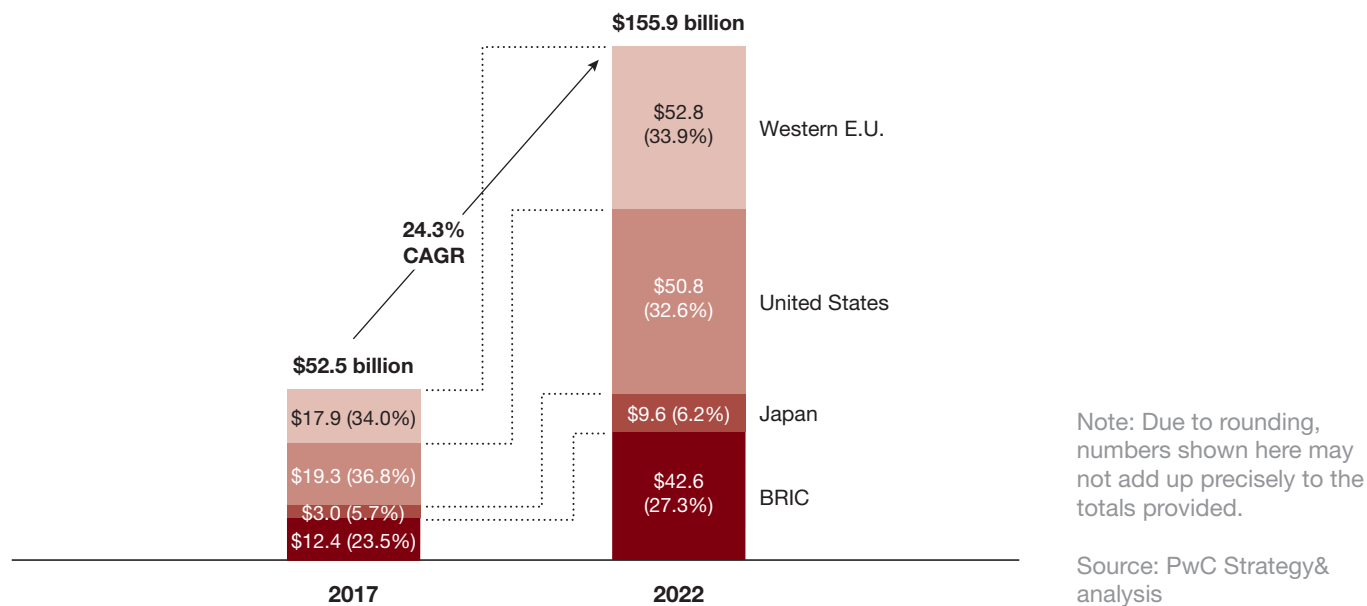

Premium models

2017	2022
$50,862	$52,899
8.3%	14.2%
91.7%	85.8%

Volume models

2017	2022
$25,689	$25,843
5.4%	6.9%
94.6%	93.1%

■ Average price for connected car features per vehicle
■ Average price for non–connected car features per vehicle

Note: Vehicle price tag = average total vehicle price.

Source: Strategy& analysis

will be strong, the price of these cars will likely decline. As a result, the connected car value potential in the European Union and the U.S. together, about 70 percent in 2017, will decline only slightly, to about two-thirds in 2022, while the value of the BRIC markets will rise to about 27 percent from next year's 24 percent (*see Exhibit 7, next page*).

The great risk faced by all OEMs as they move further into the world of connected cars is that they could be outpaced by third-party providers, which can bring the same or similar services to market, either at a significantly lower cost or for free, through an entirely different monetization model — that is, a model for drawing revenue from these offerings. If that happens, the OEMs will no longer be able to monetize their services as planned, and these services will quickly become commoditized and integrated into the cars' list prices as must-haves, rather than as nice-to-haves. This is already happening with basic connected car packages in volume segments.

In essence, the OEMs and the third-party providers are facing a race for innovation in connected cars that will enlarge the share of commodity services in connected car packages. OEMs must remain at the innovation forefront by regularly delivering new, innovative (and high-priced) services to differentiate their premium segments. But they will also feel
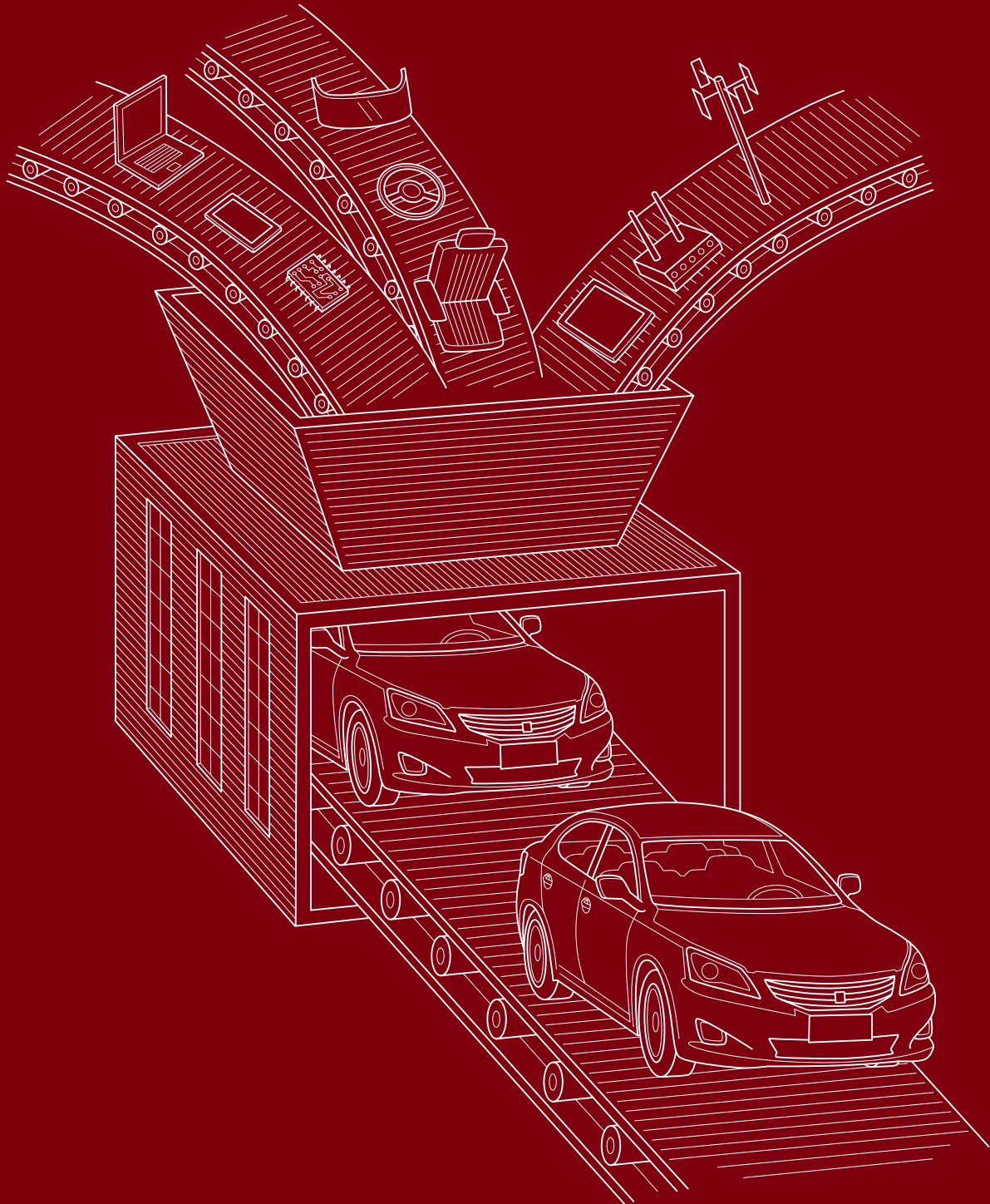
pressed to make available an increasing array of commodity services that can be operated as efficiently as possible, in both premium and volume segments. In either case, the OEMs will have a hard time staying competitive against large digital players, which do not carry the cost of physical assets and the many burdens that come with those assets. As a result, many OEMs may eventually decide to focus on their old core business, producing commodity cars through which others capture the premium value associated with connected car services.

Exhibit 7
Connected car revenue potential, by region, 2017–22

Note: Due to rounding, numbers shown here may not add up precisely to the totals provided.

Source: PwC Strategy& analysis

Building the connected car

by Evan Hirsh, Juliane Stephan, and Trent Warnke

Driven by the huge demand for the new digital technologies associated with connected cars, an exploding list of companies from outside the traditional automotive supply base — not just giant tech companies but ambitious startups as well — are playing an ever-bigger role in providing all manner of automotive systems. Not to be outdone, the industry's OEMs and traditional suppliers are working feverishly to expand their own access to the new technology and talent needed to compete, even as they invest heavily in downstream businesses such as ride sharing.

As a result of all this activity, the industry's overall supply chain has changed more quickly, and more dramatically, in just the past several years than ever before — and the changes to come in the next five to 10 years will be even more impressive. The costs, and the risks, are huge, and it remains unclear what the industry will look like 10 years from now.

Even capturing the current state of the industry — what kinds of companies are supplying what kinds of systems — is no easy task. Yet doing so is critical to an understanding of the changes taking place across the industry's entire supply chain. Suppliers will be competing for position in this new world just as keenly as the automakers they work with. Successful strategies will include the following measures:

- Form partnerships with technology firms to come up to speed rapidly, especially for components or in new areas that require fast time-to-market or are already served by your competitors.

- Invest in acquisitions, but limit them to strategically relevant areas (for example, to help you build capabilities that are critical to future differentiation or are at the core of your future business model).

- Innovate in-house in areas that have sufficient lead time and require complex integration by many players (for example, in algorithms related to autonomous driving).

- For OEMs: Increase your vertical integration where it will help you build the market and play a strong role in future markets.

- For suppliers: Trade off some of your activities to OEMs. Focus on where you want to compete, and outsource the rest. Areas of intensive early competition might include data-dependent business models, mobility services, and autonomous algorithms.

New technology players moving fast

The fast growth of new players entering the fray from outside the automotive arena is already beginning to transform the structure of the auto industry. Making more intelligent, connected, and ultimately autonomous vehicles a reality requires a level of hardware and software technology innovation and adoption never before seen, and much of it has its roots in other industries. We see two kinds of new entrants in this space: established companies from adjacent industries and technology startups.

Established players in areas such as telecommunications (think AT&T), IT and software (Cisco Systems), and consumer electronics (Apple) are actively moving to apply their capabilities to the automotive world, leveraging the huge scale and learning effects from much larger consumer and commercial markets to new automotive technologies. Those with an established ecosystem and existing network are working particularly hard to use these assets to entice and lock in new car buyers (e.g., Pandora, Airbiquity, and Apple with its iTunes offering).

Meanwhile, in just the past few years, a strikingly large number of startups have emerged in the connected vehicle space amid a burst of venture capital activity. OEMs and suppliers alike are paying close attention to the rise of these brand-new players, and even participating with them. Examples include Quanergy, Otto, and AdasWorks. Although the emergence of these new companies may be threatening to some of the established players — both OEMs and suppliers — it can also give the traditional companies the opportunity to access new technology or capabilities that would have been otherwise unavailable.

That's why some established companies are looking to invest in, partner with, and even acquire some of these new entrants. Deals include Bosch's investment in AdasWorks, Delphi's partnership with Quanergy, Volvo's investment in Peloton, and GM's and VW's partnerships with Mobileye. Gaining access to relevant technologies such as sensors, connectivity solutions, semiconductors, artificial intelligence, and the like will become increasingly critical for suppliers and OEMs. Most of these companies simply don't have the means, talent, organizational skills, or fast-moving culture to build these new technologies in-house on their own.

If speed-to-market is a critical factor in developing a particular feature, partnering with a provider may be advisable. If the capability requires control or is highly complex, however, companies should consider acquiring the provider. A further motivation can be the wish to keep

a new technology out of the hands of competitors. In late 2015, Daimler, Audi, and BMW combined forces to buy Nokia's precision mapping division, called Here, partly to prevent the service from falling into the hands of a potential future competitor such as Google or Apple.

Leveraging new players will likely be especially important in the areas of software development and artificial intelligence, given the rapid innovation and development processes and trial-and-error mentality so critical to success in both domains. Though the new-car development cycle can be as long as seven years, the software iteration cycle is typically just months long, making coordination between the two very difficult. Software development and coordination are similarly complex for the artificial intelligence features in ADAS and HMI systems that enable vehicles to learn the preferences and styles of different drivers and eventually operate on their own.

OEMs and suppliers have been actively bulking up their software capabilities in-house over the last decade. GM, for example, has been reducing outsourcing contracts and instead has hired more than 8,000 software developers, while Bosch is looking to employ 14,000 software engineers in 2016 alone to develop features for the connected vehicle as part of its push into the Internet of Things. This emphasis on software development will continue, and the ability to oversee a software team — either in-house or outsourced — will become a critical part of the managerial competence of an automotive leader.

New partnerships for innovation

All three kinds of players — OEMs, suppliers, and new entrants — are striving to gain a foothold in the business of building the different elements that make up more intelligent and connected vehicles: ADAS, infotainment, HMI, and communications. This last element, communications, includes a wide range of connected vehicle and device services. How companies fare in the race to provide these features will largely be a function of whether they can build, buy, or partner for the distinct technologies and capabilities on which each feature depends (*see Exhibit 8, pages 35–36*).

ADAS. The technology for these driver assistance and safety systems is quickly evolving from discrete warning and assistance features to more comprehensive, integrated, and connected systems. Technology, hardware, and software players are entering the market and are helping to accelerate these developments, either by transferring their technologies from other industries to automotive or by starting new companies to focus on specific new technologies for future vehicle applications.

The ability to oversee a software team will become a critical part of the managerial competence of an automotive leader.

Exhibit 8
The supply side of connected cars: Deals, investments, partnerships, and new entrants

Technologies				Enabling services	
Adaptive driver assistance systems	**Infotainment**	**Human–machine interface**	**Communications, computing, and cloud**	**Connected vehicle services**	**Connected device services**

OEMs (major automakers)

Acquisition Audi/Daimler/BMW: Here (2015) GM: Cruise Automation (2016) *Investment* Volvo: Peloton (2015) *Partnership* Audi & Nvidia (since 2005) Bosch & TomTom (2015) GM & Mobileye (2015) VW & Mobileye (2015) BMW & Intel & Mobileye (2016) Hyundai & Cisco (2016)	*Investment* Ford: Livio (2013) *Partnership* Audi & Nvidia (since 2005)		*Partnership* Daimler & Qualcomm (2015) Hyundai & Cisco (2016) Toyota & KDDI (2016)	*Partnership* Ford & State Farm (2012) BMW & Pivotal (2015) Ford & Microsoft Azure (2015) Volvo & Microsoft (2015) Nissan & Microsoft Azure (2016)	*Acquisition* Daimler: Mytaxi (2014) GM: Sidecar (2016) *Investment* BMW: RideCell (2014) BMW: Zendrive (2014) GM: Telogis (2014) BAIC: Didi Chuxing (2015) Ford: Pivotal (2016) GM: Lyft (2016) Toyota: Uber (2016) VW: Gett (2016) *Partnership* BMW & Baidu (2015) BMW & Microsoft Azure (2016) Seat & Samsung & SAP (2016) Toyota & Microsoft Azure (2016)

Traditional suppliers

Acquisition Continental: Elektrobit (2015) Delphi: Ottomatika (2015) ZF: TRW (2015) Continental: ASC (2016) *Investment* Delphi: Quanergy (2015) Bosch: AdasWorks (2016) *Partnership* Valeo & Mobileye (2015)	*Acquisition* Harman: Aha (2010) Harman: S1nn (2014) Continental: Elektrobit (2015) Harman: Symphony Teleca (2015) *Partnership* Harman & Luxoft (2011) Harman & Microsoft (2016)	*Acquisition* Continental: Elektrobit (2015) *Partnership* Valeo & Safran (2013)	*Acquisition* Bosch: ProSyst (2015) Valeo: Pelker (2015)	*Acquisition* Harman: Redbend SW (2015) Harman: TowerSec (2016) *Partnership* Valeo & Capgemini (2015)	*Acquisition* Harman: Aditi (2015)

(continued)

Technologies				Enabling services	
Adaptive driver assistance systems	**Infotainment**	**Human–machine interface**	**Communications, computing, and cloud**	**Connected vehicle services**	**Connected device services**

New entrants from outside automotive

Acquisition Panasonic: Ficosa (2014) Google: FCA (2016) Nvidia: AdasWorks (2016) *New entrants* AdasWorks, Baselabs, Vector, Velodyne, Wind River	*New entrants:* Apple, Baidu, Google	*Investment* Intel: Omek (2013) *New entrants* Atmel, Fujitsu, Kyocera, LG, Toshiba	*Acquisition* Cisco/NXP: Cohda Wireless (2013) *New entrants* Cohda Wireless, Kymeta, Veniam	*Investment* Verizon: Hughes (2012) *Partnership* Airbiquity & Arynga (2016) *New entrants* Airbiquity, Allstate, Fleetmatics, Pivotal, Progressive, SiriusXM, Trimble, Verisk	*Partnership* Daimler Moovel & IBM (2014) Airbiquity & Arynga (2016) *New entrants* Airbiquity, Apple, Contigo, Dash, Google, iTrack, Lyft, MyCarTracks, Uber

Key: A colon is an acquisition or investment where the company listed first is dominant. An ampersand is a partnership.

Source: Strategy& analysis

For example, Nvidia, a leading maker of microchips and systems for visual computing, got its start making graphics chips for the gaming industry, and then branched out into automotive in the 2000s. Its powerful Tegra X1 chip can process images from various data sources, such as cameras, radar, and laser imaging, and enable machine learning for automotive systems. Companies like Nvidia leverage their years of experience in their fields to gain a foothold in automotive and quickly reach a high degree of scale and maturity.

This makes it almost impossible for OEMs and traditional suppliers to develop competing technology on their own, and as a result, many of them must access such technologies by other means. This year, for example, automotive supplier Continental acquired ASC's Hi-Res 3D Flash Lidar business and its technology for using laser beams to measure distances to cars and other objects on the road, expanding its portfolio of sensor technologies. In 2015, Delphi made a strategic investment in Quanergy with the goal of jointly developing a low-cost Lidar system, a core technology needed for mass-market autonomous vehicles. And Valeo signed a technology cooperation agreement with Mobileye, also in 2015, to develop front-facing camera systems and sensor fusion. (Sensor fusion is a technology that analyzes data drawn from a variety of sensors and other monitoring sources to provide more comprehensive insight — for example, using multiple cameras to simulate depth perception).

Meanwhile, to keep up with the demands of rapidly advancing digital technology, most OEMs and many suppliers are aggressively trying to build up their software development capabilities. Early in 2016, GM acquired Cruise Automation, a maker of self-driving technology, to bring in-house its ADAS-specific software capabilities and to tap into Cruise's deep software talent and rapid development capabilities. Last year, German auto parts maker ZF acquired its U.S.-based supplier TRW. As executive vice president of sales and business development Peter Lake noted in a company statement, this was part of ZF TRW's "building block approach for automated driving." The deal adds TRW's capabilities in radar and vision systems, safety-oriented onboard computers, and electronic power steering to ZF's current portfolio, enabling it to offer OEMs more sophisticated, integrated ADAS systems.

Infotainment. Many OEMs have developed their own proprietary branded infotainment systems — including the dashboard units and the software that runs them and enables them to interact with other devices in the car, such as smartphones. Now they are also working to modularize the architecture for these systems, which would allow them to speed up the development of different aspects of the systems while reducing the complexity of maintaining them.

Audi, for instance, began partnering with Nvidia in the mid-2000s to speed up the automotive innovation cycle. Collaborating closely, the team developed a modular infotainment system, decoupling software from hardware development and cutting down the development time for a new system from as long as seven years to just one.

On a parallel track, a variety of software players, including giants like Apple, Google, and Baidu, are vying to capture a share of the infotainment space. Today, most OEMs offer in-vehicle smart-device mirroring systems such as Apple CarPlay and Android Auto, while support for Baidu's offering in Asia is increasing. Integration with smartphones is becoming a key dynamic in infotainment. Ultimately, cars will contain a mix of embedded and smart-device-based infotainment features, with variations by brand and geography.

Indeed, software continues to be at the center of progress in infotainment systems, with traditional suppliers focusing on improving their development capabilities. For example, Harman set out to make several critical strategic acquisitions, buying three software companies: S1nn and Symphony Teleca in infotainment and Redbend in connected vehicle services. The deals have helped make Harman arguably the industry's most successful provider of infotainment systems and related services, and have given it access to over-the-air update and cybersecurity technologies.

Continental has also been active in this space. Despite its army of 11,000 software engineers, the company found itself unable to meet the increasingly software-intensive demands of its OEM customers, a common problem among Tier One suppliers. So in 2015 it bought Elektrobit Automotive and its 1,900 software engineers for $680 million. The acquisition helps Continental serve as a true partner with OEMs in the development of complete systems, rather than simply as the hardware integrator.

HMI. This is a technology layer through which the driver and passengers interact with the vehicle's different systems, primarily infotainment and connectivity features, but increasingly also vehicle management systems such as ADAS. The business is still dominated by traditional suppliers such as Continental and Visteon. Much of the current focus of these companies involves the effort to simplify the cockpit electronics by consolidating the car's electronic control units (ECUs). Otherwise, there could be as many as 60 separate ECUs in a car, all performing different tasks and often making the controls too complex to manage. Some companies are also pioneering the integration of ADAS and infotainment into one integrated digital interface for the driver.

Integration with smartphones is becoming a key dynamic in infotainment. Ultimately, cars will contain a mix of embedded and smart-device-based infotainment features.

These suppliers see HMI as a key area for differentiating their offerings, and are actively building internal capabilities to do so. Their long history of analyzing driver behavior gives them a distinct advantage, and they understand the rules by which regulators such as the U.S. National Highway Transportation Safety Administration try to ensure safe, undistracted driving.

But consumer electronics companies, too, have considerable experience in creating functional, user-friendly experiences for consumers. So far, they have not been very active in the HMI market, although Google's Android Auto and Apple's CarPlay are already on the market. These companies will certainly seek to increase their engagement in the HMI market.

Meanwhile, auto suppliers and OEMs alike are actively integrating more specific HMI technologies from non-automotive companies such as Nuance (voice control), Immersion (interactive touch features, or haptics), and MyScript (handwriting recognition, which is useful for decoding finger movements). Developing such technologies in-house is often not feasible, given that these other companies benefit from the investment scale and learning from other industries, not just automotive.

Vehicle services. Although the smartphone is still the most common form of in-vehicle connectivity, companies are working hard to embed connectivity in the car itself. These efforts can be divided into three types: the underlying communications infrastructure, connected vehicle services, and connected device services.

Communications infrastructure. Among the traditional suppliers is Valeo, which acquired Germany's Peiker in 2015 to gain access to its onboard telematics and mobile connectivity technology in order to build secure, high-speed connectivity solutions. Among the new entrants are Cisco Systems and NXP Semiconductors, which banded together in 2013 to invest in Cohda Wireless, a specialist in wireless communications for automotive safety applications.

Connected vehicle services. On top of the communications infrastructure, companies are developing a variety of services that can aid in the safety and management of the vehicle itself, such as remote vehicle diagnostics, cybersecurity, over-the-air system updates, fleet management, and usage-based insurance. The range of companies already active in the market is remarkably wide, including analytics companies, insurance companies, and mobile network operators.

The urge to build new capabilities has driven many of the vehicle services partnerships. Ford and State Farm Insurance formed a

partnership in 2012 to provide usage-based insurance services to customers. Ford contributed the ability to obtain data from the Ford Sync system, while State Farm used that data to calculate insurance rates. In 2015, BMW and Pivotal formed a partnership to provide the automaker with big data and predictive analytics capabilities, allowing BMW to better understand the driver experience and to gain valuable insights into vehicle performance — for example, correlating part failures with data on bumpy streets, extreme temperatures, and other driving conditions.

Connected device services. These are offered directly to drivers and passengers. They include smartphone-based services such as music streaming, e-commerce, social media, integration with smart homes, access to city services like traffic management, and transportation services including ride hailing and car sharing.

OEMs have been particularly energetic in their efforts to participate in the ride-hailing space. Notably, in 2014, Daimler Moovel partnered with IBM to develop the car-sharing app for its Car2go service. And in 2016, GM invested $500 million in Lyft, a ride-sharing service that competes with Uber, in hopes of opening up new vehicle sales channels and eventually driverless taxis. GM also acquired Sidecar, the patent holder of the ride-hailing idea, and has launched a car-sharing service called Maven intended to compete with companies like Zipcar and Hertz 24/7.

Finally, among the main objectives of Ford's strategic investment in Pivotal was the acceleration of its cloud-based software development, in hopes of delivering innovations in the area of mobility services to customers more quickly.

The roles throughout the automotive supply chain are blurring and recombining, and it is critical that every player understand where it stands, and where it should be heading, if it is to capture its fair share of value in this swiftly changing market. Maintaining their positions won't be a given for traditional OEMs and their traditional suppliers, as ambitious, fast-moving tech companies enter the field.

Will China be the fastest innovator?

by Marco Fischer, Kaushik Gnanaserakan, and Julia Kusber

Since mid-2015, China's economic growth rate has been slowing, reaching a 25-year low for the year. This deceleration, coupled with a government crackdown on corruption and a weaker renminbi, is broadly affecting businesses. Most observers expect China to continue moving its economy away from an investment-intensive, export-heavy model to a more sustainable model driven by consumption. No matter how the government's political and economic policies evolve, per-capita disposable income is likely to increase for both urban and rural residents, and the country's middle-class consumer base — already among the largest in the world — will continue to grow.

As with the country itself, the growth of China's auto industry has been remarkable, and it is already the largest in the world. But its growth is expected to slow somewhat. Sales of light vehicles through May 2016 were on pace with the economy as a whole, up 6.9 percent to 10.2 million units, thanks in no small part to the tax stimulus that will continue through 2016. And even as locally made vehicles grow in popularity, China will continue to be a key growth market for automakers and suppliers around the world.

The growth of connected car and autonomous vehicle technologies makes the Chinese market even more critical. The country's automakers and suppliers already seem to have a distinct advantage over their foreign competitors. Indeed, thanks to a virtuous circle of connected consumers, supportive government, and advanced technologies, China may take the lead in the worldwide race to build connected cars. Much depends on its pace of innovation: its companies' ability to move faster than their Japanese, U.S., and European counterparts and own the future of the connected car.

The Chinese consumer in the driver's seat

Consider the young, highly connected, and increasingly wealthy Chinese consumer. According to estimates from Goldman Sachs, people born between 1980 and 1990 made up roughly 30 percent of China's total population in 2015. This youthful cohort is growing more urban and more affluent — and rapidly adopting new technologies. Almost two-thirds of Chinese customers shop online once a month, compared with just 22 percent of customers in the U.S., according to PwC's Total Retail Survey 2016. And more and more shop on their mobile devices. On Singles Day (China's Black Friday) in 2015, mobile accounted for 72 percent of all purchases on Tmall, the country's largest online retailer. This should come as no surprise, given that 500 million Chinese already have smartphones.

These connected consumers are now turning their attention to the country's car market. Already, China has the youngest premium car buyers in the world, and these tech-savvy customers are demanding connected cars at far higher rates than elsewhere. In fact, several surveys have shown that when making purchasing decisions, Chinese customers are more concerned about a car's in-car technologies than its design or performance, and would be willing to change brands for better connectivity.

They are willing to pay more as well. More than 75 percent of Chinese customers would be willing to spend more for safety features, and more than 60 percent would pay more for vehicle management features that track usage, run diagnostics, and record accident data. More than 85 percent of Chinese customers in the volume segment would be willing to switch to a different brand of car if it offered more connected features at a reasonable price. These consumers rank safety-related features such as collision prevention, danger warning, and emergency calling highest on the list of connected car offerings they would like, followed by such features as infotainment, navigation, eCall, bCall, and vehicle status and maintenance, according to the GfK Insights Blog.

Government oversight

Chinese car buyers are already primed for the imminent arrival of the fully connected car. And they are getting considerable support from the Chinese government. In 2015, its State Council announced its latest 10-year plan, called "Made in China 2025," with the goal of transforming the country into an innovation hub in a variety of sectors, including the auto industry. The government plans to support domestic companies working on connectivity and renewable energy technologies, in hopes of making them industry leaders, both locally and globally. In one statement, the Ministry of Industry and Information Technology announced these goals for intelligent and connected cars by 2025: reducing traffic accidents by more than 30 percent, setting safe autonomous driving speeds of 120 kilometers per hour, lowering energy consumption by 10 percent, and reducing emissions by more than 20 percent.

"The Chinese government is very actively supporting R&D in our auto industry," says Keqiang Li, professor at the Research Centre for Intelligent and Connected Vehicles at Tsinghua University. "There are several research institutes supported fully or partially by the government and industry associations. Already we have helped the government implement several big R&D projects for the connected car."

Chinese customers are more concerned about a car's in-car technologies than its design or performance.

As a result of its efforts, by 2030, Chinese companies are expected to control 80 percent of the domestic market for vehicle entertainment modules and perhaps 100 percent of the market for satellite navigation systems. Of course, the Chinese government protects its home market from foreign competition through trade and regulatory barriers; Google Maps, for instance, is not accessible in the country. And the new 10-year plan may further increase entry barriers for Western competitors like Google, Apple, and Amazon.

Innovative Chinese companies

Thanks in part to this government support, Chinese OEMs, traditional suppliers, and technology companies now entering the market are poised for real growth in, and even potential dominance of, the market for connected cars and related systems and packages. Some are operating through partnerships with OEMs from outside the country, and some through entirely local activities.

Two of the country's largest tech companies, Baidu and Alibaba, are already pushing hard to develop their own platforms for connected cars. Baidu, for instance, has secured BMW, Mercedes-Benz, Ford, and Hyundai, as well as China's own BYD, to use its CarLife connectivity platform, which, like Apple's CarPlay or Android Auto, enables cars' internal infotainment systems to connect with smartphones. Volkswagen, which is by far the largest-selling automaker in China, has agreed to use the software. So have General Motors and Audi. Baidu is also working on a telematics service for cars, called MyCar, that would monitor car- and traffic-related data, which will also aid the company in its ongoing effort to develop an autonomous vehicle.

And Alibaba, in partnership with Chinese automaker SAIC, unveiled the RX5, a so-called Internet car, in June 2016. The car's features include Alibaba's Alipay payments service, allowing drivers to pay for parking spaces, fill up with gas, or buy coffee. In addition, it offers three LED screens and space for as many as four detachable 360-degree cameras to record video and take photos, a smart rearview mirror, support for voice controls, and an onboard "intelligent" mapping system.

In a press release Jian Wang, chairman of Alibaba's technology steering committee, was quoted as saying, "What we are creating is not 'internet in the car', but a 'car on the internet.' This is a significant milestone in the automobile industry. Smart operating systems become the second engine of cars, while data is the new fuel. Going forward, cars will become an important platform for internet services and smart hardware innovation. We will be embracing a world where everything is closely connected."

The range of other partnerships illustrates China's thriving connected car market:

- Two of China's domestic automakers, Dongfeng and Changan, signed agreements in 2014 with telecom giant Huawei Technologies, establishing technological cooperation on vehicle connectivity and autonomous driving.

- Audi announced plans to work with Tencent, which operates the country's hugely popular messaging service WeChat, to allow location sharing in vehicles.

- France's PSA, which makes Peugeots and Citroëns, will equip some of its cars with a Wi-Fi hotspot in collaboration with Alibaba, and offer an app to remotely check the vehicle's location and fuel levels.

- China Mobile and Deutsche Telekom have signed a deal to create a platform for Internet-connected cars in China.

- The U.S.'s Airbiquity, the global leader in connected vehicle technology, and Baidu, the leading Chinese Internet services provider, announced a partnership to provide connected car Internet services to the Chinese automotive market.

As advanced as China's efforts have been in the connected car space, the country has yet to progress very far on the autonomous vehicle front. That's somewhat ironic, given that it would seem to have the ideal environment — including strong government support and high interest among customers — for developing one.

The difficulties have to do with the complexity of the driving environment. Most of the current efforts to develop a self-driving car have been taking place in Europe and the U.S., and do not work or are not applicable in China. That's in part because China's driving conditions are complex in terms of traffic, road conditions, and driving behavior, compared with countries like Sweden and the U.S., where companies are actively testing these systems.

This level of complexity has forced China to maintain its ban on road tests of self-driving cars until rules can be set by its Ministry of Industry and Information Technology, further delaying progress. Although China will ultimately end up with a system tailored to its own realities, these complexities will undoubtedly slow its progress, which depends in part on adopting insights and technologies from elsewhere.

Prospects for investment

China's combination of customer interest, government support, and technological innovation provides it with several natural advantages in building the connected car. But as promising as the Chinese market is, and certainly will be, challenges remain, not just for Chinese companies but for every global automaker and supplier that wants a share of this huge market.

The Chinese OEMs themselves, for instance, are still not competitive in markets outside China, and none of them has made much headway in developing technologies and systems for the connected car on their own. That's unfortunate, given just how ripe the environment in China is for progress in this area. To achieve their goals, these companies need to become more active in this space, focusing on offering more connected car features to their domestic customers and improving their innovation capabilities internally or through partnerships, as SAIC is doing with Alibaba.

Despite the benefits of such deals, Chinese automakers face a further risk: These very same tech companies may soon begin competing directly with the OEMs. Already they are gaining considerable experience in the industry and gathering valuable customer information. And Chinese consumers know and trust these new entrants. Indeed, if this trend continues, China's tech companies, already the first movers in the country's highly innovative market, may very well begin competing successfully in global automotive markets as well.

Still, it is likely that tech companies will always need to work with China's OEMs to succeed. "Internet companies cannot succeed in connected cars all on their own," says Professor Li. "Making and selling cars requires special capabilities, which tech companies don't have. It would be difficult for them to match the quality, reliability, and safety standards the OEMs have already achieved, while fuel consumption, the development of alternative and renewable fuels, and environmental issues will also be barriers."

Given its size and growth potential, the Chinese market is critical to the future growth plans of every OEM around the world. To be sure, China's government has erected barriers to these companies' participation, while offering considerable support to the domestic players. And as the country's connected car industry grows in size and sophistication, such barriers may only grow stronger, leaving foreign companies out in the cold.

It is likely that tech companies will always need to work with China's OEMs to succeed.

But the market is still large and the competition still potentially significant. In response, outside companies should take advantage of China's increasingly innovative technology environment to develop and test their own connected car applications and services, and focus more on strategic partnerships with Chinese tech companies, in order to better meet the needs and demands of the Chinese consumer.

Pitstop: Making the connected car cyber-safe

by Joachim Mohs and Manuel Schulte
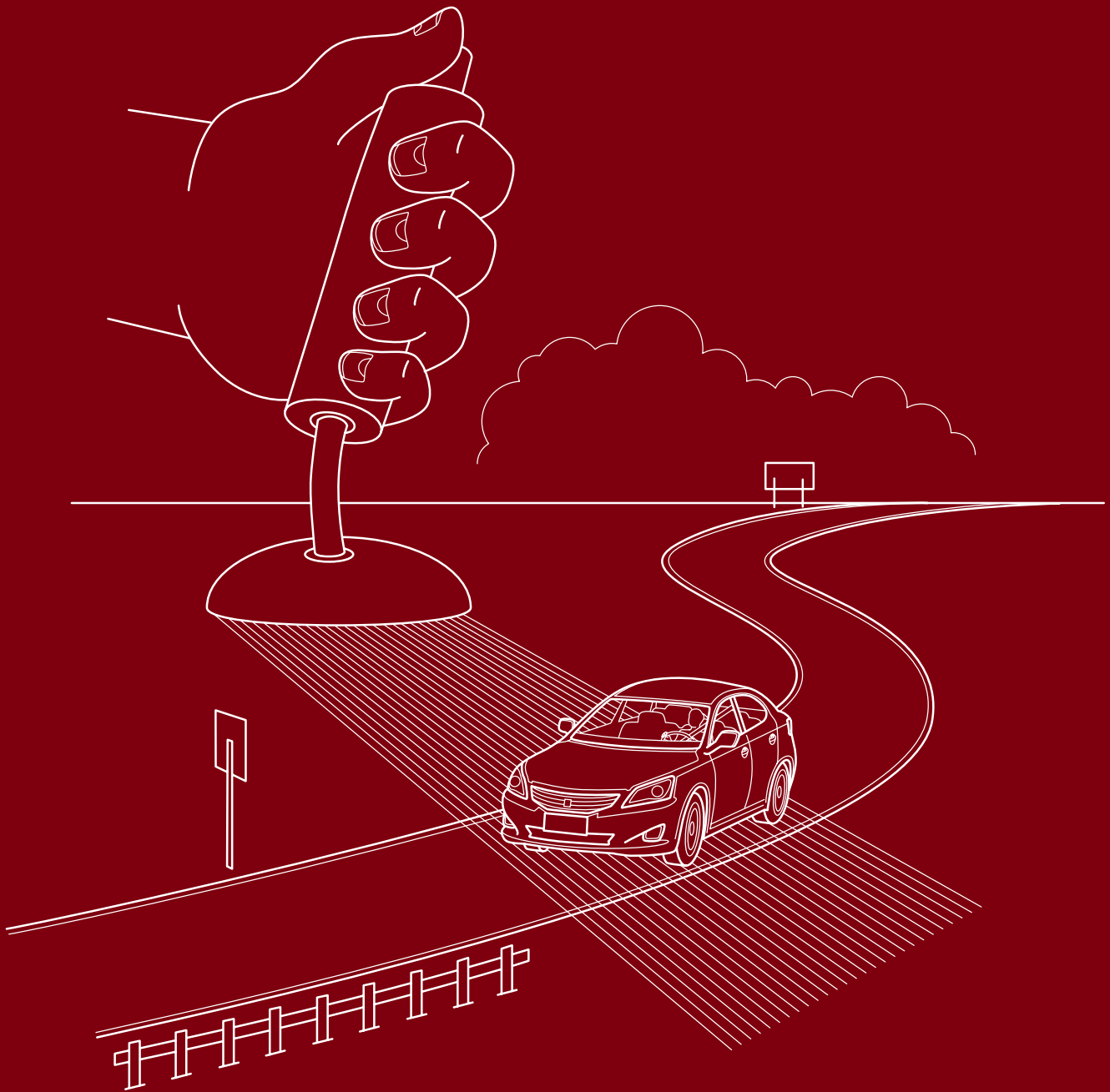
OEMs, suppliers, and technology companies are beginning to realize that the connected car could be a cybersecurity nightmare — unless the right steps are taken now. Determined hackers have already broken into some cars' systems, taking over vehicle functions, from navigation to safety features, and causing problems with the driver's ability to control the car. Future break-ins could even affect more than one car at a time, disrupting traffic flow or targeting an entire fleet of cars. Hackers could go after the increasing amounts of personal data flowing between the car and the cloud through car-based consumer apps and services. And they could even use the car to worm their way into the IT systems of the car's OEM, suppliers, or service providers.

As cars' digital functions and services become more sophisticated, hackers are likely to turn their attention to stealing the software code for new functions and offering it to users for free, disturbing the entire business case for the connected car. Consumer awareness of the problem is on the rise, and could eventually lead to mistrust of the connected car. Increased regulatory scrutiny could increase the cost of building these vehicles.

Connected cars are vulnerable, in part, because they are complex machines made up of many different digital systems, any of which might be a weak link. And they are built through a combined effort of the OEMs and a host of third parties — both traditional Tier One suppliers and new entrants like tech and software companies. No single company has been ultimately responsible for securing them, and much of the current lack of security can be traced to the organizational difficulty of orchestrating the complex effort to make these vehicles.

No connected digital system is perfectly secure, of course. But the connected car must be as secure as possible, and it should be the responsibility of the OEM to make sure it is. Aside from the purely technical issues involved, doing so is a matter of putting together the proper project environment in which the security software needed can be developed, tested, and maintained. Here's how.
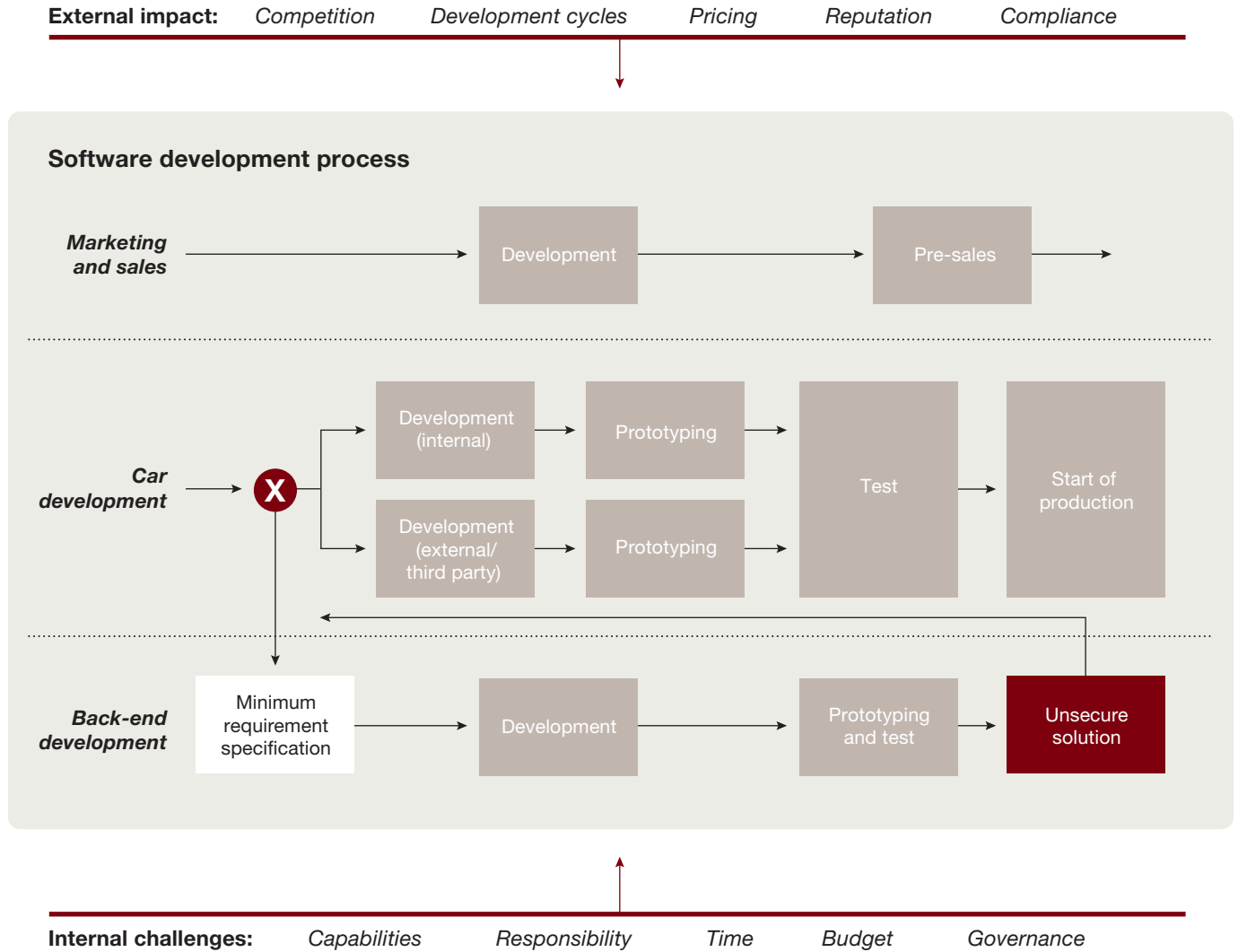
Organizing the effort

In making sure the connected cars they sell are as secure as possible, automakers face a number of technical and organizational challenges (*see Exhibit 9, next page*). These have so far been difficult to overcome. Two in particular stand out:

- **Embed security in the development process.** Many of the problems OEMs face don't come from the actual effort to develop the

Exhibit 9
Factors affecting cybersecurity software development for cars

External impact: *Competition Development cycles Pricing Reputation Compliance*

Software development process

Marketing and sales → Development → Pre-sales →

Car development → X → Development (internal) → Prototyping → Test → Start of production
X → Development (external/third party) → Prototyping → Test → Start of production

Back-end development → Minimum requirement specification → Development → Prototyping and test → Unsecure solution

Internal challenges: *Capabilities Responsibility Time Budget Governance*

Source: Strategy& analysis

best security software, but are inherent in how these companies build any new car. Car companies are complex organisms with many competing interests. Developing a new car forces the entire supply chain to be focused on the next "start of production" date. After passing that bar, the vehicle, a combination of hardware and software, will stay on the market for years. Thus, cars have an especially long life cycle, and any software updates needed typically require an expensive product recall.

- **Build your cybersecurity capability.** Many automakers simply don't have the necessary development capabilities. They are not software companies, whose strengths lie in the very rapid innovating and constant iterating of complex computer code. Their current development process for security software involves binding it to the car's hardware. As a result, updating the software, as well as the related back-end systems, is a very cumbersome process that slows down the response to new threats. And because each newly developed car requires its own separate combination of hardware and software, companies must keep supporting hundreds of different versions.

  If the car's software could be updated remotely, through its connectivity functions, the process could be considerably streamlined. Many companies are working to accomplish this, but so far only a handful (including Tesla) have managed it.

  Most OEMs are still not sure how their effort to develop and maintain the secure connected car should be integrated into their corporate structures. The responsibility for getting the actual work done, and for making sure it is done right, is not clear. The solution will involve integrating all the relevant business functions, such as R&D, corporate IT, finance, and sales, into the development effort, and managing the many suppliers whose systems must also be made secure.

  Finally, the development of secure software requires its own complex set of support functions, including risk management, progress monitoring and reporting, and incident management, and all of these must also be put in place if the software development effort is to succeed.

The development cycle

Resolving these challenges means managing a time-based conflict: Auto product development cycles are long, but software development cycles are short. Moreover, the cultures in which the two very different

organizations operate exacerbate the discrepancy. Automakers are very much inclined to resort to their traditional inflexible schedules set by their typical product life cycles. These schedules are often determined by their internal software development organizations, which can be very powerful and are more accustomed to writing the software that governs the car's internal functions. Corporate IT, too, may have considerable sway over all development activities, even those for the connected car, and this department is not known for moving quickly.

The task of coordinating the security software developed internally with the security efforts of third-party suppliers of systems and services adds considerably to the development challenge. Every OEM has long-standing and very tightly intertwined relationships with its top electronics suppliers, but those suppliers are typically in sync with the OEM's product life cycle. Suppliers of connected car systems work differently, especially the technology and software companies just now entering the market.

Testing for quality

Developing the security software, of course, is only half the battle. The software must be fully tested to make sure the connected car is as secure as possible. Yet here again, discrepancies in product development cycles cause difficulty for automakers — all too often, under pressure of poorly coordinated schedules, software is released before it is adequately tested.

If companies direct most of their efforts toward development, testing is likely to suffer. Companies may fail to put a complete testing strategy and the proper procedures in place. If so, the testing process will lack the necessary key components, including the test catalogs that define the processes by which the software should be tested. Without them, it isn't possible to determine whether the software meets all the necessary requirements as to quality and security, or to identify and resolve any defects in the software.

A lack of proper testing procedures, moreover, also affects how companies determine the risks involved in the technology in the connected car, and whether their software has adequately addressed them. Without a clear testing methodology, the required risk management procedures cannot be carried out, leaving developers uncertain about the security and reliability of their software.

Remedying these issues requires that companies develop a comprehensive test strategy and the proper test procedures, and implement a complete test catalog. Moreover, these procedures must

Developing the security software is only half the battle. The software must be fully tested to make sure the connected car is as secure as possible.

be standardized as much as possible to ensure that the quality of the software is consistent, and that the tests provide measurable results regarding the risk potential and confidence level that can be compared across different elements of the software.

Once testing is completed, and the security software is implemented in cars, software teams will also need to regularly update the software as potential new threats emerge, and send it out — no easy task given the technical complexity of the software, the need to coordinate the updating process with third-party suppliers, and the long product life cycles of cars. Here again, the process requires consistent procedures and strict enforcement of the distribution process, all of which must be the responsibility of the OEM.

The OEM at the center

Clearly, strong cybersecurity is critical to the success of the connected car — not just to keep the car and its growing number of connected services safe from hackers, but to instill the high level of trust needed to keep car buyers coming back for more.

The complexity of the technology and processes involved in connected cars is what makes the task of the developer of security software so difficult. Cars now have many systems for sending and receiving information, and they are all vulnerable to attack. So are the back-end systems that process the wealth of data the car sends out. No wonder consumers are becoming increasingly aware of the difficulty of keeping their brand-new cars secure.

One possible solution may involve cloud computing. Advances in cybersecurity now allow embedded protections in distributed remote computing. Instead of focusing on firewalls, companies can instead monitor and track behavior, and thus isolate and identify suspicious patterns of entry in almost real time. As the connected car becomes more prevalent, opportunities will emerge to integrate automakers' efforts with this type of cybersecurity innovation.

Given how complex the effort to secure the connected car is, and the sheer number of different players whose software is used to keep the car connected, securing these vehicles must be a collaborative effort. The OEMs are certainly in the best position to lead that effort. But that means they must accept full responsibility for the task, and be accountable when things go wrong. Yes, there are and always will be risks, but those risks can be mitigated if the many challenges — of organization, development, and testing — are met squarely and overcome.

The autonomous frontier

by Dietmar Ahlemann and Walter Gerling
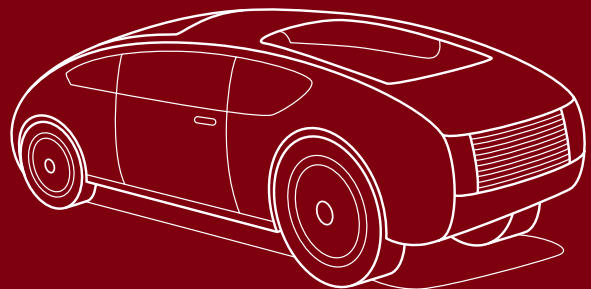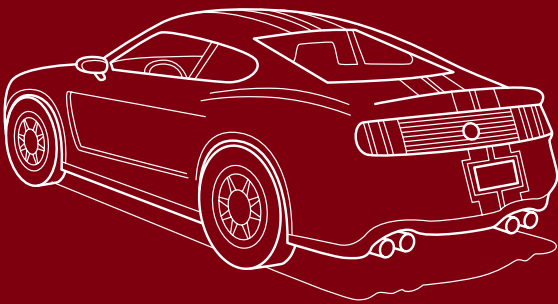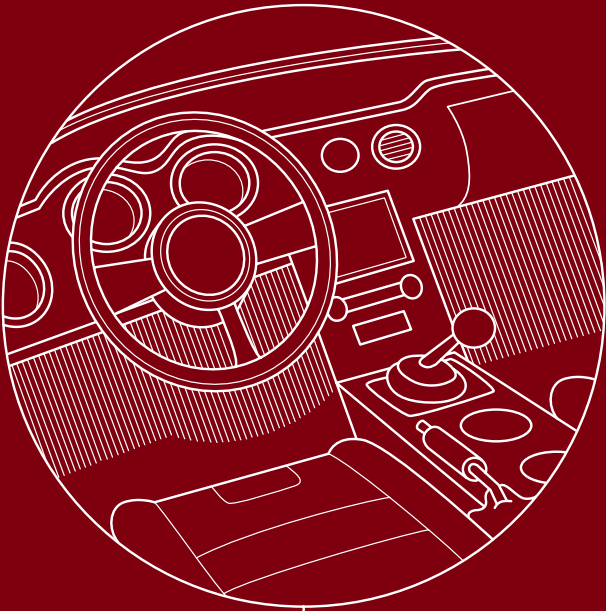
The connected car is an interim step on the way to the truly autonomous vehicle — the much-discussed future when driverless vehicles zip about, picking up "users" on demand, safely carrying them to their destinations along optimized routes in personalized comfort, dropping them off, and then disappearing to their neutral corners. Depending on your point of view, either this vision won't become reality for decades, or it's already happening. Perhaps it is, in some relatively rudimentary form — Uber and Volvo announced plans to put driverless cars on the streets of Pittsburgh in September 2016, and Ford says it expects to introduce its first self-driving cars in 2020.

The fully autonomous car, however, isn't likely to be at your beck and call for at least another decade or so, when several critical but still-nascent technologies — notably artificial intelligence (AI), machine learning, the human–machine interface (HMI), and key elements of the car's underlying infrastructure — and the various features they might enable finally reach a higher level of maturity (*see Exhibit 10, next page*). Where do these technologies stand now? Will they reach a state so advanced that they become standard features on even the least expensive subcompact? Or will they be relegated to the dustbin of wrongheaded future predictions, along with the videophone, the jetpack, and the flying car?
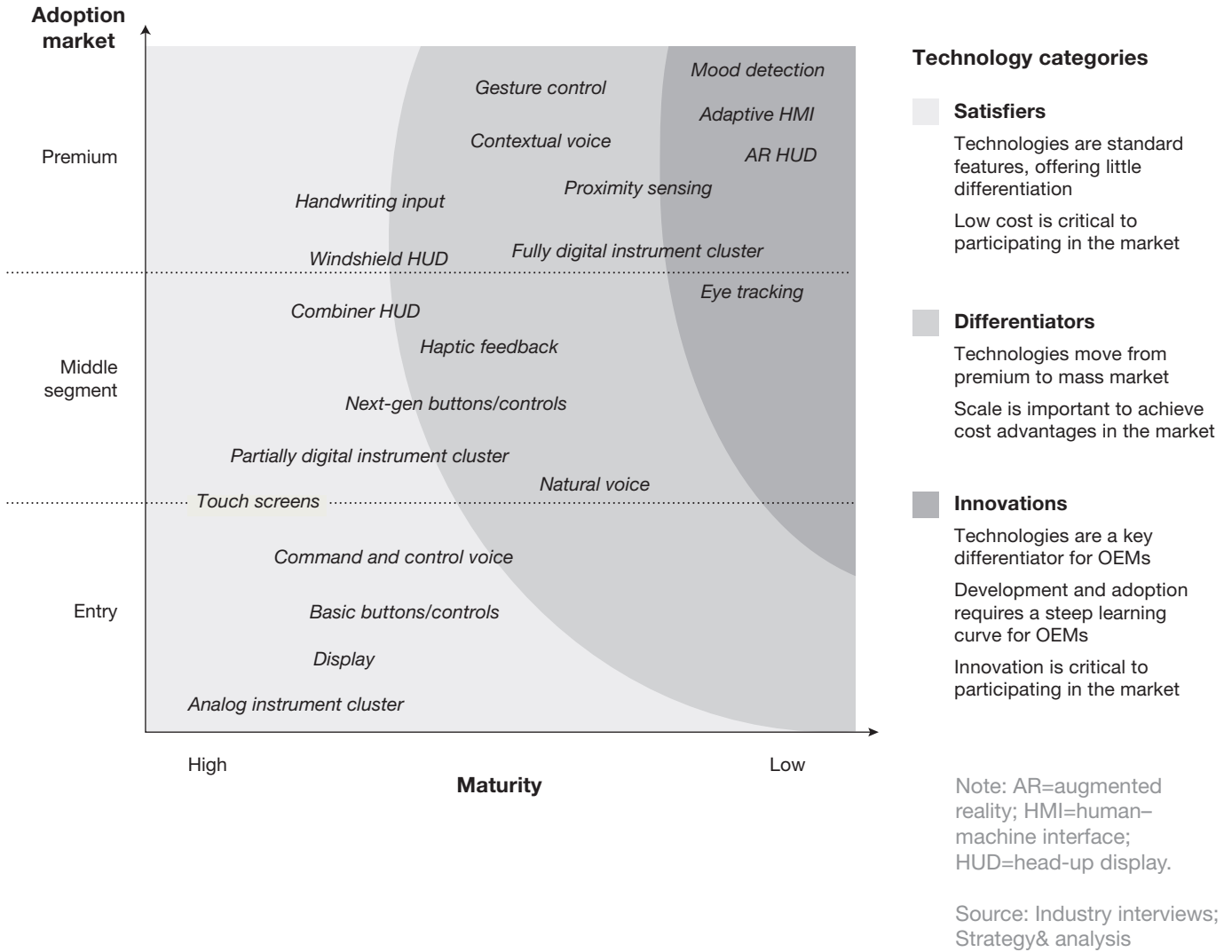
A smarter car

At present, even the smartest cars are pretty dumb, at least when it comes to recognizing differences among people. They're programmed to do the same things for you that they do for everyone else — whether you like it or not. They lock the doors even if you don't want them locked, they won't start unless you buckle your seatbelt, and they direct you along routes that make no sense to drivers with local knowledge. In many ways they're engineering marvels, but they're inflexible marvels. They behave the same way whether you are at the wheel, or your grandmother is.

Advances in artificial intelligence and machine learning promise to change all that. Even if it's owned by an operator of fleets of robo-taxis, the car that picks you up will recognize you, and reset its systems to meet your preferences and expectations. Once you get in, the seat will conform to your favorite position, and the cabin may even change to your favorite color. The infotainment system will tune itself to your preference, perhaps business news during your morning commute, and the latest episode of the TV drama you've been watching on the way home. If you seem sleepy, it will turn the volume down, and then turn it back up again just before you get to your destination. What's your driving style? A little aggressive, or more defensive? The car will conform itself to that too.

At present, even the smartest cars are pretty dumb. They're engineering marvels, but they're inflexible marvels.

Exhibit 10

Technologies for the connected car: Maturity and adoption rates

Adoption market

Premium

Mood detection

Gesture control

Adaptive HMI

Contextual voice

AR HUD

Proximity sensing

Handwriting input

Fully digital instrument cluster

Windshield HUD

Eye tracking

Middle segment

Combiner HUD

Haptic feedback

Next-gen buttons/controls

Partially digital instrument cluster

Natural voice

Touch screens

Command and control voice

Entry

Basic buttons/controls

Display

Analog instrument cluster

High — **Maturity** — Low

Technology categories

Satisfiers

Technologies are standard features, offering little differentiation

Low cost is critical to participating in the market

Differentiators

Technologies move from premium to mass market

Scale is important to achieve cost advantages in the market

Innovations

Technologies are a key differentiator for OEMs

Development and adoption requires a steep learning curve for OEMs

Innovation is critical to participating in the market

Note: AR=augmented reality; HMI=human–machine interface; HUD=head-up display.

Source: Industry interviews; Strategy& analysis

The goal: to build the intelligence and learning capacity into cars that will enable them to know who you are, understand your changing moods, adapt to varying circumstances, and react to new demands and new tasks on the fly. This kind of intelligence has already been taken to a high degree of maturity in robotics; industrial machines have access to a wide range of sensors and network data that give them a detailed picture of their workplace and enable them to interact smoothly with humans or call for maintenance in advance. Of course, cars on the road face much more complex, ever-changing situations — traffic and weather conditions, the moods of the driver and passengers — so they need to be that much smarter.

The inputs to the machine learning system will also be much more sophisticated. Autonomous cars are already equipped with sensors, cameras, and laser systems that monitor the road situation and traffic conditions. Soon these technologies will move inside the car, observing and analyzing the condition of the occupants, their level of comfort, their degree of awareness, perhaps even their health. And the AI systems will take into account external data sources such as social media, marketplaces for e-commerce and entertainment, and smart home systems, offering updates and suggestions. Further in the future, perhaps, your car will learn not just from you and its immediate environment, but through its connections with other people and cars, leading to a kind of swarm intelligence that will exponentially increase its understanding and learning potential, enabling it to combine its sensor data with other cars' data and take advantage of cloud-based analysis to derive new scenarios and problem-solving strategies.

The effort to boost the intelligence built into cars has been gaining speed. In 2015, Toyota announced that it will invest more than $1 billion in AI over the next five years to improve car safety. Its business case: Better safety can be used as a major selling point for its cars. Whether AI and machine learning can become a differentiating capability for Toyota, or any other automaker, will depend on just how far it can push the technology, and whether the advantages and features, which will no doubt be offered first as expensive options in premium cars, will rapidly end up as standard equipment in mass-market cars, built into the list price.

Your car has a question

The car of the future will know a great deal about you and about its environment. But what will you know about your car? It used to be that a car's instrument panel included a fuel gauge and a few dials — or worse, "idiot lights" — indicating things like temperature and oil pressure. Then dashboards grew more and more complex, and more and more digital;

now virtually all cars offer little more than an LED screen through which you control the infotainment, navigation, and climate control systems and which provides a wealth of data about the status of the car — everything from tire pressure to outside temperature.

Yet the graphical user interfaces and control mechanisms of many of these systems have proved woefully counterintuitive, making it difficult, even distracting, for drivers to figure out how to adjust them and access information they need. And now, just as these systems are getting better, the sheer amount of data available — not just from the car itself, but through the navigation system, the road infrastructure, and the entire Internet — has exploded. Simplifying the user interface and making how it is controlled more intuitive, through the ears and our sense of touch (the science of haptics), as well as visually, is the task of human–machine interface technology.

Already, some cars offer head-up displays in the form of basic information such as speed projected onto the windshield in front of the driver. And with additional data from the car's sensors and its surroundings, it will be possible to project all kinds of information — about parking places, hotel and restaurant locations and reservations, upcoming traffic signs, and the like. The car's side and rear windows will also become potential projection surfaces for such functions as entertainment and surfing the Web.

Other cars now have cameras pointed at the driver that can recognize when he or she appears to be getting drowsy, and they can make the steering wheel vibrate to help the driver pay attention. This, too, will become more sophisticated, enabling the system to recognize a wider variety of expressions and states of mind; a look of surprise or anger, for instance, might trigger the car to go into emergency mode, slowing down to determine the cause. Other surfaces might change color or texture to further guide the attention of the driver or to reflect the varying moods of passengers. Materials already exist that can change their appearance and feel. A car seat, for instance, might change firmness and texture depending on whether the passenger or driver wants to engage more fully with the navigation process, or sit back and relax, and on whether or not it detects muscle stiffness.

Voice recognition, too, will certainly become an increasingly vital part of how we interact with our cars. Most cars can already link to our smartphones, allowing us to make calls using voice commands; some allow us to tell the car to navigate home, or to change the cabin's temperature setting. Soon, the car will be able to communicate much more information this way, warning us verbally about a traffic jam ahead and suggesting alternative routes, telling us which hotels in the area have vacancies, or updating us on the score of a current football match.

The car's side and rear windows will also become potential projection surfaces for such functions as entertainment and surfing the Web.

And once the car is fully autonomous, and fully connected to the surrounding infrastructure, its powerful combination of AI and HMI will let you (as the driver) tell it to drop you off at home, go off by itself to find a parking space — preferably one where it won't get a ticket — and then text you a description and map of where it's parked. Of course, you won't really need to know its location, since all you'll need to do next time you need it is to text it to unpark itself and come to pick you up.

What's under the hood?

The truly intelligent, fully connected car will require a massive amount of computing power and super-high-speed communications systems, and both are already in development.

The next step forward in widely available and stable connectivity will be fifth-generation networks that can operate at rates 100 times faster than the current LTE technology. Already, a consortium of telecom players including Vodaphone, Huawei, Nokia, Ericsson, Qualcomm, and Nvidia have demonstrated such a network, which will be critical to the real-time provision of information in rapidly changing situations such as sudden emergencies. Where these networks aren't available, short-distance Wi-Fi networks such as DSRC (dedicated short-range communications) will enable cars to maintain their connections to the environment and to other cars. Such networks are already in use, especially to provide traffic-related information on expressways.

At present, the car's internal data networks — which connect its sensors, controllers and processors, HMI systems, and Wi-Fi modules — aren't especially fast, even when compared with the external networks they can connect to. That will have to change as the technological sophistication and data-processing and transfer needs of cars continue to grow. Any delay in managing a self-driving car in heavy traffic or complex urban environments cannot be tolerated. Eventually, OEMs and suppliers will need to develop gigabit data transfer networks that will support the ultrafast "systems on a chip" required to process the data needed for autonomous driving, especially the processing of camera, radar, and laser images. Although outsourcing some of the car's computing needs to the cloud on the fly is possible, response must be instantaneous, 100 percent available, and easy to plug in, even when moving between cell nodes.

Engineering our world

Whether any or all of these technologies will really bear fruit is still up in the air. Still, many of their benefits, and risks, are already coming into focus.

Certainly, the benefits for drivers and passengers are many. How we use and interact with our cars will become much more customizable, as they become more responsive to our needs and preferences. They will get us where we want to go much more efficiently and safely, choosing the fastest routes, reducing traffic jams, and lowering the potential for accidents.

Companies will benefit as well. OEMs, suppliers, and any company providing onboard services will have access to far more information about drivers and passengers, and their behavior, interests, and preferences, which can be used to market to them much more precisely. A large market for aftersales upgrades and services will likely be established, much like the market for apps and accessories that grew so quickly around smartphones; this will provide incremental revenue for OEMs and open up opportunities for new startups and technology providers. And automated customization of fleet cars to the preferences of users will smooth the transition from individual ownership to ride hailing and ride sharing and make the use of robocars more attractive.

Concerns remain, of course. As we have seen, securing the connected car from cyber-attacks is no easy task. And the wealth of data available about the cars and its occupants — their whereabouts, driving habits, behavior, preferences, and interests — will need to be carefully managed, to keep it private and to decide who gets to use it and how.

Indeed, for drivers and companies alike, the risks are considerable. Failures in any of these areas — accidents, data breaches, misuse of personal information — may threaten the entire effort to build the self-driving car.

Finally, this vision of autonomous vehicles customizable to our every need and intimately connected to the world around us will require a considerable amount of trust and flexibility for many people to accept. It's going to be a strange new world when the status of our cars hovers somewhere between a highly advanced personalized environment and an appliance we don't even get to drive. One can even imagine a future where driving your car yourself is illegal, and people who enjoy driving are relegated to tracks isolated from public roads.

That's a long way in the future, of course, and we will have plenty of time to get used to the coming changes. If the transition happens as quickly as the shift from horses to horseless carriages did, it will likely go smoothly.

Stop-and-go innovation: A conversation with Stefan Bratzel

by Edward H. Baker
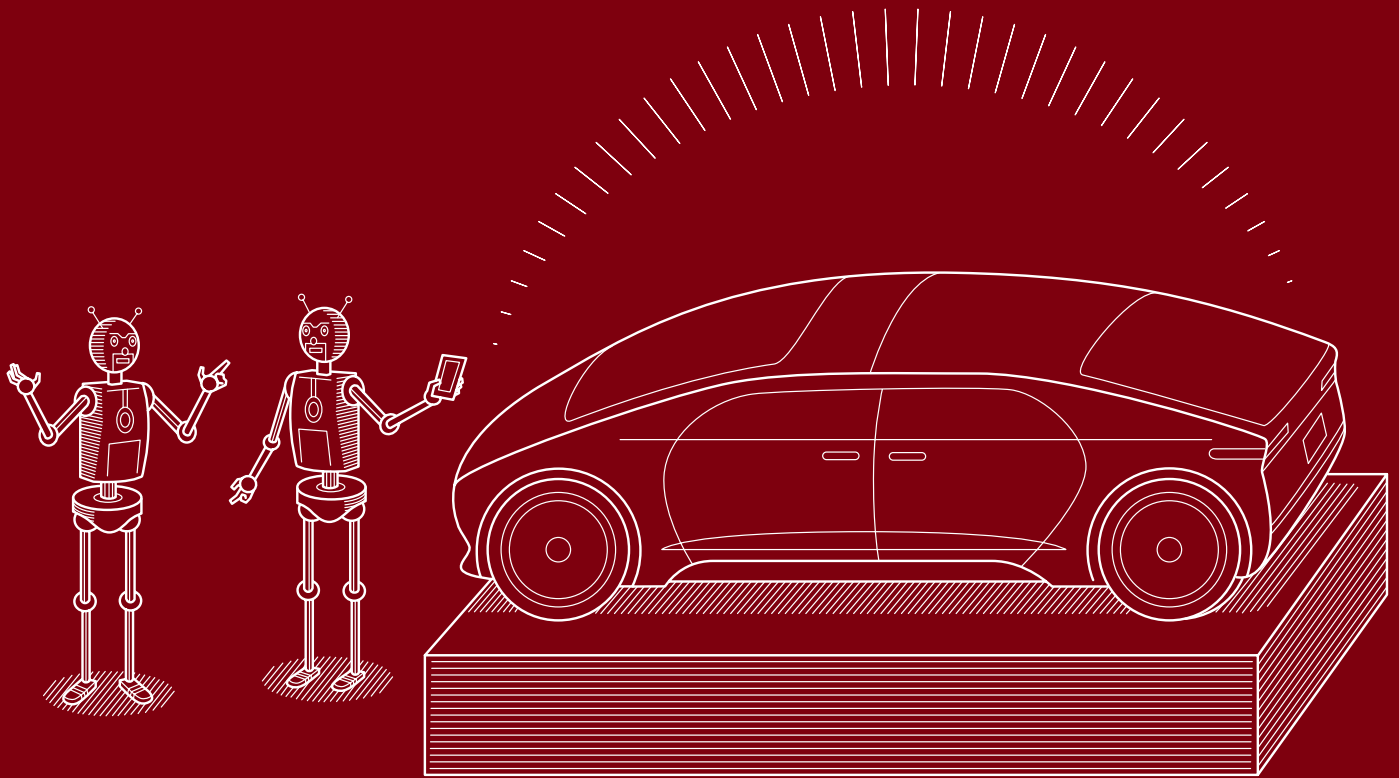
Players throughout the global auto industry are working hard to make the vision of the connected car and autonomous vehicles a reality, experimenting, testing, and building the technology that will further connect cars to the world around them, and developing prototypes of cars that can already drive themselves.

For a report on the progress these companies are making, we turned to Stefan Bratzel, director of the Center of Automotive Management at the University of Applied Sciences in Bergisch Gladbach, Germany. Trained as a political scientist, Bratzel gravitated toward the auto industry while working on environmentally friendly transportation issues. In 2004, he founded the center, which is devoted to research on innovation in alternative powertrains as well as the connected and autonomous car. He and his colleagues there have been conducting a multiyear assessment of the innovation efforts of the industry's OEMs, suppliers, and technology companies that are racing to perfect the car of the future. Bratzel spoke with Strategy& from his office at the center's headquarters.

Strategy&: Your institute's study shows that a great deal is happening in the auto industry. Which innovations have most surprised you in the last 12 months? Which ones will be the most disruptive?

Bratzel: Global OEMs have rapidly boosted innovation in the area of safety. The number of accident prevention innovations has increased by more than 500 percent, and advanced driver assistance system [ADAS] innovations by more than 400 percent, over the past eight years. These innovations bring two major customer benefits: First, driving is getting safer. Active collision warning technology can recognize pedestrians in the street, and active cross-traffic assistant systems can prevent very dangerous accidents. With vehicle-to-vehicle communication becoming a reality, as in Daimler's new Mercedes E-Class, cars can now effectively warn drivers of dangers before they can see them.

Second, driving is getting more convenient. Improved human–machine interfaces can now use natural language processing to control many of the car's functions, and further advances in ADAS will continue to make driving easier. The new 7 Series BMW offers the garage parking assistant, and Tesla recently introduced its Summon feature. Most disruptive will be the continuing advances in autonomous driving being made by both the incumbent car manufacturers and new players like Google and Tesla.

Strategy&: Are the various players taking different approaches to the car of the future?

Bratzel: The traditional OEMs are following an evolutionary track to autonomous driving, by incrementally improving the technology and

adding features like vehicle-to-vehicle and vehicle-to-infrastructure communications, to make car travel safer and more comfortable. It's a "driver- and automobile-centric" approach, focusing on the more traditional ways of improving the quality, reliability, and sophistication of the technologies, introducing them into their high-value cars first, and selling them to status-seeking purchasers.

But there is also a revolutionary approach, being taken by nontraditional players like Google and Uber. Rather than carefully moving through the first three levels of autonomous driving, where there is still a driver in the car, they are focusing on levels four and five — entirely driverless cars. These players don't concern themselves with improving the quality of the cars themselves. Nor do they care about bringing the Internet into the car. Instead, they see the car as an integral part of the Internet. Their goal isn't to offer autonomous driving as a feature, but rather to offer "mobility," and to try to make money using the free time of the driver.

Strategy&: That seems like a very different business model. How do you see the auto industry's business models evolving with the introduction of self-driving cars?

Bratzel: These new players that are interested primarily in the concept of mobility, mobility-on-demand, and service-oriented business models will evolve out of the trends of connectivity, alternative power sources, mobility services, and autonomous driving. The customer benefits and value added are low when these trends are considered in isolation. Answering e-mails in the car via voice control is nice, but not exactly a "killer app." In the next 10 years or so, however, a new innovation and business dynamic will arise out of the convergence of these trends, generating completely new customer benefits in the world of mobility and beyond, and creating a high probability of disruptive change. These trends will bring about a virtuous circle of self-energizing and self-reinforcing innovation activity.

Mobility services and autonomous driving, for example, will lead to "mobility-on-demand," with no driver necessary. The rise of fleets of shared robo-taxis will lead to a sharp drop in passenger price per kilometer. Robot cabs with battery-electric propulsion will be able to drive themselves to inductive charging stations and can even be used as energy storage buffers. And connectivity between vehicles through the Internet of Things will guarantee that enough robo-taxis are available to satisfy the mobility needs of all customers.

Ultimately, this will lead to a "battle of the business models" between the incumbent OEMs and the new players in the next 15 years. Indeed, the next 10 or 20 years will be perhaps the most disruptive period in the industry's long and complex history.

Nontraditional players' goal "isn't to offer autonomous driving as a feature, but rather to offer 'mobility,' and to try to make money using the free time of the driver."

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